



Appendices

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Appendix A

Appendix A | Dr David Robertson - Response regarding Ironbark communities



19 August 2011

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Dear Anthony

RE: ADDENDUM TO FINAL PEAKE REVIEW OF ECOLOGICAL ASSESSMENTS OF WARKWORTH EXTENSION EA AND HVO SOUTH MODIFICATION PROJECTS

In my previous Letter Report regarding Warkworth Sands Woodland Matters, I provided a detailed response to the Draft Peer Review by Mr Travis Peake commissioned by Department of Planning for the Warkworth Extension EA (“the EA”) and entitled:

Draft Review of Ecological Assessments for Warkworth Extension EA and HVO South Modification Projects.

I note that Mr Peake has also commented on supplementary information in response to the Draft Peer Review provided to him by RTCA concerning offset lands and survey information. He subsequently finalised the Peer Review and prepared an Addendum to that Peer review in August 2011 (the “Addendum”).

The purpose of this letter is therefore to provide a response to the Addendum focussing upon Ironbark-dominated forest and woodland communities. I have prepared a separate letter which adequately covers issues raised by the Final Peer Review concerning Warkworth Sands Woodland (WSW), so I will not comment further about it within this letter. Similarly in the other response, I noted that the Peer Reviewer had no issues with various other vegetation communities that will have only small areas impacted by the proposal. I agree, so will not provide additional comment about such vegetation.

This letter examines the recommendations of the Addendum about impacts to Central Hunter Grey Box Ironbark Woodland Endangered Ecological Community (CHGBIW) and Central Hunter Spotted Gum Grey Box

Endangered Ecological Community (CHISGGBF). To be consistent with the terminology used by the Addendum, I use the following terms to refer to offset areas covered by the EA:

- BOA = biodiversity offset area;
- NOA = northern offset area;
- SOA = southern offset area; and
- Other offset areas: Goulburn River BOA, Seven Oaks BOA, Putty BOA, Springwood BOA.

1. AGREEMENT ABOUT CHGBIW AND CHISGGBF REHABILITATION

With regard to the proposed rehabilitation of forest and woodland following mining at Warkworth, I note that DnA Environmental has prepared a rehabilitation strategy for Warkworth entitled:

DnA Environmental (August 2011) Rehabilitating Central Hunter Grey Box – Ironbark Woodland. Warkworth Rehabilitation Strategy

This document, referred to hereafter as the “Warkworth Rehabilitation Strategy”, was not available for the Peer Reviewer.

I note that the Warkworth Rehabilitation Strategy, when considered with the latest proposals for rehabilitation outlined in the letter by RTCA to Department of Planning dated 30 June 2011, collectively now address all of the recommendations for CHGBIW and CHISGGBF rehabilitation within the Addendum.

In Table 1 below, I have verified that all key recommendations for commitments to Ironbark rehabilitation will be met by RTCA. Recommendations for rehabilitation from the Addendum about CHGBIW and GHISGGBF are repeated verbatim in the left hand column, with my responses to each presented in the right hand column.

Table 1 Responses to the Addendum Recommendations for Rehabilitation of CHGBIW and CHISGGBF

Peake’s Addendum recommendations for Rehabilitation of CHGBIW and CHISGGBF (Addendum Section 3.2.1.3)	Response by Cumberland Ecology
4. The revised EEC rehabilitation targets should be adopted.	The revised rehabilitation target of 2114 ha of CHGBIW and CHISGGB rehabilitation will be adopted and committed to by RTCA as reflected in the revised Statement of Commitments. The means by which rehabilitation will be undertaken will be guided by the Warkworth Rehabilitation

Table 1 Responses to the Addendum Recommendations for Rehabilitation of CHGBIW and CHISGGBF

Peake’s Addendum recommendations for Rehabilitation of CHGBIW and CHISGGBF (Addendum Section 3.2.1.3)	Response by Cumberland Ecology
<p>5. RTCA re-issue the rehabilitation map to clarify where the EEC is proposed to be rehabilitated.</p>	<p>Strategy. The Warkworth Rehabilitation Strategy has a Figure that shows where the Ironbark EECs are to be rehabilitated. Revised Figure 5.5 from the EA is also provided in RTCA’s response.</p>
<p>6. RTCA clearly documents how the rehabilitation of this community would be undertaken, how it would be measured or contingency in the case of failure.</p>	<p>The Warkworth Rehabilitation Strategy provides a strategy for the rehabilitation of CHGBIW and CHISGGB and other woodland types. The Rehabilitation Strategy contains recommendations for monitoring of rehabilitation. It will be updated to include specific measures that can be undertaken for various contingencies. The \$500,000 of funding to applied university research will help to improve rehabilitation of the ground stratum of the CHGBIW and CHISGGB rehabilitation works.</p>
<p>7. RTCA document the measures that will be undertaken to improve the timeliness in which the rehabilitation is likely to be colonised by threatened fauna species through the augmentation of habitat with appropriate artificial features such as nest boxes, logs and other groundcover and microhabitats.</p>	<p>The Warkworth Rehabilitation Strategy includes a suite of recommendations for agumentation of habitat within rehabilitation and regeneration areas. The measures include nest boxes, salvaged logs and tree hollows and other ground cover for use as microhabitats.</p>
<p>8. The funding of \$500,000 towards research into improving the rehabilitation of ground stratum plant species in the CHGBIW and CHISGGBF EECs be secured, and that the findings of the research are made publicly available through reports, presentation at conferences and the internet.</p>	<p>This is an important committment by RTCA that will be done to improve the success of the rehabilitation program. The \$500,000 of funding to applied university research will help to improve rehabilitation of the ground stratum of the CHGBIW and CHISGGB rehabilitation works.</p>

2. AGREEMENT ABOUT OFFSETS FOR CHGBIW AND CHISGGBF

I note that the latest proposals for offset sites outlined in the letter by RTCA to Department of Planning dated 30 June 2011, collectively now address most of the recommendations for offsetting impacts to CHGBIW and CHISGGBF within the Addendum.

In Table 2 below recommendations from the Addendum for offsetting impacts to CHGBIW and GHISGGBF are repeated verbatim in the left hand column, with my responses to each presented in the right hand column.

Table 1 Responses to the Addendum Recommendations for Offsetting of CHGBIW and CHISGGBF

Peake's Addendum recommendations for Offsetting for CHGBIW and CHISGGBF (Addendum Section 3.2.1.3)	Response by Cumberland Ecology
<p>9. Areas 1, 2 and 3 are included within the offset package; they are secured appropriately for long-term offsetting; and the regeneration/re-establishment approach documented in Recommendation 3 above be applied to these properties.</p>	<p>I note that the letter from RTCA dated 30th of June commits to include areas 1-3 within the offset package and have also been included in the revised Statement of Commitments as part of the Southern Biodiversity Area . They will be secured in the long term and managed according to the actions of the Biodiversity Management Plan to be revised and submitted to the Department for conservation purposes.</p>
<p>To address the up-front CHGBIW EEC offsetting shortfall of 763.7 hectares, and taking into account the \$500,000 commitment towards funding CHGBIW EEC rehabilitation research, it is recommended that:</p>	<p>The Proponent has committed to progress commercial discussions with O'brien. Should these not reasonably progress, the proponent commits to acquiring an offset of similar size and quality to the O'Brien property for addressing the required additional area of 763.7 ha of ironbark-dominated forest and woodland.</p>
<p>10. The O'Brien property be included specifically to provide for an up-front offset for CHGBIW, and associated threatened fauna species, and that this property be ecologically improved over time to ensure a strong "environmental gain".</p>	
<p>It is recommended that:</p>	
<p>11. The overall offset package for the Warkworth Extension Project include:</p>	
<p>Southern BOA</p>	<p>This is included in the offset package and will be actively managed and conserved in the long term.</p>
<p>Springwood BOA</p>	<p>Springwood will be incorporated into the Southern BOA and will be actively managed and conserved</p>

Table 1 Responses to the Addendum Recommendations for Offsetting of CHGBIW and CHISGGBF

Peake's Addendum recommendations for Offsetting for CHGBIW and CHISGGBF (Addendum Section 3.2.1.3)	Response by Cumberland Ecology
Northern BOA	in the long term. This is included in the offset package and will be actively managed and conserved in the long term.
Goulburn River BOA (in its entirety)	The entire Goulburn River BOA will be actively managed and permanently conserved as an offset for the impacts of the project.
Seven Oaks BOA Areas 1, 2 and 3	As above. Areas 1, 2 and 3 will be incorporated into the Southern BOA and will be actively managed and conserved in the long term.
O'Brien property	The Proponent has committed to progress commercial discussions with this landholder. Should these not reasonably progress, the proponent has committed to acquiring an offset of similar size and quality to the O'Brien property for addressing the required additional area of 763.7 ha of ironbark-dominated forest and woodland.
Rehabilitation of 2114 ha to CHGBIW and/or CHISGGBF; and	RTCA have committed to rehabilitating 2114 ha to CHGBIW and/or CHISGGBF as per the Warkworth Rehabilitation Strategy.
\$500,000 funding to research aimed at improving rehabilitation of ground stratum plant species to CHGBIW and/or CHISGGBF.	The \$500,000 of funding to applied university research will help to improve rehabilitation of the ground stratum of the CHGBIW and CHISGGB rehabilitation works.
The recommendations regarding the impact avoidance and offsetting for WSW documented in Section 6.1 of Umwelt (2011b) as it relates to WSW.	As stated in my previous correspondence, modification of the mine plan to facilitate avoidance of WSW is not justified or required in order to ensure the survival of WSW.

3. OTHER PROPOSED OFFSETS & FAUNA

Like the Final Peer Review, the Addendum focuses on rehabilitation and offsetting for vegetation, with very little said about fauna. For this reason, both documents miss a major aim of rehabilitation and offsetting for the Warkworth Extension. That is to provide additional habitat for a suite of threatened fauna species, including those protected under the Commonwealth Environmental Protection and Biodiversity Conservation Act (EPBC Act),

that are known or considered likely to inhabit or use vegetation communities that are predicted to be impacted by the Warkworth Extension.

The Addendum concludes by stating that Putty BOA and the Bowditch property are not required to address offsetting needs for either the Warkworth or the HVO projects. However, such a recommendation does not consider that both such properties contain vegetation with high quality habitat for threatened species, particularly birds and including potential habitat for the Nationally listed endangered birds, Swift Parrot and Regent Honeyeater. For this reason, the two properties have merit for inclusion within the offset package and should be retained.

4. CONCLUSION

The current commitments by RTCA to providing rehabilitation and offsetting for Ironbark-dominated vegetation (CHGBIW and CHISGGB) now align with all recommendations of the peer reviewer, Mr Travis Peake.

Yours sincerely



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Appendix B

Appendix B | Warkworth Rehabilitation Strategy



**Rehabilitating
*Central Hunter Grey
Box – Ironbark
Woodland***

**Warkworth
Rehabilitation
Strategy:**

for
Coal & Allied

Prepared by



August 2011

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1 Rehabilitating Central Hunter Grey Box – Ironbark Woodland: Warkworth Rehabilitation Strategy

1.1 Executive Summary and introduction

DnA Environmental was commissioned by Coal & Allied to develop a strategy for the rehabilitation of the Central Hunter Grey Box (*Eucalyptus moluccana*) - Narrow-leaved Ironbark (*E. crebra*) woodlands after proposed mining at the Warkworth mine, Singleton, NSW. Central Hunter Grey Box – Ironbark Woodland and Central Hunter Ironbark – Spotted Gum – Grey Box Forest were recently determined by the NSW Scientific Committee on 12 February 2010 as Endangered Ecological Communities (EECs) under the Threatened Species Conservation Act (TSCA).

As part of the proposed Warkworth mine extension, 627.5ha of the Central Hunter Grey Box - Narrow-leaved Ironbark community is anticipated to be cleared, with approximately 2114ha of this community to be progressively rehabilitated on waste emplacements over the 21 year life of the Warkworth mine.

With the increasing numbers of vegetation communities being state and federally listed (with many of these occurring within the Hunter Valley coal fields), there is a particular need for mining companies to adopt well planned rehabilitation strategies that address a multitude issues that have not necessarily been practiced or expected in the past. In particular, rehabilitation that aims to recreate a self-sustaining woodland ecosystem of specific community types and assemblages are now being primary rehabilitation objectives or consent conditions, but improved rehabilitation standards need to be adopted if these outcomes are to be achieved.

There has been great success in establishing trees and shrubs on mine sites, and establishing introduced pastures, but here are few successful examples of “sustainable” native ecosystems, such as the Central Hunter Grey Box – Ironbark woodlands. Whilst there are many reasons for mine rehabilitation failure they are usually due to a sequence of poor management decisions and the lack of understanding about ecological successional processes, leading to the establishment of an undesirable or unsustainable vegetation community.

The most crucial part in planning for sustainable restoration of listed woodlands is to have a suitable landform with a stable substrate capable of supporting a diverse grassy woodland ecosystem. The condition and composition of the grassy understorey is equally important and it will dictate the future ability of the community to be functional in the longer-term and therefore to be self-sustainable.

There are many variables and combination of variables that need to be considered for this to be successfully accomplished and often this depends on the specific circumstances, scale and resources available at the individual mine site, but essentially translates into a well planned, integrated rehabilitation program that incorporates a range of facets including:

- Suitable management of remnant vegetation well in advance to clearing/stripping to increase soil health, reduce the weeds and the weed seed bank, while enhancing the size and diversity of the native soil seed bank;
- Undertaking pre-clearance surveys and establishing replicated references (analogue) sites in non disturbed areas to obtain baseline data and to provide reference for rehabilitation monitoring requirements and performance criteria targets;
- Surveying and identifying suitable seed collection areas, with the aim to establish a community that is similar in structure, composition and function as the reference communities;
- Using only local provenance native species associated with the target ecological community, ie species found within Central Hunter Grey Box – Iron Bark communities in the Warkworth locality;
- Establishing a well developed seed collection program that targets a range of local endemic native species that will form the foundation of the ecological community, including native trees, shrubs, grasses and herbs. Harvesting and storing summer and winter active growing grasses is also beneficial;
- Establishing and/or maintaining native seed production areas that will provide an ongoing source of native seed required for rehabilitation and to reduce pressure on extant populations;
- Securing elements of critical habitat (trees, tree hollows, logs etc) and key stone species (those difficult to propagate, rare or locally uncommon) from areas to be cleared;
- Establishing working relationships with the mining engineers and planners and providing input and feedback into rehabilitation design and topsoil management;
- Creating moderate undulating slopes typical to those of the surrounding landscapes and establishing a diversity of overland obstructions and micro topographic relief to retain mobile resources and potential flora and fauna habitat;
- Developing a network and/or maintaining relations with industry experts, researchers or other mining companies undertaking successful rehabilitation and/or rehabilitation trials;
- Undertaking rehabilitation trials to determine the most effective and appropriate rehabilitation methodologies for the target areas on your individual sites;
- Undertaking soil tests prior to stockpiling and again before application onto the rehabilitation area. Discarding or bury inappropriate soils and spreading native topsoil directly onto rehabilitation areas where possible;
- Adding soil ameliorants (eg gypsum) prior to applying topsoil or organic soil mediums according to the results of the soils analyses;
- Rapidly stabilising soil substrates and increasing organic matter by using organic soil mediums and sterile cover crops;
- Increasing and prolonging the soil organic matter and microorganism activity through the use of biosolids and/or Organic Growth Media (OGM) if applicable;
- Encouraging litter and utilising weeds to your advantage as weeds are often part of the successional process. Unnecessary disturbances should be avoided as this will help them persist. Control noxious or particularly invasive species selectively; and
- Undertaking an annual monitoring program (at a minimum) and implementing amelioration or action strategy when required.

This rehabilitation strategy subsequently aims to identify and describe key management areas involved in the rehabilitation and ongoing management of the endangered Central Hunter Grey Box – Ironbark communities on overburden emplacements at the Warkworth mine.

1.2 *Warkworth mine*

1.2.1 Warkworth mine background

Warkworth Mine is located in the Hunter Valley Coalfields approximately 15km south west of Singleton in the Hunter Valley which commenced mining in 1981. The Upper Hunter Valley has a strong historical association with the rural sector and has traditionally been dominated by a mix of grazing and cropping landscapes, with dairy farms clustered along the Hunter River floodplain. The region is also a well established grape growing area with over 80 vineyards located throughout the Upper Hunter. The thoroughbred industry is established further west near Jerrys Plains and north near Scone (Coal & Allied 2010).

The Warkworth mine is generally bounded by the Golden Highway to the north and the east, Putty Road to the south and Wallaby Scrub Road to the west. Surrounding mines and infrastructure include HVO and Wambo Mine to the north and north west, the MTCL and Mount Thorley Industrial estate to the east and Mount Thorley Mine and Bulga Mine to the south. Coal & Allied are seeking approval to extend mining into areas to the west of the existing development consent based on a 21 year footprint (Figure 1-1).



Figure 1-1. Warkworth mine showing the proposed extension boundaries (Sourced from Coal & Allied 2010).

1.2.2 Vegetation communities at Warkworth

Cumberland Ecology (Coal & Allied 2010) have undertaken comprehensive studies of the flora and fauna occurring on the Warkworth mine area and have identified six vegetation communities likely to occur within the proposed disturbance area. These communities include:

- Warkworth Sands Woodland (WSW);
- Central Hunter Grey Box – Ironbark Woodland;
- Central Hunter Ironbark – Spotted Gum – Grey Box Forest;
- Hunter Lowlands Red Gum Forest;
- Warkworth Sands Derived Native Grassland; and
- Derived Native Grassland.

The WSW and Hunter Lowland Red Gum Forest communities are listed as Endangered Ecological Communities (EECs) under the Threatened Species Conservation (TSC) Act. Central Hunter Grey Box – Ironbark Woodland and Central Hunter Ironbark – Spotted Gum – Grey Box Forest were recently determined by the NSW Scientific Committee (12 February 2010) as EECs under the TSC Act. There were no EECs or Critically Endangered Ecological Communities [CEECs] listed under the Environmental Protection Biodiversity Conservation Act (EPBC) identified within the proposed disturbance area (Coal & Allied 2010). The Warkworth Sands Derived Native Grassland and Derived Native Grasslands are not listed communities under any legislation (Coal & Allied).

There are five additional vegetation communities that occur within the general Warkworth area. These communities surround the proposed disturbance area but will not be directly affected by proposed mining operations. These communities include:

- White Box Woodland;
- Yellow Box Woodland;
- Hunter Valley Vine Thicket;
- River Red Gum Floodplain Woodland; and
- Hunter Valley River Oak Forest.

White Box and Yellow Box Woodland both fall into the State description of EEC Box-Gum Woodland and the Commonwealth listed CEEC Box-Gum Grassy Woodland, however neither of these communities will be impacted under the proposed Warkworth Extension.

1.2.3 Flora

The species list from all surveys totals more than 400 flora species, of which more than 75% are native. Two threatened flora species have been recorded within the study area since 1995, however no threatened flora species have been recorded within the disturbance area.

Lobed Blue Grass (*Bothriochloa biloba*), listed as Vulnerable under the EPBC Act, was recently recorded by Cumberland Ecology [2009]. Lobed Blue Grass was previously listed as Vulnerable under the TSC Act but has since been removed from the state listing due to a relative prevalence of this species in NSW. *Ancistrachne maidenii*, listed as Vulnerable under the TSC Act was

recorded during a previous survey of the study area [Andrews Neil, 2006]. No known populations of either of these species will be impacted by the proposed Warkworth Extension. A number of threatened flora species are known from the locality, however given the habitat within the study area, location of records in the locality and the extensive flora surveys undertaken in the study area, most of these species are considered as having a low potential to occur.

1.2.4 Impact Assessment

The primary impact from the proposed Warkworth Extension will be the clearing of vegetation, a “Key Threatening Process” resulting in the direct loss of biodiversity. Table 1-1 provides a summary of the areas of vegetation to be cleared by community type for the proposed Warkworth Extension.

The summary indicates that approximately 764.7ha of woodland communities and 447.5ha of grassland communities will require clearing for the proposed Warkworth Extension. Of the woodland vegetation communities to be cleared, the Central Hunter Grey Box – Ironbark woodlands are likely to be the most impacted on in terms of area to be cleared, with approximately 627.5ha (82%) estimated to be cleared over the life of the 21 year project. Clearing will not occur in a single event but will be phased over the life of the project. The anticipated rate of clearing of the woodland vegetation is likely to be in the order of 25.9 ha/year in the first nine years and approximately 44.3 ha/year between Year 10 and Year 21. There has already been 145.8ha of vegetation cleared under the existing approval that has been included in these estimated figures (Coal & Allied 2010).

Considerable areas of the woodland communities within the footprint of the proposed Warkworth extension were extensively cleared prior to the 1960s and as a result there are few old growth trees remaining. However due to the change in landuse since mining commenced, there are now considerable areas of regrowth woodland which provide habitat for a range of species. The proportionate impact would be greatest upon the WSW which has a restricted distribution; being found only within the locality in and around the study area.

Table 1-1. Summary of the vegetation communities and the areas proposed to be cleared (Sourced from Cumberland Ecology 2010)

Vegetation Community	Approved Extension Area	Additional Extension Area	Total Extension Area
Central Hunter Ironbark - Spotted Gum - Grey Box Forest	1.5	29.0	30.5
Hunter Lowlands Red Gum Forest	3.2	0	3.2
Central Hunter Grey Box - Ironbark Woodland	249.1	378.4	627.5
WSW	35.6	67.9	103.5
Total Woodland	289.4	475.3	764.7
WSW [Sand/Grassland]	16.7	1.4	18.1
Derived Grassland	227.1	202.3	429.4
Total Grassland	243.8	203.7	447.5
Total	533.2	679.0	1,212.2

Notes: 1. These areas are based upon the most recent and updated vegetation mapping and GIS analysis
 2. The total extension area covers a physical area of 1,271ha of which 1,212.2ha is vegetated
 3. Approximately 146.5ha of vegetation has been previously cleared from the proposed Warkworth Extension area

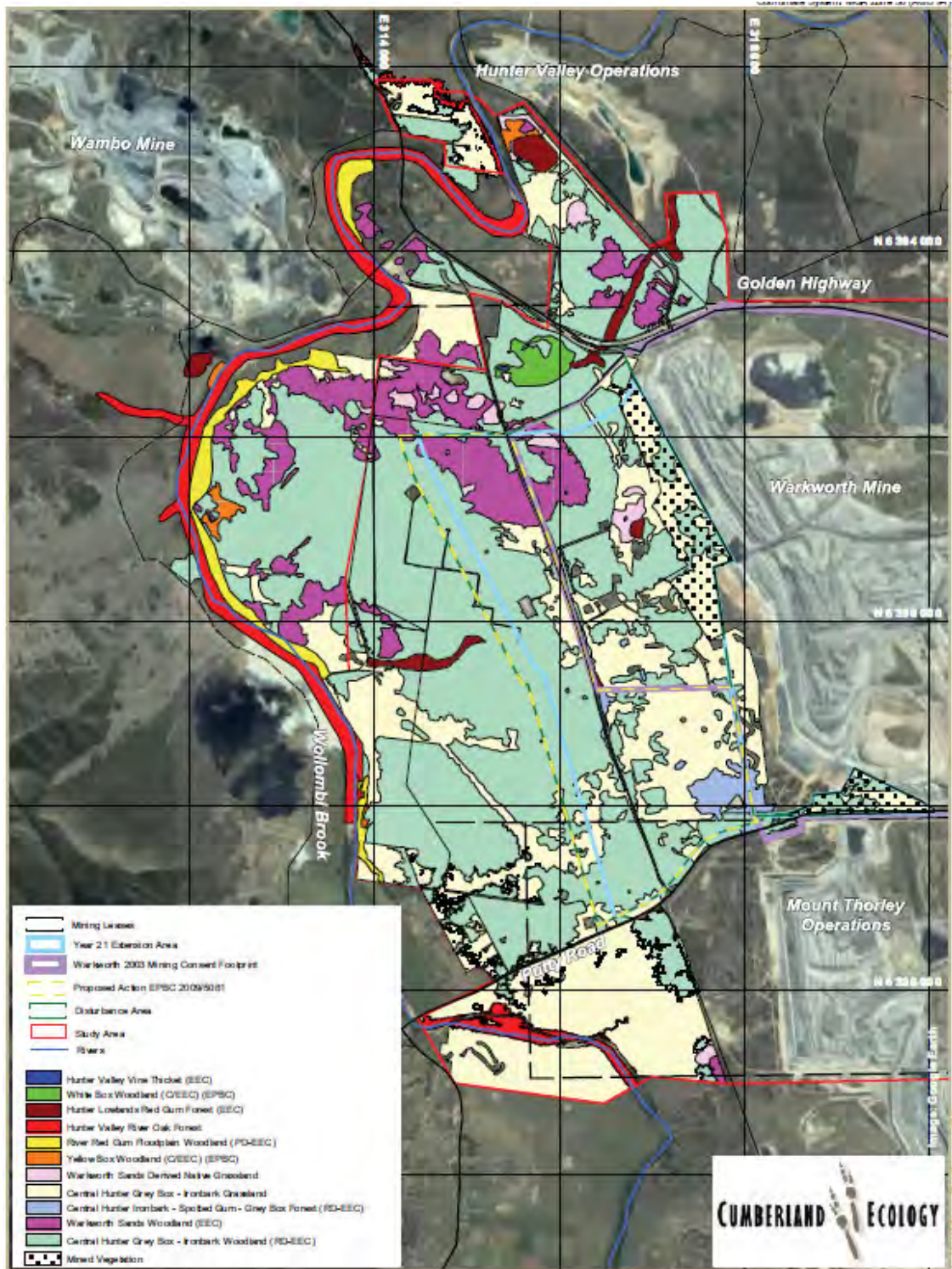


Figure 1-2. Vegetation communities occurring at Warkworth (sourced from Coal & Allied 2010).

1.3 *Variables impacting rehabilitation objectives*

Whilst there are many reasons why desired rehabilitation outcomes may not be achieved, they are usually due to a sequence of poor management decisions and the lack of understanding about successional processes, leading to the establishment of an undesirable or unsustainable vegetation community. The following table (Table 1-2) provides a summary of some basic strategies that can be collectively implemented to improve the establishment of sustainable native ecosystem on mine sites.

Table 1-2. A summary of common reasons for unsuccessful mine rehabilitation and recommended management strategies to address them

Common reasons for unsuccessful rehabilitation	Suggested management strategy
Lack of a well developed and refined rehabilitation management strategy that addresses final landuse objectives and management requirements.	Develop long-term rehabilitation management plan according to final landuse objectives and best practice rehabilitation guidelines. This should include management of and use of natural resources occurring within non disturbed and established revegetation areas.
Poor construction of the rehabilitation site	Establish a working relationship with the mining engineers and planners and provide input and feedback into rehabilitation design and topsoil management Create moderate undulating slopes typical to those of the surrounding landscapes and establish a diversity of overland obstructions and micro topographic relief to retain mobile resources and potential flora and fauna habitat
Inappropriate soil chemical properties (eg pH, sodicity, EC etc)	Undertake soil tests prior to stockpiling, and again before application. Discard/bury inappropriate soils If possible, spread native topsoil directly onto rehabilitation areas
Low or unsustainable nutrient levels	Increase and prolong the soil organic matter and microorganism activity through the use of organic mulches or growth mediums. Encourage litter and utilise weedy species to your advantage. Weeds are often part of the successional process and eventually decline from the system as the environment becomes more suitable for desirable species. Unnecessary disturbances should be avoided as this will help them persist. However, noxious or particularly invasive species may require selective control.
Wind and water erosion	Rapidly stabilise the substrate and increase organic matter by using sterile cover crops and applying mulch (eg Seed bearing native pasture hay in alternating rows). Sow with perennial ground cover species appropriate to the final landuse.
High levels of weed competition (broadleaf and introduced perennial pastures species)	Careful use of weed free topsoil and/ or topsoil management. Encourage rapid establishment of ground cover. Direct application onto or within organic mediums (biosolid/OGM) is preferred option. Mulching can reduce weed invasion but may also limit native grass establishment at high application rates. Do not use introduced perennial pasture species as these restrict establishment and recruitment of native plants. Use sterile cover crops which will initially stabilise the site and add to the organic litter in following seasons.
Poor species selection	Undertake pre-clearance surveys and establish replicated references (analogue) sites in non disturbed areas to establish baseline data and to provide reference for rehabilitation monitoring requirements and performance criteria targets Carefully select species that occur in similar environments in the local area (local provenance). These will be determined from pre-clearance surveys and/or reference sites. Include summer and winter active grasses. Use only local provenance native species associated with the target ecological community, ie species found in association with Central Hunter Grey Box – Iron Bark as per the reference sites Refine (and reduce) seed mixes to species found naturally occurring within specific vegetation communities, most suited to the resultant rehabilitation area. For example, the overburden emplacements would be more suited to vegetation assemblages such as those occurring on the rockier, less productive and marginal agricultural areas, that is, predominantly Narrow-leaved Ironbark – Grey Box – Spotted Gum communities, while the smaller drainage lines are dominated by Swamp Oak

Poor establishment success	As above. Undertake rehabilitation trials to determine the most effective and appropriate rehabilitation methodologies for the target areas on your individual sites
	Develop a network and/or maintain relations with industry experts, researchers or other mining companies undertaking successful rehabilitation and/or rehabilitation trials
Lack of endemic seed, plant propagules and organic materials	Establish a well developed seed collection program that targets a range of local endemic native species that will form the foundation of the ecological community, including native trees, shrubs, grasses and herbs. Harvest and store summer and winter active growing grasses.
	Actively manage areas of remnant vegetation, particularly native grasslands well in advance to clearing/stripping to increase soil health, reduce the weeds and the weed seed bank, while enhancing the size and diversity of the native soil seed bank
	Secure elements of critical habitat (trees, tree hollows, logs etc) and key stone species (those difficult to propagate, rare or locally uncommon) from areas to be cleared
Inability to source select seed or plant materials	This may include contracting seed collectors at least a year in advance to allow them to identify suitable collecting locations and obtain any approvals required. Some species may require planned grazing management within buffer lands.
	Establish and/or maintain native seed production areas that will provide an ongoing source of native seed required for the rehabilitation areas and to reduce pressure on extant populations;
Low seed viability and or issues with dormancy	Ensure seed has certification and/or undertake a seed viability testing or germination tests.
	Ensure invasive weeds are kept to a minimum as native grasses have staggered and prolonged germination in response to environmental variables.
Lack of follow up maintenance	Undertake regular monitoring and implement action strategy when required
Lack of understanding of ecological processes	Allow time for native grasses to establish as they have staggered dormancy and may be slower to become well established. Implement weed control with consideration for other broadleaf species – some weeds may be assisting with the recovery of the site.
	Successful tree seeding does not necessarily translate into successful rehabilitation in the longer term as high stems densities can limit ground cover, and reduce the likelihood for future population recruitment. Establish an appropriate density of trees to ensure high ground cover levels and open grassy clearings are maintained for future recruitment events
Limited rainfall	Plant local native species adapted to the local climatic conditions. Plant/sow during the autumn - spring periods.
Insect attack disease etc	Aim to encourage diversity within the vegetation community and undertake regular monitoring. Encourage spiders, insects, frogs, lizards and insectivorous birds possible by providing suitable habitat and food resources such as nesting boxes, logs, rocks, wetland areas etc.
Over abundance of pest species	Monitor the extent of predation by macropods by erecting a series of exclosures (at least 50x20m in size) in high concentration areas to exclude Kangaroos to monitor the impact and extent of browsing on the vegetation. This will enable a quantitative assessment to be made and provide evidence of and for a control program to be implemented.
	Implement rabbit/hare control programs

1.4 ***Some examples of unsustainable rehabilitation***

While there has been great success in establishing trees and shrubs on mine sites, and establishing improved pastures, there are few successful examples of “sustainable” native ecosystems, particularly in the Hunter Valley. Successful tree seeding does not necessarily translate into successful rehabilitation in the longer term. Often there is little to no ground cover leaving the site susceptible to erosion and weed invasion, particularly from *Galenia pubescens* (Figure 1-3, Figure 1-4).

Other common problems encountered include the a particularly high density of the trees and shrubs and while there is a high leaf litter component, there is limited perennial ground cover vegetation, no room for future recruitment events and in some cases, the site has been sown with non endemic species such as *Acacia saligna*, which can become invasive (Figure 1-5).

When introduced pastures species such as *Chloris gayana* (Rhodes Grass) and *Pennisetum clandestina* (Kikuyu) are used, they become very dominant and outcompete young seedlings, limit species diversity, as well as prevent further recruitment potential (Figure 1-6).



Figure 1-3. Whilst tree and shrubs have been successfully established, there is little to no ground cover leaving the site susceptible to erosion and weed invasion.



Figure 1-4. Galenia has colonised this site and while the site is stable, competition levels are too high and will restrict the establishment of desirable species.



Figure 1-5. High density of trees and shrubs limit perennial ground cover and restricts future recruitment.



Figure 1-6. High levels of introduced perennial cover provide good ground cover but tree and shrub establishment is limited and there is no opportunity for future recruitment to occur.

1.5 *Implementing a well designed rehabilitation strategy*

There are many variables and combination of variables that need to be considered for successful rehabilitation to be accomplished and often this depends on the specific circumstances, scale and resources available at the individual mine site, but essentially translates into a well planned, integrated rehabilitation program. The rehabilitation strategy could be broken down into seven broad management areas including and relating to:

1. Determination of final landuse;
2. Designing and constructing appropriate landforms and substrates;
3. Establishing baseline data and developing performance criteria;
4. Determining species selection based on performance targets;
5. Maintaining sufficient supply of endemic seed, plant propagules and organic materials
6. Undertaking rehabilitation trials;
7. Implementing best practice rehabilitation techniques (based on the above);
8. Undertaking regular monitoring and assess against performance targets; and
9. Amelioration and/or maintenance.

These broad management areas and associated management requirements have been summarized in Figure 1-7

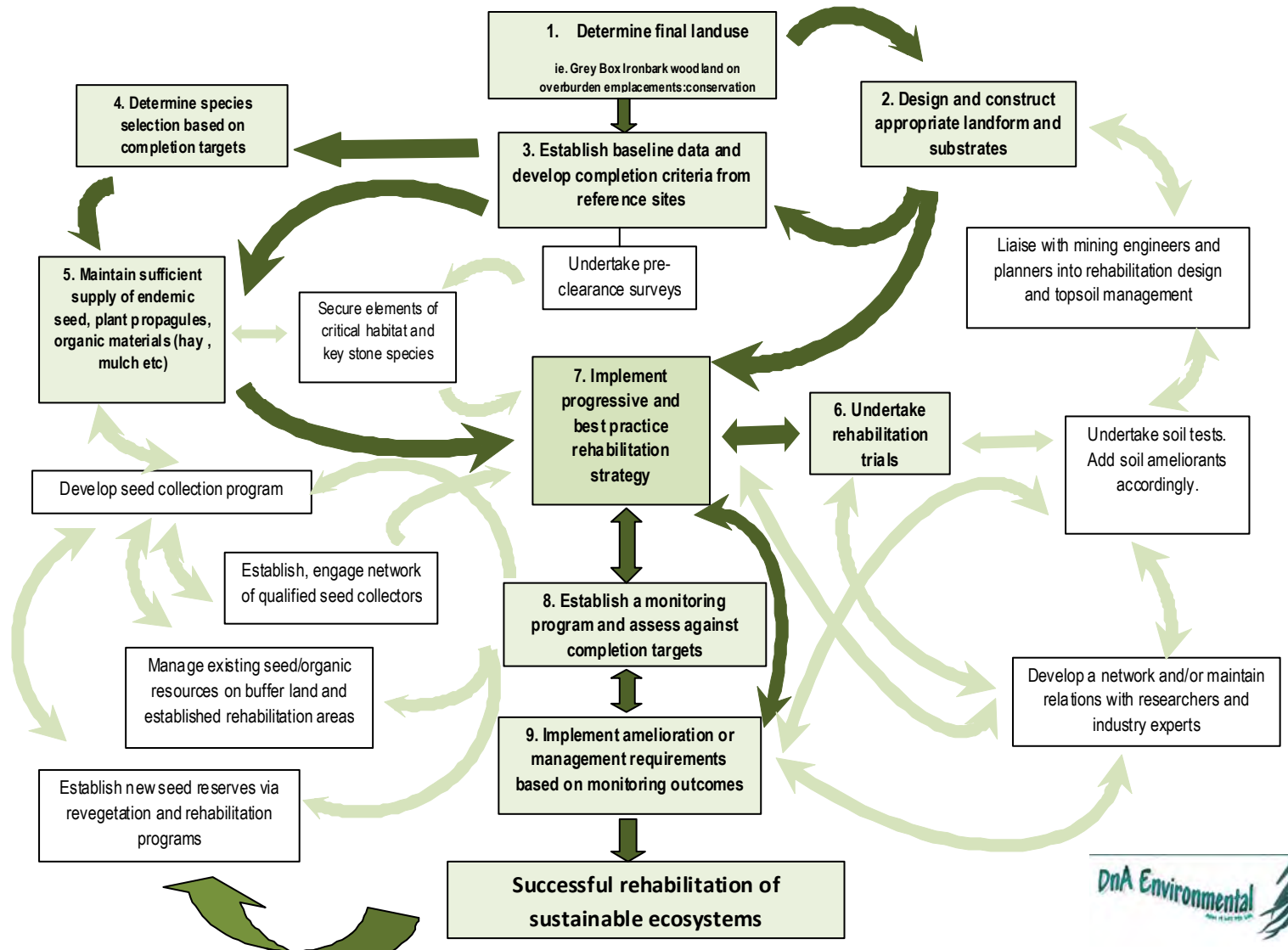


Figure 1-7. Summary of key management requirements and their relationship with successful mine rehabilitation and the establishment of sustainable ecosystems.

1.6 *Warkworth rehabilitation strategy*

1.6.1 Final land use and general rehabilitation objectives

The final land use objectives at Warkworth aim to integrate the rehabilitation of mining disturbed areas within the surrounding landscape, with multiple outcomes for sustainable agricultural production and conservation and biodiversity. This includes maximising the biodiversity and connectivity within landscape, through improved management of existing remnants and the establishment of a network of vegetation corridors.

Rehabilitation will be undertaken progressively across the mined area and will be undertaken in accordance with the REMP and will build on the management and strategic performance criteria described for each rehabilitation domain in the Biodiversity Management Plan (BMP, Coal & Allied 2010).

The primary rehabilitation objectives include:

- Re-creating approximately 2114ha of EEC woodland communities to a standard comparable to similar reference EEC communities [reference sites];
- Establishing approximately 218ha of woodland trees within pasture areas, but not necessarily conforming to any particular vegetation community;
- Recreating grassland communities with a native component on the residual disturbed mining areas;
- Establishing a network of tree corridors to ensure connectivity of woodland community areas;
- Provide additional habitat for threatened species; and
- Create an additional north/south wildlife corridor providing connectivity to other habitat.

While these form the overall rehabilitation strategy at the Warkworth mine, this rehabilitation plan aims to focus on the progressive rehabilitation of the Central Hunter Grey Box – Ironbark woodlands and derived grasslands on the major overburden emplacements.

1.6.2 Designing and constructing appropriate landforms

1.6.2.1 Landform design

The existing Warkworth Mine already results in alterations to the local landform and includes overburden emplacements, final voids, Tailings Storage Facilities (TSFs), roads and other infrastructure. Some of the overburden emplacement areas have already had some rehabilitation with areas of exotic pasture and patches of trees. The final landform will be undulating, with slopes of generally 10 degrees for overburden emplacements and up to 18 degrees for internally draining areas such as low walls and ramps consistent with approved landform design in the current MOP (Coal & Allied 2010).

The projected final landform and rehabilitation domain types for Warkworth Mine at closure and completion of rehabilitation are shown in Figure 1-8.



Figure 1-8. Final rehabilitation plan (sourced from Coal & Allied 2011).

1.6.3 Vegetation clearing and topsoil stripping

The mining sequence employed at Warkworth Mine comprises:

- vegetation stripping and topsoil management;
- open cut mining to remove overburden, interburden and coal; and
- overburden shaping and rehabilitation (Coal & Allied 2010).

Vegetation removal and topsoil stripping precede mining operations and are implemented in accordance with Coal & Allied EMS Flora and Fauna procedure and the Topsoil Stripping and Stockpiling Management procedure. The objectives are to ensure the appropriate management and mitigation of any significant flora and fauna communities, and to maintain the quality of the topsoil for subsequent use in rehabilitation (Coal & Allied 2010). The procedures include requirements for flora and fauna impact assessments in predevelopment and mining approvals, protocols for pre-clearing and clearing activities, and management measures for weed and pest control.

A pre-clearing survey is undertaken before vegetation is cleared and topsoil stripped. The purpose of the pre-clearing survey is to identify habitat trees and understory habitats such as fallen logs. Before clearing, trees suitable for timber are selectively marked and removed. Tree stands providing a viable seed source are harvested where practical. Vegetation may be chipped for rehabilitation mulch. The topsoil stripping and stockpiling management plan is produced as part of detailed mine planning and incorporated into the Mining Operations Plan (MOP). A MOP requires mining operators to actively consider the environmental and rehabilitation outcomes and to provide management systems to integrate these outcomes, mine planning and production (Coal & Allied 2010).

Topsoil is removed according to the MOP ahead of mining, using dozers whenever possible. Soil is stripped at least 15m outside the design excavation limit to provide for access tracks which avoid soil compaction. Where possible, stripped soil is placed directly onto areas where the landform reconstruction is complete, otherwise soils are stockpiled for later use. The former practice is preferable to minimise the need for storage and rehandling (Coal & Allied 2010).

1.6.4 Additional pre-stripping recommendations

Due to the importance and scarcity of woodland vegetation and habitat attributes, effort should also be made to collect and salvage as much critical habitat and key stone species as possible prior to clearing and stripping. Attention should be given to the following:

- Undertake vegetation assessments to obtain baseline data and determine species composition required for the later revegetation of that community;
- Determine suitability of topsoil by undertaking soil tests
- Determine the vegetation condition and that it does not contain an undesirable abundance of weeds;
- Implement strategy to collect seed of;
 - Grasses;
 - Forbs;
 - Shrubs; and
 - Trees.
- Remove locally rare or important species for later transplanting: and
 - Re-pot and store in nursery; and
 - Translocate to similar remnant vegetation community.
- Salvage entire mature trees bearing hollows.

1.6.4.1 Open Cut Mining Process

Mining currently occurs in the North, South, Woodlands, CD and West pits (Coal & Allied 2010). The mining technique currently employed at Warkworth Mine is open cut mining which enables resource recovery beyond the economic limits of other forms of mining. Warkworth is mined using typical open cut methods incorporating dragline and truck/shovel operations. Overburden is removed using electric rope shovels and excavators, before coal is extracted using front end loaders and excavators. Depending upon thickness, interburden is removed using shovels, excavators or draglines. Draglines are typically tasked with removal of the deeper and thicker interburden zones to expose the deepest coal seam extracted (Coal & Allied 2010).

1.6.4.2 Overburden Management

Overburden is the term given to the strata between the top-most coal seam and the land surface (Coal & Allied 2010). Almost all overburden is drilled and blasted. Interburden is a layer of rock between coal seams that is unsuitable for processing. Interburden is either ripped or drilled and blasted. Both overburden and interburden (referred collectively to as overburden) are removed by dragline, shovel, excavator or front end loader, depending on the thickness, for haulage to designated emplacements or to areas where mining is complete within the pit. Overburden is transported and disposed of within mined out sections of the open cut mine to create a final landform. The elevation of the final landform is generally higher than the pre-mined elevation due to swelling of the excavated soil that is disposed, which is typically in the order of 20-30% of the in-situ volume. The placement of overburden occurs in accordance with the mine plans for each of the pits at Warkworth Mine. Overburden material may also be transferred to Mount Thorley, via the bridge crossings over Putty Road, to assist in creation of the final landform.

Where overburden contains potentially acid forming materials, when exposed to oxygen, this could lead to acidification of surface water runoff. Net acid producing potential, pH and total sulphur are used to determine the acid generating potential. Testing at MTW indicates that although sulphide materials as pyrite [FeS₂] are known to occur, their content is relatively low [average sulphur content 0.46%]. With natural buffering capacity, these materials have low acid rock drainage potential. Drainage of water runoff which may be saline is directed to the mine water system (Coal & Allied 2010).

1.6.4.3 Overburden shaping and rehabilitation

Rehabilitation of the disturbance footprint is an integral component of the mining operations and is conducted progressively over the life of the mine. Rehabilitation plans are produced as part of the detailed mine planning. These plans form part of the MOP and are approved by I&I NSW. The current consent authorises the transfer of overburden between Warkworth Mine and Mount Thorley Mine to assist with final landform shaping and rehabilitation. The existing approved overburden heights for Warkworth Mine and Mount Thorley are RL 160m AHD and RL 155m AHD, respectively.

1.6.5 Maintain relations with mining department

As part of the rehabilitation strategy, overall landform design and topsoil management practices could be further refined by maintaining or establishing good communications with the mining department. Often landform topography, substrate health and surface relief are not conducive to or advantageous when it comes to ecosystem function and vegetation establishment. Often rehabilitation areas are left with steep slopes with particularly smooth surfaces which are unable to reduce surface runoff, and do not provide essential microsites for the retention of soils and seeds. In some cases, the use of inferior overburden are used which also inhibit rehabilitation efforts, and can be detrimental to rehabilitation goals. Other common problems also encountered and may include:

- Inferior topsoil or spoil materials due to a lack of good management and/or soil testing;
- Topsoil stockpiles which are too high and potentially destroy soil organisms and seedbanks;
- Topsoil that had been handled too many times and loses structure;
- Bulldozer tracks which extend along the contour, which subsequently exacerbate erosion and rilling; and
- Inappropriate application and/or application rates of soil ameliorants, due to a lack of soil testing.

Many of these issues could be readily resolved with good communication and management between departments and their contractors.

1.7 *Establishing baseline data and developing performance criteria*

In any rehabilitation project it is fundamental to determine what constitutes the type of community being rehabilitated, what it is comprised of and what the key characteristics are that will need to be identified and assessed to determine if successful rehabilitation has been accomplished. These can be obtained through the process of establishing baseline data from undisturbed areas of representative communities, commonly referred to as reference sites. These sites are monitored simultaneously throughout the life of the rehabilitation project and fundamental aspects will be assessed and compared to the rehabilitation area to determine if rehabilitation is progressing in a satisfactory trajectory, or enable unsatisfactory aspects to be detected at an early stage of the project.

As part of the rehabilitation strategy, a series of reference sites will need to be established using a quantitative methodology which will also be used to develop performance criteria. An example of a comprehensive monitoring program is provided in section 1.15

1.8 *Determine species selection based on performance targets*

The Central Hunter Grey Box – Ironbark woodlands have been listed as an Endangered Ecological Communities and are protected under the TSC Act. A general description of the listed community as described by the Threatened Species Scientific Committee (TSSC) is given section 1.8.1. A description of the community as it occurs at Warkworth is provided in section 1.8.2. Species used in the revegetation project should be consistent with the reference sites and conform to these community descriptions.

1.8.1 Central Hunter Grey Box – Ironbark Woodlands Community profile

Scientific name: *Central Hunter Grey Box - Ironbark Woodland in the NSW North Coast and Sydney Basin Bioregions* (DEC NSW 2010)

Central Hunter Grey Box – Ironbark Woodland typically forms woodland dominated by *Eucalyptus crebra* (Narrow-leaved Ironbark), *Brachychiton populneus* subsp. *populneus* (Kurrajong) and *Eucalyptus moluccana* (Grey Box). Other tree species such as *Angophora floribunda* (Rough-barked Apple) and *Callitris endlicheri* (Black Cypress Pine) may be present and occasionally dominate or co-dominate. A shrub layer is often present and common shrub species include *Notelaea microcarpa* var. *microcarpa* (Native Olive), *Breynia oblongifolia* (Coffee Bush), *Bursaria spinosa* subsp. *spinosa* (Native Blackthorn), *Cassinia quinquefaria* (Cough Bush) and *Dodonaea viscosa* (Hop Bush). Sub shrubs may also be common and include *Solanum cinereum* (Narrawa Burr), *Phyllanthus virgatus* (Spurge) and *Maireana microphylla* (Eastern Cotton Bush).

Ground cover can be moderately dense to dense, and consist of numerous forbs and grass species as well as a small number of ferns, sedges and twiners. The more common species include *Cymbopogon refractus* (Barbed Wire Grass), *Aristida ramosa* (Three-awned Wire Grass), *Dichondra repens* (Kidney Weed), *Cheilanthes sieberi* subsp. *sieberi* (Poison Rock Fern), *Cheilanthes distans* (Bristly Cloak Fern), *Chloris ventricosa* (Tall Chloris), *Desmodium varians* (Variable Tick-trefoil), *Calotis lappulacea* (Yellow Burr Daisy), *Lomandra multiflora* subsp. *multiflora* (Mat Rush), *Brunoniella australis* (Blue Trumpet) and *Glycine tabacina* (Variable Glycine).

1.8.2 Description of the Warkworth community

The Central Hunter Grey Box – Ironbark woodland is the most dominant vegetation at the Warkworth mine and is comprised of Central Hunter Grey Box (*Eucalyptus moluccana*) and Narrow-leaved Ironbark (*E. crebra*), but often occurs in association with Bulloak (*Allocasuarina luehmannii*) and White Feather Honey-myrtle (*Melaleuca decora* (Coal & Allied 2010)). Common shrubs include Fan Wattle (*Acacia amblygona*), Native Blackthorn (*Bursaria spinosa*) and Coffee Bush (*Breynia oblongifolia*). The understorey is commonly comprised of perennials such as Purple Burr-Daisy (*Calotis cuneifolia*), Blue trumpet (*Brunoniella australis*), Kidney Weed (*Dichondra repens*), Blue Flax Lily (*Dianella revoluta*), Wattle Matt-rush (*Lomandra filiformis*), Common Fringe-sedge (*Fimbristylis dichotoma*), Threeawn Speargrass (*Aristida vagans*) and Rock Fern (*Cheilanthes sieberi*, (Coal & Allied 2010)).

1.9 **Maintaining sufficient supply of endemic seed, plant propagules and organic materials**

Large quantities of native seed and mulch are anticipated to be required to rehabilitate the significant area of proposed mining disturbed land. At Warkworth this is expected to be around 2114ha (Cumberland Ecology 2007).

To implement large scale rehabilitation, activities surrounding the seed collection and plant materials will need to be planned in the early stages and strategies put in place to ensure that adequate resources will be available when required. Some major activities may include:

- Management of native grasslands particularly on buffer lands for harvesting; and
- Establishing native seed orchards.

1.9.1 Management of native grasslands for harvesting

Strategic grazing is often claimed to be one of the most robust solutions for improving unhealthy soils and pastures and should be implemented wherever possible. Strategic grazing and other management options that could be considered are described in Table 1-3. One or a combination of methods may be used but the best option will vary between pasture composition and seasonal conditions. It is important to closely monitor each site to ensure optimum timing, application rates and duration.

Weed infestation is one of the primary reasons for a site to be deemed “potentially suitable” (as opposed to “suitable”), thus in some sites weed control programs could be implemented to improve the density, particularly in more favourable stands. Many weed species invade areas of disturbance, therefore minimizing disturbance levels can be an effective way to reduce the level of weed species. Maintaining or encouraging good ground cover of desirable perennial species, generally results in undesirable conditions for weeds to establish but this may take time.

Table 1-3. Management options for improving native pastures

Target for control	Method	Management options
Annual grasses (eg. Vulpia, Barley grass, Wild Oats and Ryegrass)	Grazing for short periods at high stocking rates (eg. Rotational grazing)	Graze the target species without affecting native perennial pastures. Graze late summer after seed set of C4 species and late winter to early spring before native grasses commence active growth. It will be important to closely monitor each site.
	Grazing for short periods at high stocking rates (eg. Rotational grazing)	Encourage vigorous growth and allow recovery of native perennial species. Improved soil conditions and establishment of dense swards of native grasses are not conducive to weed invasion, but this may require a few seasons to achieve, depending on the conditions of the pasture in question. Most native pastures benefit from infrequent grazing to encourage new growth and recruitment niches, providing they are able to set seed at least every two years.
	Burning	Burning can be a useful tool in managing native ecosystems but can be detrimental in some circumstances if used incorrectly (eg too hot and too frequent). Often there are many variables to consider and usually the preferred option in agricultural systems is strategic grazing management where it is useful for livestock fodder. Some studies have found that a spring burn can reduce the abundance of introduced annual grasses, but may favour broadleaf weeds.
	Spray Topping using non selective herbicides	After first series of frost both C3 and C4 species should be dormant and spray topping at approx 400 – 700 ml/ha can dramatically reduce the abundance of annual grasses without having a detrimental effect on the native grasses. As pasture composition and seasonal conditions vary between districts, consult your local agronomist for appropriate application rates and guidelines. <i>Austrodanthonia</i> species (Wallaby grasses) are particularly susceptible to knockdown herbicides so care should be taken. This method is used in the pasture cropping system prior to direct drilling and favours the proliferation of C4 grasses.
	Reduce nitrogen	Many introduced annual grasses prefer high nitrogen levels and their dominance is usually encouraged via set stocking grazing regimes. Some recent studies have used sugar to lower abnormally high nitrogen levels that are typical in degraded paddocks. Sugar, enhances the activity of nitrogen loving microbes. Increasing organic carbon content is also a slower but useful alternative.
Broadleaf annuals (eg Fireweed, Paterson’s Curse, Thistles, Capeweed,	Grazing for short periods at high stocking rates	Rotational grazing allows ‘rest and recovery” of the paddock and improves soil conditions, encourages vigorous growth and establishment of native perennial species. Improved soil conditions and establishment of dense swards of native grasses are not

Target for control	Method	Management options
Heliotrope)		conducive to weed invasion, but this may require a few seasons to achieve depending on the level of degradation of the pasture in question.
	Broadleaf herbicides (eg. MCPA, dicamba, metsulfuron, paraquat, diquat, simazine, chlorsulfuron etc)	These broadleaf specific herbicides can be used whilst pastures are actively growing but the tolerance of the individual species, as are the rates of application required, are highly variable. Some species of native grasses may be more susceptible than others so consult your agronomist prior to spraying. This method of control is likely to kill non-target but desirable species such as native forbs (eg Glycines, Desmodium, Lotus etc) as well as non native but important medics and clovers.
	Slashing/mulching	Many broadleaf weeds can be brought under control by slashing prior to seed set. The organic matter is beneficial for improving soil structure and protecting the soil surface, whilst the weed seed bank slowly declines. Many deep rooted weeds can play an important role in ameliorating degraded soils by uptaking essential nutrients and minerals that could not otherwise be utilised by shallower rooted species. Often, if disturbances are minimised, weed species gradually disappear over time as they are replaced by more desirable grasses as the soil condition improves.
	Burning	Burning can be a useful tool in managing native ecosystems but can be detrimental in some circumstances if used incorrectly (eg too hot and too frequent). Often there are many variables to consider and usually the preferred option in agricultural systems is strategic grazing management where it is useful for livestock fodder.

1.9.2 Harvesting native grasses

Although the native grasses have been given great recognition in the last decade, they present some challenges when it comes to their harvesting, sowing and establishment requirements and techniques. Many native grasses have spiky seeds containing long bristles (awns) and/or are often fluffy. In addition variations in dormancy, germination and establishment requirements are exhibited between species and within genetically different populations. Thus biological constraints of many native grass species make harvesting, cleaning and sowing difficult using conventional methods. Waters *et al* (2000) provide additional reading material and techniques for harvesting, sowing and establishing native grasses.

1.9.2.1 Harvesting equipment

A variety of harvesting methods can be used for the collection of native grass seed. Harvest methods will largely depend on the species type, size of the harvest area, presence of obstructions and weed infestations. If obstructions and weed infestation occur in patches, these can easily be avoided by harvest machinery. If weed infestation is similar in height to the desired harvest species, then harvesting by machinery is not recommended. Most operators will not undertake the harvesting due to contamination of the machinery as well as the seed. Table 1-4 provides a basic guide to the type of harvest machinery currently available and suitability depending on the harvest stand. New machines and techniques are constantly being developed so it is probably best to contact your nearest grass experts to discuss further options and obtain additional advice.

Harvest timing will generally depend on the species type and if the season is typical or atypical for the area. Altitude can also influence seed ripening and maturity between different areas but summer is

usually the harvesting season. The best advice is to keep a close check of species in your area to determine when harvesting is likely to be appropriate.

Table 1-4. Summary of available harvesting machinery and techniques that can be used with variously sized species and stand sizes and relative effort requirements.

Harvest method	Species height	Stand size	Effort
Roller brush harvester: Rosevale Reaper	Low-medium	Large	Low
Roller brush harvester: Grasshopper	Low-medium	Large	Low
Roller brush harvester: Scorpion	Low-medium	Large	Low
Tractor/slasher/ hand rake	Low-medium	Medium -small	High
Silage harvester	Medium	Large	Medium
Whipper snippers/scythe/ hand rake	Any	Small	High
Secateurs	Any	Small or isolated plants	High
4WD motorbike with collection tray	Medium-high	Small-medium	Medium

1.9.3 Establishing seed production areas

Currently the demand for native seed far outweighs the supply, and demands are likely to peak with the implementation of significant restoration projects driven by the Catchment Management Authorities and other Landcare initiatives and the increasing demand from mining companies. Shortages in native seed supply have been exacerbated by prevailing drought conditions and the shortage of experienced seed collectors. Without appropriate protocols and frameworks in place, obtaining seed and tubestock of local provenance across the catchment is likely to be difficult and there is potential of causing harm to the environment through the introduction of incorrect genetic material, species and/or structural compositions of communities being restored. There is also potential to further impact on and degrade remnant vegetation by over collection of seed from some areas as there is no regulated network of seed collectors or designated seed collection areas to cater for various provenances within the catchments.

Seed production areas or native seed orchards are important in large scale restoration initiatives for several reasons including:

- There is not enough native seed to meet the ever increasing demand and diversity of our revegetation and restoration work;
- The quality and quantity of seed collected from wild populations is often unreliable;
- Harvesting seed from the wild is also constrained by ethics, permits, legislation, licensing and travel time; and
- The drought, plant and seed predation and diminishing healthy stands of remnant vegetation have contributed to this seed shortage.

Greening Australia are actively promoting the need for Seed Production Areas, particularly to landholders groups. The following extract is from Greening Australia's (2008) information brochure about the Seed Production Areas.

1.9.3.1.1 What is a Seed Production Area?

Seed Production Areas (SPAs) are areas where native plants of known seed source are grown to produce seed. This can be done using a horticultural type method or as part of a mixed biodiversity planting. Greening Australia (GA) is encouraging and assisting land managers to establish SPAs to

bolster the supply of understorey species and complement the seed sourced from wild populations or Seed Collection Areas (SCAs).

The establishment of SPAs represents an innovative solution to:

- Securing much needed understorey species and improving regional biodiversity;
- Ensuring a continued supply of known provenance seed;
- Providing opportunities for alternative land use and income;
- Planting multi functional vegetation – windbreaks, soil improvement;
- Increase the availability and genetic diversity of local native seed; and
- Providing land managers with a guaranteed purchaser and distributor of seed.

1.9.3.1.2 Types of Seed Production Areas

1. Mixed species environment restoration includes seeds or plants of known provenance that are commonly available and either direct seeded or planted as part of revegetation works. This seed production method is suitable for commonly used larger trees and shrubs and is both low risk and low maintenance. The disadvantages are that the site is likely to be remote and therefore harder to manage and harvest. The seed is likely to attract lower market values, although the volumes may be higher. Some farmers utilise the seed from these areas for additional revegetation in a 'grow your own' approach.

2. Same species tree lines are also suitable for medium to tall shrubs. This method is suitable for larger areas and those with a high disturbance history. These sites have an added advantage of delivering other environmental benefits such as windbreaks, visual screens, habitat corridor linkages and opportunities for crash grazing to suppress weeds.

3. Mounded rows suitable for herbs, small shrubs and grasses are ideal for smaller intensive areas under 2 ha. The mounds are covered with weed mat or mulch to minimize weed competition and contamination to collected seed. Maintenance between the rows can either be mowing or spraying or a combination of both depending on equipment. Irrigation runs down the centre of the mound on drip irrigation.

4. Mounded rows with weed mat covering the entire area are suitable for small shrubs, scramblers, creepers, herbs and grasses in areas of high weed infestation and for species that eject or rapidly release seed. The weed mat provides a clean ground surface to assist harvesting. Irrigation runs down the centre of the mound on drip irrigation.

5. Containerised boxes suitable for herbs and grass. This is a highly intensive system requiring good irrigation and infrastructure. Although labour intensive, this approach has the potential to produce high market value seed from species less commonly collected or grown. Growing plants in such a regulated environment means management and harvesting seed is more controllable.

6. Trellised rows suitable for climbers and scramblers and small areas. The system makes harvesting these species easier but requires additional structures.

1.10 *Undertaking rehabilitation trials*

1.10.1 Establish appropriate soil substrate

The most crucial aspect of this rehabilitation trial is to first establish an appropriate substrate capable of supporting a grassy understorey. There have been some studies investigating the establishment and persistence of native grasses directly onto raw spoil compared with areas spread with topsoil (Windsor *et al* 2000, Huxtable *et al* 2005). Whilst initial plant numbers were low, several species of native grasses persisted better in raw spoil material due to the absence of weed competition, with much reduced costs associated with topsoil spreading and ongoing weed control. Best establishment however, resulted from the direct application of topsoil from native grasslands that had been directly applied onto raw spoil material (Huxtable *et al* 2005).

White Box (*Eucalyptus albens*) - Yellow Box (*E. melliodora*) – Blakely's Red Gum (*E. blakelyi*) Grassy Woodland and Derived Native Grassland is another EEC listed under the NSW TSC Act and is also a CEEC listed under the EPBC Act. This community has received considerable attention and been the subject of extensive research. Studies by Prober (1996) found that that soil and parent materials had pH values between 6 – 6.5, but were more alkaline on the more northern extent of their distribution (>7pH units). In addition, soils in the north more commonly had a heavier surface texture and a uniform profile (Prober 1996) indicating the need for soil amelioration and/or additives if it is to sustain a woodland ecosystem. It is however a usual revegetation practice in the Hunter Valley to apply gypsum to revegetation areas prior to seeding, but soil tests may improve reliability of the rates actually required.

Given these results, careful use of topsoil material is required. There are also numerous trials using biosolids and Organic Growth Medium (OGM) occurring at various mine sites around the Hunter Valley, with most reporting significant improvement in pasture establishment, tree growth and soil physical properties (eg slaking) with little to no increases in weed competition in the short term. The additional organic material and associated biological activity is likely to be beneficial to the establishment of the grassy understorey vegetation and reduce erosion.

As a result of these findings and the potential limited availability of suitable topsoil and often the need to stockpile it, three different strategies are likely to be required depending on the circumstances. Three main scenarios that could be trialed include:

1. Direct application of native topsoil;
2. Stockpiled native topsoil;
3. Raw spoil material plus biosolid and/or OGM; or
4. Native topsoil plus OGM.

1.10.1.1 Direct application of topsoil

At the Hunter Valley Operations (HVO) existing rehabilitation trials have shown that the careful management of topsoil can lead to highly successful rehabilitation, including the establishment of a diverse grassy understorey, with many characteristics similar to those at Warkworth. These findings are also consistent with studies undertaken by Huxtable *et al* (2005). Therefore, where possible the direct application of suitable native topsoil should be used.



Figure 1-9. HVO rehabilitation using direct application of topsoil (left) has led to a diverse grassy understorey that are typical of the local area including those at Warkworth (right).

1.10.1.2 Stockpiled native topsoil

In many situations it is not likely to be possible to directly apply topsoil material onto rehabilitation areas and some stockpiling will be required. Best practice techniques should include soil testing prior to stockpiling and ensure no unsuitable material is mixed with good topsoil. Stockpiles should be rapidly stabilized at and weed management following stockpiling should also be undertaken including control of introduced perennial grasses if required.

When a suitable rehabilitation area becomes available, topsoil should again be tested and respread onto the area with minimal handling. A sterile cover crop is likely to be required to ensure rapid site stabilisation.

1.10.1.3 Raw spoil plus addition of Biosolids or Organic Growth Media

Raw spoil has proven to provide more satisfactory establishment and persistence of native grasses than using topsoil retrieved from areas of modified agricultural land that are dominated by introduced pastures and weeds (non native topsoil), largely due to a significant reduction in weed competition (Windsor et al 2000, Huxtable *et al* 2005). However in some spoils, the low levels of nutrient and organic matter, may not be capable of supporting a diverse plant community overtime, therefore resulting in a population decline despite initially good establishment (Huxtable *et al* 2005). Subsequently, an organic additive such as Biosolids or Organic Growth Medium (OGM) may be required.



Figure 1-10. Raw spoils clearly require soil amelioration and additives if they are to support a diverse plant community

1.10.1.4 Addition of other organic materials

Smits (2008) trialed the effectiveness of different mulches in mine rehabilitation: short-term effects on the surface stability and the conditions for plant growth at the Cowal Gold Mine, NSW. Her study, a ten month trial (June 2007 to April 2008) quantified the relative effectiveness of different mulches in stabilising surface soils, improving seedbed conditions for the establishment of a cover crop, and improving landscape function of sodic soils. The mulch treatments investigated included scattered timber, manure, pasture hay, cypress pine woodchips, lucerne hay, rock and nil mulch (control). Prior to the application of the mulches, all the plots (including the control) were treated with gypsum (3t/ha) and sown with a sterile rye corn seed (60 kg/ha).

In broad terms, all mulches (with the exception of scattered timber), significantly improved the conditions for plant growth compared to the control. Overall, the lucerne hay and woodchip mulches were the most effective in improving conditions for plant growth and increasing biomass over the trial period. The woodchip and manure mulches were most effective at increasing the stability of soil macro-aggregates > 2 mm. However, the woodchips also increased the tendency for the <2 µm clay fraction to disperse. All mulches (except scattered timber) led to significant increases in landscape function and reduced rill erosion when compared to the control; however, the woodchip treatment performed the best in the short term.

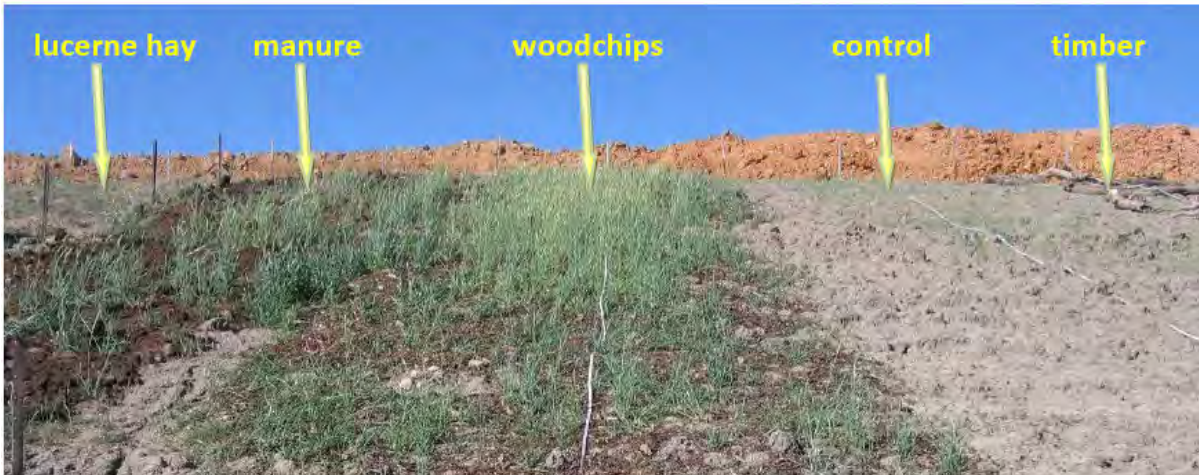


Figure 1-11. Rye corn cover crop growing on the lucerne, manure, woodchips, control and timber (left to right), October 2007 Note: The control and timber treatment have very low biomass (Smits 2008).

It has also been established in this study that:

- Gypsum and cover crops without a mulch cover failed to stabilise and improve the landscape at CGM (even when irrigated during drought); however, when used with mulch, they contributed to improved landscape function in the short-term, and
- Mulch is only one step in landscape development on sloping rehabilitation areas prone to erosion — all available strategies (i.e. good landform design, chemical amelioration, cover crops, mulch cover and implementation of regular monitoring programs) must be employed in the early stages of rehabilitation at CGM to ensure rehabilitation success.
- The major benefit of mulch application was protection of the soil surface from raindrop impact and overland flow and the subsequent flow-on effects, including the maintenance of the surface soil structure, improved infiltration and reduced erosion.

Figure 1-12 depicts the LFA indices of nutrient cycling, stability, and infiltration respectively, of the different mulches average across subsoil and no subsoil as measured at March 2008 (Smits 2008). As expected, the mulches woodchips, hay, lucerne, rock and manure consistently out competed the control and timber mulches in the LFA indices.

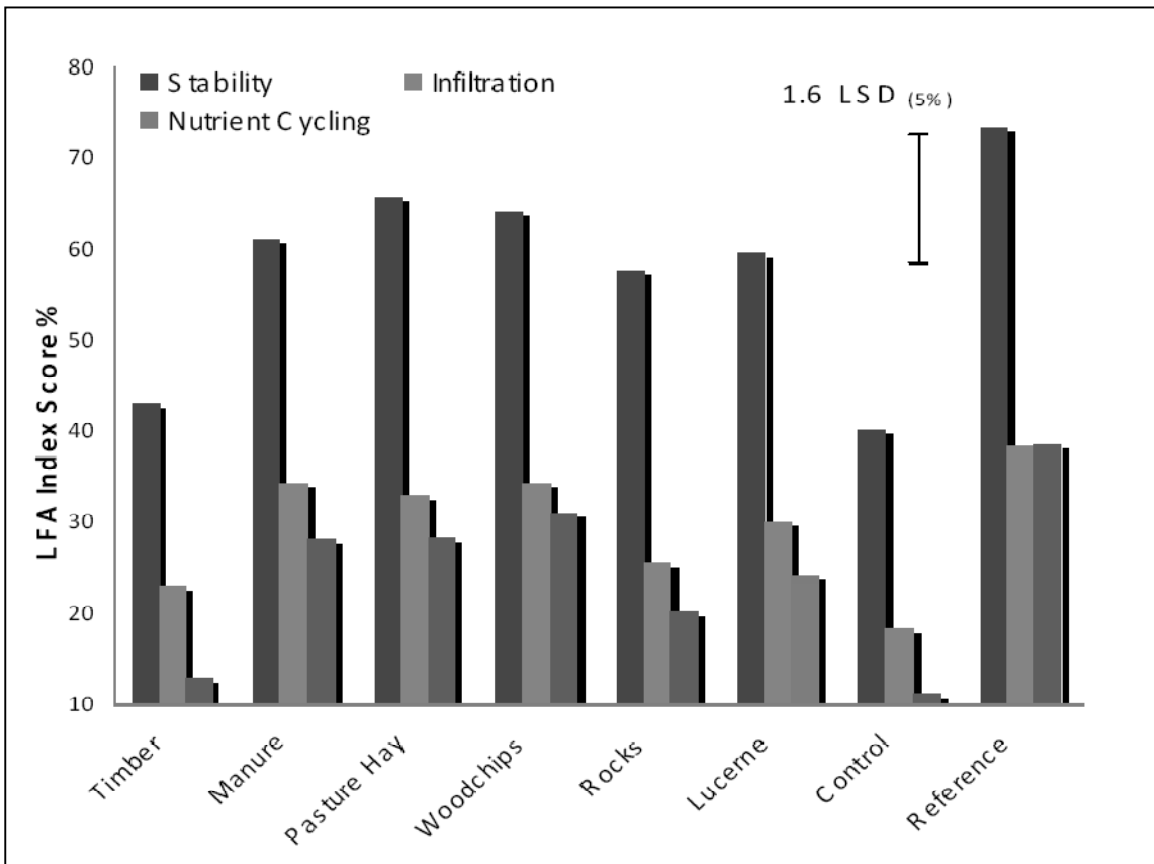


Figure 1-12. Landscape Function Analysis (LFA) indices in March 2008 (Reference site for comparison – Summerfield 2006) from Smits (2008).

Table 1-5 provides a summary of positive and negative effects of each surface treatment (Smits 2008). Due to the ready availability of woodchips and native pastures on RTCA buffer land and their positive effects on surface stabilisation, the inclusion of wood chips and seed-bearing pasture hay in the rehabilitation trials warranted.

Table 1-5. Summary of positive and negative effects of each surface treatment (Smits 2008)

Mulch treatment	Positive effects	Negative effects
Manure	<ul style="list-style-type: none"> ▪ Increased landscape function ▪ Soil protection ▪ Increased soil organic carbon (OC), soil moisture, and aggregate stability ▪ Reduced soil ESP ▪ Supported significantly more biomass than the control ▪ High levels of plant nutrients (N & P) 	<ul style="list-style-type: none"> ▪ Average dry biomass levels were less than one third of biomass supported on the woodchip treatment ▪ Caused excessive levels of exchangeable Mg ▪ Water repellent surface caused lower infiltration than other mulches; this increased runoff and led to erosion ▪ Saline properties (reduced growth of sensitive plants)
Pasture hay	<ul style="list-style-type: none"> ▪ Increased landscape function ▪ Reduced soil temperature ▪ Increased aggregate stability ▪ Had its own seed store ▪ Supported significantly more biomass than the control ▪ High levels of plant nutrients (N & P) 	<ul style="list-style-type: none"> ▪ Soil OC still rated low ▪ Overstocking effect (due to seed in the mulch) reduced plant performance ▪ Average dry biomass levels were almost half the biomass on the woodchip treatment
Cypress pine woodchips	<ul style="list-style-type: none"> ▪ Increased landscape function ▪ Soil protection ▪ Supported significantly more dry biomass (average) than all other mulches ▪ Large improvements to soil temperature, infiltration, soil water, soil OC and macro-aggregate stability 	<ul style="list-style-type: none"> ▪ Increased clay dispersion due to: ▪ increased infiltration which leached electrolyte (gypsum) from the surface organic and humic acids from decomposition acting to repel clays in soil solution. This negative effect can be managed with increased or multiple applications of chemical ameliorants such as gypsum which would reduce the dispersive properties of the soil until the landscape is self-sustaining).
Rocks	<ul style="list-style-type: none"> ▪ Increased landscape function due to the protection of soil surface ▪ Supported significantly more biomass than the control ▪ Provided permanent soil protection 	<ul style="list-style-type: none"> ▪ May limit future management options ▪ Soil moisture, temperature, OC and macro-aggregate stability were not significantly improved ▪ Average dry biomass levels were less than half of biomass on the woodchips
Lucerne hay	<ul style="list-style-type: none"> ▪ Increased landscape function ▪ Soil protection ▪ Increased aggregate stability ▪ Reduced soil ESP ▪ On average supported significantly more biomass than the other mulches (excluding woodchips) 	<ul style="list-style-type: none"> ▪ Presence of a mould or an allelopathic effect delayed germination ▪ Soil OC still rated low ▪ Expensive
Timber	<ul style="list-style-type: none"> ▪ None, but could become an important addition to the landscape development in the long-term if combined with mulch. Logs can encourage soil biota such as ants. These create bio-pores, e.g. tunnels and chamber (increasing infiltration), and assist in nutrient cycling and aeration of the soil. 	<ul style="list-style-type: none"> ▪ No soil cover protection led to rain splash impact and high velocity overland flow leading to increased sheet or rill erosion ▪ No improvements to the soil or seedbed ▪ Relatively no improvements to the ability of the landscape to capture and retain vital resources ▪ Conditions for plant growth were not ideal (reflected by low biomass) ▪ Makes future management difficult (e.g. restricts machinery)
Control (gypsum and cover crop only)	<ul style="list-style-type: none"> ▪ None ▪ Although the dispersive behavior was less than other mulches (but still unstable) as gypsum had not yet been leached from the system, erosion was prevalent 	<ul style="list-style-type: none"> ▪ Perfect example of a dysfunctional landscape ▪ Rye corn cover crop failed due to poor conditions for growth, an unstable surface and the landscape's ability to capture and retain vital resources. ▪ Poor infiltration and nutrient cycling processes

Following the initial results of these revegetation trials, trials undertaken by Jenny Smits (ANU Honours student) showed that the soils of the Lake Cowal area require direct contact and cover with some form of mulching material. Her studies have initially indicated that woodchips and pasture hay provide better rapid stabilisation and biological requirements than other forms of mulch treatments, but any mulch was better than none.

At Cadia Valley Operations, studies have been undertaken to determine best practices revegetation of alkaline, saline and nutrient deficient tailings materials (Reid 2004, 2009). Her research indicated that while vegetation can become established for directly sowing into the tailings materials, higher biomass was produced in sites covered with topsoil or biosolids materials. Nutrient deficiencies, especially phosphorous were also found to be a limiting factor and required repetitive applications over time.

The results to date indicate that the direct application of seed without additional soil conditioning or mulch treatments is not a viable rehabilitation technique. As a result of these studies, better rehabilitation outcomes can probably be obtained using a combination of methods, ensuring good ground preparation and ameliorants, mulching using organic material in combination with the establishment of annual and perennial vegetation. Further objectives can then be achieved using additional seeding, planting and the introduction of missing habitat features such as logs.

1.10.2 Experimental design

The primary objective in undertaking the rehabilitation trials is to create a native understory that is comparable to the Central Hunter Grey Box – Ironbark woodland occurring on overburden emplacements at the Warkworth mine. The large proportion of the revegetation strategy described above can be undertaken with much less uncertainty and subsequently is not the focus of the trials at least in these early stages. Thus the main emphasis of the trials is to establish native grasses (or native understorey) into three different substrate preparations. Once successfully established, additional revegetation activities can follow.

Little emphasis has been placed on establishing the tree and shrubs component at this point, as it is particularly important to manage and control the highly invasive *Galenia pubescens* which tends to rapidly invade new rehabilitation areas. The premature establishment of the trees and shrub could potentially limit weed control options which could result in rehabilitation failure.

1.10.2.1 Experimental treatments

The following diagram illustrates a proposed trial design that will test the effectiveness of:

1. Soil substrate and site preparation techniques
 - a. Direct application of native topsoil;
 - b. Application of stockpiled native topsoil; and
 - c. Raw soil overburden and the addition of biosolid/OGM;
2. Application of mulch;
 - a. seed-bearing pasture hay;
 - b. woodchips; and
 - c. no mulch
3. Application of native grass seed (species will depend on availability):
 - a. With grass seed; and
 - b. Without grass seed.

The factorial design is a split-plot with three replications, incorporating three substrate preparations (whole plots or Blocks), three mulch treatments and two native grass seed treatments. The resultant number of treatments being tested is therefore 18. The total number of experimental plots is 54. All treatments are randomly allocated.

1.10.2.2 Scale of the trials

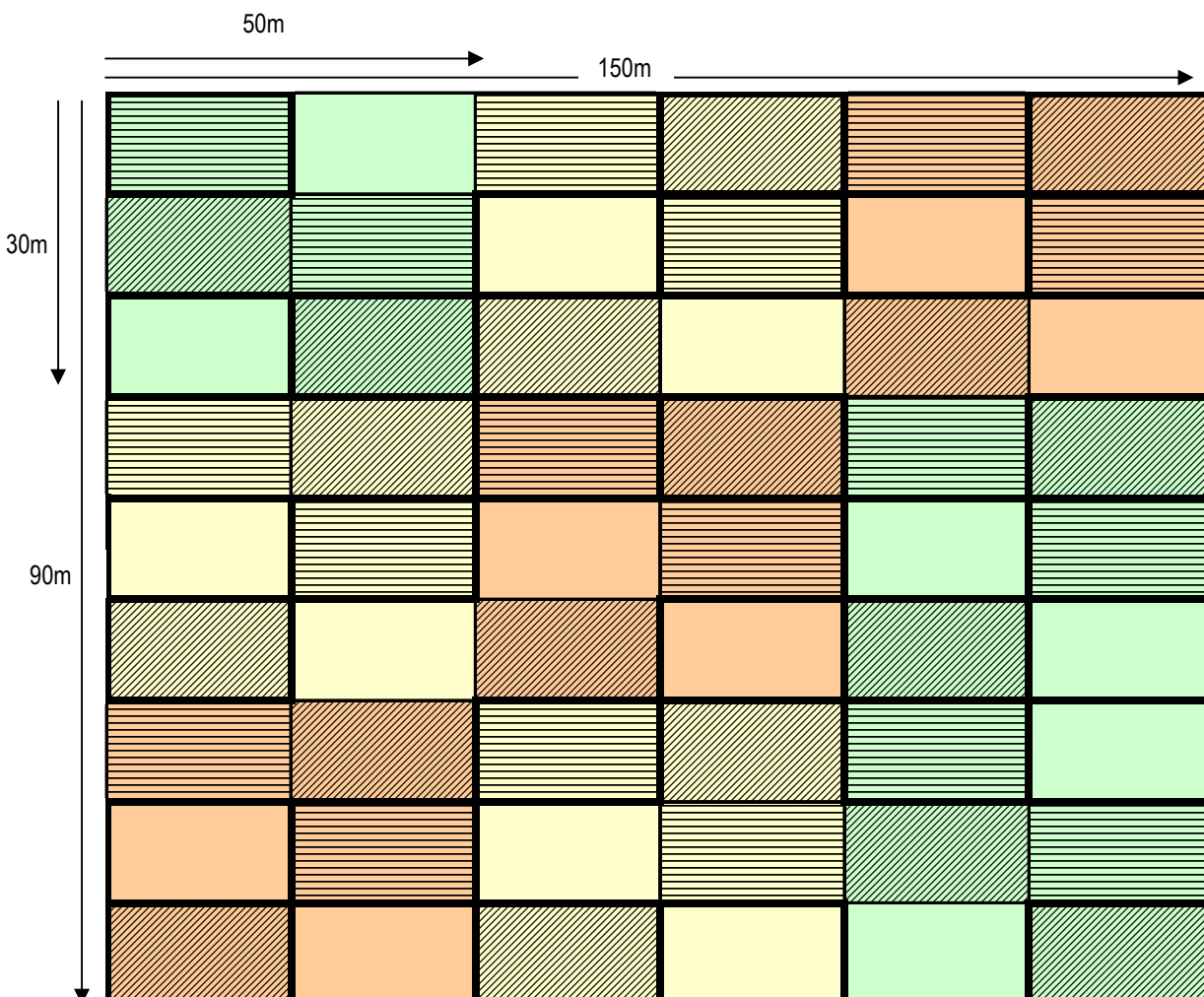
The proposed scale of the trials aims to reflect a 'typical' large-scale rehabilitation project, but not so large it becomes unmanageable. It also hopes to be at a scale that the quantity of treatment materials required can be readily obtained and applied effectively within the desired time frame.

The resultant size of the individual experimental plots is 10 x 25m (0.025ha) with three replications. The total trial area is 150 x 90 m or 1.35ha.

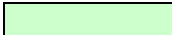




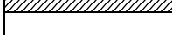
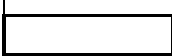
1.10.2.3 Proposed trial design

The proposed experimental design is illustrated in Figure 1-13.

Figure 1-13. Proposed trial design



Key to diagram

	Native topsoil: direct application
	Native topsoil: stockpiled
	Raw spoil + biosolid/OGM
	Woodchips
	Seed bearing pasture hay
	no mulch
	native grass seed mix

NB: all have equivalent gypsum and fertiliser according to soil tests and cover crops as these are standard practice

A detailed methodology including application rates and species used will need to be determined.

1.11 *Implementing progressive and best practice rehabilitation strategies*

1.11.1 Establishment of the grassy understorey

The establishment of the grassy understorey is and will be the primary driving factor behind success or failure of establishing a self-sustaining woodland ecosystem and will largely be determined by the availability of fresh native topsoil. When fresh native topsoil is available, there will be a much reduced effort required to re-establish the desired community.

In the absence of fresh native topsoil, which is anticipated to be a common occurrence, additional seeding and other revegetation techniques will be required and some of these will be identified through the revegetation trials.

Appropriate choice of species will also be necessary and this may be determined by the occurrence of species in similar disturbed environments, such as the reference sites established at Warkworth. Species that may be best suited are likely to occur on steeper slopes with shallower, poorer soils with higher pH levels. In most cases, both summer (C4) and winter growing (C3) species are usually present.

1.11.1.1 Grass species suitable for mine rehabilitation

Extensive studies have been undertaken in the CEEC Box Gum woodland remnants across the known distribution of woodland communities (Prober 1996). Species usually associated with these unmodified communities are often intolerant of high grazing pressure and have therefore become restricted to small areas subjected only to infrequent grazing or other disturbance events. The undisturbed woodlands were found to consist of a mix of *Themeda australis* and *Poa sieberiana*, with subsidiary herbs and grasses such as *Chrysocephalum apiculatum*, *Hypericum gramineum*, *Geranium solanderi*, *Glycine clandestina*, *Dianella revoluta*, *D. longifolia*, *Asperula conferta*, *Leptorhynchus squamatus*, *Goodenia pinnatifida*, *Pimelea curviflora*, *Stackhousia monogyna*, *Cheilanthes sieberi*, *Stipa scabra*, *Bulbine bulbosa*, *Lomandra filiformis* and *Oxalis perennans* scattered between the grass tussocks (Prober 1996).

Less productive and often un-arable lands such as those in Nature Reserves and State Forests have steeper slopes and shallower soils and often have a higher shrub abundance. Species growing in these environments may result in better establishment success in mine rehabilitation, due to the similarity of preferred habitat requirements. Common shrubs include *Cassinia quinquefaria*, *Acacia implexa*, *Dodonaea viscosa*, *Bursaria spinosa*, *Lissanthe strigosa*, and *Olearia elliptica*, or climbers such as *Hardenbergia violacea* and *Clematis microphylla* (Prober 1996). On these steeper and poorer soil types the dominant grasses were more varied and included, in addition to *Poa sieberiana* and *Themeda australis*, the native grasses *Cymbopogon refractus*, *Stipa scabra*, *Aristida ramosa* and *Danthonia* spp., as well as exotic grasses such as *Vulpia myuros*, *V. bromoides*, *Aira elegantissima*, *Lolium* spp., *Bromus diandrus* and *Avena fatua*. Herbs such as *Sigesbeckia australiensis*, *Cynoglossum australe*, *Arthropodium millejlorum* and *Poranthera microphylla* also occurred mainly in State Forests and Nature Reserves.

Prober *et al* (2002) found that topsoils of degraded remnants showed a repeated pattern, with the most compacted, most acidic and most depleted topsoils occurring in remnants dominated by *Aristida ramosa* or *Austrodanthonia* spp. and *Austrostipa scabra*, and the least compacted and most enriched topsoils in remnants dominated by annual exotics; and generally intermediate topsoils in remnants dominated by *Bothriochloa macra* or *Austrostipa bigeniculata* (Prober *et al* 2002).

In flora surveys (Coal & Allied 2010) in the disturbed grazing environments at Warkworth, the native species, *Aristida* spp (Three-awned Speargrasses) dominated most of the ground cover. Numerous other, often smaller herbaceous species occurred between the tufts of this grass. Other common and widespread native grasses in the Grey Box – Ironbark communities and derived grasslands included *Bothriochloa decipiens* (Pitted Bluegrass), *Chloris ventricosa* (Tall Windmill Grass), *Cymbopogon refractus* (Barbed Wiregrass), *Sporobolus creber* (Rats Tail Grass) and occasionally, *Themeda australis* (Kangaroo Grass).

Huxtable *et al* (2005), Windsor *et al* (2000) and Nolan *et al* (1997) trialed a range of native grasses on mine sites. Species having the most successful establishment are indicated in the table below. In the Hunter Valley trials, species that had low establishment but did not persist included *Chloris truncata*, *C. ventricosa*, *Microlaena stipoides* and *Themeda australis* (Huxtable *et al* 2005) but these may be worth including in future trials.

The results of these studies indicate that a range there are a range of species that may be more suitable than others in mine rehabilitation and subsequently each species was been assigned high, medium or low priority depending on their apparent habitat requirements (Table 1-6).The specific species of *Austrodanthonia* was often not provided in the published literature but all have been recorded in grassy woodland communities. It is common to have several species occur in any one area and therefore their inclusion would largely depend on their availability.

Table 1-6. Common grass species according to their natural habitat requirements and/or suitability in mine site rehabilitation.

Scientific name	Common name	Important species	Little disturbed areas (Prober 1996)	Steep slopes, poorer soils (Prober 1996)	Warkworth grazed (Coal & Allied 2010)	Rehabilitation trials (Huxtable et al 2005)	Rehabilitation trials (Windsor et al. Nolan et al (1997)	Priority for rehabilitation	C3/c4
<i>Aristida ramosa</i>	Purple Wiregrass,			?	√			H	C4
<i>Austrodanthonia bipartita</i>	Bandicoot Grass,					√		H	C3
<i>Austrodanthonia caespitosa</i>	Ringed Wallaby-grass			?				M	C3
<i>Austrodanthonia eriantha</i>	Hill Wallaby-grass			?				H	C3
<i>Austrodanthonia laevis</i>	Wallaby Grass							M	C3
<i>Austrodanthonia pilosa</i>	Velvet Wallaby Grass			?				H	C3
<i>Austrodanthonia racemosa</i>	Clustered Wallaby-grass			?	√			H	C3
<i>Austrodanthonia richardsonii</i>				?				H	C3
<i>Austrodanthonia setacea</i>	Bristly Wallaby Grass			?				H	C3
<i>Austrostipa bigeniculata</i>	Tall Speargrass			√			√	H	C3
<i>Austrostipa scabra</i>	Corkscrew,			√	√			H	C3
<i>Austrostipa verticillata</i>					√			L	C3
<i>Bothriochloa macra</i>	Redgrass			√			√	H	C4
<i>Bothriochloa decipiens</i>					√			M	C4
<i>Chloris truncata</i>	Windmill Grass				√	? √	√	M	C4
<i>Chloris ventricosa</i>	Tall Windmill Grass				√	? √		H	C4
<i>Cymbopogon refractus</i>	Barbed Wire Grass			√	√			H	C4
<i>Dichanthium sericeum</i>	Queensland Blue-grass	√			√	√		M	C4
<i>Elymus scaber</i>	Common Wheat-grass							M	C3
<i>Eragrostis leptostachya</i>					√			M	C4
<i>Microlaena stipoides</i>	Weeping Grass				√	?		L	C3
<i>Poa sieberiana</i>	Snow Grass		√					M	C4
<i>Sorghum leiocladum</i>	Wild Sorghum	√	?					L	C4
<i>Sporobolus creber</i>	Western Rat-tail Grass				√			H	C4
<i>Themeda australis</i> (syn. <i>Themeda triandra</i>)	Kangaroo Grass	√	√		√	?	√	H	C4

1.11.1.2 C3 and C4 grasses

Three photosynthetic pathways occur in higher plants, namely the Calvin Benson cycle (C3), Hatch-Slack cycle (C4) and Crassulacean Acid Metabolism (CAM). Within the grasses, the photosynthetic pathways are C3 and C4. The C3 photosynthetic pathway is the most common and most primitive. C4 grasses have a high water use efficiency and a C4 leaf is expected to photosynthesise more than a C3 leaf operating under the same set of environmental conditions.

C4 species predominate during the dry summer season whereas C3 species predominate during the rainy winter season. C4 plants are able to allocate nitrogen to increased root production and hence increase plant growth and presumably competitive ability, due to higher nitrogen use efficiencies. Herbivory rates are greater on C3 plants than C4 plants possibly because of their higher nutrient levels. Competition between C3 and C4 grass species is reduced due to their different growing seasons and ground cover is likely to be maintained throughout the year. Cluff (2003) has summarised other differences and attributes of C3 and C4 grasses which is provided in Table 1-7.

Table 1-7. Plant requirements and characteristics of C3 and C4 plants

Requirements	C3	C4
Moisture	Higher	Lower
Sunlight	Lower	Higher
Temperature	0 – 35°C: optimum 25°C	15 - 45°C: optimum 35°C
Nutrient	Higher	Lower
Growth rates	Slower	Faster
Plant nutrition	Higher	Lower

1.11.2 Germination requirements

The most important factors affecting seedling germination and establishment are temperature and moisture. Table 1-8 is a guide to optimal germination and emergence of some native grasses. The most favourable period for the successful emergence and establishment of warm season grasses is from late spring-early autumn. Cool season perennial grasses establish best from seedlings that appeared from late autumn- early spring (Lodge 1981).

Lodge (1981) found that seedlings of most species germinated within one month of seed maturity, providing suitable temperature and rainfall conditions were present. His studies of the germination of freshly fallen seed in field conditions indicated that seed dormancy did not completely limit germination during and immediately after seed fall (Lodge 1981). In native pastures, this dormancy processes would ensure that not all seeds germinated with the first occurrence of rain and that each successive rainfall event germinable seed was available until the next seed fall (Lodge and Whalley 1981). In this context, long term dormancy mechanisms would have an important role in that the longer the time from seed fall to the germination of the last viable seed, the more likely it would be that the right combination of weather and freedom from competition would occur for successful germination and establishment (Lodge and Whalley 1981).

Table 1-8. Optimum temperature ranges and month of maximum emergence of some native grasses (extracted from Lodge 1981).

Species	Optimum Temp	Month Highest germination	Months of Maximum emergence
<i>Themeda triandra</i>	25	Nov	Late spring/early autumn
<i>Bothriochloa macra</i>	20-30	Nov	Late spring/early autumn Jan, May, June
<i>Austrodanthonia</i> spp	>0 and <35	March/April	Late autumn- early spring
<i>Austrostipa bigeniculata</i>	>0 and <35	March/Oct/Nov	Late spring/early autumn
<i>Dicanthium sericeum</i>	15-35		Jan, Feb-May
<i>Sporobolus elongatus</i>	20-30		Dec
<i>Aristida ramosa</i>	20-35		Feb, March
<i>Eragrostis leptostachya</i>	20-25		Jan, March, May
<i>Chloris truncata</i>	15-35		Jan, March, May, June
<i>Stipa variabilis</i>	15-25		May - August (April-June); late autumn- early spring
<i>Austrodanthonia linkii</i>	15-25		April-June (May); late autumn- early spring

Due to this staggered dormancy occurring within many species of native grasses, it is essential to keep weed competition to a minimum over the first twelve months.

1.11.3 Sowing rates

As the quantity of seed will vary greatly between the species types, harvesting periods and type of harvesting procedure, there is no clear rate of application and it also depends on the required density of plants and the viability of the seed. Seed counts and viability testing of the seed can improve the accuracy levels of application rates required. For sowing “florets” of native grass seed (collected with a brush harvester and contains additional plant material), an application rate of around 100kg/ha can be used as a general guide (Seis pers comm.). Windsor *et al* (2000) found establishment of *Themeda australis* was better in a newly prepared rehabilitation area when the seed bearing hay was applied at the lower rate of 225g/m² (compared to 900g/m² which limited germination). Nolan *et al* (1997) reported using rates of seed bearing hay of *Themeda australis* as low as 50g/m² with success, as individual plants matured to provide significant ground cover and recruitment was observed occurring after the first year.

Recommended sowing rates for pasture species in the Hunter Valley are 20-60kg/ha which equates to 2000 – 8500 seeds/m² (Huxtable *et al* 1997 cited in Huxtable *et al* 2005). In Huxtable *et al* (2005) rehabilitation trials, a much lower rate of 100seeds/m² was used but establishment rates were very low with only half of the 24 species trialed, establishing to levels considered to be acceptable.

1.11.4 Establishing herbs and forbs

When no suitable native topsoil is available and/or particular species of plants need to be established a few techniques can be used depending on the availability of seed, suitability for propagation and the abundance of the species themselves in pre-stripping areas. Some techniques may include:

- Hand collection of seed for direct sowing on site;
- Propagation of seed in nursery followed by hand planting; and/or
- Removal and translocation of entire plants to a remnant woodland community for conservation, whilst the rehabilitation site provides suitable microhabitat for their persistence.

Common and abundant herbs and forbs can be readily introduced whilst the grassy understorey is becoming established. Some species however, including locally uncommon or rare species would be best left until the native “grassland” has reached a stable and functional level.

Seed should be collected or sourced locally where ever possible to maintain the genetic traits of the local populations.

1.11.5 Establishing the shrubby understorey

The establishment of the shrubby understorey is essentially a similar process to that described above for the herbs and forbs. However, it will be fundamental to create small patches of the same species or have a scattering of shrubs. Grassy woodlands characteristically have a low abundance of shrubs and high seedling densities will have a negative impact on the structure and composition of the desired community and rehabilitation objectives.

Seed should be collected or sourced locally where ever possible to maintain the genetic traits of the local populations.

1.11.6 Establishing the overstorey

The establishment of the overstorey species is probably the easiest of the structural layers to establish and can result from the addition of seed or by planting tubestock. In either case it is essential that tree densities remain low (as low or lower than 40 stems/ha or similar to sustainable reference sites) to retain the open woodland structure. The grassy clearings are a fundamental component of the future sustainability of the woodland community as tree recruitment does not occur beneath tree canopies. In addition high density of trees and shrubs usually limits the abundance and diversity of the ground cover leading it vulnerable to erosion, weed invasion and/or an inability to meet performance criteria requirements.

Seed should be collected or sourced locally where ever possible to maintain the genetic traits of the local populations.

1.11.7 Seed distribution methods

1.11.7.1 Hand-broadcasting

Hand-broadcasting first involves the collection of seed from nearby remnant vegetation and applying appropriate seed preparation techniques. A mixture of seed can be made up in a bucket and applied over the prepared revegetation site throwing out in a systematic way. Likewise, individual species may be applied over the same area when as they become available. Again, it is important to have a weed-free substrate (natural soil or subsoils) to begin with, as many exotic pasture species will prevent their germination and establishment. Hand-broadcasting is an extremely useful sowing technique in small revegetation areas or areas inaccessible to vehicles.

1.11.7.2 Brush-matting

Brush-matting is also a useful technique that has been used successfully in mine rehabilitation, particularly for sowing eucalypt seed. The small seed-bearing stalks or eucalypt branches can be directly thrown over the rehabilitation site at spacings of approximately 15 m apart, depending on the required density. Providing seed has matured before collection, the eucalypt capsules soon open after cutting, and drop the seed directly onto the prepared substrate. The additional biomass provided by the branches, helps to stabilise the soil surface and assist in lodging the small seed into place as well as providing some protection for the small seedlings once they have germinated.

This method does not require a drying and storage area and therefore helps to save time normally used when drying and cleaning seed. It also helps to overcome 'double handling' of seed, but seed branches can be bulky to move over sites, particularly sites inaccessible to vehicles. This technique could be used for sowing some native grasses over small rehabilitation areas.

1.11.7.3 Hydro-mulching

This technique is often used for the rehabilitation of roadside cuttings, where straw is spread out over the exposed embankments by a hydro-mulching machine. This method could be useful for sowing native grasses combined with a mix of other desirable local native species, providing the area is

accessible and seed is appropriate for use in the machinery. It is an expensive option but is used widely by the RTA.

1.11.7.4 Spreading seed-bearing hay

Hand spreading seed-bearing hay of *Themeda australis [triandra]* (Kangaroo grass) has been used successfully at Junction Reefs Gold Mine (see Windsor *et al* 2000). The harvesting techniques evolved from slashing and hand raking, using a silage (forage) harvester to the more sophisticated roller brush harvesters. All techniques proved to be successful but time and labour was considerably reduced using the latter harvest method. As the studies that were undertaken indicated germination and establishment of this species was reduced using high mulch applications, it then became unnecessary to harvest the leaf material as well. This also considerably reduced the bulk of material requiring storage and handling.

Similar in principle, first baling native grasses when seed is mature, followed by respreading this hay onto the desired revegetation areas has also been trialed at North Parkes Gold Mine (McCallum personal communication). This technique appears to be an appropriate harvest and sowing technique given the availability of farm machinery to undertake the process. Due to the nature of the mowing, drying and baling processes, a lot of seed is likely to be lost from the hay material. In addition, most native grasses generally don't germinate well beneath heavy mulch layers, so it would be important to spread the seed-bearing hay thinly or in rows or mosaics.

1.11.7.5 Direct Seeding

Direct seeding is fast becoming a cheap and economic alternative to tubestock planting for the revegetation of large, accessible sites. It is however, heavily reliant on soil type and the amount of effort put into appropriate ground preparation as well as climate. It is usually not appropriate for sowing native grass seed, but specialised machinery have now become available.

Two types of direct seeders are available (eg. by contract or hire from Stipa or Greening Australia). The Rodden III (now called Burford) is towed by a 4WD vehicle whereas the Hamilton tree seeder requires a tractor with three-point linkage. The disc of the seeder makes a furrow in front of the seed, which is dropped at a rate calculated by the experienced operator. A press wheel follows behind to embed the seed within the furrow.

Due the often unreliable establishment of the small seeded species, particularly eucalypts, it may be beneficial to plant tubestock of these types of species after the rows have been direct seeded, at spacings of approximately 50m. This will ensure appropriate species diversity is achieved.

1.11.7.6 Air seeders

Air seeders are specially designed to cope with the nature of many species of native grasses. Native grass seed are often very hairy and/or contain long awns (bristles) which make them unable to be used in conventional sowing machinery. Many seeders rely on the movement of air to circulate and distribute the seeds. There are now a range of specialised machinery used for sowing native grass seed which rely on the fact most native grass seed are light and fluffy, and therefore involve some sort of blowing action to prevent the machines from clogging up and /or distribution of the seed itself. Some popular

sowing machines include the “Crocodile” seeder and the “Germinator”. These can be available by contract or hire from Stipa or Greening Australia. There are also a range of other sowing gear available including specialized seed boxes and air seeders. For more information visit <http://www.agric.nsw.gov.au/reader/gu-guidelines>.


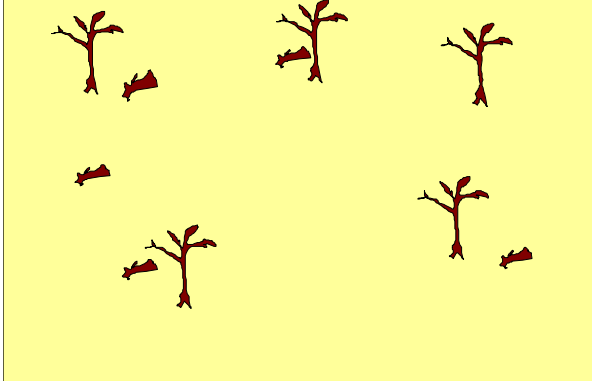
1.12 Progressive rehabilitation strategy

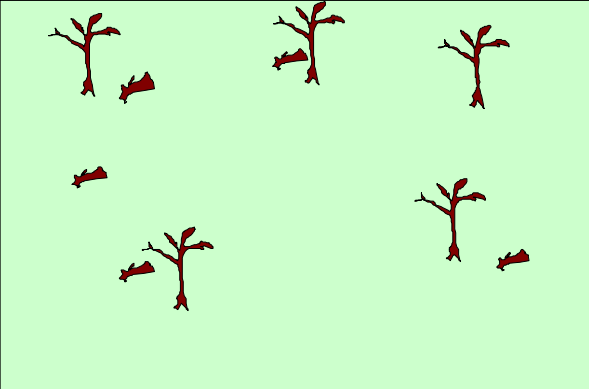
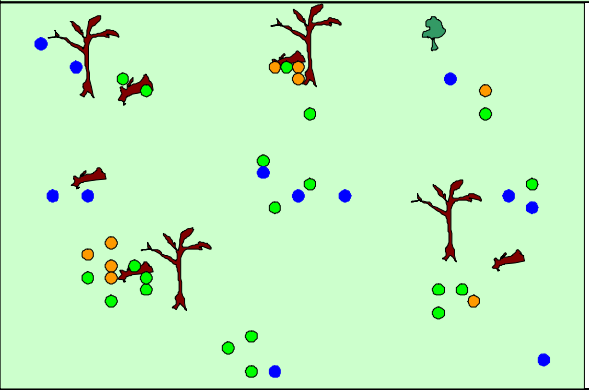
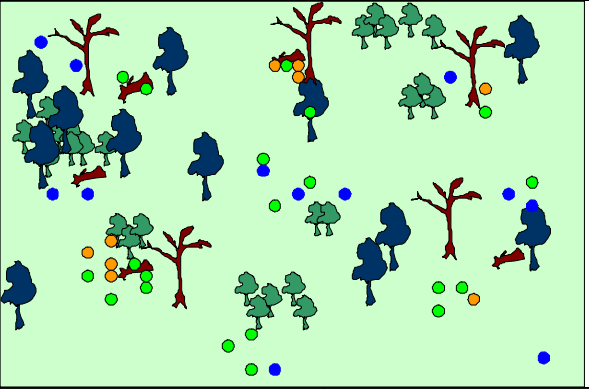
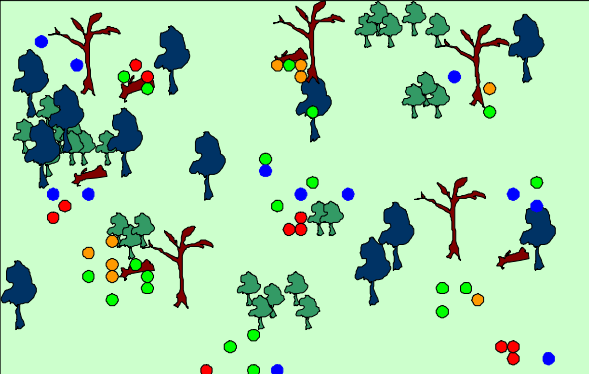
The following section aims to provide an overall summary of the steps required to implement a sound and ecologically sustainable grassy woodland ecosystem. Final recommendations will need to be made according to the results of the rehabilitation trials (See Section 1.10). The rehabilitation trials initially aim to determine the most appropriate methodology for establishing a suitable soil substrate (Step 1) and a grassy understorey layer (Step 3).

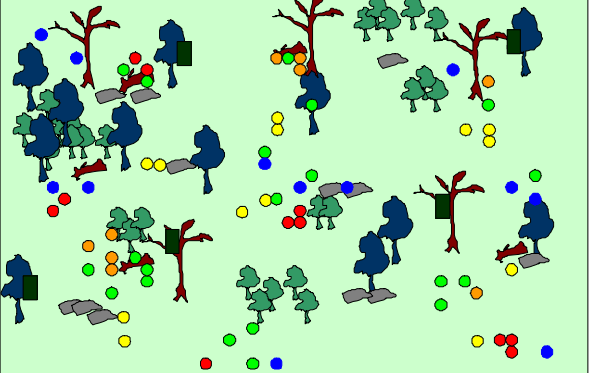
1.12.1 Sequence of rehabilitation strategies

The following table is a representation of how the revegetation should be undertaken progressively over 5-10 years, depending on the success of each successional phase (Table 1-9). In the event unsuccessful establishment has occurred, a second attempt should be made after first determining the cause of failure and remediation has been undertaken. Each phase will have to consider the management and/or the control of weeds, but the appropriate control strategy will have to be first assessed against the potential impacts on the rehabilitation established thus far and the target species involved.

Table 1-9. Representation of the progressive revegetation strategy over 5-10 years

Step	Representation
<p>Step 1: Time zero</p> <p>Undertake soil test (pH, sodicity, EC). This will assist in determining ameliorants and likely application rates. It will also assist monitoring the effectiveness of the biosolid/OGM treatments over time as a benchmark will be set.</p> <p>Construct suitable site, spread native topsoil or stockpiled native topsoil. Add appropriate ameliorants and organic materials using BMP and manufacturers specifications</p>	
<p>Step 2: Time one - two months</p> <p>Introduce mature stags and large branches prior to seeding to minimize disturbance on sown trial areas</p> <p>NOTE: For the trials stags and branches will not be erected at this stage</p>	

<p>Step 3: Time 3 months</p> <p>Add pasture hay or woodchips depending on the outcomes of the trials.</p> <p>Sow native grasses (if native topsoil is not used) and cover crops.</p>	
<p>Step 4: Time 15 months</p> <p>When successful establishment of the native grasses has occurred and the “skeleton” of the community is progressing, common herbs and forbs can be introduced via seed or hand planting. If native topsoil has been used, identify herbs and forbs that may be missing and introduce</p>	
<p>Step 5: Time 15 months</p> <p>Seed and plant small patches of shrubs and plant sparsely scattered overstorey (eucalypt) trees. It is important not to plant too densely < 40 trees/ha plus some small patches of shrubs of the same species taking care to leave sufficient grassy clearings</p>	
<p>Step 6: Time 3-5 years</p> <p>When the ecosystem has become stable and suitable microclimate has established introduce rare and locally uncommon plants.</p>	

<p>Step 7. Time 5 - 10 years</p> <p>Introduce other rare or locally uncommon species.</p> <p>Install nesting boxes, rocks and other habitat features.</p>	
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1.13 *Large scale paddock and corridor revegetation*

1.13.1 Planning habitat restoration projects

Habitat restoration is not about planting any old tree anywhere, but it should aim to restore the ecological integrity of the different vegetation communities that change in structure, composition and function across the landscape so that they ultimately become sustainable ecosystems. Aerial photographs or large-scale maps of the project areas make a good basis for the revegetation plan. Careful planning means that the project can serve different purposes depending on their location and design and bring multiple benefits to the community and the environment.

Some important things to consider when planning restoration projects include:

- THE BIGGER THE BETTER!
- Increasing the size of existing remnants by using remnant vegetation or other revegetation projects as focal areas to build onto or around;
- Revegetating patches in close proximity to existing remnants to act as a stepping-stones for wildlife and encourage colonisation of the revegetation areas. Studies suggest that patches about 500m apart are beneficial to assist small bush birds move safely around the landscape;
- Providing essential links between remnants in the form of shelterbelts or windbreaks that provide dual roles as wildlife corridors, as long as they are greater than 30m wide. Studies have shown that shelterbelts less than 30m apart are usually inhabited by introduced or pesky birds that prefer to live on the edges of remnant vegetation, such as Noisy Miners. Other studies suggest the corridor should be a minimum of 100m wide to truly be a corridor for wildlife;
- Revegetating large blocks (>5ha) to reduce 'edge effects' and in the longer term, a functioning ecosystem. Small blocks and linear shapes are essentially all "edge" and will not be sustainable.
- As natural regeneration is severely impaired in areas where introduced pasture species are dominant, target areas where there are native pastures as the resilience of the community is greater and a sustainable ecosystem in the longer term is more likely to be achieved. Note that these areas must *NOT* be areas of the endangered grassy woodlands and derived grasslands.

1.13.2 Designing a sustainable restoration project

- Once the area of the revegetation project has been determined, the internal structure of the vegetation needs to be carefully designed.
- Plant patches or mosaics to leave natural regeneration gaps within and around the revegetation site. If plantings are too dense, natural regeneration will not occur.
- Consider introducing native grasses and/or creating open grassland areas to create regeneration gaps and to increase the structural and spatial diversity in the area. Many woodland animals require grassy clearings to move between more densely planted areas as well as to feed in.
- Maximise biodiversity and habitat by planting a variety of native tree and shrub species endemic to the revegetation site. Monoculture plantings are susceptible to high mortality rates due to increased predation by insects and diseases and usually provide little habitat value anyhow.
- Consider the structure and ecological function of the vegetation community and be mindful of what purpose it will serve and what it will grow into. For example woodlands are structurally different to bushland in that historically they had about 10-30 large trees per hectare and had scattered patches shrubs amongst native grasslands. Alternatively bushland areas typically contain a larger number of trees and a greater proportion of shrubs. The way you plant will depend on what you are hoping to achieve.
- Choose species not only endemic to the general revegetation area, but species suited to the variable conditions of the individual site and plant them according to their preferred habitat conditions. This will not only increase and be consistent with the local biodiversity, but will usually result in better revegetation outcomes.

1.13.3 Create gaps for future regeneration

- Keep in mind that in many areas where revegetation is required, resilience is usually low and so therefore the capacity of a planted block to regenerate naturally is likely to be limited. Natural regeneration is unlikely to occur outside the fenced revegetation areas as grazing, cropping and improved pastures will restrict these processes.
- When the understorey consists of improved pasture species such as Phalaris, Ryegrass or Cocksfoot for example, natural regeneration is unlikely to occur. Staggering planting programs over successive years to achieve diversity in structure and age may be one way to overcome this problem in the short term.
- In revegetation projects, it is important to ensure that natural regeneration occurs otherwise the vegetation community is restricted to the lifespan of the individuals and consequently the community will be *unsustainable*. Disturbance regimes such as grazing, fire and weed management will need to be considered to encourage natural regeneration into the future.
- Encourage wildlife by planting a diversity of plant species, maintaining grassy clearings and by introducing logs and rocks and providing suitable nesting sites (e.g. nest boxes). Often we overlook the importance of insects, fungi and reptiles in providing ecosystem services.

1.13.3.1 Wildlife corridors

These corridors of vegetation aim to link areas of existing bushland/vegetation together to assist the movement of wildlife from area to another.

- The movement of animals is important to ensure the appropriate mix of genes and prevent inbreeding of isolated populations
- To allow animals to escape in the event of wildfire's
- In the event that one population is 'wiped out' due to fire or disease in one remnant area, new animals can recolonise that area.

To ensure animals can use the tree corridor it is important that most species that require protection, such as small animals that cannot travel great distances in the open have the appropriate resources. Most wildlife corridors to be functional need to be in excess of 100m wide and contain a diverse range of plant species. However, smaller corridors are also important for some less specialised species and nonetheless carry out important landscape function.

1.13.3.2 Buffers/ shelter belt

Relatively dense plantings of a range of local native vegetation can provide effective shelterbelts for livestock, orchards and crops. They also provide a buffer between sometimes conflicting landuses. These forms of planting's can prevent the spread of weeds, spray drift, disease, noise and dust and are often used in a variety of ways for different landuses. Shelterbelts can also be used to help reduce the quantity of water entering the watertable, thus helping to control dryland salinity. These types of planting's are referred to as intercept planting's and are often used with a dual purpose of providing shade and shelter to livestock or other farm enterprises. Effective intercept plantings need to be at least eight rows wide and are usually positioned at the brow of hill or slope.

1.13.4 Ground preparation

The amount of ground preparation required prior to planting depends on your site's land use history and the types of pasture plants that dominate it. Ground preparation is critical when the site has had a long history of cropping or heavy grazing, or on sites with a high component of introduced species. The trick is to prepare the soil to a level where *soil compaction is alleviated and weed competition is minimal but with the least amount of soil disturbance.*

1.13.5 Deep ripping

Deep ripping can be used to reduce soil compaction and penetrate the "hard pan" which is common in frequently cultivated paddocks or heavy traffic areas or act as an erosion control measures in the short term. Deep ripping loosens the soil, assists water infiltration and aeration which encourage the seedlings to rapidly develop an extensive root system as well as making planting much easier. Take care to rip along the natural contour of your site to avoid initiating soil erosion, and do not rip along steep sided banks or extremely erodible, rocky or sandy soils.

In heavy soils, ripping when the soil is very dry works well as it literally smashes the compaction layers. Avoid ripping when the soil is wet, as this will leave a glazed surface in the rip line, which may subsequently encourage root growth only along the rip line. Driving over the rip lines with the tractor tyres will help settle down the soil clods and make the rip lines more level and on heavier soils, a light cultivation along the rip lines removes the large clods and creates a finer tilth ready for planting.

Allow sufficient space between the rows to accommodate whatever machinery will be required for post-planting maintenance of the site, such as a tractor mounted weed sprayer or slasher but at least five metres between rows is recommended.

1.13.6 Weed control

The amount of ground preparation required is usually minimal if native species dominate the ground layer as native grasses don't compete with tree seedlings as vigorously as many introduced species. In some cases, deep ripping may not be required in these areas, as a hard pan is unlikely to be present. To reduce competition, a single or double application of non-selective herbicide such as glyphosate in 1m wide strips along the planting row 2 – 4 weeks prior to planting will generally be sufficient, as it is important not to kill the native grasses.

If the revegetation area is dominated by introduced pastures or weeds, good ground preparation, especially weed control, is crucial. Introduced grasses and weeds are vigorous growers and will usually out-compete young tree seedlings. Apply a non-selective herbicide such as glyphosate in 1-2m wide strips (or 1m diameter circles if rows are not desired) to reduce weed and grass cover. *Spraying a year in advance with several follow up applications when weeds have germinated* will achieve the best results. A final application of herbicide should be applied within a couple weeks prior to planting. Avoid spraying or disturbing the areas between rows as ground cover between the rows prevents weed establishment, protects the soils and provides important habitat.

1.13.7 When to plant

Plan to plant in autumn after the first rains provide adequate soil moisture. Time of planting is important and will vary depending on your climate, but during autumn and winter are the best. On the Slopes and Plains where the winter months are milder and summers are often hot and dry, it is better to plant in autumn. This allows seedlings to become well established before the hot dry summer. On the Tablelands where the winters are cold and the summers not quite as hot and dry, planting in late winter and sometimes into early spring can be beneficial. Seedlings will avoid the cold frosts and the chance of predation or fungal diseases will be reduced.

Wherever the project is, wait until there has been sufficient rainfall so the soil is moist at the time of planting and there is adequate subsurface moisture. There should be no need to water in the trees if moisture conditions are right and the appropriate ground preparation has been undertaken.

1.13.8 Planting arrangements and spacings

For large scale paddock and shelterbelt plantings, rows are commonly spaced at least 5m apart and a

tubestock planted every 5m along the rows, resulting in a density of 400 trees per hectare. ***This density is likely to be far too high, especially if your objective is to create grassy woodland and in some projects this density should at least be halved.*** The plant spacing can be varied depending on the size of the mature plants, the purpose of the planting and the type of vegetation community being established. It is important that natural regeneration can occur in the future so it is also important to leave some wide gaps and or areas of grassy clearings.

If you don't like the thought of planting trees in straight rows, remember there are a few ways of overcoming this without comprising the ease of ground preparation and maintenance of the straight row effect. By planting a diversity of trees and shrubs and varying spacing between the plants and within the rows as well as staggering between rows in your planting design, the end result will be a more random appearance in due time. Creating "wavy" lines when deep ripping or spraying can also assist in achieving a more natural appearance.

Try to imagine what individual trees and shrubs will look like when they have matured and allow them enough room. A mixture of one large tree (eg. eucalypts) to two smaller shrubs (eg. Acacias, Hopbush etc) planted at 5m spacings is a common practice. Smaller shrubs, ground cover and grasses can be planted closer depending on their mature heights and width. Planting a row of smaller trees and shrubs closest to prevailing winds, then a row or two of larger trees and shrubs, followed by a row of smaller trees and shrubs to maximise the effect of the windbreak could also be considered.

Remember you can always come back and underplant in time to create higher species diversity or achieve the desired structure. Some plants such as smaller understorey species require certain conditions and shelter created by overstorey plants before they can establish.

1.13.9 What species to plant

Select species local to the project area, propagated from locally collected seeds. Local provenance plants contain the genetic makeup that make them adapted to the soils and climate in the area and once established are more likely to survive long-term climatic extremes, especially severe drought or heavy frosts. Local native species help to preserve the character of the landscape, they are more likely to be of benefit to the local wildlife and they will not become environmental weeds.

Although a plant may grow in your local area, you also need to consider the specific conditions of the planting site and the plant community you are trying to create. In some cases, there may be a variety of habitats and therefore a variety of plant communities would be desired and matched to the changing conditions of the site. By doing this establishment success is usually improved and the characteristics of the different vegetation communities in the local area will be retained and a more diverse environment will be established. The use of undisturbed remnant vegetation as reference sites is one way to determine the different structure and species composition and these should be replicated in the restoration project.

1.13.9.1 Diversity is the key

It is important that a diversity of species is used, including a range of trees, large and small shrubs and where possible, native grasses, rushes and herbs. The diverse mixture of plants can provide different heights, foliage cover, flowering times, fruit, nuts or nectar, which are all aspects important to the local wildlife. Local wildlife then play an important role in pollination, seed dispersal, and providing niches for

plants to regenerate as well as regulating insect populations. Most revegetation programs recommend a planting mix of two shrubs to one tree, but this can be varied according to your project objectives.

Once you have decided what species to plant, it is important to choose good quality seedlings for your revegetation project.

Good seedlings grow from good quality seed so make sure your nursery uses locally collected seed from quality sources. Good seedlings increase establishment success and grow into strong, healthy trees.

1.13.10 Improve wildlife habitat

1.13.10.1 Create areas of open woodland

A lot of declining woodland bird species select relatively open habitats (e.g., hooded robin, southern whiteface and diamond firetail). Trees and shrubs should not be planted too densely across the entire site but you should aim to create “patchiness” and include relatively large patches of grassland with scattered trees. Edges between woodland and grassland are favoured by lots of woodland birds such as the jacky winter, restless flycatcher, hooded and 'red' robins.

1.13.10.2 Create thickets of shrubs

Aim to create a patchwork of dense thickets of shrubs (favoured by wrens, thornbills, yellow robin), areas of relatively open woodland as well as areas of open grassland clearings. Diverse habitat means improved biodiversity.

1.13.10.3 Plant prickly things

We should also realise that human nature dislikes prickly or seemingly useless plants and many of these types of plants have been eradicated from the environment. They are certainly not considered for planting in revegetation projects, despite the fact these types of plants often provide critical habitat for our wildlife. One such plant *Bursaria spinosa* (Native Boxthorn) is primary habitat for the endangered Bathurst Copperwing Butterfly.

There are hundreds of small prickly species that provide important roles in our ecosystems and these too should also be planted into our revegetation projects if we truly want to achieve a sustainable ecosystem. Unfortunately there are still issues associated with the availability of many of these types of plants from our nursery providers. Many nurseries however will do their best to grow on request especially if the seed has been provided.

1.13.10.4 Include old dead trees and fallen logs

Old mature trees, dead or alive, especially those containing hollows are essential habitat for many native fauna species. Therefore aim to locate parcels of land for revegetation which have at least a few

large trees and old stags. Where and when possible, if hollows are missing from the patch or in short supply, insert hollows of all types (large to small, up high to low down, vertical 'spouts' to sideways entrancing) into the area to encourage small bush birds such as pardalotes and some 'thornbills', parrots, sugar gliders, kingfishers, treecreepers, owllet nightjar and owls. They DO need to be monitored to deter undesirables!

1.13.10.5 Include a lot of different types of plants

Often, restoration projects aim to attract a "variety" of local wildlife species, and so a variety of local trees, shrubs and understorey plants, including grasses will need to be included to achieve species and structural diversity. Plants which are not local to the project area *should not* be incorporated into revegetation projects due to legislation which protects native vegetation, especially those listed as Endangered Ecological Communities.

1.13.10.6 Include or introduce other habitat needs

Reintroduce rocks, large and small branches, and "coarse woody debris" (CWD) of all sorts/sizes to the land, to trap water flows and nutrients and to provide microsites for all the microbial diversity we tend to ignore (which in turn help feed a lot of our declining woodland birds!). We need to think 'patchy' and diverse at the ground layer as well. Open grassy areas, patches of open ground with litter scattered with logs and rocks. If the ground layer is too uniform and lacks this sort of diversity our target ground-feeding species such as painted button-quail, robins, brown treecreeper, whiteface, will be excluded. Monitor and undertake feral animal control when required.

1.13.10.7 Seedling types

Traditionally, native plants have been grown in plastic tubes called Forestry tubes, which are 50 mm across the top and 120 mm deep. Forestry tubes can be purchased between \$0.80 - \$1.50 and may be cheaper if large quantities are ordered. Seedlings can also be obtained in smaller containers, such as Hiko cells or Speedlings. Cell grown seedlings are ideally suited to mechanical planting and may be appropriate for massed plantings such as saltbush for fodder or farm forestry plantations. Good ground preparation is critical for planting out Hikos and Speedlings.

However, for most farm situations, the traditional Farm Forestry tube is preferred as shown below, as the seedlings are larger, more robust and have a greater root volume which gives them a better chance of survival if the topsoil dries out within the first 6 to 8 weeks after planting.

Long-stemmed tubestock may also be available from some nursery suppliers. Long stemmed tubestock are grown especially for use along creeks and rivers where they may be subjected to flooding. The seedlings are usually very tall (up to 1m) and are planted deep within the soils so that about 1/3 of the stem is also buried. The planting hole is usually made by blasting water into the soil using specialised pumping equipment. This technique ensures that the roots are placed well beneath the loose soil or sand and the risk of the seedling roots being exposed is greatly reduced.

1.13.11 Ordering your seedlings

A mixture of one large tree (eg. eucalypts) to two smaller shrubs (eg. acacias, hophush etc) planted at 5 m spacings (400 stems per hectare) is commonly recommended for large scale tree planting projects, but this density is likely to be too high for a “sustainable” woodland community that will require grassy clearings for future regeneration. The more appropriate planting density is probably half that quantity (200 stems per hectare).

If you order your tubestock well ahead, they can be grown to your requirements and will be available when you are ready to plant them. Don't assume that the nurseries will have local provenance species in stock, especially if you have a large order. Check with the nursery to find out how much lead-time is needed to produce seedlings to your specifications, but for an autumn planting, ordering in spring the previous year is usually sufficient, providing they have access to local provenance seed. Many nurseries are happy to grow tubestock from seed that you supply to them.

1.13.11.1 Buying quality seedlings.

Most nurseries now grow tubestock in special raised racks so that the roots do not grow out through the bottom of the container as the air literally prunes their roots. “Air pruning” results in much healthier root systems and therefore much healthier seedlings. Avoid buying tubestock that have not been air pruned. Seedlings should have a ratio of shoot growth to root growth of around 3:1. If purchasing Forestry tubes, this means the seedlings should be no taller than around 30cm. Avoid large plants as they are probably root bound and will be slow to establish in the field. You will find that smaller seedlings will outgrow larger seedlings within a few months of planting out anyway. If eucalypt seedlings have been damaged or stressed you may find that the seedling has many stems growing from growths near the base of their stem called a “lignotuber” or the lignotuber may be excessively large. If you want straight, healthy, single-stemmed trees, don't buy these ones!

Inspect the root system for any deformities, particularly near the base of the stem as incorrect handling when transplanting the seedlings from the germination trays into the tubes can result in a condition called “J-rooting”. Plants with a “J” or “S” bend in the root system should be avoided, as they will almost certainly die, even after some years in the field. Many nurseries now directly sow seed into the tubes, thereby eliminating the need to transplant seedlings and avoiding problems with J-rooting.

1.13.11.2 Well hardened plants

Plants should be hardened off prior to planting out. Plants that look particularly lush or “sappy”, or that wilt when exposed to sunlight are likely to suffer extreme stress and have reduced survival rates. You can ask your nursery to supply you with “hardened off” plants, or you can harden them off at home. To harden off tubestock, place them in a location in partial sun and gradually move them into an area with full sun. Limit the amount of water they receive, but not to the point where they wilt excessively and never let them dry out. Don't take plants directly from a greenhouse or shadehouse and plant them in the field, as they probably won't cope well.

1.13.11.3 Prepare the seedlings for planting out

Make sure your seedlings are “hardened off” before they are planted out to ensure the plants have become acclimatised to the seasonal conditions. Water the seedlings thoroughly before taking them out to the planting site. If you plan to be out for a long time, make sure you keep them wet.

The best method for doing this will depend on the quantity you are planting, but submerge the plants in a bucket, bath or dam for around 2 hours to ensure the plants are thoroughly soaked. This is especially important if the seedlings have been allowed to dry out at any time. Never plant out dry or wilted plants.

1.13.12 Tree guards

Installing tree guards is optional but are usually used to protect small seedlings from browsing by hares and rabbits and provide protection from extreme exposure within the first year of planting. Impervious tree guards, such as milk cartons can assist you with the maintenance of the site by protecting seedlings from herbicide drift when you do post-planting weed control. Plastic tree guards are not recommended as they are not biodegradable, more expensive and have a greater risk of blowing away and polluting waterways. They also need to be removed once the seedlings have become well established.

Purpose made 2L milk cartons with two bamboo stakes are frequently used, as they are cheap, biodegradable and easy to install. Make sure the stakes are secure as seedlings can die if the cartons close up over the top of them or blow away. Some manufacturers make perforated holes for the stakes to be threaded through but if not, cut two horizontal slits top and bottom across the opposing edges of the carton and then thread the stakes through the holes. It is much easier to prepare these guards before you intend to plant. .

1.13.13 Mechanical tree planting

There are mechanical tree planters available for contract hire that are capable of planting thousand of trees per day. Planting speed varies with the ground conditions, the species and size of seedlings, and the experience and skill of the crew. Rates of 400 to 1,000 trees per hour are reported.

Many types of mechanical tree planters are available; they all consist primarily of a device pulled behind a tractor that creates a slit in the soil. A seedling tree is placed in the slit and the packing wheels on the planter close the slit and firm the soil around the seedling. In addition, some are equipped with furrowing attachments to scalp part of the planting area, while more recent designs have spray attachments for applying herbicides to control unwanted vegetation. Mechanical planting usually is not warranted for less than 1,000 seedlings because of the time involved in acquiring, transporting and using the equipment.

1.13.14 Watering

If the soil has been well prepared and selected appropriate species and have maintained good weed control, the tubestock should get through the first summer on natural rainfall. Watering in at the time of planting will help to settle the soil around the roots of the plants and provide them with a small reservoir

of water during the critical establishment phase. Watering-in is not essential provided that the plants are well hardened and the soil is moist at the time of planting.

Watering may be required, if you experience a period of 6 weeks or more without an effective fall of rain during the seedlings' first season in the ground. If you do water, make sure they have a "big" drink (20L each) to enhance their survival prospects. Infrequent, deep watering will encourage seedlings to grow a deep root system because the plants' roots will seek the moisture from deep in the soil. Small, frequent watering can do more harm than good as they will encourage the plants to produce shallow root systems which means the trees will not grow as well and will struggle through dry periods. In more arid environments, drip irrigation is often used to assist establishment within the first year, but is expensive to install and maintain.

1.13.15 Tree seeding and direct seeding

Tree seeding and direct seeding refers to the sowing of seeds directly into the soil on the revegetation site. It is different from natural regeneration in that the seeds are artificially applied to the land. Tree or direct seeding is suitable when you need to plant large areas in a short time and is a much cheaper method for revegetation than tree planting.

Large areas can be sown in a day and the cost per tree of successful direct seeding may be only one quarter of planting tubestock. Tree seeding and direct seeding is suitable when planting for habitat and biodiversity but is not as suitable for situations requiring a very even spacing of trees. It has unreliable and mixed success in the catchment, but has proven a cheap and effective method. The advantage of direct seeding is that it is a much cheaper method for revegetation than tree planting.

The density of a tree seeded stand is frequently greater than with planted seedlings, and there is some evidence to suggest that direct seeded trees, once established, are more resistant to drought and better able to recover from insect defoliation. The main disadvantage with direct seeding is that consistent results cannot always be guaranteed. The success of direct seeding is dependent on seasonal conditions and seed viability. Germination may be patchy, and in some cases may not happen at all. Like tree planting, the success of direct seeding is dependent upon forward planning, site preparation and maintenance.

1.13.15.1 Direct seeding machines

There are many types of Direct Seeding machine available today, from simple bait layer types through to more sophisticated machinery that has various improved attachments to suit the different geographical areas. All carry out the same function - to distribute the seed onto or into the soil bed. This is carried out by having a circular disc or blade that removes a strip of top soil, usually a thickness of approximately 3-6 cm. Behind this, a tyne is set 2-3 cm below the disc base where heavy seed is sown. Fine seed free falls behind the tyne. Light tickler tynes may be used to break up the lumpy soil before the total sown area is pressed firmly into the soil by a press wheel. If soil is somewhat dry, water can be added behind this in a manner to indicate a heavy shower of rain, or on non wetting sands wetting

When adjusting for seed viability assume less than 1% of viable eucalypt seeds will establish and survive and about 5% of viable acacia seed. Due the often unreliable establishment of the small seeded species, particularly eucalypts, additional "in-fill" planting of tubestock may be beneficial.

1.13.16 Site maintenance

Competition from weeds and grasses is the biggest single cause of failure of farm tree plantings, especially in exotic pastures such as Phalaris, Paspalum or Cocksfoot. If you have done the correct ground preparation, weed competition should be minimal. However try to maintain a weed free zone about one metre diameter around each seedling until the plants are about 2m tall. You can do this by spraying very carefully with glyphosate around the tree guard. *Do not spray in windy conditions.* Protective cones around the spray nozzles can minimise the chance of spray drift and in smaller sites, a plastic bucket placed over the seedling during spraying is also an effective method. Slashing between the rows can also be beneficial and allow better access and reduce the fire hazard potential posed by hayed-off pasture grasses. However, long grass can also be important habitat for some species of wildlife. Pest animals will also need to be controlled.

1.13.17 Where not to plant!

It is always important to remember that the little seedlings you plant now will in time grow quite large. Make sure you have considered possible impacts these trees may have when fully mature. Don't plant large trees beneath powerlines, close to buildings or underground pipes and cables. In fire prone areas, avoid planting rough barked or flammable species on the fire-danger side of buildings.

Plant seedlings at least 2.5 m from fence lines or driveways to minimise damage to the fence by livestock or falling branches. Avoid restricting the roadway and don't plant in front of gateways. Remember you will also need to maintain the site so allow vehicle access within the planting, especially if you are planting along rivers or creeks.

1.14 *Seed and seed collection*

1.14.1 Planning for seed collection

Extract from: How to collect native tree seed easily (Greening Australia 1991)

Obtain Permission. Laws protect a range of native flora. Permits are required for collecting on public land and for some species on private land also. Initial enquiries can be directed to the State national parks service, or the forest service or State herbarium.

Identify species. Correct species identification is vital and several excellent field guides are available (see references). If you are doubtful, forward a botanical specimen (leaves, fruits and flowers or buds pressed between sheets of newspaper or blotting paper) together with a description of the tree's location, size, general appearance and bark to your nearest State herbarium for checking.

Locate suitable collecting sites. Seek advice from local forestry staff, State herbaria or others with local knowledge, or refer to books which show species distribution.

Decide when to collect. Check the literature for guidance on flowering and seeding times and, if possible, visit trees regularly to check on seed ripeness and availability. From early spring to late summer can be especially busy for collectors. Allow for the fact that heat waves and bursts of hot windy

weather can accelerate ripening and seed drop in species like wattles. In a 'seed year' the seed quality is better and harvesting is easier.

Assemble the right equipment for the job and make sure it is in top condition. For small collections you may simply need a few paper bags and some secateurs but detailed planning is required for large collections at remote sites.

Play it safe. Safety precautions will vary with local conditions, tree species and collection methods used. Some safety hints are: work as a team; wear appropriate clothes, safety hat and footwear; and take a first aid kit. Seeds can often be collected safely from the ground or by using a step ladder, but if you plan to climb high trees, take extra care.

1.14.2 Seed collection techniques

There are many ways that seed can be collected and different methods are required for different species. Many plants can also take advantage of 'good' seasons, and therefore flower and set seed opportunistically, therefore this is to be used as a guide only. It is essential in any seed collecting that no more than 10-30% of seed is collected from any one tree or remnant and that all impacts of seed collecting are minimal. For harvesting stands of native grasses, seed must be allowed to set at least every second year.

It is also important that seed is collected from a healthy group of trees or remnant so that genetic variation is maximised. Collecting from 'good looking' healthy trees will increase the chances of having good looking and healthy seedlings.

1.14.2.1 Eucalypts

Eucalypts are most readily collected using long-handled tree pruners or for low growing branches, secateurs can be used. For tall, forest trees seed can be collected by shooting off branches, but a firearm license must be obtained. A bow and arrow can also be used to direct a piece of cutting wire (similar to a chainsaw blade) over high branches. The see-saw action then cuts the appropriate limb. The smaller branchlets containing the seed can then be cut from the larger limbs to reduce the quantity of bulky material, unless it is to be utilised in brush-matting.

Matured eucalypt capsules should show a 'cross' on the top of the capsule. This 'cross' is actually the valves from which the seed (and chaff) is released on ripening. In hot weather, seed may be dispersed within an hour or so after picking, or it may take up to three weeks during winter. It is important that freshly collected eucalypt capsules are placed in a container (eg a bucket/paper bag for small quantities) or a tarpaulin or sheet of plastic (for large quantities) and kept clean and dry. Excess seed can be shaken from the branchlets, swept up and sieved.

1.14.2.2 Wattles

Acacias, commonly known as wattles are legumes and therefore produce pods, similar to our garden peas. There are also many other native legumes such as the Happy Wanderer (*Hardenbergia violacea*) or Bacon and Eggs (*Pultenaea* or *Dillwynia* spp.). In the Hunter Valley, the majority of legume seed should have ripened by October to December, depending on the season. It is important that seed is

closely watched as hot dry weather will result in the rapid dispersal of the seed. Seed can be collected by hand-picking, cutting small branchlets containing the seed or for wattles, placing a tarpaulin on the ground beneath the tree and shaking the branches so seed falls on the tarpaulin. Seed and pods are usually collected together and can be separated by sieving. If seed is to be hand-broadcasted out on site, there is no need to separate the seed, as the pods and seed can be sown out together.

1.14.2.3 Other species

Most other species can be collected similarly to the eucalypts or wattles. Many species will require hand-picking which can be a time consuming but often rewarding job. Native grasses can also be collected by hand-picking, using whipper snippers, scything or for large quantities, grass seed roller brush harvesters are available from the local Catchment Management Authority, Greening Australia (Sydney or Canberra) or members of the Stipa Native Grasses Association. There are also a number of seed collecting contractors available and they usually require sufficient notice.

1.14.3 Seed Storage

Once collected, seed can be used immediately or stored in an appropriate container such as a sealed plastic bag or glass jar. Insects are also often collected with the seed and if left, can eventually destroy your seed. Refrigerating the seed is one way you can prevent small amounts of insect damage. Another old method includes inserting small pieces of naphthalene (mothballs) in your seed container, but this is now not a recommended practice. Seed companies use a machine which fills the seed container with carbon-dioxide and then seals the seed bags. It is important to remember that seed must also stay dry and in constant temperature regimes. If stored properly, most seed can be kept for several years.

1.14.4 Seed preparation

Most seed does not require any preparation apart from that associated with collection and storage. However, Acacia's and related species such as *Hardenbergia violacea* (False Sarsaparilla) require a boiling water pre-treatment to reduce the quantity of wax surrounding the seeds. This allows the more rapid germination of seeds which if left untreated can remain in the soil for over 100 years or more, depending on their given situation.

There are also native plants that are difficult to propagate (eg. *Styphelia triflora*) and require some specialised form of pre-treatment. Some pre-treatments such as gibberellic acid, awn removal (eg. Clematis spp., native grasses), scarification or cold stratification are some methods used. Smoke treatments have also found to be successful in some Western Australian species but it is not really known how successful these treatments can be in the eastern temperate woodland species.

Native grasses can also have dormancy periods, which essentially ensures not all seed germinates at once. This allows seed to have staggered germination, thus extending the chance of the given population to at least some successful establishment. For some species, such as Kangaroo Grass, twelve months dormancy has been described for populations near Canberra. For populations from the Central Tablelands, some germination was observed almost immediately after sowing in February, declined over winter and continued germinating throughout spring (Windsor et al 2000).

For large-scale rehabilitation such as mining, it is probably better to concentrate on species that are readily collectable and that are known to be successfully established from seed. More obscure, but nonetheless important species can later be introduced into the rehabilitation areas or alternatively, planted out as tubestock.

1.14.5 Predation

There are many factors to consider when trying to revegetate areas, particularly large areas. Predation by rabbits, hares and large macropods can have devastating effects on young seedlings. Whilst tree guards can protect young seedling relatively efficiently from hares and rabbits, there seems to be no simple answer to predation from macropods, particularly when the revegetation area lies adjacent to bushland areas where large populations inhabit. Tall tree guards (plastic, netting or mesh) or rabbit proof fencing can help to protect tubestock however the cost of re-establishment becomes quite large. Fencing is not always an option and large kangaroos can easily hop standard fences anyway.

While there is no clear answer to these problems, a few simple suggestions may just work, but need to be monitored and adjusted accordingly.

- Try to minimise soil disturbance as the fresh soil is thought to attract herbivores
- Try to keep the revegetation areas free of lush grass that may only be attracting the herbivores.
- Try not using tree guards as again this may only attract herbivores
- Spraying a solution of chilli, citrus or pepper over young seedlings (subsequent applications may be necessary as rain is likely to wash it off)
- Try re-establishing areas by seed, as young seedlings hopefully grow unnoticed

Again, these are only suggestions without having been substantially tested. Areas of revegetation that are constantly prone to predation may have to be reassessed whether it is feasible to keep on persisting. It may in fact be more cost effective to have installed macropod proof fencing or large tree guards in the first place.

1.15 ***Managing remnant Central Hunter Grey Box – Ironbark woodlands***

The long-term rehabilitation objectives at Warkworth are to establish self-sustaining woodland communities, but these too require management intervention in order to maintain diversity, ecosystem health and encourage natural recruitment. When managing remnant vegetation, it is important to recognise that each remnant area is likely to be different to the next and may require a different approach to improve and maintain its health. It is also important to have clear objectives on what and how this is to be achieved over the longer term. If you have a great patch of remnant vegetation, remember that it is probably great because of the way it has been managed in the past, so first appreciate the management regimes under which has survived before making dramatic changes to the management of the site. Also keep in mind that these remnant patches are dynamic ecosystems that will undergo a series of stages in response to the management practices applied as well as seasonal and climatic conditions.

1.15.1 **Management considerations**

The composition and structure of the remnant is important and should be assessed before any onground activities are undertaken. It is also important to:

- Be mindful of recent land use activities and seasonal conditions when making assessments;
- Know the structure and composition of the woodland community;
- In areas with good quality remnants, limit major on-ground works for at least 18 months—2 years to determine what may occur naturally;
- Regeneration will occur less reliably with increased levels of pasture improvement, regardless of the presence or health of the trees;
- The understorey regulates natural regeneration so learn your species and how to manage them;
- Consider the presence or absence of “indicator” or “special” species. Find out more about them and learn how to manage them; and
- Aim to encourage desirable species, discourage undesirable species by implementing required disturbances at appropriate times
- Try to encourage patchiness and encourage diversity;
- Regeneration events often occur after periods of drought followed by above average rainfall as plant competition is low – be patient; and
- Protection from burning and grazing is likely to be required in the first few years.

There are a variety of techniques that can be pursued to improve the quality of the remnant woodland and often a combination of techniques can and should be used. In some cases, the response of the woodland will remain unknown, unless a few techniques are trialed and assessed, as the response will vary according to a multitude of factors, including seasonal and climatic conditions. A few common techniques can include one or more of the following combinations including:

- Encouraging natural regeneration;
- Trial techniques;
 - Burning
 - Grazing
 - Mowing/slashing

- Scalping and scarifying
- Herbicides
- Tree planting scattered individuals and clumps; and
- Hand seeding;

The following sections describe some management activities that may be considered according to the three main “conditions” or levels of degradation that occur in across the site. These main “conditions” observed within the remnant woodland site include:

- Remnant woodland with a dominant native understorey;
- Native grassland (areas without a tree dominance); and
- Remnant woodland with an exotic pasture understorey.

These have been described in more detail below.

1.15.1.1 Managing woodlands with a dominant native understorey

A remnant containing these characteristics would require little restoration effort as the understorey still retains a dominance of native species, indicating that impacts on the overall ecology of the community have been relatively minor.

In woodland communities where native grasses were once dominant, the tussocky habit of the native grasses such as Kangaroo grass, Poa, Wallaby grass, Speargrass and the subsequent gaps between them, are critical to the regeneration of the grasses themselves as well as many other native plants. Orchids, lilies, daisies, sundews, many other small herbs and shrubs, wattles and eucalypts depend on these spaces for their species' persistence.

Management of areas such as these is usually in the form of maintaining these gaps such that species diversity is maintained. As the rather robust grasses get tall and rank, the gaps between tussocks are reduced, thereby reducing the potential for other species to establish. Over time, these once diverse areas have the potential to be dominated by only a few species, such as more robust perennial grasses. Therefore some form of management is usually required.

1.15.1.1.1 Fire

To maintain the critical regeneration gaps, fire is a useful management tool. Remember to apply a regime that, that does not either enhance or exclude any particular species. Life cycles of all species known to be present should be considered and patch burning, such that heterogeneous patches or mosaics are formed, is essential. This will also ensure residing fauna also have the resources they need for their protection during and after burning.

Prior to undertaking any burn or burning trials, it would be important to first seek advice.

1.15.1.1.2 Crash grazing

Another common management practice is strategic grazing using cattle (or sheep) in appropriate numbers and grazing regimes. Strategic grazing refers to high impact short duration grazing with appropriate rest breaks between grazing cycles. Examples of these systems include Holistic

management, pulse grazing, cell grazing, rotational grazing for example which can also be applied to achieve conservation objectives. Strategic grazing is most effective when paddocks are not too large as it is important to ensure that animals are not in any one area too long. Grazing during spring and early summer is usually not recommended, as many plants are setting seed during these times.

1.15.1.1.3 Mowing/slashing

Mowing or slashing is another management option especially in the first few years to control weeds and assist in fire management, particularly managing the fuel loads around the boundaries of the site. It is also easily undertaken and controlled, even within small target areas, unlike the more complex tasks and unknown risks associated with burning.

Slashing and mowing can also be used as an intermittent management tool to promote the diversity within the site, but the ongoing build up of mulch can lead to the loss of gaps and subsequently reduce species diversity over the longer term.

1.15.1.1.4 Soil disturbance

Regeneration of woodland eucalypts is inhibited by a number of factors including (1) competition from annual exotics (particularly in their first year) and (2) competition from perennial exotics establishing at the same time as the eucalypt seedlings

Many studies suggest that in the absence of a major disturbance such as scalping of topsoil, regeneration of eucalypts in introduced pastures is unlikely. Despite being a rather extreme measure, scalping off the topsoil followed by scarification appears to have provided suitable conditions for the establishment of not only eucalypts (Windsor 1998; 2000, Windsor & Clements 2001, Semple & Koen 1996) but for *Themeda australis* (Windsor 1994; Windsor & Clements 2001; Cole *et al* 2004) a variety of other understorey herbs (Gibson – Roy 2007, Gibson – Roy *et al* 2010) and improved direct seeding outcomes (Geeves *et al* 2008) although they found some other techniques (eg. herbicide application) also proved beneficial and with less extreme preparation requirements.

1.15.1.1.5 Follow up weed control

Weed invasion is a serious threat to native vegetation and any disturbance can create conditions suitable for weeds to establish. Follow up weed control may be necessary and it is important to minimise weeds that can be introduced through livestock excreta or on their coats. Animals should not be moved from a weedy pasture directly to native vegetation areas and a period of quarantine should be considered. Ensure a selective and targeted weed control program is implemented as non targets species would otherwise be disadvantaged if not killed outright.

1.15.1.2 Managing native or derived grasslands

An area containing a dominant native understorey also requires little restoration effort, although the dominant structural layer may appear to have been removed. Naturally occurring “treeless” grasslands were also once present across significant areas of the region and some grassland areas may in fact be 'derived' grasslands, that is, where the overstorey has been removed and the native pastures species

remain. In a restoration project, it is important to consider the effects of establishing large trees and shrubs into these grasslands as competition and shading from mature trees may result in the loss of some species, particularly those requiring full sun. The longer-term management of native grasslands or derived grassland is similar as that described above for remnant woodland communities.

If trees are required in these areas, tubestock planting, direct seeding or hand broadcasting are options for their reintroduction. As the understorey is again predominantly native, it may be as simple as throwing out some seed collected from nearby trees after strategic grazing. Natural regeneration may also result if the area lies adjacent to existing vegetation.

If tubestock planting is desired, it is important to minimise disturbance, so that weeds are not encouraged into these areas. Soil compaction is probably not an issue (as the understorey still remains relatively intact), therefore deep ripping is probably not required. To reduce competition from understorey species, spraying in narrow strips (0.5m wide) along areas where tubestock are required or spot spraying prior to planting is a good idea, but again may not be essential.

1.15.1.3 Managing remnants with an exotic pasture understorey

In these situations it is unlikely that natural regeneration will eventuate, despite the absence of domestic livestock or the presence of seed producing trees. The exotic grasses are often not tussocky and do not leave gaps between plants. They are vigorous competitors for soil moisture, nutrients and space, thus small native plants usually cannot become established.

The presence of exotic species is also an indication of other environmental modification. These may include increased nutrient levels, as exotics pasture species generally require higher nutrient inputs and have subsequently been fertilised. In addition, nutrient build up from livestock excreta may also have occurred, particularly around watering points, hill tops or beneath trees where animals tend to congregate. Soil compaction as a result of sowing or fertilising machinery or domestic livestock may also have occurred. The combinations of these factors are not generally favourable for native plant establishment.

Regeneration success is also highly dependent on the type of species dominating the understorey. Exotic annual grasses such as *Bromus molliformis* (Soft Brome) are less vigorous species compared to exotic perennials such as *Phalaris aquatica* (Phalaris) or *Chloris gayana* (Rhodes Grass). The types of species and their density in the understorey will dictate what method to use.

Some techniques that can be used to enhance these areas can consist again of tubestock planting, or direct seeding. Appropriate ground preparation and follow up weed control is critical under these circumstances.

Other techniques that could be used include an application of glyphosate around the seed producing trees. As regeneration of woodland eucalypts usually restricted under tree canopies, spraying beyond the canopy drip line paying particular attention to the leeward side of the tree where most seed is likely to be dispersed can be used. Most eucalypt seed tends to be dispersed during the warmer months. Applying herbicide in conjunction with scarifying may also result in some successful regeneration.

Another successful method that could be used involves first scalping followed by scarifying. This method involves removing 5-10 cm of topsoil that contains not only the weeds themselves, but removes weed seeds and reduces nutrient levels. The scarifying helps reduce soil compaction and creates

suitable sites for seed germination. Scalping can probably be viewed as a form of longer-term weed control as the seed-bed conditions are generally not favourable to many exotic species.

Scalping and scarifying near seed producing seeds could also be undertaken, providing the prepared areas are positioned where seed is likely to be dispersed. Alternatively, seed can be sown by hand-broadcasting or other seeding equipment, depending on the characteristics and size of the site. Scalping and scarifying however, is labour intensive but should result in successful regeneration particularly when sites have been highly modified. It should be used carefully when sites are sloping, as there is a degree of risk for soil erosion.

1.15.2 Some important management tips

- Reducing plant competition and creating ‘regeneration’ gaps can be achieved by strategic grazing or burning;
- Ant predation may have dramatic impacts on the availability of seed. This may need to be monitored;
- Rabbits and hares can also damage seedlings so undertake pest control;
- Eucalypt regeneration is unlikely to eventuate beneath tree canopies so fencing well beyond the drip-lines of the trees is necessary. Eucalypt regeneration may occur in grassy clearings amongst the stand of trees but will not occur amongst the trees when the stand of trees is thick.
- The native grass tussocks and the subsequent gaps between them are critical to the survival of most woodland species. In spring—summer, a range of wildflowers and other seedlings will occupy these spaces;
- Maintaining these gaps is important and can be achieved by applying appropriate disturbance regimes, usually in the form of burning or strategic or planned grazing regimes
- Remember “REST & RECOVERY”. Do not graze or burn too frequently and remember to patch burn to create and maintain patchiness and retain refuges for grassland fauna.
- The life cycles of key species should be considered before burning or grazing. For example, grasses produce seed annually but eucalypts may require up to seven years to produce seed;
- Crash graze areas after the desirable plants have set seed. The animals will help to incorporate litter into the ground. Avoid grazing during spring and early summer, as many plants are setting seed during these times.
- When crash grazing, animals should not be moved directly from a weedy pasture into the remnant area. A quarantine period should be undertaken so additional weeds are not introduced;
- In smaller areas (e.g. cemeteries), mowing or slashing may also be an option, but mulch build up could lead to the loss of gaps and subsequently reduce species diversity over time.
- Weed invasion is a serious threat to native vegetation and any disturbance can create conditions suitable for weeds to establish. Follow up weed control may be necessary especially after fire.
- Ecosystems are dynamic and will continue to change. You can expect weeds but many weed species are colonising plants and will diminish over time as the ecosystems recovers— so don’t panic!;

1.15.3 Summary of the impacts on remnant vegetation and management recommendations

Table 1-10. Summary of the impacts on remnant vegetation and management recommendations.

Impact to be addressed	Management actions and recommendation
Loss of mature hollow bearing trees	<ul style="list-style-type: none"> ○ Install a range of nest boxes targeting known threatened species ○ Prevent illegal firewood removal by improving fencing around the site and construct "conservation area" signage
Loss of fallen logs, branches and rocks	<ul style="list-style-type: none"> ○ Strategic placement of large logs and branches onto the site ○ Prevent illegal firewood harvesting by improving fencing around conservation areas and erection of "conservation area" signage
Lack of connectivity across the landscape;	<ul style="list-style-type: none"> ○ Undertake a revegetation program aiming to connect large areas of remnant bushland/woodland across the local catchment area <ul style="list-style-type: none"> ▪ Determine seed availability for large scale direct seeding project ▪ Order or make preparations for local provenance tubestock ▪ Undertake appropriate ground preparation ▪ Undertake direct seeding (if desired) ▪ Undertake community tree planting event ▪ Hire tree planting contractor
Altered hydrology due to landscape clearing, soil compaction and/or disturbance and the construction of fence lines, roads and dams;	<ul style="list-style-type: none"> ○ Identify the likely impacts associated with changed hydrology. Investigate feasibility for amelioration. ○ Divert problematic water, construct siltation fences and create wetland systems to ameliorate high sediments loads and/or polluted water. ○ Mulch with weed free local pasture hay and/or scarify compacted or high runoff area ○ Plant wetland species in appropriate areas
Loss of biodiversity, especially native perennial ground cover species;	<ul style="list-style-type: none"> ○ Don't allow grazing for at least two years to gauge a natural response, especially after the drought ○ Slashing around the boundary or in problematic areas may also be required to reduce fuel loads and seed set of undesirable species. ○ Determine the extent of predation by Kangaroos by constructing enclosure areas and monitor the effect. ○ Implement rabbit (and Kangaroo?) control program. ○ Reintroduce plants known to inhabit grassy woodland ecosystems. ○ Harvest local stands of native grasses and sow in strategic locations ○ Undertake seed collection and propagation of absent or locally rare species (including native grasses and forbs). ○ Undertake strategic grazing management and/or trial mosaic burning to promote native perennial species and reduce fuel loads. ○ Undertake other trial techniques as advised (eg Scalping and scarifying) ○ Improve soil health (mulch, lime?)
Loss of genetic variability;	<ul style="list-style-type: none"> ○ Determine the availability of suitable seed in existing seed banks ○ Collect and propagate seed from a nearby remnant (not within the remnant) to introduce a new gene pool. ○ Plant or hand broadcast seed in strategic locations within the remnant
Lack of regeneration due to continuous or inappropriate grazing regimes;	<ul style="list-style-type: none"> ○ Trial techniques such as strategic burns, scarification and scalping. ○ Apply locally collected seed by hand or direct seed in appropriate locations ○ Plant appropriate tree species in strategic locations ○ Plant or hand broadcast seed in strategic locations within the remnant
Susceptibility to "edge effects"	<ul style="list-style-type: none"> ○ Increase the buffer zone around the remnant by revegetating the adjacent cleared land. ○ Plant and/or direct seed grassy woodland ecosystem in adjacent cleared paddock
Increased exposure to herbicides and pesticides	<ul style="list-style-type: none"> ○ Minimise the use of herbicides and pesticides in the vicinity of the remnant. ○ Revegetate the adjacent cleared land.
Increased levels of feral pests	<ul style="list-style-type: none"> ○ Undertake a feral animal control especially targeting foxes, cats and rabbits ○ Implement control of feral honey bees ○ Monitor regularly for feral pests, including the newly installed nest boxes
Increased levels of weed invasion due to overgrazing including agricultural and noxious weeds;	<ul style="list-style-type: none"> ○ Reduce disturbance and encourage native perennial grasses and other understorey species. ○ Slash areas to prevent seed set of undesirable species (eg. patches of Phalaris). ○ Spot spray target weeds. ○ Plant dense thickets of shrubs in strategic locations to suppress weeds. ○ Improve soil health (mulch, lime?) according to soil tests!

Increased levels of weeds due to water runoff from adjacent paddocks, drainage lines and road verge;	<ul style="list-style-type: none"> ○ Reduce and/or prevent dumping of topsoil, weeds and rubbish by improving fencing and erection of signage; ○ Increase perennial ground cover in high runoff or high invasion areas. ○ Monitor and control weeds along road verges and drainage area
Stockcamps beneath mature trees;	<ul style="list-style-type: none"> ○ Restrict livestock access. Time will take care of most weeds in these areas providing disturbance levels are kept to a minimum.
Increased levels of soil erosion	<ul style="list-style-type: none"> ○ Increase and maintain high levels of perennial ground cover ○ Keep disturbance to a minimum ○ Mulch with weed free local pasture hay and/or scarify compacted or high runoff area
Increased water tables and a possibility of salinisation	<ul style="list-style-type: none"> ○ Determine if salinity is present in the area. ○ Improve perennial vegetation cover in the catchment recharge areas. ○ Implement large scale revegetation program in adjacent properties as described above
Increased levels of insect attack	<ul style="list-style-type: none"> ○ Implement feral animal control ○ Increase suitable habitat (ie thickets of shrubs in strategic locations ○ Plant appropriate shrubby understorey shrubs ○ Monitor insect and predator levels (including wasp and other desirable insect predators) ○ Improve overall health of the remnant and connectivity within the catchment

1.16 *Establishing a monitoring program*

A monitoring program that will assess the recovery of undisturbed remnants and rehabilitation areas on Warkworth will also be undertaken. Various methods for monitoring and assessing the health of native ecosystems are outlined below. Some of these methods may be incorporated into the monitoring program but the monitoring program must also utilise a methodology that can provide quantitative data to assess changes occurring over time.

A consistent and quantitative methodology should be implemented and undertaken on a periodic basis, ensuring a satisfactory number of baseline sites are established prior to any management intervention. Permanent quadrats should be established and reassessed at a maximum of two year intervals at least in the short term to ensure restorative strategies (eg natural recruitment, maintenance of ground cover, increasing native perennial cover etc) are progressing as desired.

In new revegetation sites, an annual monitoring program is likely to be required as the site rapidly changes and can be vulnerable to effects of climates, pests and diseases. Annual monitoring will also align with regulatory requirements such the Annual Environmental Management Reports (AEMRs) and REMP's (NSW I&I 2010). In addition, general inspections for survival, mortality, weed control and pests should also be undertaken more regularly and at least biannually, up until the sites have become well established. The duration between monitoring periods can be lengthened to five yearly intervals once it has been established that the restorative strategies are appropriate and that conservation objectives are being met. The same methodology should also be applied to pre-mining disturbance areas at Warkworth to gather detailed information of the affected communities and assist with rehabilitation objectives.

1.16.1 **Monitoring and assessing ecosystem health**

Assessment of ecosystem health is a potentially useful concept because it describes the current state of the system without predicting future condition with particular time scales but can be subjective and difficult to quantify (CSIRO Tropical Agriculture 1998). Several means of quantification have been developed and evaluated and these provide useful benchmarks for vegetation management strategies. They range from methods for monitoring landscape productivity to assessment of biodiversity benefits

and disbenefits likely to result from land use change, benchmarking methods of assessing vegetation quality and a visual scoring system (Wakefield and Goldney 1997).

Despite widespread acknowledgement of the importance of maintaining, managing and improving the condition of native vegetation, accepted standards for site-based assessment remain elusive. Oliver *et al* (2002) raises two 'positions' for discussion that are relevant to this problem: (i) methods for assessing vegetation condition are best developed within, and applied to, a single clearly defined context; and (ii) the current focus on 'pre-1750 vegetation' and 'naturalness' concepts may, in some circumstances, limit efforts to deliver site-based methods for assessing vegetation condition for 'biodiversity conservation'.

1.16.1.1 Landscape Function Analysis

Landscape Function Analysis, (LFA; Tongway and Hindley 1997) is a monitoring procedure that assesses how well a landscape functions as a biophysical system using simple indicators. The indicators used quantify the utilisation of the vital landscape resources of water, topsoil, organic matter and seeds in space and time. A functional landscape conserves these resources while they will 'leak' from a dysfunctional landscape beyond its boundaries. The critical landscape interactions that are the basis of LFA are illustrated in Figure 1-14. Soil and climate regulate the conditions for plant growth. Grazing affects vegetation directly by harvesting and can result in plant death if too persistent. The more serious affect occurs if the grazing changes the soil quality and suitable soil habitat is removed. The procedures developed for LFA enable these two alternatives to be distinguished and whether, during a drought, a soil is 'bare but productive' or 'bare and unproductive' (Tongway and Hindley 1997). This method has been extensively effectively used.

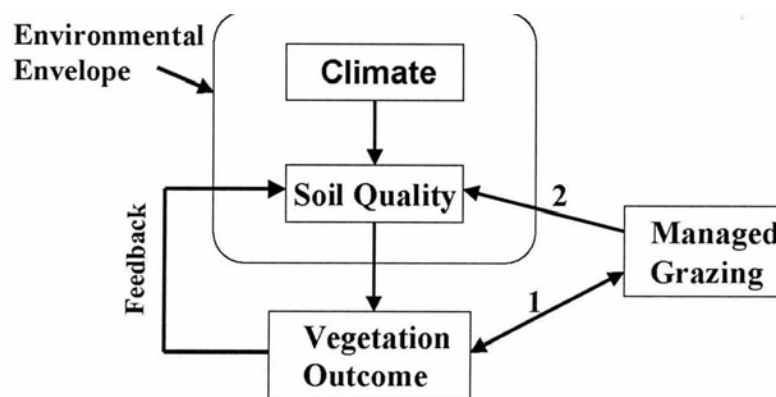


Figure 1-14. The interaction of climate and soil quality gives a vegetation response. The amount of material that is recycled to maintain soil quality is determined by grazing management (Tongway & Hindley 1997).

1.16.1.2 Biodiversity Benefits Toolkit

The aim of Biodiversity Benefits Toolkit (Oliver and Parkes 2003) is to quantify the current biodiversity value of a site, estimate the magnitude and direction of change in biodiversity value as a result of land use change and incorporate these current and potential values into a biodiversity benefits index (BBI). This index is calculated on the basis of three surrogate measures of biodiversity: vegetation condition, conservation significance and landscape context. While this assessment approach may have value it has not been further developed or widely used.

1.16.1.3 'Habitat Hectares'

Habitat Hectare is the method for assessing vegetation quality used by the Victorian Department of Sustainability (www.dse.vic.gov.au 2004). The method is designed so that assessors do not need highly specialised knowledge of native vegetation but some knowledge is important. It requires that the condition of the vegetation be assessed in comparison to a 'benchmark' that represents the average characteristics of a mature and apparently long undisturbed state for the same vegetation type. The habitat hectares approach involves assigning a habitat score to an area of habitat that indicates the quality of the vegetation in relation to the pre-determined benchmark. This score is then multiplied by the area of the habitat patch (in ha) to determine the quality and quantity of the vegetation (habitat hectares). This is a detailed and complex approach that requires the development of vegetation benchmarks.

1.16.1.4 'Save the Bush Toolkit'

The simplest method for assessing the health of native vegetation has been developed by Wakefield and Goldney (1997). As part of their 'Save the Bush Toolkit' for the Central West Region (CWR) they provided bushland health rating categories based on some key indicators and supported by photograph. They have also developed a simple assessment sheet which provides a score for the vegetation patch which can be converted into a health rating. This method is particularly valuable because it is accessible for the landholder to use but has limitations when assessing grassland ecosystems.

1.16.1.5 Rangeland health evaluation matrix

A rangeland health evaluation matrix has been developed by the Committee on Rangeland Classification which provides a valuable guide to the assessment of ecosystem health in the CW catchment (LWR 1998). The criteria used in this table incorporate elements of ecosystem resilience – the system's ability to regain health if the degrading process (especially grazing) to be halted. This does not incorporate naturally patchy plant distribution but is addressed by Tongway and Hindley (1995).

1.16.1.6 Grassy Ecosystems Management Kit

A Grassy Ecosystems Management Kit (Sharp 2003, Sharp *et al.* 2005) is a manual designed for the assessment of grassy vegetation and its habitat at all scales of the landscape and can therefore be used by regional planning groups, Landcare groups, individual landholders and land managers. The step by step activities outlined in the kit can be used to develop a conservation management plan using best practice to maintain the natural functioning of remnant grassy ecosystems.

1.16.2 Ecological performance indicators and monitoring ecosystem succession of mine rehabilitation: DnA Environmental

Presently there has been little rigour associated with progressive rehabilitation monitoring and defined criteria that need to be met in order to receive sign off of rehabilitation after mining disturbance (Nichols 2005). In the past, closure “sign off” has been dependant on the knowledge and experience of individual regulators whom need to be satisfied that the site has been satisfactorily rehabilitated. This process inherently presents a multitude of difficulties and in particular there is no concise objectivity, defined guidelines nor may the process of ecological succession or sustainability be adequately considered (Nichols 2005). In addition variations in seasonal and climatic conditions, final land use and associated management practices, vegetation community and degree of modification of the wider environment can also impact on rehabilitation and rehabilitation objectives.

To overcome some of these difficulties, a defined set of realistic rehabilitation criteria is required that assist all stakeholders involved work towards and make fair comparisons of the rehabilitation attempts and importantly, assist regulators make an informed decision about the ecological sustainability of the rehabilitation areas in the context of the local environment. The criteria must also be flexible enough to account for the dynamic nature of the environment and consider the ecological successional processes that occur over the longer term.

1.16.2.1 Developing performance criteria

A new approach to rehabilitation monitoring and closure criteria within the mining industry has recently been released (DII 2010). Essentially in order to receive sign off of rehabilitation, it will be necessary to demonstrate that selected indicators (or criteria) have reached their established closure criteria or that a satisfactory successional trajectory has been established that will result in a self-sustainable ecosystem. The new approach has been broken down into five major stages of ecosystem development as demonstrated below, by which a set of indicators or criteria will need to be monitored and either be *equivalent to or exceed* those assessed for the reference sites or show positive recovery trends.



In addition, Nichols (2005) produced a report funded by the Australian Centre for Minerals Extension and Research in Queensland to develop an agreed, workable process for addressing relevant issues relating to mine closure and associated completion criteria when establishing native vegetation communities following coal mining in the Hunter Valley of New South Wales (ACARP report). The findings were synthesized into a set of principles that mines can use in designing monitoring programs and in the selection of rehabilitation performance criteria, reference sites and key performance indicators. The new “hierarchy of sustainable ecosystems” proposed by DPI in conjunction with many facets of Nichols (2005) report have formed the foundation of this monitoring procedure.

This document provides a summary of the processes undertaken in order to establish a rigorous monitoring program and/or determine a set of realistic criteria for closure. The process incorporates the use of clearly defined, repeatable and consistent methodologies for monitoring changes in various aspects of ecosystem function, succession and long-term sustainability. Part of this process includes:

- Undertaking simple, reliable and repeatable measurements in different aspects of ecosystem function and development;
- Establishing a range of relevant reference sites to compare and track the progress and inherent ecosystem function of rehabilitation areas;
- Selecting a range of suitable reference sites that reflect the desired final land use, historical disturbances, biodiversity targets and local community expectations; and
- Undertaking a monitoring program that provides simple but informative and reliable information that indicates positive recovery trends or rapid detection of rehabilitation failure.

1.16.2.2 Establishing “suitable” reference sites

The use of reference sites to set the benchmark for rehabilitation has been considered in the mining industry (Nichols 2005) and is likely to be an appropriate way to track rehabilitation outcomes. However the appropriate selection of “relevant” reference sites appears to be essential if the process is to be effective. Selecting suitable reference sites is essential as it will ultimately set the benchmark for rehabilitation targets and the criteria to be met for closure.

A range of reference sites that will best reflect the post-mining *land use* of the rehabilitation areas is utilised. Essentially, this dictates the type of *vegetation community* that will need to be established and the final *management regime* that it will be subjected to. The methodology also considers the *condition* of the reference sites as it has a significant bearing on the composition, structure and function of the community and subsequently its long-term sustainability.

Reference sites are generally selected that will provide a realistic set of data that will form the basis of *achievable* closure criteria in the context of the local environment. The appropriate selection of reference sites can therefore provide:

- A series of revegetation benchmarks. That is, revegetation areas can be compared to sites with a history of disturbance through to relatively undisturbed sites, in the local context;
- A record of changes in community structure and function under different management regimes, climatic conditions or disturbance events. For example the final land use may be a grazed pasture or woodland area therefore the closure criteria also should reflect this planned disturbance event; and
- A range of data from representative ecosystems in the local area thus assisting with the planning, implementation and maintenance of revegetation projects.

1.16.2.3 Rehabilitation monitoring methodology

The monitoring methodology adopted is a standard and simple procedure that can be easily replicated over any vegetation community or rehabilitation area and importantly results in a system that essentially compares “apples with apples”. The methodology uses a combination of Landscape Function Analyses (CSIRO Tongway & Hindley 1996), accredited soil analyses and various measurements of ecosystem diversity and habitat values (adapted from CSIRO Gibbons 2002).

1.16.2.3.1 LFA methodology

LFA is a methodology used to assess key indicators of ecosystem function including landscape organisation and soil surface condition as measure of how well the landscape retains and uses vital resources. It was developed by CSIRO scientists Tongway and Hindley (Tongway 1994, Tongway and Hindley 1995, 1996, 2003, 2004). The indicators used quantify the utilisation of the vital landscape resources of water, topsoil, organic matter and perennial vegetation in space and time.

LFA methodology collects data at two “nested” spatial scales.

1. At coarse scale, **landscape organisation** is characterised. Patches and interpatches, indicators of resource regulation, are mapped at the 0.5 to 100 m scale from a gradient-oriented transect (making sense of landscape heterogeneity); and
2. At fine scale, **soil surface assessment** (soil “quality”) examines the status of surface processes at about the 1-m scale, with rapidly assessed indicators on the patches and interpatches identified at coarse scale.

At each scale, parameters are calculated that reflect several aspects of landscape function. In the first stage, we identify and record the patches and interpatches along a line oriented directly down slope. Sometimes there are several different types of each patch/interpatch which provides a measure of heterogeneity or “**landscape organisation**”.

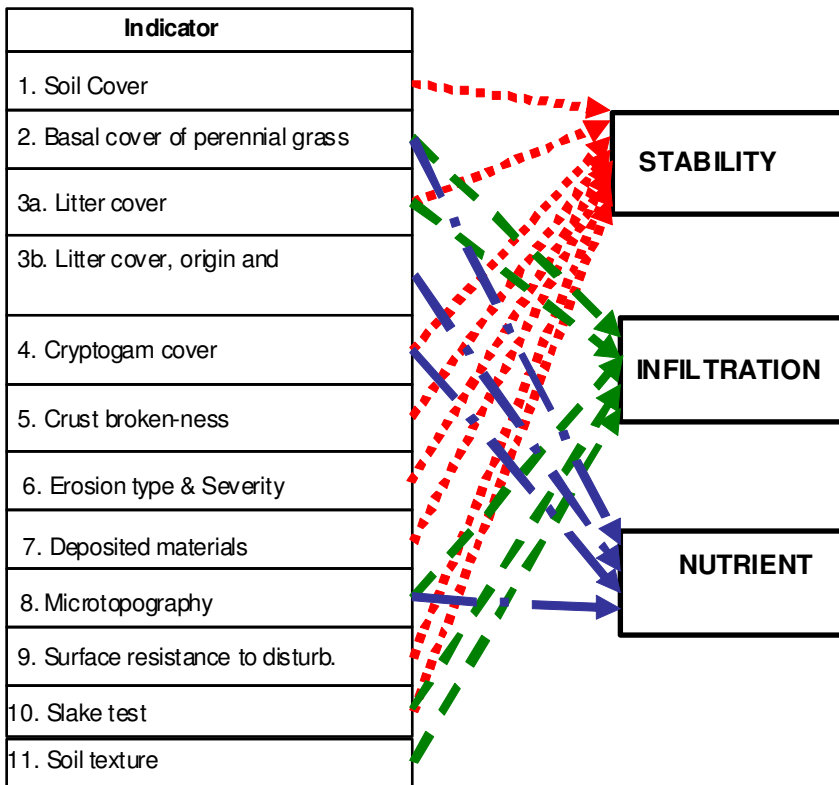
In the second stage, called “**soil surface condition**” (**SSC**) assessment, it is possible to assess and monitor soil quality using simple indicators including:

- Rain splash protection;
- Perennial vegetation cover;
- Litter;
 - Percent litter cover;
 - Origin of the litter;
 - Extent of decomposition;
- Cryptogam cover;
- Crust Brokenness;
- Soil Erosion Type and Severity;
- Deposited Materials;
- Soil Surface Roughness;
- Surface Nature (resistance to disturbance);
- Slake Test; and
- Soil Surface Texture.

These 11 features are assigned a class value, compiled and calculated into three indices of soil quality:

1. **Stability** (that is, resistance to accelerated erosion),
2. **Infiltration** (the rate soil absorbs water) and
3. **Nutrient Cycling** (the way plant litter and roots decompose and become available for use by other plants).

The results are scaled from 0 – 100.



LFA has been used and tested widely and successfully in the mining industry across the globe. LFA is designed for repeated use so that the development, or degradation, of a site can be assessed over time. The interpretation module proposes an analytical process that enables the user to examine the “trajectory” of the ecosystem being monitored and to use this information to decide if the site is converging on a “target” functional state, or needs further work to ensure ultimate success. Target values signifying rehabilitation success can be obtained by assessing reference sites that represent the desired end point of rehabilitation.

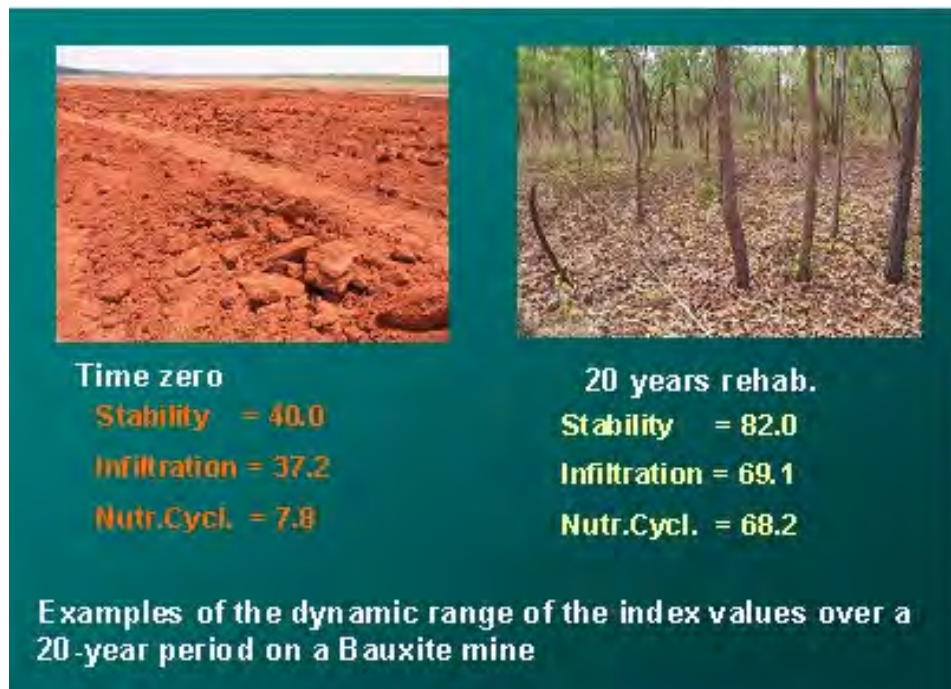


Figure 1-15. An example of how LFA can be used to track the progress of rehabilitation sites. Slide courtesy of David Tongway.

Whilst LFA is a quick, consistent and reliable measure of landscape function, it does not capture changes in vegetation structure, composition and spatial distribution or other biodiversity components.

1.16.2.4 Soil analyses

Soil samples are undertaken using standard soil sampling techniques with a core sampler within the monitoring quadrat. At least 12 cores are taken at each site and bulked together. Soil samples are sent to Southern Cross University at their National Association of Testing Authorities (NATA) accredited laboratory for analysis. Soil analysis consist of assessing the parameters, pH, EC, Available Ca, Mg, K, Ammonia, sulphur, organic matter, exchangeable Na, Ca, Mg, K, H, Al, cation exchange capacity, available and extractable phosphorus, micronutrients (Zn, Mn, Fe, Cu, B), Total Carbon and Nitrogen. A report with analysis and appropriate recommendation is provided by the laboratory. Exchangeable Sodium Percentages were calculated as a measure of sodicity or dispersion.

1.16.2.5 Monitoring structural diversity, floristics and other biodiversity attributes

Assessments of various biodiversity components must also be made to monitor changes in particular plants and groups of plants through the various successional phases and to document and/or identify critical changes or management actions required.

Some simple and rapid procedures for making these assessments were developed by CSIRO scientists and were developed for assessment habitat quality across a range of vegetation types in the southern NSW Murray-Darling Basin (Gibbons 2002), and Biometric Model used in the Property Planning Process (Gibbons *et al* 2008a,b). Some adaptations have been made to reduce monitoring effort where possible, and to incorporate aspects of newly formed revegetation sites or sites in the early stages of recovery. For example some habitat features such as the detailed measuring and assessment of

decomposition of the logs and branches has been omitted, whilst the understorey assessment included planted tubestock, direct seeding as well as natural recruitment and naturally occurring shrubs.

The rapid ecological assessment provides quantitative data that measures changes in:

- Floristic diversity including species area curves and growth forms;
- Ground cover diversity and abundance;
- Vegetation structure and habitat characteristics (including ground cover, cryptogams, logs, rocks, litter, projected foliage cover at various height increments);
- Understorey density and growth (including established shrubs, direct seeding and tubestock plantings and tree regeneration);
- Overstorey characteristics including tree density, health and survival; and
- Other habitat attributes such as the presence of hollows, mistletoe and the production of buds, flowers and fruit.

Permanent transects and photo-points are established to record changes in these attributes over time.

1.16.2.6 Performance criteria and key performance indicators

Proposed ecological performance targets relevant to rehabilitation of native ecosystems have been identified in Table 1-11 and these directly relate to primary ecosystem components and ecological succession as identified by Nichols (2005) and NSW I&I (2010). These primary ecosystem components include:

- Landform slope and gradient;
- Landform function;
- Active erosion;
- Soil chemical/physical properties and amelioration;
- Vegetation diversity;
- Vegetation density;
- Ecosystem composition.
- Protective ground cover;
- Understorey diversity;
- Ecosystem growth and natural recruitment;
- Ecosystem structure;
- Tree diversity
- Tree density; and
- Ecosystem health.

These ecosystem components have been grouped to align with natural ecosystem succession and subsequently the “hierarchy of ecosystem succession” model. From these, a range of Ecological Performance Indicators (KPI’s) have been established and are quantified by data obtained from using the methodologies as described above. All performance indicators are quantified by range values measured from the replicated reference sites which form both an *upper* and *lower* limit.

The appropriate selection of reference sites is fundamental to this model and they must be considered to be representative examples of that community type under the final land use management in the local area. The reference site ecosystems must be “acceptable”, “sustainable” and “typical” of the local area. It is also important to note that the criteria by which rehabilitation sites will be assessed against will also be dynamic throughout time, to best represent seasonal and climatic conditions. Whilst the particular

season for undertaking the monitoring is relatively unimportant, it is imperative that both reference and rehabilitation sites are monitored at the same period in time, to reduce seasonal variations.

These key performance indicators are then further separated into “*Primary performance indicators*” and “*Secondary performance indicators*”. Primary performance indicators are those chosen as Key (or completion) targets, while secondary performance indicators are those that would be desirable to achieve but will not have an influence on completion targets. Primary performance indicators have been identified as those that will satisfy requirements specified within the Mining Operations Plan or other approved documents, and in particular the final land use and any relevant conditions of consent relating to vegetation type, specific use of species and condition for example.

Not all Performance Indicators obtained from the monitoring program are set as primary completion targets.

Table 1-11. Proposed Primary and Secondary Ecological Performance targets and their relationship to the 'hierarchy of ecosystem succession' model.

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement
<i>Performance indicators are quantified by the range of values obtained from replicated reference sites</i>						
Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	Degrees (<18°)
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies		Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising	No.
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m ²
Growth medium development	Soil chemical, physical properties and amelioration	Soil properties are suitable for the establishment and maintenance of selected vegetation species	pH	pH is typical of that of the surrounding landscape or falls within desirable ranges provided by the agricultural industry		pH (5.6-7.3)

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/cm (<0.150)
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)
			Phosphorous	Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (50)
			Nitrate		Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (>12.5)
			CEC		Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)
			ESP		Exchangeable Sodium Percentage (a measure of sodicity) is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	% (<5)
Ecosystem establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter less than 5cm is comparable to that of the local remnant vegetation.		species/area
				The percentage of shrubs and juvenile trees with a stem diameter less than 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population
			Total species richness		The total number of live plant species provides an indication of the floristic diversity of the site and is comparable to the local remnant vegetation	

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area
			Exotic species richness	The total number of live exotic plant species provides an indication of the exotic plant diversity of the site and that it is less than or comparable to the local remnant vegetation		<No./area
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		>
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees	The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area
Shrubs			The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	
Sub-shrubs				The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area
Herbs			The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	
Grass			The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area
			Cactus		The number of cactus comprising the vegetation community is comparable to that of the local remnant vegetation	No./area
			Aquatic		The number of aquatic species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area
Ecosystem development and habitat complexity	Protective ground cover	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	Litter cover		Percent ground cover provided by dead plant material is comparable to that of the local remnant vegetation	%
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	%
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement	
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (less than 50cm in height) is comparable to that of the local remnant vegetation		%	
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation		%	
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it has more than or an equal number of native species as the local remnant vegetation	> species/m2	
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it has less than or an equal number of exotic species as the local remnant vegetation	< species/m2	
			Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m) compared to exotic species is comparable to that of the local remnant vegetation		%
			Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height	The number of shrubs or juvenile trees less than 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement
			shrubs and juvenile trees 0.5 - 1m in height		The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area
			shrubs and juvenile trees 1.5 - 2m in height		The number of shrubs or juvenile trees less than 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees less greater than 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area
Ecological stability	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover
			Foliage cover 2 - 4m			Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement
			Foliage cover - 6m	4	Projected foliage cover provided by perennial plants in the 4 -6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover
			Foliage cover >6m		Projected foliage cover provided by perennial plants greater than 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter greater than 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area
					The percentage of maturing trees and shrubs with a stem diameter greater than 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	%
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The diversity of trees or shrubs with a stem diameter greater than 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	No./area
				Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population

Hierarchy of ecosystem succession	Aspect or ecosystem component	Ecological Performance Targets	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measurement
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	% population
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population
			Flowers/fruit: Trees	The presence of reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population

1.16.2.7 Number of sites required

1.16.2.7.1 Reference sites

The number of reference sites required depends on the range of final land uses specified in the Environmental Impact Statement, Mining Operations Plan or REMP. These may be one or a combination of the following including:

- Grazed introduced pastures;
- Derived grasslands;
- Open forests;
- Tree and shrub plantations;
- Open grassy woodlands
- Riparian ecosystems (ie. Wetlands, creeks drainage lines); or
- A mixture of all of the above.

It will be essential to identify all proposed land uses prior to commencing any rehabilitation monitoring program as appropriate reference sites will need to be located. It is usual to establish three reference sites representative of each of the final land uses ranging in condition but typical of the local area.

1.16.2.7.2 Rehabilitation sites

The number of sites requiring monitoring on the rehabilitation areas is also dependant on the number of different ecosystems being restored as well as the rate at which they are being established. It will also be dependent on other factors such as the number of treatments applied or different ways the area has been established. The number therefore is likely to increase as progressive rehabilitation is undertaken. Additional sites, such as those in areas of concern or particular interest may also be required. DEC (2004) guidelines recommend that the number of sites required increases as the areas increase. There should be a minimum of one monitoring site per 2ha of one vegetation community, 2 quadrats per 2-50ha, 3 quadrats per 51 - 250ha and 5 quadrats per 251 -500ha.

1.16.2.8 Monitoring frequency

1.16.2.8.1 Reference sites

Initially, a lot of effort will be required to locate and obtain baseline data from the range of suitable reference sites identified. However, after the first series of monitoring has been undertaken, follow up monitoring effort can be reduced to include aspects of ecosystem development that are relevant or dependant on seasonal conditions or disturbance event. For example, it should/would be unnecessary to undertake a full tree count every year, unless there is a particular reason to do so.

1.16.2.8.2 Rehabilitation sites

The number of sites requiring monitoring on the rehabilitation areas is also dependant on the number of different ecosystems being restored as well as the rate at which they are being established. It will also be dependent on other factors such as the number of treatments applied or different ways the area has been established. The number therefore is likely to increase as progressive rehabilitation is undertaken. Additional sites, such as those in areas of concern or particular interest may also be required.

The rate of transition on newly formed rehabilitation areas is relatively quick and these changes should be recorded to identify if rehabilitation is trending in the right direction and/or if additional management actions or interventions are required. A monitoring program should be scheduled at time zero, (6-9 months optional), 1 year, 2 years, 3 years, 5 years and thereafter at five year intervals. However, it is usual that an annual monitoring is implemented to satisfy regulatory processes.

1.16.2.9 Monitoring summary

The proposed methodology provides a process to achieve realistic objectives through the choice of reference sites under varying degrees of modification or disturbance, thereby allowing for a more realistic approach to achieving completion criteria. For example, a grazed woodland site is not likely to reach the criteria set against an ungrazed woodland. It also allows greater flexibility through the simultaneous assessment against relevant reference sites over time that reflect the dynamic nature of ecosystems, seasonal and climatic conditions occurring in the local area and/or changes in management regimes. For example a rehabilitation site in the midst of drought is not likely to reach criteria set against a reference site in an above average rainfall year.

The proposed methodology has considered many ecological impacts and processes associated with past land use and future rehabilitation objectives. In particular it has established criteria by utilising “real” data from “real” ecosystems, thus providing realistic rehabilitation milestones and goals in the context of the local environment under a range of different disturbance events. It will also provide a series of benchmarks, rather than a single target, against which rehabilitation can be measured over time.

Finally the proposed methodology appears to provide a clearly defined, simple, repeatable and consistent monitoring process that can be used on any vegetation type or plant community. It also appears to fit within the hierarchy of ecosystem succession (DPI) against which rehabilitation and mine closure will be assessed and addresses the range of technical issues identified by Nichols (2005).

1.17 Conclusion

Regardless of the method used for establishing vegetation, availability of viable seed, availability of a suitable niche for germination (disturbance events), suitable rainfall and temperatures for

germination and establishment, absence of disease, seed harvesting and grazing and lack of competition from herbaceous plants have been accepted conditions required for optimising the germination and establishment of a range of native species. These conditions can often be provided after disturbance events such as after bushfires, prolonged drought, crash grazing or by other physical disturbances. The positive response of many native species (and vegetation communities) to disturbance events is a phenomenon that becomes a fundamental attribute to acknowledge and is a primary driver of maintaining ecosystem health, diversity and sustainability. These conditions could also be provided in mine revegetation but additional intervention is required.

In most situations, rehabilitation areas are free from livestock grazing and with appropriate attention given to creating a weed free environment through a variety of mechanisms and the correct choice of seed of a range of native species onto a properly prepared substrates during favourable seasonal conditions, it is not unreasonable to expect successful establishment of a range of native species on mine sites, particularly if the rehabilitation strategy is sound and well executed.

Whilst there are presently few known examples of successful revegetation of sustainable grassy woodland ecosystems on mine rehabilitation areas, this is largely due to the lack of understanding about ecological successional processes combined with inadequate planning and lack of an integrated and coordinated rehabilitation strategy. In many cases, the majority of mining operations have not yet attempted to rehabilitate specific vegetation communities with characteristics and ecological function similar to the local remnant vegetation and those that have are still trialling techniques or are in their early establishment phases (Pers. Obs). With the appropriate implementation strategies in place combined with the financial resources to support them, rehabilitation of the Central Hunter Grey Box – Iron Bark (*E. moluccana* – *E. crebra*) woodlands on spoil dumps in the Warkworth coal mine should be a realistic and viable rehabilitation outcome.

1.18 **References**

Cluff, D (2003). Farming without farming. Stipa Native Grasses Association, Wellington, NSW. ISBN 0-9751118-0-9.

Coal & Allied (2010). Proposed Warkworth Extension. Environmental Assessment, Volume 1. Main report. April 2010.

Coal & Allied (2010). Proposed Warkworth Extension. Environmental Assessment, Volume 2. Technical report: Annex E. Ecology Study. April 2010.

DEC (2010). Central Hunter Grey Box - Ironbark Woodland - Hunter/Central Rivers: Distribution and vegetation associations in the Hunter/Central Rivers <http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile>. Accessed 27/7/10.

DECCW. (2010). Draft National Recovery Plan for White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Department of Environment, Climate Change and Water NSW, Sydney.

Gibbons (2002). Methodology for the Grassy Box Woodlands Benchmarking Project in southern NSW Murray-Darling Basin. CSIRO, Canberra.

Gibbons, P., Briggs, S.V., Ayers, D.A., Doyle, S., Seddon, J., McElhinny, C., Jones, N. Simes, R. and Doody, J.S. (2008a). Rapidly quantifying reference conditions in modified landscapes. *Journal of Biological Conservation*.

Gibbons, P., Briggs, S.V., Ayers, D.A., Seddon, J., Doyle, S. and Briggs J.S. (2008b). Biometric 2.0. A terrestrial Biodiversity Assessment Tool for the NSW Native Vegetation Assessment Tool. Operations Manual. NSW Department of Environment and Climate Change, C/- CSIRO Sustainable Ecosystems, GPO Box 284, Canberra ACT 2601.

Gibson – Roy (2007). Werribee Zoo. Preliminary twelve Month findings. Grassy Groundcover Gazette. Pp 9-11. April 2007.
www.greeningaustralia.org.au/GA/VIC/OngroundAction/Projects/SW/ggr.htm

Gibson-Roy, G. Moore, G., Delpratt, J and Gardner, J. (2010). Expanding horizons for herbaceous ecosystem restoration: the grassy groundcover restoration project. *Ecological Management and Restoration* 11(3): 176 – 186.

Greening Australia (2008). Introducing...Seed Production Areas. An Answer to Native Seed Shortages. Information Brochure.

Huxtable, C. H. A., Koen, T. B. and Waterhouse, D. (2005). Establishment of native and exotic grasses on topsoil and mine overburden in the Hunter Valley NSW. *The Rangeland Journal*, 27: 73 – 88.

Lodge, G.M. (1981) Establishment of warm and cool-season perennial grasses on the North-West Slopes of New South Wales. 2. Establishment and seedling survival in the field. *Australian Journal of Botany*, **29**, 121 - 33.

Lodge, G.M., & Whalley, R.D.B. (1981) Establishment of warm and cool-season native perennial grasses on the north-west slopes of New South Wales. 1. Dormancy and germination. *Australian Journal of Botany*, **29**, 111 - 19.

Long, K. and Nelson, J. (2010). *Draft National Recovery Plan for the Spotted-tailed Quoll *Dasyurus maculatus**. Department of Sustainability and Environment, Melbourne.

Nolan, M. B., Windsor, D. M. and Williamson, S., (1997). Dormancy and viability of *Themeda australis* (Kangaroo Grass) and its implications for mining revegetation in the Central Tablelands of New South Wales Pp. 149-154 in *Second Australian Native Seed Biology for Revegetation Workshop* ed by S. M. Bellairs and J. M. Osborne.

NSW I&I: Department of Industry and Investment (2010). Rehabilitation and Environmental Management Plan (REMP) Guidelines. Consultation Draft V2.0, June 2010. Minerals and Energy Division, Mineral Resources Branch. Maitland, NSW.

Prober, S.M. (1996). Conservation of Grassy White Box Woodlands: rangewide floristic variation and implementations for reserve design in *Australian Journal of Botany* **44**: 57-77.

Prober, S.M., Thiele, K.R. & I.D. Lunt (2002b). Identifying barriers to restoration in temperate grassy woodlands: soil changes associated with different degradation states in *Australian Journal of Botany* **50**: 699-712.

Reid, N. L. (2004). *An evaluation of substrate and flora treatment for rehabilitation of tailings dam storage facilities, Cadia Valley Operations*. Honours thesis, Faculty of Rural Management, University of Sydney, Orange, NSW.

Reid, N. L. (2009). *Vegetation and substrate development on mineral tailings: Cadia NSW*. Master of Philosophy dissertation, Faculty of Rural Management, University of Sydney, Orange, NSW.

Smits, J. (2008). *The effectiveness of different mulches in mine rehabilitation: short-term effects on the surface stability and the conditions for plant growth, Cowal Gold Mine, NSW*. Honours Thesis, Australian National University, Canberra, ACT.

Tongway, David J., and Norman L. Hindley. 1995. *Manual for Soil Condition Assessment of Tropical Grasslands*. 60 p. Canberra: CSIRO Division of Wildlife and Ecology.

Tongway, D. & Hindley, N. (1996). *Landscape Function Analysis. Understanding more about your landscape. A method for monitoring landscape productivity*. CSIRO Sustainable Ecosystems. CD Version 3.1

Tongway, D. & Hindley, N. (2003). *Indicators of Ecosystem Rehabilitation Success. Stage Two – Verification of EFA Indicators. Final Report for the Australian Centre for Mining Environmental*

Research. CSIRO Sustainable Ecosystems In association with Ben Seaborn CMLR, University of Queensland

Tongway, DJ and Hindley, NL 2004. Landscape Function Analysis: Methods for monitoring and assessing landscapes, with special reference to minesites and rangelands. CSIRO Sustainable Ecosystems, Canberra. www.cse.csiro.au/research/efa/index.htm.

Waters, C., Whalley, W. and Huxtable, C. (2000). Grassed Up. Guidelines for revegetating with Australian native grasses. NSW Agriculture, Dubbo, NSW. ISBN 0 7347 1256 1.

Windsor, D. M. and Clements, A., (2001). Germination and establishment field trials of *Themeda australis* (Kangaroo Grass) for rehabilitation of a New South Wales, Central Tablelands gold mine. *Restoration Ecology*: 9(1): 104-110.

Windsor, D. M., Clements, A., Nolan M. and Sandercock, H. (2000). Recreating eucalypt woodland with a grassy understorey on a gold mine in the Central Tablelands of New South Wales Pp 298-317 in *Temperate woodlands in Australia: Biology, conservation, management and restoration*, ed by R. J. Hobbs and C. J. Yates. Surrey Beatty & Sons.



Appendix C

Appendix C | Dr David Robertson - Response regarding Warkworth Sands Woodland

31 August 2011

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**RESPONSE TO PEER REVIEW BY TRAVIS PEAKE ENTITLED:
“REVIEW OF ECOLOGICAL ASSESSMENTS FOR WARKWORTH
EXTENSION EA AND HVO SOUTH MODIFICATIONS PROJECTS”**

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Dear Anthony

I have now read the aforementioned peer review by Travis Peake (the “Peake Report”) commissioned by Department of Planning for the Warkworth Extension EA (“the EA”). The purpose of this letter is to provide a response to the conclusions and recommendations of the Peake Report.

To be consistent with the terminology used by the Peake Report, this letter uses the following terms to refer to offset areas covered by the EA:

- BOA = biodiversity offset area;
- NOA = northern offset area;
- SOA = southern offset area; and
- Other offset areas: Goulburn River BOA, Seven Oaks BOA, Putty BOA, Springwood BOA.

I note that despite complaints about explanation of methodology by Cumberland Ecology, Peake agrees with many of the conclusions made by us in the Flora and Fauna section of the Environmental Assessment (EA) for the Warkworth Extension. In particular, the Peake Report agrees:

- That vegetation maps provided of the impact area and most offsets are adequate for the purposes of impact assessment and offsetting;
- That the impact assessment for most threatened species (including birds, bats and Squirrel Glider) is adequate;
- That strategic offsets such as Goulburn River, Seven Oaks and

Springwood are appropriate for inclusion in the offset package;

- That ironbark forest and woodland present at the aforementioned strategic offsets can play an important role in offsetting impacts to Central Hunter Grey Box – Ironbark Woodland (CHGBIW); and
- That a Biodiversity Management Plan (or plans) should be prepared to prescribe the long term management of offsets within the offset package.

The Peake Report summarises its key findings by making a detailed series of recommendations. The Peake recommendations have been reproduced verbatim in a table at the end of this letter and I have made a response to each. This demonstrates that for most of the recommendations, Peake and Cumberland Ecology are in either complete or partial agreement.

Notwithstanding the level of agreement, I am concerned about some analysis made, and the conclusions drawn, by the Peake Report with regard to Warkworth Sands Woodland (WSW) and, to a lesser extent, Central Hunter Grey Box – Ironbark Woodland (CHGBIW). As I discuss below, key recommendations to modify the mine plan and avoid WSW are extreme, not justified and are not the only way by which the security of the remaining Warkworth Sands vegetation can be addressed. The first section of this letter provides a summary of the latest area data for WSW and provides a summary of my views about how the proposed Warkworth Extension would impact the community, versus the current approval (2003) and the proposal by Peake.

The major outstanding issues relate to Warkworth Sands Woodland: the impacts to it and the feasibility of offsetting. According to Peake, the community is too small and precariously situated to allow further impacts and so the mine plan should be changed to avoid it. I strongly disagree. This section explains the key reasons why I believe that the proposed offsetting and conservation measures are justified and why the mine plan should not be changed.

In order to explain my views, the latest area estimates for WSW and Warkworth Sands Grassland (WSG) are summarised in Table 1. These are based upon data in the current Peake report together with revised estimates of the total amounts of WSG thought to be present at the time of the decision to provide the 2003 approval.

In Table 1, three scenarios for WSW are summarised:

- Scenario 1a - 2003 development consent based on 2003 data;
- Scenario 1b - 2003 development consent based on 2011 data; and
- Scenario 2 - current proposal based on 2011 data.

Note that for the purposes of compiling Table 1, I have checked the report entitled: *Warkworth Sands Woodland - An Endangered Ecological Community Distribution, Ecological Significance and Conservation Status* (Peake et al) on Hunter Botanic website. The report states that out of 800 ha of WSW estimated to remain in 2002, half was estimated to be dominated by Narrow Leaf Ironbark (*Eucalyptus crebra*), Grey Box (*E. moluccana*) and Spotted Gum (*Corymbia maculata*). As such species are actually dominants of other communities, half of the 800 ha was actually another forest community. Therefore at the time of the decision to approve the previous mine extension, there was much less than 800 ha. For this reason, the data provided in Scenario 1a uses an estimate of 400 ha of WSW remaining as that was what was really known at the time based upon the aforementioned estimates by Peake et al. The other two scenarios present the more accurate figure of 464.8 ha, the current estimate based upon recent survey work of WSW.

Table 1 Latest Data for WSW and WSG

Item	Scenario 1a		Scenario 1b		Scenario 2	
Item	Area	% Pre-European	Area	% Pre-European	Area	% Pre-European
WSW Pre-European	6,153.8		3,038.0		3,038.0	
WSW Remaining	400.0	6.5%	464.8	15.3%	464.8	15.3%
WSW to be cleared	35.6	0.6%	35.6	1.2%	103.5	3.4%
WSW left after clearing	364.4	5.92%	429.2	14.1%	361.3	11.9%
Rio - WSW offset of existing vegetation	71.2	1.2%	71.2	2.3%	130.1	4.3%
Other - WSW offset of existing vegetation	111.7	24%	111.7	24%	111.7	24%
WSW to be regenerated	71.2	1.2%	71.2	2.3%	234.1	7.7%
WSW left post regeneration	435.6	7.1%	500.4	16.5%	595.4	19.6%
WSW in an offsets including reestablishment	142.4	2.3%	142.4	4.7%	364.2	12.0%
WSW not in an offset	181.3	2.9%	246.3	8.1%	119.5	3.9%

I will explain my views by providing answers to a series of questions that relate to the viability of WSW under the three scenarios. The questions are provided in italics followed by my response in plain text.

1. What are the risks of extinction to the WSW community if the clearing currently approved under the 2003 approval (Scenario 1) occurs (not taking account of proposed regeneration)?

WSW could in theory become extinct, via some stochastic event such as severe drought or a sequence of other extreme events (eg repeated extreme bushfires). In 2003 clearing was approved to reduce the WSW community to 364.4 ha based on 2003 data.

Extinction is unlikely and I am unaware of any such scenarios where several hundred ha of such vegetation was largely set aside for permanent conservation. The community will be conserved within several separate properties owned by different mining companies at Mt Thorley Warkworth, Wambo and Bulga. Such lands are proposed for conservation and not for clearing and so it is hard to conceive of a reason why the vegetation would become absolutely extinct.

The vegetation is in relatively small patches and is subject to edge effects. However, on current data it appears to be in good condition. It does not appear to be suffering from major deleterious weed invasion or other comparable threats that would make it become extinct. While such edge effects may harm the vegetation (such as by reducing the abundance of some native species in favour of weeds), they do not make it become extinct as such.

2. What are the risks of extinction to the WSW community if the clearing proposed for current approval (i.e. if Warkworth Extension is approved) occurs (not taking account of proposed regeneration)?

If the current proposal is approved I believe that again the risks of extinction are minimal despite the small size of the community. This is because the main remnants will be conserved in perpetuity, UNE research will guide and monitor the restoration ecology work, there will be funding for the Recovery Plan provided by the proponent and because the areas of WSG will be regenerated.

There would be 361.3 ha of WSW left post regeneration, most of which would be in permanent conservation. This is not greatly dissimilar to the scenario 1b in ecological terms.

This is a similar to area to what was approved in 2003 based on the data available at that time, i.e. 364.4 ha (i.e. scenario 1a). Even if the 2011 data was known at the time of the 2003 extinction, which would result in the clearing to 429.2 ha, the areas are not greatly dissimilar in ecological terms.

3. Do the risks of extinction between the scenario in question 1 differ from those in question 2?

The risks of extinction will not vary markedly between scenario 1 and scenario 2. Small areas of the vegetation will remain and it will be relatively secure.

On major difference between scenario 1b and 2 is that although scenario 2 would result in less vegetation remaining excluding regeneration (364.4 versus 429 ha), the vegetation remaining would have better long term conservation as more of the proponent's land would be permanently protected and because of the funding of the Recovery Plan (which is not available under scenario 1). The regeneration is supported by the University research program and the additional funding of \$500,000 for research into genetics/climate change, and the proponent's commitment to fund the recovery plan are not available under scenario 1.

4. To what extent does the regeneration proposed reduce the risk of extinction if it is successful?

Regeneration would help secure the vegetation in several ways. First, in both scenario 1b and 2 it would increase the total area of WSW. This would be from 429.2 ha to 500.4 ha in scenario 1b, and from 361.3 ha to 595.4 ha in scenario 2. When expressed in percentage terms, scenario 2 would result in an increase in the pre-European extent of WSW to 19.6% compared to an increase of 14.2% under scenario 1. Additional vegetation area does help provide security against such factors as edge effects, ect. It also buffers against major stochastic events such as severe repeated bushfires.

I believe though, that regeneration of surrounding areas of other native forest vegetation, and rehabilitation will also play an important role in securing this vegetation. The existing forest and woodland remaining after mining will be augmented by both regeneration and rehabilitation. Large blocks of forest and woodland will be formed including WSW and various box/ironbark/spotted gum forest. The resultant large area will also be more stable and better buffered against weeds and stochastic events.

5. What is the likelihood of the regeneration being successful if it is adequately funded to support best practice regeneration techniques to be used?

In my experience, projects such as the WSW research program are highly likely to be successful. This is because there is already compelling evidence that heavily cleared sand landscapes regenerated unaided to form the WSW at the subject site today. The EA provided compelling evidence from historic aerial photographs to show that the sands vegetation has regenerated from essentially grassland to woodland since the 1960s as grazing was removed. Peake acknowledges this and agrees with the finding.

If best practice methods are used to aid the regeneration, then this would greatly increase the probability of successful regeneration.

6. What are the risks to WSW that is not in an offset?

WSW that is not in an offset will not receive the protection of offset lands. There will be no permanent protection against weeds, feral animals, land clearing, etc. There would also be no firm guarantee that such vegetation wouldn't be degraded by further human activities that may lawfully occur in some areas such as grazing.

7. Are there benefits to the survival of the WSW to having an extra 200 hectares of WSW managed in an offset area?

As stated in 4 and 6 above, increased areas of WSW in protected offset areas will greatly increase the prospects for long term survival of this plant community. The additional 200 ha would be extremely valuable as a contribution to ensure survival of this community.

8. Does the increase in WSW of 95.4 hectares from regeneration of WSG decrease the risk of extinction if it is successful?

As above. The WSG to be regenerated will add a significant area of WSW to the overall area of WSW in existence. In total, if this were regenerated there would be 595.4 ha in existence and most would be within lands proposed for conservation in perpetuity.

9. Assuming that the regeneration of WSW proposed in both Scenario 1 (currently approached) and 2 (proposed to be approved) are successful is the prospects of survival higher under Scenario 2?

The prospects for survival would be higher in Scenario 2 for the following reasons:

- There would be a bigger area of WSW (95.4 ha larger than scenario 1b);
- There would be additional contributions to research on climate change tolerance of the re-established community and the preparation of a recovery plan;
- Scenario 2 would increase WSW by 19.6% of the pre-European area compared with 14.2% at the time of the 2003 approval; and
- There would be a greater proportion of the vegetation proposed in long term conservation areas.

Some of these points are further explored in the letter below:

The Peake Review essentially concludes that the current level of vegetation mapping and baseline survey information available for the impact area and most offsets is appropriate and sufficiently accurate for impact assessment and determination of offsetting. I concur with this view as explained below.

The Peake Report examined the EA and concluded that the explanation of how vegetation mapping was conducted was “generally inadequate”. However, Peake concluded:

“through a process of providing additional information in response to specific requests (Russo 2011b, 2011c), RTCA has demonstrated that, in general, the level of robustness and reliability of vegetation mapping is adequate.”

It also concluded that:

Survey effort for the Southern, Northern and Springwood BOAs is adequate and survey effort for the Goulburn River BOA appears to be adequate for the purpose. Survey effort for the Seven Oaks and Putty BOAs appears to be inadequate for the purpose of reliably defining the types of vegetation, fauna habitats and likely threatened flora and species present in relation to their potential use of the offset areas.

The Peake Report also notes that the mapping of relevant endangered ecological communities (EECs) including WSW, Central Hunter Grey Box – Ironbark Woodland (CHGBIW), Central Hunter Ironbark-Spotted Gum – Grey Box Forest (CHISGGBF), Hunter Lowland Redgum Forest (HLRF), are accurate.

The Peake Report generally concluded that the level of survey for threatened species was adequate within the impact area and most proposed BOAs other than Seven Oaks and Putty. However, the Peake Report stated the following about orchid surveys:

“In general, the level of survey effort for flora, fauna, populations and habitats appears to be adequate, although there are some notable omissions, such as appropriately timed and targeted surveys for terrestrial orchid species, of which at least three threatened species are known to occur in the local area (Pterostylis gibbosa, Diuris tricolor and Diuris sp. Aff. Dendrobiodes).”

I disagree about the comments made concerning orchids. The Peer Review notes that Cumberland Ecology conducted flora surveys during September, a time when the aforementioned orchids can flower. Cumberland Ecology conducted flora surveys widely in the impact area and the NOA and SOA during this time and no threatened orchids were found. However, as we have consistently explained, there have been numerous other surveys within this vegetation during the time when orchids flower, since the time of the original ERM surveys in 2002. The UNE has had research staff present on the impact area and proposed offset areas at many different seasons, including winter, spring and early summer. The UNE has compiled a detailed data set about plant species present in the study area but has not yet found any of the threatened orchids. While I believe there remains potential for the orchids to occur, I do not agree that there has been a notable lack of survey for orchids or other ground stratum threatened plant species.

The peer review concluded that WSW has a very limited occurrence and that much of the woodland that remains occurs on land owned by the proponent. On page 3.9 the key facts according to Peake are:

- Likely pre-European extent 308 ha;
- Extant area of WSW – 464.8 ha;
- Area of WSW to be cleared by the project – 103.5 ha;
- Area of WSW to be offset up front by the project – 130.1 ha.

The Peake Report makes the following points about Warkworth Sands Woodland (WSW):

- The relocation of Wallaby Scrub Road was not factored into the analysis in the EA; and
- There is a high risk that the perched aquifer would be severed, and therefore the impacts on WSW could extend beyond the project impact boundary.

The author also forms the opinion that the vegetation community is eligible for listing as a critically endangered vegetation type for both the *State Threatened Species Conservation Act 1995* and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* on the basis of its rarity, limited geographic occurrence and the extent of past clearance.

I concur with the analysis of area and also note that in the absence of the proposed mitigation and conservation measures, the WSW would be eligible for TSC Act listing. However, as discussed by Peake on page 3.15, the vegetation on the proponent's site has clearly regenerated from grassland since the 1960s and the regeneration has been effective in that it has regenerated to what Peake agrees is probably representative of pre-European floristics and structure.

The impacts from the closure and relocation of Wallaby Scrub Road would not be of major significance to the WSW woodland. While some WSW woodland would be cleared, the overall area discussed above would remain as would the proposed mitigation measures. The net result would still be that the majority of WSW and WSG would be proposed in conservation.

Peake also acknowledges the value of the UNE research that is aimed at improving the understanding of the restoration ecology of WSW. He notes *"the early indications suggest that there is a high likelihood that WSW can be re-established providing adequate resources and an appropriate monitoring program and feedback/action loop are provided."*

The proponent's proposal is to continue the UNE research, to put considerable resources into actively regenerating the woodland and grassland areas, to permanently conserve the woodland and grassland that would remain on the proponent's land after the Warkworth Extension and to provide funding for the recovery planning for the vegetation community as a whole.

I also understand that the proponent will monitor the vegetation and provide mitigation measures as needed to deal with various edge effects such as weeds and, if the event arises, even impacts from changes to the perched aquifers. However, on current data, it seems unlikely that the perched aquifer will be significantly impacted.

Peake forms the view *"using a suitable application of the Precautionary Principle it is concluded that there is a real risk that the perched aquifer would be severed, and that the impacts on WSW could extend beyond the project impact boundary, without implementation of a specific control to avoid or at least minimise seepage from the sand sheet."*

I disagree with his use of the Precautionary Principle as there is considerable scientific evidence that the sands can be successfully regenerated and managed. While the Peake report does not make use of references about hydrological effects of the proposed Warkworth Extension, I have been supplied with a hydrological report that provides evidence that the hydrological impacts predicted by Peake are unlikely.

4.1 Recommended Avoidance of Impacts

Peake takes the extreme view that all additional impacts to the WSW should be avoided and that the mine plan should be modified to protect an additional 67.9 ha of woodland, ensuring that 198 ha is left available. He concludes that the additional 67.9 ha will essentially reduce the edge effects that would otherwise occur to the community – particularly from the potential impacts to the perched aquifer.

I do not subscribe to this view. I believe that even if it is implemented, the total area of the community will be small. I believe that the acceptance of the WSG as an offset is an

appropriate measure because of the past successful unaided regeneration of similar vegetation and because the University research will be available to guide the future rehabilitation.

I believe that the offset package is suitable in its current form. However, additional recommendations could include:

- Providing for increased duration of the UNE research program for WSW, to make sure that there is sufficient time and funding for the research to be a success;
- Provision of more specific research objectives and key performance targets relating to WSW and regenerating WSG;
- Providing for some rehabilitation of WSW in the rehabilitation areas and backing up this objective with some additional research by the University.

4.2 Offsetting for WSW

Peake opines that the Warkworth Sands Grassland should not be accepted as part of the offset package when determining the offset ratio. On page 3.10 of the review, the Peake Report states:

“In each scenario, the relative contribution to the conservation and protection of WSW by the restoration actions being undertaken in the Northern BOA has not been taken into account. This is because although these actions are positive, there is no guarantee that they will be successful. They are therefore excluded from this scenario-based assessment, although not from the overall report.... Likewise, however, the potential impacts resulting from edge-effects from the relocated Wallaby Scrub Road, temporary impacts associated with the construction of Wallaby Scrub Road, or any impacts from the potential severing of perched aquifers have not been considered in this assessment.”

The author coins and uses the term “up front offsets” with reference to Warkworth Sands Woodland (WSW). According to its use in the Peake Report an “up front” offset consists of offset land comprising target vegetation that is already in good condition – ie not WSG.

The approach taken to offsetting impacts to WSW by the Peake Report is also somewhat extreme. I would especially draw your attention to the author’s coining and use of the term “up front offsets” with reference to Warkworth Sands Woodland (WSW). As you are aware, my company has recently drafted an offsets policy for major projects for the Department of Planning. I know of no such term as “up front offsets” and do not believe it has been used much if ever before in NSW. The Peake Report seems to imply that the only current offsets that should be considered are “up front” offsets, where such offsets only include the target vegetation that already exists in good condition. Consequently, the Peake Report only recognises “an up-front offset of 119.7 ha” for WSW in its peer review analysis of the offset package. Moreover, if some of the recommendations of the Peake Report are adopted by Department of Planning, they will represent a major divergence from recent precedents/approvals concerning offsetting by the Department.

As you are aware, Cumberland Ecology has recently drafted an offsets policy for major projects for the Department of Planning. I know of no such term as “up front offsets” and do not believe it has been used much if ever before in NSW. The Peake Report seems to imply that the only current offsets that should be considered are “up front” offsets, where such offsets only include the target vegetation that already exists in good condition. Consequently, the Peake Report only recognises “an up-front offset of 119.7 ha” for WSW in its peer review analysis of the offset package. The author bases all WSW offset analysis on 119.7 ha and dismisses 233.5 ha (66%) of Warkworth Sands Grassland (WSG) in the analysis even though:

- This is contrary to BioBanking philosophy and practice for BioBanking offsetting. Under BioBanking even private land owners can sell BioBanking credits based upon the assumption that a buyer will pay for restoration of habitat in the long term, including derived native grassland formed from semi-cleared agricultural land. No university research program is needed for the government to accept a BioBanking agreement on private land. Why then is a site such as Warkworth Extension and its offsetting proposal so readily dismissed by the Peake Review when the proponent has and will continue to fund high quality university research to verify and drive the rehabilitation program?;
- Current NSW legislation and policy for offsetting, and recent precedents for approval of offsetting by Department of Planning are predicated on offsets that generate an improved outcome from degraded vegetation to high quality vegetation via active management, such as grazing management.
- There is compelling evidence that most of the current WSW now in existence regenerated unaided from WSG since the 1960s when livestock were removed – no mention of this is made in the Peake Report. This evidence has been presented to Department of Planning and to the author of the review, however, it has not been mentioned in the Peake Report;
- Results from the University of New England Research (UNE) program indicates that it is highly likely that the grassland can be regenerated to WSW and the proposal is for the UNE research to continue to help guide the rehabilitation of the WSW;
- Restoration of other sand-based plant communities has been successful where a company has invested in an appropriate level of research and funding; and
- Projects that the author of the peer review has worked on previously and which the Department have approved, have gained approval for offsets that factor in the value of degraded open grassy areas, on assumption that such areas can be sustainably restored in the long term (eg the Ulan Mine Extension, which has assumed that Derived Native Grasslands can be restored to Box Gum Woodland).

For the aforementioned reasons, I believe that the WSG should definitely be included in the offsetting equation for WSW.

Peake notes that for this community the practice of appropriately using “similar” vegetation types as offset substitutes should in principle be permitted. In the case of CHGBIW, it is closely related to several other vegetation types in the Hunter Valley and judicious use of one or more of these is appropriate. In Appendix A, I have provided a table that compares salient features of the CHGBIW with closely related ironbark communities in the proposed strategic offsets. This analysis clearly demonstrates the suitability of such vegetation.

Peake recommends that a long term ratio of 4:1 is set, requiring a total of 2,632 ha. He believes that achievement of the long term offset target of 4:1 could be achieved by factoring in regeneration/restoration of the derived native grasslands. It could include those in the Northern BOA, Southern BOA and in the Springwood BOA.

Peake recommends that the proposed 780.6 ha of CHGBIW be factored into the offsetting proposal but discounted by 50% to allow for uncertainties associated with the rehabilitation process.

Peake believes that a 4:1 ratio is required for offsetting the 658 ha of this community predicted to be impacted. He states that the offset should comprise 2632 ha and should include:

- 543.4 ha of “up front offset”;
- 213.7 ha of regeneration of CHGBIW;
- The discounted 390.3 ha of rehabilitation;

He therefore states that a further 1484 ha is required.

Peake is not aware of the latest amendments to the offsetting and rehabilitation package for this vegetation type. The proponent will significantly increase the areas of rehabilitation for CHGBIW. There is also a proposal for funding of University research to improve the rehabilitation of ground stratum and understorey vegetation. This is likely to provide for a much more sustainable and higher quality rehabilitation of this community in the long term.

The proponent also proposes the provision of another major strategic offset containing Ironbark Forest and this now means very substantial areas of Ironbark forest and woodland will be provided by the strategic offsets. The substantial areas of rehabilitation, together with the areas of CHGBIW in the SOA and the ironbark forest and woodland in the strategic offsets will provide substantial, sustainable and appropriate offsetting for threatened fauna.

As suggested by Peake’s recommendations, the rehabilitation, Northern, Southern and strategic offsets can address the impacts to this community. I believe that the additional rehabilitation, the University research program, the additional strategic offset proposed (eg Hunt/O'Brien) will provide for an adequate overall offset for this community. There is no need to consider purchase of additional CHGBIW on the Hunter Valley floor.

Peake states that 30.5 ha CHISGGBF would be cleared, not including impacts of Wallaby Scrub Road, if moved. He states that it is appropriate to consider offsetting this together with CHGBIW due to their similarity. I concur with this view.

Peake states that 4.0 ha of HLRF would be cleared, not including impacts from Wallaby Scrub Road. He then states that the proposed offset will include 31.7 ha of this vegetation in the SOA at a ratio of 7.93:1, which he believes is acceptable. I concur with this view.

There are a series of other issues that I have with the Peake Report that need to be explained here as they lead to flawed or overstated assessments by the author of the peer review.

8.1.1 Potential Impacts from the Perched Aquifer

Peake expresses concern about the potential impacts from project on the perched aquifer. I note that he believes that this is highly likely to result in a major deleterious impact. Notwithstanding that, he has not provided any literature to support this view and the latest analysis commissioned by the proponent by a hydrogeologist indicates that the aquifers are not likely to be connected and that no major impacts are likely.

I believe that to take such an extreme position concerning the impacts to the WSW from altered hydrology, the Peake Report needs to have provided some compelling examples of similar deleterious impacts.

Under the proposal, the offsets containing WSW will be constantly monitored during the life of the project and research will be conducted by university staff about the ecology and condition of this community. Moreover, if hydrological impacts become apparent, then steps can be taken to address and mitigate such impacts. Hence, for these reasons, I do not accept that WSW is at such a high risk of indirect impacts from the proposed Warkworth Extension.

8.1.2 Use of Relevant Literature

The Peake Report makes a suite of major assumptions and claims about likely impacts to various EEC plant communities, particularly WSW. However, the assumptions and claims are not supported by any research literature. No such literature is provided about edge effects, the other projects that have entailed restoration of sand-based vegetation communities in Australia, etc. This should be considered when evaluating the Peake Report.

Similarly, the Peake Report does not make use of State or Commonwealth offsetting policies when commenting on the veracity of the offsets proposed for the project. It also fails to take account of relevant legislation and policy (eg BioBanking) which supports the concept of using offsets that entail regeneration of partially cleared vegetation.

8.1.3 Other Offsets

The Peake Report accepts that the BOA areas proposed by the proponent are generally appropriate and that they should be accepted as offsets for the project.

- Springwood BOAs;
- Goulburn River BOA;
- Seven Oaks BOA; and

- Putty BOA.

No allowance is made for the special habitat values presented in the offsets, particularly streams.

No allowance is made in the Peake Report about fauna habitat.

The table below reproduced the recommendations of the Peake report verbatim and provides responses to each by Cumberland Ecology. This tabular analysis of the Peake recommendations clearly shows that we are in agreement with many of the recommendations. The key areas of disagreement, are in relation to the need to modify the mine plan to avoid clearance of WSW beyond what has currently been approved.

Table 2 Response to Peake’s Recommendations

Peake's Recommendations	Cumberland Ecology Response
Warkworth Extension	
Footprint	
<p>1. Excise all WSW from west of Wallaby Scrub Road (i.e. outside of the 2003 Extension Area) from the disturbance area in a manner that ensures that impacts on WSW are reduced to a level that is already approved under the 2003 Extension Area. In doing so, the final disturbance boundary and associated mining controls should ensure that there is reduced risk of edge effect impacts on adjoining WSW or impacts caused through severance of the perched aquifer.</p>	<p>This is unnecessary. The impacts to WSW can be offset by regeneration of the WSG, which should be appropriately accepted within the proposed offset. An area of WSG should be recreated within the rehabilitation areas of the proposed Warkworth Extension and guided by university research.</p> <p>WSG must be regenerated as per the proposal and factored into the proposed offset for WSG.</p>
<p>2. Confirm the commitment that Wallaby Scrub Road will not be relocated. The area that it would have occupied will provide additional up-front offset areas of WSW and CHGBIW in addition to the reduction of potential risks associated with fragmentation and edge effects from the relocation of the road.</p>	<p>As above.</p>
Biodiversity Offset Areas	
<p>1. All BOAs that are ultimately included in the offset strategy should be protected in perpetuity.</p>	<p>It is agreed that all BOAs should receive long term protection via an appropriate mechanism, of which a number of alternatives exist (eg Voluntary Planning Agreement, BioBanking Agreement, public positive covenant, handover to National Parks estate).</p>

Table 2 Response to Peake’s Recommendations

Peake's Recommendations	Cumberland Ecology Response
<p>2. All BOAs should have comprehensive offset management plans prepared, implemented and reviewed on a regular basis – these should include: detailed maps; strategies for restoring native vegetation and fauna habitat through focussing on assisted natural regeneration, targeted vegetation establishment and introduction of naturally scarce fauna habitat features where necessary; use (but not overuse) of appropriate “fauna-friendly” fencing and access controls; appropriate weed and pest management procedures; the establishment of performance and completion criteria against which their recovery and management can be measured; and comprehensive and regular monitoring plans and programs which make use of analogue sites and target thresholds (or trigger points) for threatened fauna and for vegetation communities, particularly WSW and GHGBIW.</p>	<p>Agreed.</p>
<p>3. The offset management plans should also include a provision to prepare management plans, at least 2 years prior to cessation of the approval, for the ongoing management of each offset area in post mining operation environment, addressing matters such as weed and feral animal control,; fencing, access and signage; and bushfire management.</p>	<p>Agreed.</p>
<p>4. The SOA should be established and managed as proposed by RTCA, primarily to offset impacts on WSW and CHGBIW and threatened fauna species.</p>	<p>Agreed.</p>
<p>5. The WSW recommended to be avoided should be incorporated into the SOA to offset impacts on WSW.</p>	<p>Disagree, for reasons stated above.</p>
<p>6. RTCA should consider including the Buffer Lands into the SOA primarily to offset impacts on CHGBIW and threatened fauna species.</p>	<p>As I have explained above, the proponent has agreed to greatly increase the areas of rehabilitation for CHGBIW. The proponent has also proposed provision of another major strategic offset containing Ironbark Forest and</p>

Table 2 Response to Peake’s Recommendations

Peake's Recommendations	Cumberland Ecology Response
	<p>this now means very substantial areas of Ironbark forest and woodland will be provided by the strategic offsets. The substantial areas of rehabilitation, together with the areas of CHGBIW in the SOA and the ironbark forest and woodland in the strategic offsets will provide substantial, sustainable and appropriate offsetting for threatened fauna.</p>
<p>7. The NOA should be established and managed as proposed by RTCA, primarily to offset impacts on WSW.</p>	<p>Agreed, but note that CHBIW also occurs on this site.</p>
<p>8. Springwood BOA should be established and managed as proposed by RTCA, primarily to offset impacts on WSW resulting from the WSW Extension Project.</p>	<p>Agreed.</p>
<p>9. The entire 1440ha of Goulburn River BOA should be established and managed as proposed by RTCA, primarily to offset impacts on CHGBIW and threatened fauna species resulting from the Warkworth Extension Project.</p>	<p>Agreed. This offset should be established to protect vegetation and threatened fauna habitat, particularly that of threatened birds.</p>
<p>10. Seven Oaks BOA should be established and managed as proposed by RTCA, primarily to offset impacts on CHBIW and threatened fauna species resulting from the Warkworth Extension Project.</p>	<p>Agreed. This offset should be established to protect vegetation and threatened fauna habitat, particularly that of threatened birds.</p>
<p>11. Putty BOA is not required to provide offsetting on any threatened fauna or vegetation community. Although it has some value, this does not extend to adequately address the residual offsetting needs for CHGBIW.</p>	<p>Disagree because this is an offset to provide habitat for threatened birds, rather than CHGBIW. The Putty BOA provides excellent habitat for birds, including excellent potential habitat for Regent Honeyeater, Swift Parrot and various vulnerable threatened birds predicted to be impacted by the Warkworth Extension. It also contains some habitat areas that are partially cleared and that could be restored to provide better habitat in the long term.</p>
<p>12. It is recommended that, to achieve the proposed 2:1 up front offset ratio, a further 821.1 ha of CHGBIW is secured. It is suggested that the long term offset ratio of 4:1 can be <u>approximately achieved through the inclusion of</u></p>	<p>Disagree about the 821.1 ha of CHGBIW to be included. The current proposal has been updated now to include a substantially increased area of rehabilitation for CHGBIW, amounting to XX ha. It is agreed that Goulburn River BOA and Seven</p>

Table 2 Response to Peake’s Recommendations

Peake's Recommendations	Cumberland Ecology Response
<p>the entire Goulburn River BOA and the Seven Oaks BOA.</p>	<p>Oaks BOA can be added to the package to address this vegetation package.</p>
<p>13. It is recommended that RTCA commit to specific land management actions to foster “environmental gain” in the derived native grasslands of the Putty, Seven Oaks, Goulburn River, Northern and Southern BOAs.</p>	<p>Agreed.</p>
<p>14. RTCA should ensure that appropriate baseline biodiversity studies are undertaken on the Seven Oaks, Goulburn River and Springwood BOAs since an insufficient level of knowledge of biodiversity, particularly threatened fauna species, and habitats, is currently available to be able to ensure appropriate implementation of management actions necessary for the restoration and management of these sites.</p>	<p>Agreed.</p>
<p>Mitigation Measures</p>	
<p>1. An appropriately detailed tree-felling procedure should be prepared, reviewed by DP&I and OEI, and implemented by RTCA. Its main aim should be to ensure that the clearing contractors undertake every practical step to minimise impacts on fauna, particularly threatened fauna, during tree clearing operations. It should include, as a central feature (and in addition to preclearance inspections) a process of visual observation, tree shaking (or other fauna discouragement), and the inspection of felled trees for trapped or injured fauna, under the supervision of an appropriately qualified and licensed person, nominally an ecologist.</p>	<p>The proponent has a flora and fauna management procedure covering tree felling. It is part of the n ISO 14001 certified HSEQ MS, which has been audited. The proponent agrees to review the procedures and update</p>
<p>2. To achieve best practice rehabilitation for biodiversity outcomes, RTCA should:</p> <p>(i.) provide preliminary performance and completion criteria for vegetation and habitat reestablishment;</p> <p>(ii) to augment vegetation growth and habitat development through the provision of special habitat features, such as nest boxes for birds,</p>	<p>Agreed – these can be provided as a condition of consent covering specifications for a management plan.</p>

Table 2 Response to Peake’s Recommendations

Peake's Recommendations	Cumberland Ecology Response
<p>arboreal mammals and bats, and specific feed resources for other threatened fauna, such as the Regent Honeyeater, Swift Parrot and the Glossy Black Cockatoo;</p> <p>(iii) focus on the establishment of a viable north south movement corridor suitable for threatened fauna species and;</p> <p>(iv) develop an appropriate, seasonally based ecological monitoring program.</p>	
<p>3. Prepare a detailed management plan to ensure that the severance of perched aquifers does not impact upon WSW outside of the approved disturbance area, including a rigorous monitoring program to review the effectiveness of the plan. This may include the development and implementation of appropriate practices, including the application of low permeability material to the open cut face where aquifer severance takes place, to ensure that the risk of indirect impacts on WSW through aquifer seepage is low.</p>	<p>Partially agree. I agree a plan should be made to cover this potential risk. However, it is my understanding that there is not a great risk of severance of the perched aquifer and that, if impacts from such severance begin to emerge, mitigation measures can be introduced to ameliorate them.</p>
<p>4. Surveys for the terrestrial orchids <i>Pterostylis gibbosa</i>, <i>Diurus</i> sp. Aff. <i>dendrobiodes</i> and <i>Diurus tricolor</i> should be conducted prior to disturbance to determine if they are present or likely to be absent. If present, a detailed management plan, to be submitted to DP&I and OEH, should be prepared which documents a program for their translocation, management and monitoring. Once approved, this plan should be implemented at a time that is specified by the plan.</p>	<p>Partially agree. I believe that adequate surveys have generally been done for these orchid species but I concur that additional surveys should be conducted at an appropriate time, as a condition of consent. If orchids are located, they should be dealt with via the preparation of an appropriate management plan, as suggested.</p>
<p>5. Restore Warkworth Sands Grassland in the southern and Springwood BOAs in the same manner in which it will be restored in the northern BOA. Undertake annual monitoring of the restoration successes in these three areas. This should include a thorough assessment of performance measures after 10 years post establishment that would be likely to reveal the recovery trends. Closure commitments could be</p>	<p>Agreed.</p>

Table 2 Response to Peake’s Recommendations

Peake's Recommendations	Cumberland Ecology Response
<p>tested thoroughly after about 25 to 30 years.</p>	
<p>6. Restore CHGBIW in CHGBIW derived grasslands in the southern and northern BOAs.</p>	<p>Agreed.</p>
<p>WSW Management</p>	
<p>1. Work with other stakeholders to support a WSW management technical committee and to fund WSW research, monitoring and management, together with the publication of relevant material to further the understanding of WSW in the professional and public arenas.</p>	<p>Agreed.</p>
<p>2. Work with neighbouring mines to develop long term ecological linkages and conservation areas integrating existing vegetation and rehabilitated vegetation communities, with particular emphasis on WSW.</p>	<p>Agreed.</p>
<p>3. Assist OEH through the provision of knowledge, resources or funds to ensure the implementation of recovery planning for WSW.</p>	<p>Agreed.</p>
<p>4. Ensure all relevant information is made available to OEH and DSEWPC regarding the conservation status, recovery actions and ecological description – delineation of WSW through the provisions of reports, maps and technical advice to both authorities, as well as the NSW Scientific Committee and the Commonwealth Threatened Species Scientific Committee.</p>	<p>Partially agreed. The WSW is not listed by the EPBC Act and so SEWPC has no jurisdiction or mandate to take an interest in this community, unless the listing changes.</p>
<p>HVO South Modifications</p>	
<p>Biodiversity Offset Areas</p>	
<p>1. The proposed 140 ha offset at Goulburn River BOA is inadequate and should be rejected in its current configuration.</p>	<p>Disagree, but note that extensive areas of Ironbark forest are now in the offset package, which is proposed to be augmented by inclusion of the Hunt Obrien properties. These could be used to provide the additional offsets for HVO South that are suggested in the point below.</p>
<p>2. An up-front offset of approximately 280 ha (2:1) that is primarily composed of CHGBIW, or ecologically closely related communities, should be secured in perpetuity and managed for</p>	<p>As above</p>

Table 2 Response to Peake's Recommendations

Peake's Recommendations	Cumberland Ecology Response
<p>biodiversity outcomes. The offset should seek to provide for long term 4:1 offsetting (560 ha) for the CHGBIW or ecologically similar communities in strategic locations. If this is not achievable, a suitable compromise involving a balance between land availability, time, size, location and appropriateness of vegetation communities and fauna habitats should be arranged.</p> <p>3. It is appropriate that the offset should achieve the regeneration or revegetation of CHGBIW, or similar communities, to achieve a ratio of 4:1.</p>	<p>I do not necessarily agree to a mandatory 4:1 ratio for all EEC communities. There is no scientific basis for this ratio. While I agree that a 4:1 ratio for the CHGBIW community would assist the recovery of the community (or in the case of the strategic offsets, similar communities), the package can also be augmented by rehabilitation and, as is proposed, by funding research to improve the quality of understorey rehabilitation.</p>

I am available to discuss any of the matters raised in this report. Please contact me or my PA Angela Mees on 9868 3975.

Yours sincerely



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 Director
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Appendix A

Comparability of Ironbark Forests on the
Hunter Valley Floor and in the Strategic
Offsets

Table A.1 Comparison of Ironbark Forest and Woodland at MTW with Ironbark Forest and Woodland within the Proposed Strategic Offset

Variable	Ironbark Forest and Woodland at MTW	Ironbark Communities within the Proposed Strategic Offsets
Property	Northern Biodiversity Offset Area, Southern Biodiversity Offset Area, Warkworth Extension	Goulburn River, Seven Oaks, Hunt, Obrien, Putty, Bowdich
Peake Name/s	Map Unit 10 Central Hunter Box - Ironbark Woodland; and Map Unit 27 Central Hunter Ironbark Spotted Gum Grey Box Forest	Not applicable
BioBanking Name	Grey Box - Narrow-leaved Ironbark shrubby woodland on hills of the Hunter Valley, North Coast and Sydney Basin	Grey Box - Narrow-leaved Ironbark shrubby woodland on hills of the Hunter Valley, North Coast and Sydney Basin
TSC Act Name	Central Hunter Grey Box - Ironbark Woodland in the NSW North Coast and Sydney Basin Bioregions	
TSC Act Status:	Endangered Ecological Community	Not listed
Geographic Location	According to the OEH Final Determination: Cessnock, Singleton and Muswellbrook LGAs but may occur elsewhere within the Sydney Basin Bioregion.	Upper Hunter River catchment on gently undulating hills and some steeper knolls.
Geology	According to the OEH Final Determination: Associated mostly with Permian lithology, and is situated on gently undulating hills, slopes and valleys, or occasionally on rocky knolls. Sandstone geology. According to the OEH Final Determination: Newcastle Permian Coal Measures – Conglomerate, Sandstone, Tuff, shale and Coal	The strategic offset sites are associated mostly with Triassic Narrabeen Sandstone and occur on gently undulating hills, slopes and valleys, or occasionally on rocky knolls. Sandstone geology. Triassic Narrabeen Sandstone, quartzose sandstone, shale and claystone
Description	According to the OEH Final Determination: Central Hunter Grey Box –	Based upon Cumberland Ecology notes and mapping of the

Table A.1 Comparison of Ironbark Forest and Woodland at MTW with Ironbark Forest and Woodland within the Proposed Strategic Offset

Variable	Ironbark Forest and Woodland at MTW	Ironbark Communities within the Proposed Strategic Offsets
	<p>Ironbark Woodland typically forms a woodland dominated by <i>Eucalyptus crebra</i> (Narrow-leaved Ironbark), <i>Brachychiton populneus</i> subsp. <i>populneus</i> (Kurrajong) and <i>Eucalyptus moluccana</i> (Grey Box). Other tree species may be present and occasionally dominate or co-dominate, and include <i>Angophora floribunda</i> (Rough-barked Apple) and <i>Callitris endlicheri</i> (Black Cypress Pine). A shrub layer may also be present and common shrub species include <i>Notelaea microcarpa</i> var. <i>microcarpa</i> (Native Olive), <i>Breynia oblongifolia</i> (Coffee Bush), <i>Bursaria spinosa</i> subsp. <i>spinosa</i> (Native Blackthorn), <i>Cassinia quinquefaria</i> (Cough Bush) and <i>Dodonaea viscosa</i> (Hop Bush). Subshrubs may also be common and include <i>Solanum cinereum</i> (Narrawa Burr), and <i>Phyllanthus virgatus</i> (Spurge) and <i>Maireana microphylla</i> (Eastern Cotton Bush) (Peake 2006). Ground cover can be moderately dense to dense, and consist of numerous forbs and grass species, and a small number of ferns, sedges and twiners. The more common species include <i>Cymbopogon refractus</i> (Barbed Wire Grass), <i>Aristida ramosa</i> (Three-awned Wire Grass), <i>Dichondra repens</i> (Kidney Weed), <i>Cheilanthes sieberi</i> subsp. <i>sieberi</i> (Poison Rock Fern), <i>Chloris ventricosa</i> (Tall Chloris), <i>Austrostipa scabra</i> (Corkscrew Grass), <i>Desmodium varians</i> (Variable Tick-trefoil), <i>Microlaena stipoides</i> var. <i>stipoides</i> (Weeping Rice Grass), <i>Eragrostis leptostachya</i> (Paddock Lovegrass), <i>Sporobolus creber</i> (Slender Rat's Tail Grass), <i>Calotis lappulacea</i> (Yellow Burr Daisy), <i>Lomandra multiflora</i> subsp. <i>multiflora</i> (Mat</p>	<p>proposed strategic offsets, the Ironbark dominated vegetation within the proposed offsets typically forms a woodland or open forest dominated by <i>Eucalyptus crebra</i> (Narrow-leaved Ironbark), and other trees such as <i>Eucalyptus moluccana</i> <i>E.albens</i> (Grey Box x White Box intergrades). Other tree species are present and occasionally dominate or co-dominate, and include <i>Angophora floribunda</i> (Rough-barked Apple), <i>Callitris endlicheri</i> (Black Cypress Pine) and some wattles. A shrub layer is present in some areas and common shrub species include <i>Notelaea microcarpa</i> var. <i>microcarpa</i> (Native Olive), <i>Breynia oblongifolia</i> (Coffee Bush), <i>Cassinia quinquefaria</i> (Cough Bush) and <i>Dodonaea viscosa</i> (Hop Bush). Ground cover can be sparse to dense, and consist of numerous forbs and grass species. The same species mentioned for Ironbark Forest within the Final Determination also generally occur in the ironbark forest and woodlands of Hunt, Obrien and Goulburn River. They occur, but to a lesser extent in Putty and Bowdich.</p>

Table A.1 Comparison of Ironbark Forest and Woodland at MTW with Ironbark Forest and Woodland within the Proposed Strategic Offset

Variable	Ironbark Forest and Woodland at MTW	Ironbark Communities within the Proposed Strategic Offsets
Dominant Trees:	Rush), <i>Brunoniella australis</i> (Blue Trumpet), <i>Eremophila debilis</i> (Winter Apple), <i>Chrysocephalum apiculatum</i> (Common Everlasting), <i>Cyperus gracilis</i> , <i>Einadia nutans</i> (Climbing Saltbush), <i>Ajuga australis</i> (Austral Bugal), <i>Vittadinia cuneata</i> (Fuzzweed), <i>Bothriochloa decipiens</i> (Red Grass), and <i>Glycine tabacina</i> (Variable Glycine) (Peake 2006).	Narrow Leaf Ironbark plus or minus Grey Box x White Box intergrades, Rough Barked Apple
Threatened Plants that occur	None found in Warkworth Extension Ironbark Forest and Woodland.	<i>Pomaderris Queenslandica</i> , and possibly other species as detailed threatened species surveys have not been completed.
Threatened Birds:	Speckled Warbler (<i>Chthonicola sagittata</i>), Grey-crowned Babbler (<i>Pomatostomus temporalis</i>), Hooded Robin (<i>Melanodryas cucullata</i>), Scarlet Robin (<i>Petroica boodang</i>), Spotted Harrier (<i>Circus assimilis</i>), Diamond Firetail (<i>Stagonopleura guttata</i>), Brown Treecreeper (<i>Climacteris picumnus</i>), Glossy Black-cockatoo (<i>Calyptorhynchus lathami</i>), Regent Honeyeater (<i>Anthochaera phrygia</i>), Swift Parrot (<i>Lathamus discolor</i>), Little Lorikeet (<i>Glossopsitta pusilla</i>), Varied Sittella (<i>Daphoenositta chrysoptera</i>),	The following birds have been detected or are considered highly likely to occur in the proposed strategic offsets: Speckled Warbler (<i>Chthonicola sagittata</i>), Grey-crowned Babbler (<i>Pomatostomus temporalis</i>), Hooded Robin (<i>Melanodryas cucullata</i>), Scarlet Robin (<i>Petroica boodang</i>), Spotted Harrier (<i>Circus assimilis</i>), Diamond Firetail (<i>Stagonopleura guttata</i>), Brown Treecreeper (<i>Climacteris picumnus</i>), Glossy Black-cockatoo (<i>Calyptorhynchus lathami</i>), Regent Honeyeater (<i>Anthochaera phrygia</i>), Swift Parrot (<i>Lathamus discolor</i>), Little Lorikeet (<i>Glossopsitta pusilla</i>), Varied Sittella (<i>Daphoenositta chrysoptera</i>).
Threatened Arboreal	Squirrel Glider (<i>Petaurus norfolcensis</i>)	The Squirrel Glider (<i>Petaurus norfolcensis</i>) is highly likely to

Table A.1 Comparison of Ironbark Forest and Woodland at MTW with Ironbark Forest and Woodland within the Proposed Strategic Offset

Variable	Ironbark Forest and Woodland at MTW	Ironbark Communities within the Proposed Strategic Offsets
Mammals	Eastern Bent-wing Bat (<i>Miniopterus schreibersii oceanensis</i>), Large-eared Pied Bat (<i>Chalinolobus dwyeri</i>), Eastern Free-tail Bat (<i>Mormopterus norfolkensis</i>), Little Bent-wing Bat (<i>Miniopterus australis</i>), Large-footed Myotis (<i>Myotis macropus</i>), Grey-headed Flying-fox (<i>Pteropus poliocephalus</i>)	occur at all of the proposed strategic offset properties. The following threatened bats are considered highly likely to occur in the proposed strategic offsets: Eastern Bent-wing Bat (<i>Miniopterus schreibersii oceanensis</i>), Large-eared Pied Bat (<i>Chalinolobus dwyeri</i>), Eastern Free-tail Bat (<i>Mormopterus norfolkensis</i>), Little Bent-wing Bat (<i>Miniopterus australis</i>), Large-footed Myotis (<i>Myotis macropus</i>), Grey-headed Flying-fox (<i>Pteropus poliocephalus</i>)



Appendix D

Appendix D | Dr. AnneMaree Clements - Restoration of Warkworth Sands Woodland



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14 July 2011

Mr Simon Ball
Minter Ellison Lawyers
88 Phillip St
Sydney NSW 2000

RE: Potential for re-establishment of the Warkworth Sands Woodland community on Warkworth sands located within the Northern and Southern Biodiversity Area

Dear Simon,

Background and scope

I have been asked to assist with providing legal advice to Rio Tinto Coal Australia regarding the potential for re-establishment of the woodland community on Warkworth Sands previously cleared at the Northern Biodiversity Area (the Archerfield Property) and the Southern Biodiversity Area (HMA2).

Conservation land uses are often associated with large commercial, residential and mining projects. Many of the restorations were driven by social pressure such as cleaning up slag heaps adjoining British Motorways (Bradshaw and Chadwick 1980), loss of beach amenity on the Australian east coast (Lewis 1978, Brooks 1987), minimising mining impacts of productive Jarrah Forests in Western Australia (Dodd *et al.* 1984, Ward *et al.* 1990, Ward 2000, Grant (2006), Norman *et al.* 2006, Grant *et al.* 2007, Jasper 2007, Koch 2007, Koch and Samsa 2007, Majer *et al.* 2007, Herath *et al.* 2008, Glen *et al.* 2008) and responding to the Aboriginal custodians' spiritual connection to Land in Northern Australia (Ward *et al.* 1990, William *et al.* 2002, Spain *et al.* 2006, Spain *et al.* 2010).

As a trained research scientist, I work with industry, specialising in the restoration of degraded ecosystems by mimicking natural ecosystems to increase their biological resilience. Environmental research has been applied to achieve the required conservation outcomes for ecosystems, including (see examples in Appendix 1):

- Mirvac's Magenta Shores on the wind-swept highly erodible 2.3 km of coastal beach dune sands on the Central Coast (Hazelton and Clements 2009, Clements *et al.* 2010);
- Conservation offset for Settlement Shores at Port Macquarie;
- Re-establishing endangered ecological communities for approximately 1 km long riparian corridor at Goodman's M7 Industrial Estate in western Sydney;
- Re-establishing grassy woodland on formerly highly degraded grazing land for Climax Mining in Central Tableland (Clements *et al.* 1996, Nolan *et al.* 1997, Windsor *et al.* 2000, Windsor and Clements 2001); and
- Research and design of the restoration corridors of the endangered ecological community Cumberland Plain Woodland and the critically endangered ecological

community on sand Elderslie Banksia Scrub Forest for the Spring Farm Release Area.

I am a restoration ecologist with a group of botanists, ecologists and restoration ecologists who specialise in botanical conservation assessment and developing and implementing optimal conservation strategies. The company has more than 25 years of experience in flora surveys of a wide range of ecosystems, flora assessments, assessments of impacts, vegetation plans of management, the implementation of rehabilitation/conservation programs as part of sustainable development of sites and environmental management of development sites. Four of the group's environmentally managed sites have won excellence awards for their quality and innovations, including "Excellence of Excellence" in 2000, Gold and Silver in NSW Rivercare 2000, Silver and Excellence in NSW Mineral Resources Excellence Awards and Excellence in the Earthmovers Awards, 2006 Environment Award for Australian Property Industry and 2007 International Green Apple Award.

I, Dr AnneMarie Clements hold a M.Sc. (Macquarie Univ.) Thesis - *The vegetation of bushland in the northern Sydney area* and a Ph.D. (Univ. of Sydney) Thesis - *The vegetation of the sand masses of the mid-north coast of New South Wales*. Anne is a Certified Environmental Practitioner under the Environmental Institute of Australia and New Zealand CEnvP Program and has been a member of the CEnvP NSW certification panel.

Dr Pamela Hazelton, who assisted me, is a Certified Professional Soil Scientist (CPSS). She graduated from the University of Sydney with a Bachelor of Science degree; gained a Diploma of Education from the University of New England and a PhD from the University of NSW. She is an experienced pedologist of more than 30 years, and has produced over half of the Western Division (NSW) land system maps and produced soil landscape maps in the south-eastern areas of New South Wales, Australia. She has published scientific papers on a variety of soil and education topics and is the editor of a widely used research text for the interpretation of soil test data. Throughout her career she has lectured at a variety of universities, worked in a government department and worked as a consultant specialising in the association of soil types and their relationship with endangered ecological communities. Dr Hazelton's major research interests lie in the application of soil science to environmental engineering specifically in the areas of salinity, sodicity and acid sulfate soil in coastal and urban land use. At present she is the Program Head and lecturer in the Master of Environmental Engineering Management in the School of Civil and Environment, Faculty of Engineering, University of Technology, Sydney. This course is also presented in Hong Kong. She is the academic UNESCO chair for the International Institute of Women in Engineering for EPF Institut l'ingenieurs in Sceaux, France.

To provide an initial opinion, I have:

1. Reviewed the available relevant documents including:

- Peake *et al* (2002) on the ecological significance and conservation status of Warkworth Sands Woodlands;
- The NSW Scientific Committee Final Determination for listing of Warkworth Sands Woodlands as an endangered ecological community under the NSW Threatened Species Conservation Act 1995 gazetted 13 December 2002;
- Gross (2007) on the vegetation of the Warkworth Sands and associated vegetation communities;
- Cumberland Ecology (2010) of the Ecological Assessment for the proposed mining extension;

- Gross *et al.* (2008) Restoration Research for the Warkworth Sands Woodlands UNE 6-Monthly Progress Report, October.
- Kumar L., Munoz C. and Gross C. (2009) Mapping Vegetation Communities to extract Warkworth Sand Woodlands in the RTCA project area in the Hunter Valley. Ecosystem Management, University of New England.
- Gross *et al.* (2009) Restoration Research for the Warkworth Sands Woodlands Sage Ia: 0-18 Months
- Gross *et al.* (2009) Restoration Research for the Warworth Sands Woodlands UNE 6-Monthly Progress Report, March.
- Gross *et al.* (2010) Restoration Research for the Warkworth Sands Woodland UNE Progress Report, March.
- Gross *et al.* (2010) Restoration Research for the Warkworth Sands Woodlands. Presented at the UNE Quarterly Research Meeting, MTW Boardroom on 23 September 2010.
- Gross *et al.* (2011) of the progress report on Restoration Research for Warkworth Sands Woodlands;
- Story *et al.* (1963) with reference to sand deposits;
- Department of Mineral Resources (1984) Singleton 1:25 000 geological mapping.
- Lockwood (2007, 2009) soils report with reference to sands deposits;

2. Inspected the two Biodiversity Areas with Dr Pam Hazelton, a soil scientist, accompanied by Mark Nolan and Bill Baxter of Rio Tinto Coal Australia on 25 May 2011.

3. Considered the re-establishment potential of Warkworth Sands Woodlands in terms of other restoration projects that I have designed and environmentally managed; authored the conservation management plan for, and/or inspected over the past 20 years. One of the more pertinent was the dunes at Magenta Shores. The challenge of this project was to reconstruct a long-term stable natural ecosystem on weed infested mined sands that would be able to withstand and recover from storm events. Primary vegetation colonisation and the associated development of soil fungal hyphae networks were necessary prior to introduction of secondary colonising species to the dune sands. Providing bird roosts (in this case monitoring stakes) promoted re-introduction of native plant species requiring germination through bird digestion. Large-scale mechanical and chemical weed removal with bush regeneration reduced competition from weeds, allowing native vegetation cover to succeed. On going weeding and monitoring are essential for the restoration of the natural ecosystem from the remnant significant vegetation on the dunes.

My findings to date for the Warkworth Sands Woodland are:

Landform

There were differences in the landforms of the two Biodiversity Areas observed by Dr Hazelton and myself, with the Southern Biodiversity Area having regular crests separated by swales, and the Northern Biodiversity Area having wide sands crests without distinct swales. The differences are probably related to the extent of wind exposure during and after deposition of the sands, and possibly the underlying river terraces.

Understanding the shape and orientation of the sand deposits, the surrounding landform, prevailing winds at time of the dune formation (probably 17,000 years ago), any dune blow-out (parabolic formations) since initial formation and the current wind climate are important in the planning of the Warkworth Sands restoration. The restoration is to mimic the natural landform and land process. These are essential to minimise the risk of wind erosion and damage to the existing dunes and their associated vegetation, especially during droughts and other extreme climatic events.

Vegetation from the ongoing WSW research

Gross *et al.* (2007, March 2009, March 2011) recorded 430 plant species (75% being native species) and named and vouchered 394 specimens from 56 monitoring plots (20 m x 20 m in size) across the Warkworth Sands. In the progress report dated March 2011, fruiting / flowering data were presented for the most common species. Interesting soil seedbank data in March 2009 report included:

- The persistence of native species with about 40% of the total 57 species recorded being native and about 12% of the total being Warkworth Sands Woodland species on the cleared sand;
- About 25% of the 47 species recorded in the WSW being exotic indicating less than intact native vegetation; and
- About 40% of the seedbank of WSW (47 species recorded) and of Callitris Lock-Up (37 species recorded) were WSW species, indicating that the Callitris Lock-Up either occurs on sand or the WSW are widespread species.

The data supports the presence of a persistent native soil seedbank, even on the formerly grazed areas of Warkworth Sands. The restoration is to be directed to increasing the establishment of native species and decreasing that of exotic species germinating from the seedbanks of the Warkworth Sands.

Vegetation from inspection

In the sands that Dr Hazelton and I examined, pioneer native species were widespread and soil fungal hyphae present, even on the formerly cleared paddock on the Northern Biodiversity Area. These indicate that natural resilience is still present despite past land use practices and the dominance by weed species, consistent with the soil seedbank data of Gross *et al.* 2009.

I concur with Lockwood (2007, 2009) that the structuring canopy species of the Warkworth Sands Woodlands, *Banksia integrifolia* and *Angophora floribunda*, occur on the sands.

The Southern Biodiversity Area varied from relatively intact dune assemblages, to early stages of regeneration on a former peach (*Prunus persica*) orchard, to native regeneration on the quarry slopes. On the Northern Biodiversity Area, there were remnant patches with dominance by the canopy species *Angophora floribunda* and scattered *Banksia integrifolia* similar to that of Southern Biodiversity Area, as well as scattered isolated trees and understorey on cleared former grazing land.

The main native pioneer species observed on the more disturbed lands were *Pteridium esculentum*, *Hibbertia linearis* and *Chrysocephalum apiculatum*. The presence of native species is an indication that the resilience of the natural ecosystem is present, despite past land uses and the frequency of intense competition in open areas from *Melinis repens* (Red Natal Grass). On one section of former grazing paddock on the Northern Biodiversity Area, about 5 cm of topsoil had been scalped resulting in growth of the same early native colonising species observed on Southern Biodiversity Area, as well as, the native grass *Perotis rara*.

The secondary colonising species for the ecosystem included the shrubs *Breyenia oblongifolia* and *Acacia* spp. The presence of secondary species is a clear indication that there is presently sufficient biological resilience in the system suitable for germination and establishment.

The extent of soil fungi infection in the pioneer plants is essential to determine which plants are carbon sources and which plant species are hosts for the soil fungi. The timing of introduction of the community structuring plants (such as *Banksia integrifolia*

and *Angophora floribunda*) is based on rates of soil fungal colonisation from the host pioneer species.

In conclusion, having initially reviewed the documents and inspected the site, it is my opinion that a well-planned program of rehabilitation, restoration and re-construction of the Warkworth Sand Woodland will lead to appropriate conservation outcomes.

The major rehabilitation assets for WSW are:

- Sands in the Warkworth area with and without native vegetation cover;
- Pioneer species colonising existing disturbed sands (such as the former orchard and the steep slopes of the quarry in the Southern Biodiversity Area); and
- Relatively intact soils and associated trees, shrubs and groundcovers (seed sources, host areas of soil fungi) on a series of regularly spaced dune crests and swales in the Southern Biodiversity Area and small patch of the Northern Biodiversity Area.

The Northern and Southern Biodiversity Areas contain sand deposits and sufficient remnants of the Warkworth Sand Woodland that re-establishment of Warkworth Sand Woodland ecosystems is both feasible and achievable.

A properly designed, trialled and implemented re-establishment / restoration program is required to successfully restore these Biodiversity Areas to return the Warkworth Sands Woodlands community. Major development projects provide an opportunity to fully fund high quality conservation work of social and research value. The research findings and outcomes of a restoration program should be publicly available in peer-review publications.

Yours faithfully,



Dr AnneMarie Clements

References

- Brooks D.R. (1987) Rehabilitation in Australia's mineral sand industry. In Farrel R. (editor) *Mining Rehabilitation '87*. The Australian Mining Industry Council, Canberra.
- Clements A., Simmonds A., Hazelton P., C. Inwood C., Woolcock C., Anne-Laure Markovina A-L and O'Sullivan P. (2010). Construction of an Environmentally Sustainable Development on a Modified Coastal Sand Mined and Landfill Site—Part 2. Re-Establishing the Natural Ecosystems on the Reconstructed Beach Dunes. *Sustainability* 2010, 2(3), 717-741.
- Clements A, Sanderson B., Hann J., Roxburgh J, Jennings P., Ross A., Sandercock H, Nolan M, Windsor D. (1996) Natural landforms and no exotic covers led to good native establishment. In *Proceedings of the Second Australian Workshop on Native Seed Biology for Revegetation*. Newcastle. 11-12 October 1996. (Eds Bellairs S.M. and Osborne J.M.).
- Clements A., Holdway T., Moore R. and Rodd J. (2000) *Rehabilitation strategies for the Pooncarie area*. Unpublished. Prepared for NSR.
- Dodd, J., Mattiske, E.M., Pate, J.S. and Dixon, K.W. (1984) Rooting patterns of sandplain plants and their functional significance. In J.S. Pate and J.S. Beard (eds) Kwongan. *Plant Life of the Sandplain*. pages 146-177. University of Western Australia Press: Nedlands.
- Glen, M., Bougher, N. L., Colquhoun, I. J., Vlahos, S., Loneragan, W. A., O'Brien, P. A. and Hardy G. E. (2008) Ectomycorrhizal species in fungal communities of rehabilitated bauxite mine sites in the Jarrah Forest of Western Australia. *Forest Ecology and Management* 255, 214–225.
- Grant, C. D. (2006) State-and-transition successional model for bauxite mining rehabilitation in the Jarrah Forest of Western Australia. *Restoration Ecology* 14, 28–37.
- Grant, C. D., Ward, S. C. and Morley, S. C. (2007) Return of ecosystem function to restored bauxite mines in Western Australia. *Restoration Ecology* 15, S94–S103.
- Herath D.N., Byron, B.B., Enright, N.J., Miller, P.B. (2008). Comparison with post mine rehabilitated and natural shrubland communities in south-western Australia. *Restoration Ecology* 17(5): 577-585
- Jasper, D. A. (2007) Beneficial soil microorganisms of the Jarrah Forest and their recovery in bauxite mine restoration in Southwestern Australia. *Restoration Ecology* 15, S74–S84.
- Majer, J. D., Brennan, K. E. C. and Moir, M. L. (2007) Invertebrates and the restoration of a forest ecosystem: 30 years of research following bauxite mining in Western Australia. *Restoration Ecology* 15, S104–S115.
- Nolan, M. B., Windsor, D. M. and Williamson, S. (1997). Dormancy and viability of *Themeda australis* (Kangaroo Grass) and its implications for mining revegetation in the Central Tablelands of New South Wales. Pp. 149-54 in *Second Australian Native Seed Biology for Revegetation Workshop* ed by S. M. Bellairs and J. M. Osborne.
- Norman, M. A., Koch, J.M., Grant, C.D., Morald, T.K., and Ward, S.C. (2006). Vegetation succession after bauxite mining in Western Australia. *Restoration Ecology* 14(2): 278-288.

- Koch J.M. (2007) Alcoa's Mining and Restoration Process in South Western Australia. *Restoration Ecology* 15, S4, pages S11–S16.
- Koch J.M. and Samsa G.P. (2007) Restoring Jarrah Forest Trees after Bauxite Mining in Western Australia. *Restoration Ecology* 15, S4, pages S17–S25.
- Lewis J.W. (1978) *Ecological studies of coastal forest and regeneration after mining*. Unpublished PhD thesis. University of Queensland.
- Norman, M. A., Koch, J.M., Grant, C.D., Morald, T.K., and Ward, S.C. (2006). Vegetation succession after bauxite mining in Western Australia. *Restoration Ecology* 14(2): 278-288.
- Spain, A. V., Hinz, D. A., Ludwig, J., Tibbett, M. and Tongway, D. (2006) Mine closure and ecosystem development: Alcan Gove bauxite mine, NT, Australia. In: Proceedings of the First International Seminar on Mine Closure (eds. A. B. Fourie and M. Tibbett), pp. 299–308. Australian Centre for Geomechanics, Perth, Australia.
- Ward S.C., Koch J.M. and Nichols O.G. (1990) Bauxite mining rehabilitation in the Darling Range, Western Australia. *Proc. Ecol. Soc. Aust.* 16, 557-565.
- Ward S.C., (2000) Soil development on rehabilitated bauxite mines in south-west Australia. *Australian Journal of Soil Research* 38(2): 453 - 464
- Williams, R.J., Griffiths, A.D. and Allan, G.D. (2002) *Fire regimes and biodiversity in the savannas of northern Australia. Flammable Australia: The Fire Regimes and Biodiversity of a Continent*, Braddock, R.A., Williams, J.E. and M.A. Gill (eds), Cambridge University Press, Cambridge, pp. 282-304.
- Windsor D. M., Clements A., Nolan M. B. and Sandercock I.H. (2000) Recreating a eucalypt woodland on a gold mine in the Central Tablelands of New South Wales. In Hobbs R.J. and Yates C.J. (eds) *Temperate Eucalyptus woodlands in Australia. Biology, conservation, management and restoration*. Surrey Beatty & Sons, Chipping Norton, NSW.
- Windsor D.M. and Clements A. (2001) A germination and establishment field trial of *Themeda australis* (Kangaroo Grass) for Mine Site Restoration in the Central Tablelands of New South Wales. *Restoration Ecology* 9(1), 104-110

Appendix 1

Magenta Shores Tourist Facility, NSW Central Coast
Client: Mirvac

Key personnel: Dr AnneMarie Clements, Dr Pamela Hazelton, Tony Rodd, Catherine In-Christy Woolcock and Polly Simmonds

Environmental Management of the coastal sand ecosystems, especially of the coastal dunes and the Littoral Rainforest (the habitat of the Vulnerable species *Syzygium paniculatum*) as part of the ecological sustainable development of this former sand mined site included:

- Increasing the natural resilience of dune ecosystems and by mimicking natural processes on a 2.3 km length of reconstructed/rehabilitated beach dune ecosystem, covering about 50 ha, as well as restoration of Littoral Rainforest
- Researching, vegetation surveys, designing and implementing the Habitat Restoration Plan
- The dune restoration works in the Coastal Protection Zone directed to increase protection of the development resources from major coastal storms and winds. Stabilised sand volume was increased by developing a mesh of soil fungal hyphae, providing natural carbon sources, re-colonisation by sand trapping native flora and decreasing the presence of exotic species
- Re-use of the noxious weed Bitou Bush from the coastal dunes as an organic additive to golf course soils
- Increasing sustainability by using the leachate from the former landfill in the groundwater to irrigation of the nutrient demanding golf course, reduce risk to adjoining lake system
- Minimising impacts on the population of *Syzygium paniculatum* (Magenta Lilly Pilly) on and adjacent to the development and the associated infrastructure by implementing buffer zone, bush regeneration to reduce existing weed threats
- Careful document and monitoring to direct staged works with results publicly available in peer reviewed publications

Dune reshaping works at Magenta Shores

Wind eroded landform of foredune with Bitou



Reconstructing dune and sediment erosion measures



Replanted foredune



Settlement Shores, Port Macquarie

Client: Port Shores Pty Ltd

Key personnel: Dr AnneMarie Clements, Rosemary Snowdon, Tony Rodd, Dr Pamela Hazelton

Ensuring environmental compliance, including establishment of conservation offsets areas for a large residential subdivision developed by Port Shores Pty. Ltd. in Port Macquarie. The work included:

- Environmental Management during the construction phase of the earthworks associated with the development of residential land, embayments and conservation areas to ensure that the off site sensitive estuarine environment was not adversely impacted by discharge of treated acid sulfate waters and sediment movement
- Designing, supervision and monitoring of constructed estuarine wetland and adjoining Casuarina forest and rainforest on former dairy land
- Designing and supervision re-establish of natural landform and coastal dune vegetation on a former dredge disposal site and on-going monitoring
- Long-term monitoring any changes in sediment movement and vegetation on the nearby wetlands
- Establishment of seagrass beds within the constructed canals and embayment
- Ongoing monitoring assessment of water quality within the main canals, newly constructed embayments and in the adjoining river
- Compliance with consent conditions,



Constructed estuarine wetlands at Settlement Shores, Port Macquarie. Saltmarsh and mangrove ecosystems were established on excavated former grazing paddocks.

Spring Farm Urban Release Area, NSW
Client: The Consortium

Key personnel: Dr AnneMarie Clements, Dr Pamela Hazelton, Tony Rodd

Flora Assessment and Conservation Strategy for 488 ha of land in the Spring Farm area.
Works undertaken for this project included:

- Reviewing historic land use from historical aerial photographs
- Reviewing previous assessments of the vegetation and soils
- Surveying the vegetation using fixed area quadrats and spot locations and site specific soil survey
- From the survey data, assessing the relative conservation value and rehabilitation potential
- Determining the distribution of threatened plant species
- Using the vegetation survey data, soils information and other published data to determine the presence of endangered ecological communities
- Detailed assessment and mapping of all patches of vegetation with a native component
- Developing a Conservation Strategy to preserve ecologically endangered communities including Cumberland Plain Woodland, Elderslie Banksia Scrub Forest and Sydney Coastal River Flat Forest, within bushland corridors as part of the ecologically sustainable development of Spring Farm
- Presentation to public meetings and government bodies
- Submission to State and Commonwealth agencies, including Environment Australia.

Spring Farm Urban Release Area showing bushland corridors
- as displayed in Camden Council LEP 121 gazetted 21 May 2004

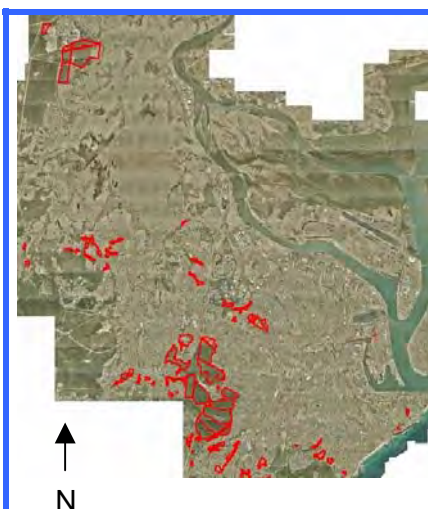


Bushland Asset Management Plan Client: Newcastle City Council

Key personnel: Rebecca Burley, Tony Rodd, Dr AnneMarie Clements

Flora and conservation significance of Newcastle bushland assets were assessed to assist Council in developing a strategy to improve bushland quality in the LGA. Management recommendations were provided to enable Council to target resources. The works for 89 Council selected bushland reserves and parks included:

- Review of previous surveys, published literature and aerial photographs
- Categorisation of areas based on geology, soil landscape mapping, park size, bushland patch size, connectivity to other bushland patches
- Development of standardised survey methods with data-collection forms for the study and future monitoring
- Flora assessment using data collected from 209 plots (0.04 ha in size with at least one plots per reserve or park). Data were consistent with the Lower Hunter and Central Coast regional study
- Providing Council with an updated and a Newcastle focused database with information added as Geographic Information System layers to the existing Council database
- Determining the extent of weed invasion through survey and aerial photograph interpretation
- Development of a strategy to identify and rank bushland in need of assisted regeneration
- Preparation of a Bushland Asset Management Plan with recommendations for each bushland parcel surveyed
- Workshop participation, presentations, discussion and collaboration with Council staff



Bushland reserves and parks surveyed in Newcastle LGA



Survey location in Blackbutt Reserve



Bushland in George McGregor Park on Killingworth Soil Landscape



Appendix E

Appendix E | Mr James Tomlin - response regarding perched aquifer



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JST/ae (G1468.1.MTW)
30 August 2011

EMGA Mitchell McLennan
Ground Floor, 20 Chandos Street
St Leonards NSW 2065
PO Box 21 St Leonards NSW 1590

Attention: Mr. Brett McLennan

Dear Brett,

RE: MT THORLEY WARKWORTH EXPANSION – WARKWORTH SANDS

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) are pleased to provide further advice on the potential impacts to the Warkworth Sands Woodland (WSW) associated with the proposed extension to the Warkworth Mine.

1.0 Background

AGE (2010)¹ assessed the impact of the proposed Warkworth Extension on the groundwater regime as part of the Environmental Assessment (EA) for the project. AGE (2010)¹ reported that “*aeolian sands overlie the coal measures to the north-east of the Warkworth Mine. Due to their ability to store water the sands support a unique woodland, known as the Warkworth Sands vegetation community. The fine grained sands are up to approximately 3m in thickness and overlie a low permeability base of residual clay associated with the underlying strata. The low permeability clays reduce vertical flow of groundwater and result in the formation of an ephemeral perched water table at the base of the sand mass.*”

A soil survey undertaken in the Warkworth Sands (Lockwood 2007) about three months after an extreme rain event indicated nearly all deep sand profiles were moist close to the clay boundary, and many were saturated. This implies that the water table formed at the base of the Warkworth Sands is perched and is not in direct hydraulic connection with the regional aquifer in the underlying Permian fractured rock. Nevertheless, some small seepages of groundwater occur from the Warkworth Sands at the break of slope created by the Wollombi Brook floodplain, but the large majority of the perched water is likely to be removed from the aquifer by direct evapotranspiration through the vegetation”.

2.0 Independent Ecology Review

It is understood an independent ecology review commissioned by Department of Planning and Infrastructure (DPI) raised concerns that the EA has not adequately demonstrated that:

¹ Australasian Groundwater and Environmental Consultants Pty Ltd, (2010), “*Warkworth Mine Extension, Groundwater Impact Assessment*”, April 2010, Project No. G1468.

- the project would not have adverse impacts on adjoining stands of Warkworth Sands Woodland through the potential severance of the perched aquifer; and
- the buffer that will remain between the Warkworth Sands and the mine disturbance area will be adequate to protect the vegetation community.

These issues are discussed below.

3.0 Potential Impacts

In order to assess the potential impacts of the proposed mine extension on the Warkworth Sands Woodland area, it is necessary to understand the extent of the sand sheets that support the ecosystem. The Warkworth Sands does not occur as one large sand sheet, but many smaller isolated sheets, separated by areas where sand is not present. In between these sand sheets, clay based bedrock derived soils occur at the surface which are colonised by Central Hunter Grey Box / Ironbark Woodlands and grasslands (Cumberland Ecology 2010)². Figure 1 shows the mapped vegetation communities in the northern area of the proposed mine disturbance boundary.

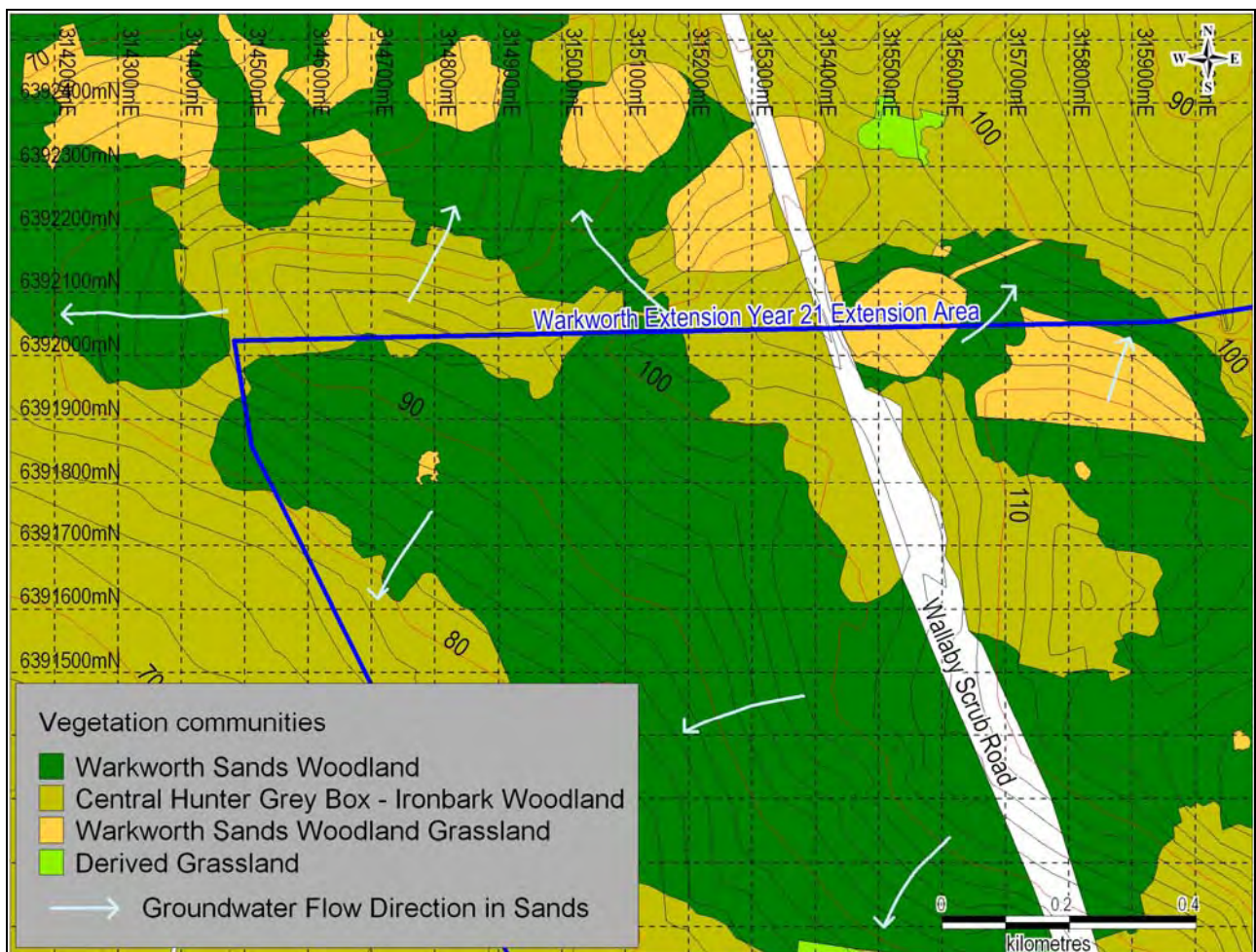


Figure 1: Warkworth Sands Woodland and Proposed Warkworth Mine Disturbance Area

² Cumberland Ecology, (2010), *Warkworth Mine Extension, Ecological Assessment*, prepared for Warkworth Mining Limited, April 2010.

The topography of the bedrock underlying the sand sheet controls the direction of groundwater flow within the sand. Figure 1 shows the expected direction of groundwater flow within the sands, assuming groundwater flow direction is a reflection of topography, which is highly likely.

It is clear from Figure 1 that the northern boundary of the area proposed to be disturbed by mining largely follows a natural division between the sand sheets. In this boundary area, sand is not mapped as being present and the Central Hunter Grey Box / Ironbark Woodlands and grasslands are present on bedrock derived clay soils. The topography of the area also means that the separate sand sheets can be considered different and not interconnected hydrogeologic units. Groundwater flow in the area to be disturbed by mining is predominantly to the west, whereas groundwater in the sand sheets outside of the disturbance area, flows to the north. Therefore, removal of the sand sheet to the west of Wallaby Scrub Road, will not affect groundwater flowing to the northern area of the sand sheets.

The only area where the Warkworth Sand Woodland will be directly intersected by the proposed disturbance area is in the north-eastern corner. In this area, a 500m length face will be excavated through the sand sheet, leaving a smaller zone remaining to the north. In this area, some lateral flow of groundwater in the sand sheet would be intersected by the excavation. The oblique view aerial photography in Figure 2 shows the division between the sand sheets.

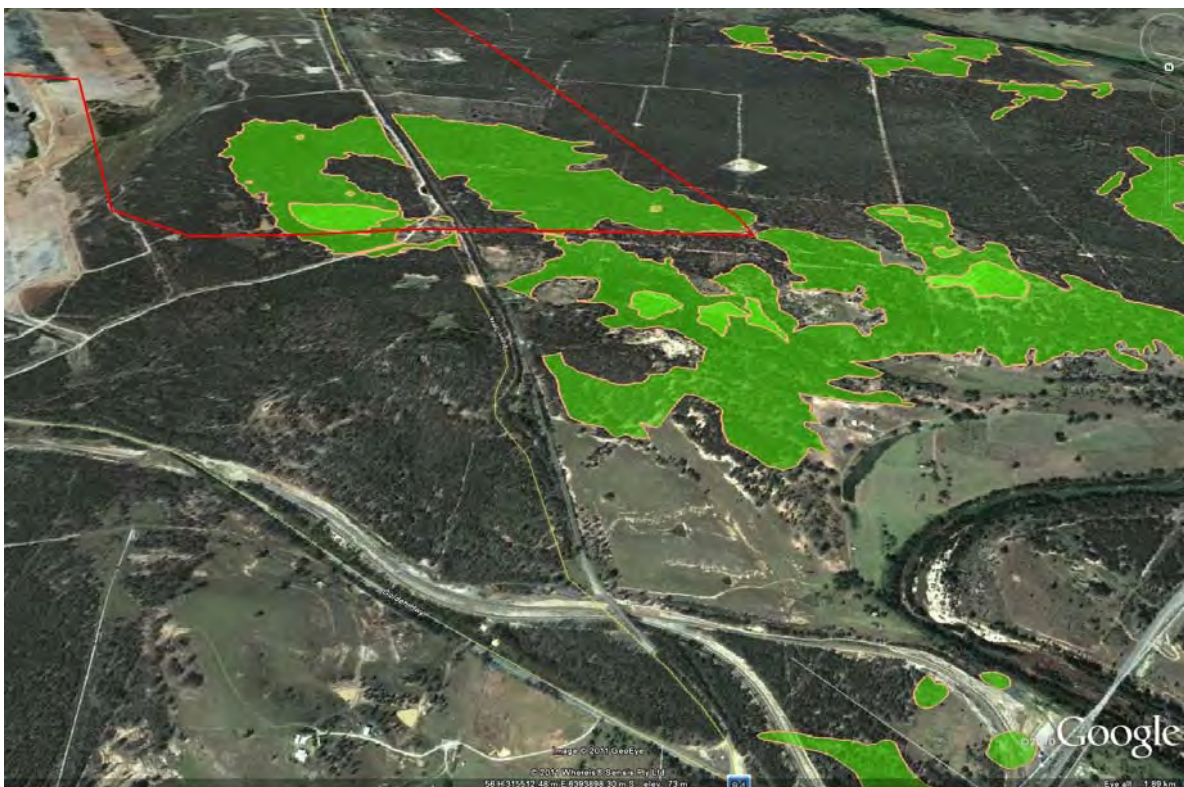


Figure 2: Warkworth Sands Woodland (darker green) and Grassland (lighter green) looking from north to south – proposed mine extension area shown in red (source Google Earth)

Figure 2 shows that the Warkworth Sands that would remain after the proposed mining are downhill from the disturbance area. This is also shown by the topographic contours in Figure 1.

These figures demonstrate that the proposed disturbance area does not directly intersect or result in a direct connection between the proposed pit and the large sand sheet that is present to the north-east. The buffer that will remain is between the disturbance area and the pit is between

about 50m and 200m. In this area, there will be no direct excavation of the sand sheet and therefore no drainage of the perched aquifer.

As noted above along the north-western boundary of the proposed disturbance area, a 500m length face will be excavated through the sand sheet, leaving a smaller remnant zone of Warkworth Sands remaining downhill and to the north. This will potentially leave an exposed sand face which could promote some groundwater seepage from the zone of Warkworth Sands that would remain in this area. The seepage may be limited by the fact that the hydraulic gradient is away from the face and down hill. Treatment of this face with low permeability material would serve to reduce the seepage from the sand sheet.

If the sand face is left untreated and exposed, then the seepage would be expected to result in a localised reduction in groundwater levels adjacent to the excavation face. The magnitude of the zone drawdown that is created when an aquifer is intersected by an excavation is determined by the aquifer type, being either confined or unconfined, and the aquifer properties of pore space storage, hydraulic conductivity and saturated thickness. The Warkworth Sands form an unconfined aquifer with very limited saturated thickness and therefore the zone in which water levels are depressed by drainage from cutting is not expected to extend a significant distance into the remaining sand aquifer.

A simplistic estimate of the extent of the zone of drawdown can be made using the analytical formulas presented by Perrochet and Musy (1991)³. A zone of drawdown was calculated as shown in Figure 3 assuming a rainfall recharge rate of 60mm/year, a hydraulic conductivity of 1m/day, a drainage porosity of 20%, and a saturated thickness of 1m.

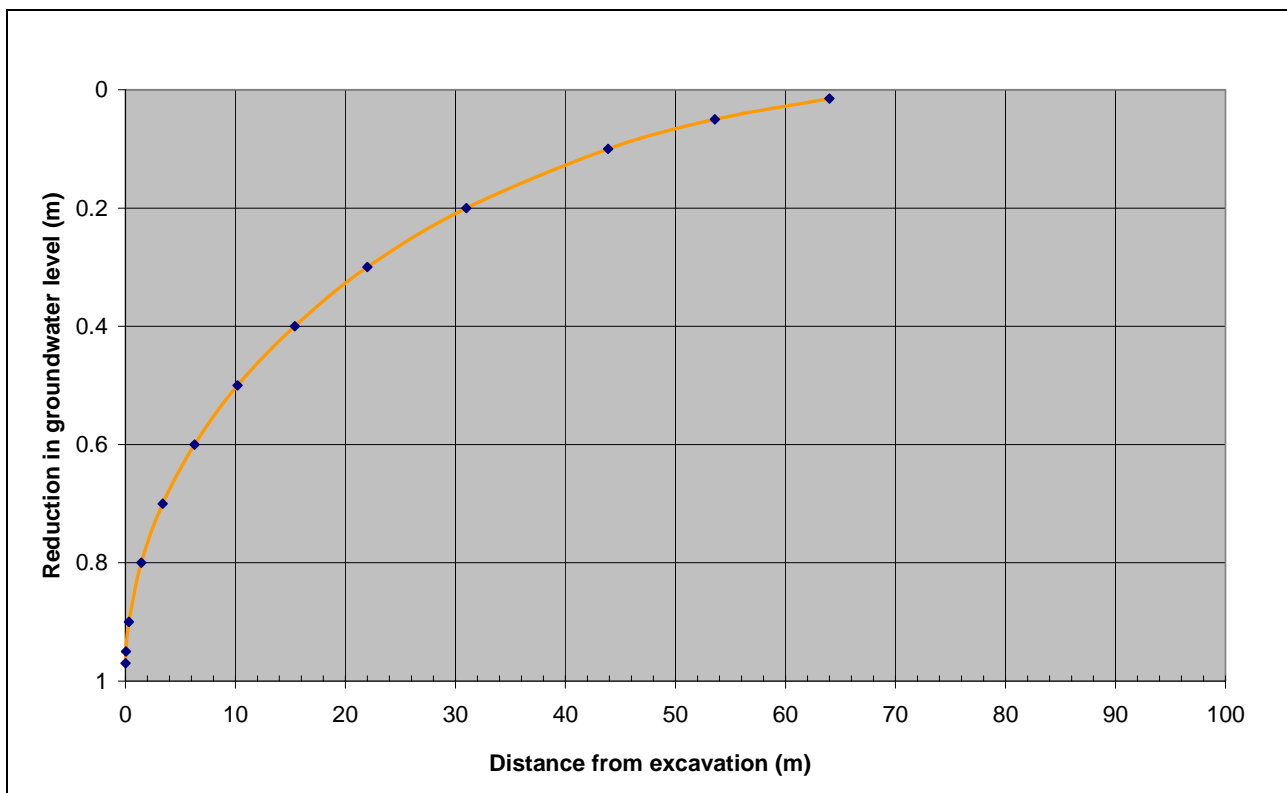


Figure 3: Zone of Drawdown

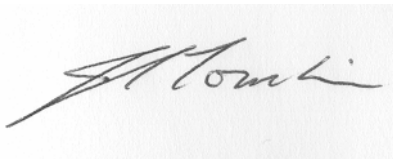
³ Perrochet, P and Musy, Andre, (1991), "A simple formula to calculate the width of hydrological buffer zones between drained agricultural plots and nature reserve areas", Irrigation and drainage systems 6:69-81, 1992. Kluwer Academic Publishers.

Figure 3 shows that 30m from the disturbance boundary, the drawdown in the sand aquifer is about 200mm. Groundwater levels fluctuate naturally in response to rainfall, rising in periods of above average rainfall, and falling in drought periods. These natural fluctuations are significantly in excess of 200mm, and potentially in the order of several metres through cycles of drought and high rainfall. The WSW vegetation is expected to be adapted to fluctuating water levels in the sand sheet, and a relatively small zone of reduction in groundwater levels along the excavation face is unlikely to be significant.

Treatment of this face with low permeability material would serve to reduce the seepage from the sand sheet. However, the most appropriate mitigation measure should be adopted following a more detailed hydrogeological study in the area of the proposed excavation. This study would include installation of a network of shallow monitoring bores to the base of the sand sheet to measure groundwater levels, hydraulic gradients, flow rates, and the permeability of the sands. This baseline information can then be used to assess the most appropriate mitigation method, if any is required. The monitoring bore network can then be used during mining to monitor the impact of the project on the groundwater levels in the sand sheet.

Thank you for the opportunity to assist with this project, please do not hesitate to contact me on (07) 32572055 with any queries regarding the above.

Yours faithfully,



JAMES S. TOMLIN

Principal Hydrogeologist / Director
Australasian Groundwater and Environmental Consultants Pty Ltd



Appendix F

Appendix F | Mr Robert Gillespie - Economic costs and benefits of environmental restrictions

Economic Costs and Benefits of Environmental Restrictions

on the

Warkworth Mine Extension

Prepared for

Warkworth Mining Limited

By



Gillespie Economics
Tel: (02) 9804 8562
Email: gillecon@bigpond.net.au

February 2011

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1.0 INTRODUCTION

Gillespie Economics prepared the *Proposed Warkworth Extension Benefit Costs Analysis* for the proposed Warkworth Extension Environmental Assessment (Annex O of Volume 5). Umwelt Australia is currently undertaking an evaluation of the Environmental Assessment (EA) for the proposed Warkworth Extension on behalf of the NSW Department of Planning (DoP). This report provides further information regarding the economic costs and benefits of environmental restrictions on the proposed Warkworth Extension.

Open cut coal mining in the Hunter Coalfield yields saleable coal for export and domestic consumption but also results in environmental disturbance. This disturbance can directly impact on flora and fauna including endangered ecological communities (EEC).

While some groups in society consider that the socially desirable level of environmental impact is zero, this view has no regard to the associated opportunity costs to society i.e. the forgone economic benefits associated with avoiding environmental effects.

Economics provides a framework for:

- considering the trade-off between reducing the environmental impacts of mining and foregoing economic benefits of production, from a broad community perspective; and
- identifying the socially optimal level of environmental restriction on mining on a case by case basis.

This framework is used here in relation to a potential environmental restriction on the proposed Warkworth Extension.

2.0 BACKGROUND

2.1 Warkworth Mine

The Warkworth Mine is located approximately 15 km southwest of Singleton in the Hunter Valley. It has approval to produce up to 18 million tonnes per annum of run-of-mine (ROM) coal and has consent to continue until 2021. Global energy markets, infrastructure and operational conditions have combined to make it financially viable to extend the mine into areas that were previously identified as not economic. The revised estimates of economic reserves are sufficient to enable mining to the year 2056. However, based on the typical consent life of 21 years, Warkworth Mining Limited (WML) is seeking approval for the extension of the Warkworth Mine for a 21 year period from the date of approval, nominally 2031.

2.2 Environmental Impacts

The proposed Warkworth Extension would result in a number of environmental impacts including generation of additional greenhouse gas emissions, disturbance of five Aboriginal heritage sites of high conservation significance and some traffic impacts from relocation of Wallaby Scrub Road. The proposal would also result in the clearing of an additional 475.3 ha of EECs including some offsets from a previous development approval. The total clearing of EEC at the Warkworth Mine from current approvals and the proposal is 764.7 ha.

The proposal includes an ecological offset strategy comprising:

- protection of 1,030.7 ha of EEC (woodlands) including 123 ha of Warkworth Sands Woodland (WSW);
- protection of 235.8ha of EEC (grassland) at the Goulburn River Biodiversity Area; and
- regeneration of 195.8 ha of WSW on Coal & Allied and Mount Thorley Warkworth land.

In addition, 780.6 ha of the mine site will be progressively revegetated with woodland species equivalent to that of an EEC. It should be noted that the offsets also include the protection of approximately 1,455 ha of woodland not currently considered EEC.

3.0 ECONOMIC TRADE-OFF FRAMEWORK

3.1 Concepts

Economics is sometimes dismissed as representing the perspective of businesses and ignoring the concerns of the community regarding environmental effects. However, economics is fundamentally concerned with allocation of resources in society to maximise community welfare or well-being (Tisdell, 1991).

Well-being in economic theory is defined as arising from both the consumption and production of goods and services. These goods and services may be many and varied and can be both traded in markets (and thus priced) or not traded (termed 'intangibles').

The benefit derived by a consumer of goods and services is defined as the difference between what that person would be willing to pay for the good or service and what they have to pay. This is the "consumer surplus" and is relevant to the community's valuation of intangible impacts including social (employment) and environmental impacts (Bennett, 1996).

The producers of goods and services can also generate surpluses. By combining resources in ways that increase their value to society, producers improve the well-being of the community. They create a "producer surplus" which is the difference between the costs of the inputs used in the production process and the price received for the finished product (Bennett, 1996). Producer surplus is the relevant measure of the value to the community of coal production.

Both the consumer and producer surplus concepts can be applied to the consideration of changes in the well-being of the community resulting from changes in resource use. If a resource re-allocation enables some of the community affected to experience greater consumer or producer surpluses, then these people are beneficiaries of the change. The extent of the change in their consumer and producer surpluses is a measure of their benefits. Conversely, if reductions in these surpluses are experienced, the people so affected are worse-off. The extent of the reductions in surpluses is a measure of the community's costs (Bennett, 1996).

To assess the impact of a proposed resource use change, the incremental benefits of the resource re-allocation are compared to the incremental costs (using discounting to compare benefits and costs in different time periods). Only where the present value of benefits exceeds the present value of costs is a resource re-allocation considered to be economically efficient. Assessments of this kind are termed benefit cost analysis (BCA).

Where there are a number of alternative resource re-allocations, the option with the greatest net benefit is considered to be the most economically efficient and preferred on economic grounds.

It follows that, in this economic efficiency framework, the existence of adverse environmental effects alone is not sufficient justification to reject a coal mine proposal. What is relevant is the comparison of the benefits of mining (increased producer and consumer surplus from production and employment) and the environmental costs (reduced consumer surplus).

3.2 BCA of the Proposed Warkworth Extension

A BCA of the proposed Warkworth Extension was undertaken as part of the EA for the Project. It included valuation of environmental and social impacts of the proposal (including the clearing of EEC and impact on significant Aboriginal heritage sites) using the non-market valuation method of Choice Modelling (CM). This was necessary because environmental and social goods are not routinely traded in the market and thus lack established prices. The CM study was a surrogate for this and involved surveying a sample of NSW households to determine the sums of money that people would be willing to pay either to avoid any adverse impacts or obtain a positive one.

The analysis found that the proposed Warkworth Extension would have net benefits to the community of \$1,862M¹ and hence is desirable and justified from a community welfare perspective.

3.3 BCA of a Restriction on the Proposed Warkworth Extension

The above economic concepts and framework can also be used to examine the economic efficiency of an environmental restriction on the proposed Warkworth Extension.

This economic trade-off analysis is conceptualised on Figure 1 using an environmental restriction on the clearing of EEC. No matter the nature of this environmental restriction, the same principles apply.

On Figure 1, the x-axis refers to an increasing level of environmental restriction on the clearing of EEC. The y-axis is a dollar value. The marginal cost (MC) curve represents the incremental foregone producer surplus from coal mining and foregone consumer surplus associated with the employment provided by the proposal, as the level of the environmental restriction increases. The greater the level of the environmental restriction the greater the marginal cost. Total cost is represented by the area under the MC curve at any level of environmental restriction.

The marginal benefit (MB) curve represents the environmental benefits (avoided environmental costs) gained from increases in the level of environmental restriction.

It can be seen that as the level of environmental restriction increases the MB decreases, reflecting the law of diminishing marginal utility i.e. the more protected environment we have, the less value is provided to the community by additional areas being protected. Total benefit is represented by the area under the MB curve at any level of environmental restriction.

In this framework, the optimal level of an environmental restriction is where the MB of a restriction equals the MC. Environmental restrictions should continue to be imposed so long as the additional restriction results in a MB that is greater than the MC. Once the MB falls below the MC, society is being made worse off by the additional restrictions. Hence, the level of restriction where MB equals MC maximises net benefits to society. This level of restriction also minimises the two sets of costs, foregone coal production (and associated foregone employment benefits), and environmental costs.

The way Figure 1 is drawn indicates that there will be some optimal level of environmental restriction. However, it is quite possible for the MB of the first increment of an environmental restriction to be lower than the value of foregone coal producer surplus and foregone consumer surplus associated with employment, and therefore for the optimal level of environmental restriction to be zero. This is illustrated on Figure 2. In such cases, the MB of a restriction is never high enough to outweigh the MC of foregone production.

¹ Estimates of the area cleared and proposed offsets have changed slightly since the benefit cost analysis was undertaken. However, these changes would only result in small changes to the estimated net benefits of the Project.

Figure 1 - Trade-off between Coal Production and Environmental Costs

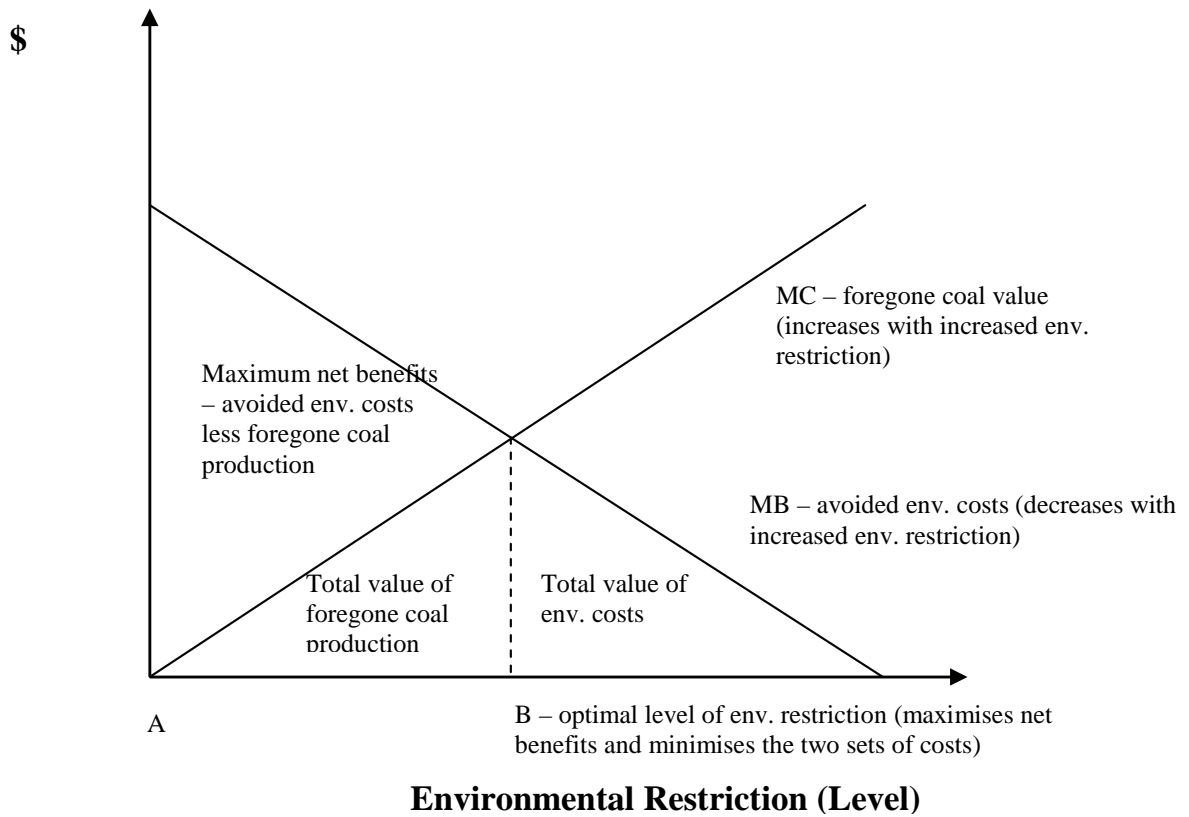
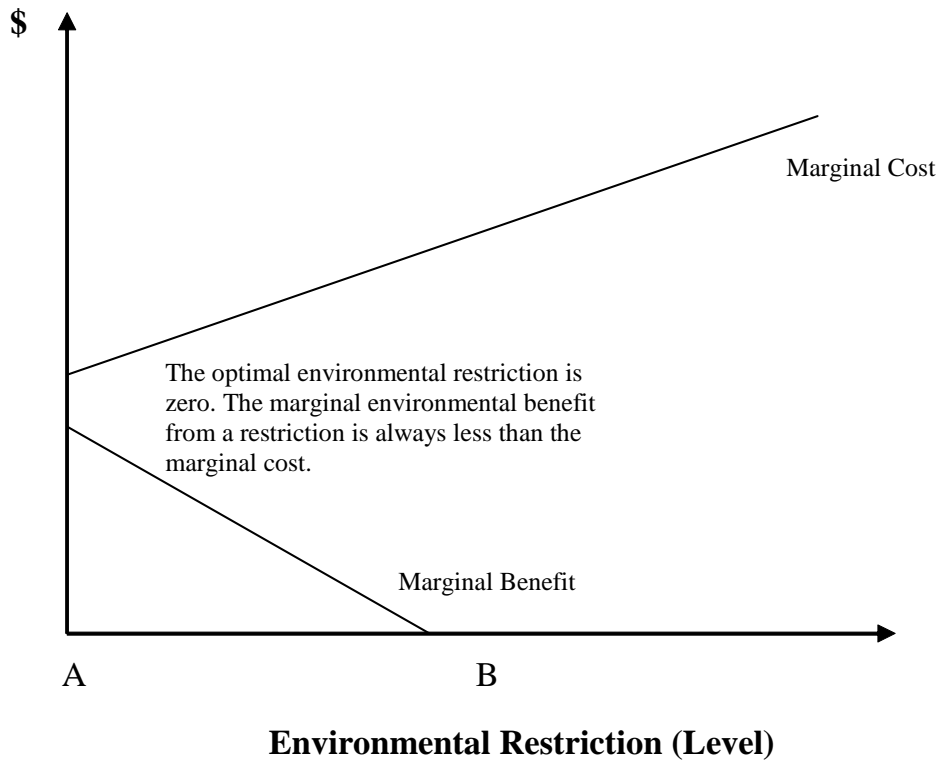


Figure 2 - Trade-off between Coal Production and Environmental Costs with an Optimal Environmental Restriction of Zero



This framework was used to examine the marginal costs and marginal benefits of restricting the proposed Warkworth Extension by conserving 67.9 ha of WSW. There would be a range of costs and benefits from conserving this additional WSW.

The marginal benefits include:

- Consumer surplus associated with the reduced area of WSW cleared;
- Consumer surplus from protecting one Aboriginal site that would be conserved in the 67.9 ha of WSW; and
- Reduced greenhouse gas generation (associated with a reduction in the volume of coal mined).

The marginal costs of the restriction include:

- Reduced producer surplus from a reduction in coal available for mining (reduction in revenues less capital and operating cost savings). It is estimated that ROM production and product coal would be reduced by 46 Mt and 30 Mt, respectively, over the Project life;
- Reduced consumer surplus values associated with a reduction in employment levels provided by the mine. It is estimated that employment at the mine would reduce by 200; and
- Reduced offset benefit i.e. the lost compensation in lieu of clearing 67.9ha of WSW. Conservatively, this is omitted from the analysis.

These costs and benefits (excluding the value of offsets) have been included in the analysis in the years in which they occur. The same market data and non-market values used in the BCA of the proposed Warkworth Extension, and market data from WML on the reduced mining scenario, have been used. The results of the analysis using a 7% discount rate (as recommended by NSW Treasury) are summarised in Table 1.

Table 1 – Marginal Costs and Benefits of EEC Conservation

Marginal Costs	\$M	Marginal Benefits	\$M
Reduced producer surplus from mining	\$352	Reduced area of WSW cleared	\$29
Reduced employment benefits	\$60	Reduced number of high conservation value Aboriginal sites impacted	\$31
Reduced offset benefits	\$0 ¹	Reduced greenhouse gas generation	\$41
Sub-total	\$412		\$101
NET COMMUNITY BENEFITS	-\$311		

¹ Conservatively, no reduction in offset benefit is included in the analysis.

*The relocation of Wallaby Scrub Road is still assumed to occur in this scenario.

The analysis shows that there would be a net cost to the community of \$311m from the restriction of mining at Warkworth to conserve 67.9 ha of WSW. It is, therefore, not justified from a community welfare perspective.

3.4 Economics of Offsets

The preceding estimate of community welfare ignores distributional aspects. The local community, particularly groups like mine employees and those people with a strong interest in conservation, would be most affected. The most efficient means of compensating the community for the loss of WSW is to provide offsets, especially in the locality of the mine.

An offset may include:

- creating new areas of vegetation by planting on cleared land in the region, including as part of the rehabilitation of the mine site; and/or
- permanently protecting other areas of vegetation in the region.

The required offset ratio is generally based on expert opinion with some attempts to formalise this expert opinion into a case by case calculator. Expert opinion takes into account a range of factors including the area of clearing and environmental values lost, the area to be offset and the environmental values gained, the risk of the offset action failing and adjustments for any time lags.

An alternative approach is to examine the values that the community hold for the vegetation that is to be cleared and the values they hold for the offset action. One method of doing this is CM.

CM involves a representative sample of people being asked to make a sequence of choices between resource management strategies. Each strategy is described in terms of its impacts on a range of environmental attributes and its cost to the respondent. From their choices, it is possible to infer the values that respondents place on the various environmental attributes (Bennett 2008). CM development over the last 10 years has shown it to be a robust and reliable tool for natural resource management (Adamowicz, 2004)

A CM study was undertaken to estimate the community's values for the potential environmental and social impacts of the proposed Warkworth Extension. The environmental and social attributes included in the study were:

- area of mine site EEC cleared (Clear);
- area of EEC planted in the region (Plant);
- area of existing EEC protected in the region (Protect);
- impact on highly significant Aboriginal sites (Ab);
- impact on rural families in the small rural community (Rural);
- number of years that the mine will provide 975 jobs (Years);
- once-off payment (Cost).

A range of economic models were estimated using NLOGIT 4.0 econometric software. The models that were used in the economic analysis are reported in Table 2. Model 5 includes the 'Years' attribute in a linear form while Model 6 includes it in a logarithmic form. The full CM study is reported separately (Gillespie 2009) in the EA (Annex O of Volume 5).

Table 2 Results of Preferred Random Parameters Logit Models

Variable	Model 5	Model 6
Random Parameters in Utility Functions		
Clear (n)	-.00109393***	-.00109391***
Protect (n)	.00077313***	.00076308***
Ab (n)	-.08009550***	-.07991032***
Rural (n)	-.09116561***	-.09111777***
Years (n)	.08001459 ***	
Yrsln (n)		1.20366361***
Non Random Parameters In Utility Functions		
Cost	-.00268927***	-.00269115***
Plant	.00026852**	.00027026**
ASC	.07007965	-.01532021
Standard Deviations of Random Parameters		
Clear (n)	.00241453***	.00239904***
Protect (n)	.00129623***	.00130574***
Ab (n)	.15693733***	.15605145 ***
Rural (n)	.06685500***	.06957842***
Years (n)	.18486163***	
Yrsln (n)		2.81087754***
Standard Deviation of Latent Random Effects		
Sigma EO1	5.98287864***	5.99723457***
Model Statistics		
AIC	1.45541	1.45545
BIC	1.46290	1.46294
Prob > chi2		.0000000
McFaddens R2	.3385148	.3385000
Log likelihood	-10264.13	-10264.36
Chi2	10505.33	10504.87

Significance levels: *.0.1, **.0.05, ***0.001

The coefficients of attributes generated from the CM models reflect their relative importance to the respondents (Bennett and Blamey, 2001). The ratio between the coefficient of an environmental or social attribute and the coefficient of the cost (Cost) attribute reveals the respondents' willingness to pay (WTP) or implicit price for a marginal change in the environmental and social attributes.

Table 3 Estimated implicit prices (A\$/household)

Attribute	Model 5	Model 6
Clear	-\$0.41	-\$0.41
Plant	\$0.10	\$0.10
Protect	\$0.29	\$0.28
Ab	-\$29.78	-\$29.71
Rural	-\$33.90	-\$33.88
Years	\$29.75	\$27.13*

*Average

From Table 3 it can be seen that the results of both models are very similar but model 6 is considered to be the more accurate representation of community values. It shows that respondents are willing to pay:

- \$0.41 per household to avoid a hectare of EEC being cleared;
- \$0.10 per household for every hectare of EEC planted in the region;
- \$0.28 per household for every hectare of existing EEC protected in the region;

- \$29.71 per household to avoid a significant Aboriginal site being destroyed;
- \$33.88 per household to avoid a rural family being displaced; and
- \$27.13 per household for every year that the mine provides 975 jobs.

The ratio of the model coefficients of environmental and social attributes provides the marginal rate of substitution between these attributes. For example, the ratio of the coefficient for the 'Clear' attribute and the 'Plant' attribute indicates how many hectares of planting is equivalent in community value to the value lost from a hectare of cleared EEC. Similarly, the ratio of the coefficient for the 'Clear' attribute and the 'Protect' attribute indicates how many hectares of existing EEC in the region would have to be protected to be equivalent to the community value lost from a hectare of cleared EEC. These ratios are essential offset ratios that reflect community values.

From the preferred CM econometric model (Model 6), 1 ha of EEC clearing can be offset by:

- 4ha of EEC planting (an offset ratio of 4.0:1); or
- 1.4ha of protection of existing EEC in the region (an offset ratio of 1.4:1); or
- a multitude of combinations of planting and protection.

The ratio of the coefficient for the 'Protect' attribute and the 'Plant' attribute indicates that the community value a hectare of protection at 2.82 times that of a hectare of planting.

The CM information on the relative importance of clearing, protection and planting to the respondents can be used to test whether the latest proposed offset strategy is sufficient from a community value perspective to counterbalance (offset) the impacts of the proposed Warkworth Extension.

Table 4 Offset Liability and Strategy

	WSW	Other EEC	Total
Clearing	106.8	690	796.8
Protection	123	907.7	1030.7
Planting	195.8	0	195.8
Onsite rehabilitation	0	0	780.6
Total	318.8	907.7	2,007.1

*The above table relates to woodland only and does not include 235.8ha of EEC grassland at Goulburn River that will also be protected.

** The area of clearing of WSW includes the area that will be cleared for the relocation of Wallaby Scrub Road.

Using the implicit prices in Table 3, aggregated to 45% of the households of NSW², the community values for the clearing liability and offsets are summarised in Table 5. This indicates that the offset strategy (excluding protection of EEC grassland, other non-EEC vegetation and mine site rehabilitation) will result in a net gain in community values for WSW and a small net loss in community values for Other EECs, resulting in a slight deficit overall. However, this does not take into account the community value for protection of EEC grassland, other non-EEC vegetation communities or the 780.3 ha of woodland rehabilitation on the mine site. No value for these was obtained from the CM study. However, if the community value for EEC grassland protection were to be the same as that for EEC woodland then, even ignoring the values for protection of other non-EEC vegetation and woodland rehabilitation, the offset strategy would provide net community benefits of \$62M.

Table 5 Community Values (\$M) for Offset Liability and Strategy Excluding EEC Grassland Offset and Mine Site Rehabilitation

	WSW	Other EEC	Total
Clearing	-\$49.1	-\$317.0	-\$366.0
Protection	\$39.4	\$290.9	\$330.3
Planting	\$22.2	\$0.0	\$22.2

Morrison (2000) found that potentially, about one-third of non-respondents have value estimates similar to respondents. Consequently, it is considered reasonable to aggregate CM values to the proportion of the NSW households indicated by the survey response rate plus one third of the non-response rate.

Total offset	\$61.6	\$290.9	\$352.5
Net	\$12.6	-\$26.1	-\$13.5

4.0 CONCLUSION

An economic trade-off framework has been applied to a scenario prohibiting mining from 67.9 ha of WSW. While there would be benefit to society from conserving this area of WSW there would also be a range of other costs and benefits.

The analysis shows that the costs would significantly outweigh the benefits and therefore the scenario of avoidance could not be justified from a net community welfare perspective.

Recognising that the proposed Warkworth Extension may have a negative impact on WSW and other EECs the most economically efficient approach to reducing this impact is via offsets. Ignoring for the moment the benefits of protecting 235.8 ha of EEC grassland, other non-EEC vegetation communities and 780.3 ha of mine site rehabilitation, the proposed offset strategy will result in a net gain in community values for WSW and a small net loss in community values for Other EECs, resulting in a slight deficit overall. However, inclusion of the protected EEC grassland, other non-EEC vegetation communities and woodland rehabilitation on the mine site is likely to result in a net benefit from the proposed offsets.

5.0 REFERENCES

Adamowicz, V. (2004) What's it worth? An Examination of Historical Trends and Future Directions in Environmental Valuation, *Australian Journal of Agricultural and Resource Economics*, 48, pp. 419-443.

Bennett, J. 1996 "The Economic Efficiency of RACAC Resource Allocation Options: A Conceptual Framework".

Bennett, J. (2008) Defining and Managing Environmental Flows: Inputs from Society, *Economic Papers* Vol. 27, No. 2, pp. 167-183.

Bennett, J. & Blamey, R. (2001) *The Choice Modelling Approach to Environmental Valuation*, Cheltenham, UK, Edward Elgar.

Gillespie, R. (2009) *Mount Thorley Warkworth Operations Choice Modelling Study of Environmental and Social Impacts*, prepared for Coal & Allied Pty Ltd.

Morrison, M. (2000) Aggregation Bias in Stated Preference Studies, *Australian Economic Papers*, 39(2): 215-230.

Tisdell, C.A. 1991 "Economics of Environmental Conservation: Economics for Environmental and Ecological Management, Elsevier, Amsterdam".



Appendix G

Appendix G | Mr Robert Gillespie - Alternative coal resources

Coal Mining in NSW

The Issue of Alternative Coal Resources

Prepared for

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By



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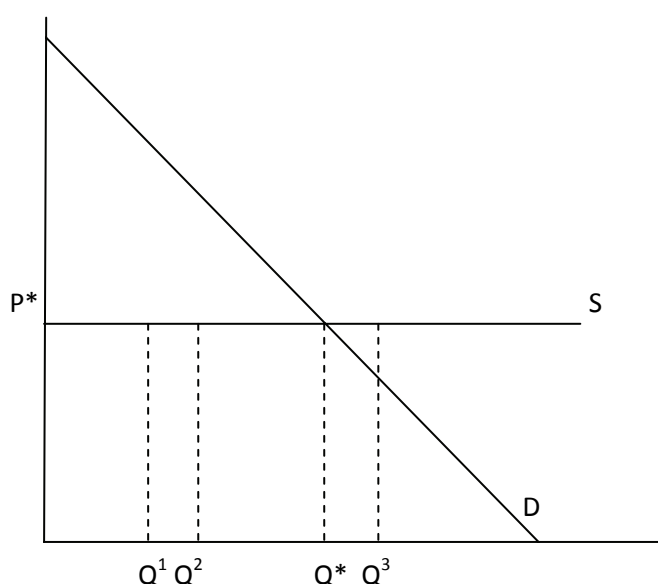
An issue that arises in relation to specific project applications for coal mine expansions or new coal mines is that there are alternative coal resources located elsewhere either currently being mined or that could be mined and therefore it is not necessary for the mine the subject of the project application to be approved.

This is a simplistic view that ignores the fundamentals of mineral economics, in particular the difference between ‘resources’ and ‘reserves’. Resources are the volume of a mineral present in the ground but which may not be able to be exploited because of financial, or other constraints such as infrastructure or land use restrictions. In contrast, reserves are those mineral deposits that have proven capacity to be developed under current or forecast financial, infrastructure, regulatory and other influencing conditions. It follows that the volume of reserves that are available to society is much smaller than the resources present. In a NSW context one major contributing factor in this regard is land use restrictions where, for instance, the declaration of national parks in the Sydney coal basin has sterilized perhaps 50% or more of the coal reserves (Mitchell McCotter, 1987).

There are many factors apart from the geological characteristics of a mineral deposit that determine whether it can be classified as a reserve and therefore has the potential to be exploited. These include tangible factors like the availability of physical and human infrastructure both in the locality and at the potential mine site itself. As important are less tangible or ‘governance quality’ factors which determine the investment climate for minerals within a particular jurisdiction, such as NSW, including tax rates, contractual certainty under law and property rights. In combination, these tangible and governance factors are often as important as geological ones in determining whether resources can be developed. The truth of this is clearly illustrated by international disparities between the presence of resources and production of minerals. For example Africa has about 30% of the globe’s resources but only produces about 10% of global minerals output (EMGA Mitchell McLennan, 2010). Thus development of the NSW minerals industry has depended on a combination of favourable factors over time: quality minerals deposits, the availability of necessary infrastructure and a positive investment climate. The key point is that for any resource to be classified as a reserve that is capable of being used all of these factors must be positive, meaning it is simply fallacious to consider all of the state’s mineral resources to be interchangeable.

The same argument can be illustrated through economic principles. Firstly, for there to be no consequence of simply relying on “alternative coal resources elsewhere”, it must be assumed that all coal resources are homogenous (same quality, size, depth of overburden etc) and all existing and future mining operations are homogenous in production i.e. would have the same production and transportation costs. This situation is represented in Figure 1 where Q^* is produced at a price of P^* .

Figure 1 – Supply and Demand for Coal Assuming Perfectly Inelastic Supply



Under perfectly elastic supply, if a mine that proposed to produce Q_2-Q_1 of coal does not supply that quantity of coal another will step in to supply it at the same cost i.e. a mine that can potentially produce Q_3-Q^* , but is not currently supplying the market. This essentially assumes either:

- *spare capacity at existing mines and hence they can increase output without a rise in costs;
- *expansion of existing mines or development of new mines is possible with no increase in costs; or
- *high levels of stocks or inventories which can be run down to supply the market (a short term response only);

However, none of these assumptions hold. Because of the high level of capital investment in coal mines, as far as possible most mines try to operate at close to physical capacity of their capital equipment (ABARE 1991). Spare capacity in the existing industry is therefore likely to be modest and without additional capital investment, additional production at existing mines will encounter rapidly rising marginal costs.

Expansion of existing mines or development of new mines inevitably involves significant capital investment. Current and expected prices for coal are a significant determinant of investment decisions of mining companies. At the current and expected prices for coal, those proponents currently seeking approval for expansion of an existing mine or development of a new mine are those that consider that they can obtain an appropriate return on their investment i.e. have sufficiently low costs of production because of the nature of the coal resource, or economies of scale, or location to market, or existing or expected contractual arrangements. Those with existing mining operations or access to greenfield sites who are not currently seeking approval for expansion or new mine development are those that are likely to be at a cost disadvantage relative to others (i.e. higher up on an upward sloping supply curve) or are facing capital or other constraints.

In reality, the supply curve for coal is upward sloping, representing increasing costs of production of different existing and potential operations.¹ Demand for coal is also relatively inelastic and hence shifts in supply can result in sharp changes in prices. All other things being equal, a constraint on supply from a single mine or mining region will contract future supply (relative to what it would be

¹ In the short term supply is likely to be inelastic e.g. with a price elasticity of 0.4, while in the longer term supply elastic is likely to be more elastic, around 1.9 price elasticity (ABARE 1991).

otherwise). Appendix 1 outlines the effect of a constraint on coal supply. In summary more expensive producers of coal will come into production leading to a price increase and a contraction in overall quantity. This will result in foregone producer surplus benefits that would have been associated with the cheaper coal production and a loss in consumer surplus as a result of the price rise.

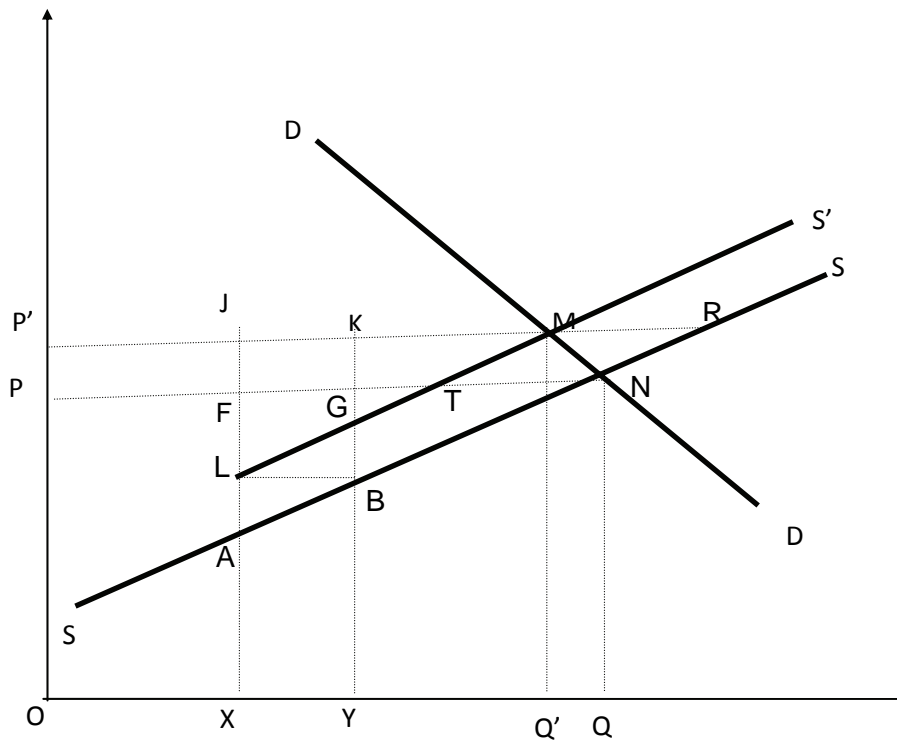
Whether these costs to society (foregone producer and consumer surpluses) are outweighed by the environmental benefits (avoided environmental impacts) is an empirical issue that is the subject of benefit cost analysis of project proposals. For the proposed Warkworth Extension it was found that production benefits (producer surplus) of the Project outweigh the environmental costs. Consequently, to not proceed with the Project would result in net costs to society although distributional issues still need to be considered to ensure the local community and sectional interests do not bear a disproportionate share of the costs.

More expensive producers of coal, whether they be associated with expansion of an existing mine or establishment of a new mine, will also have a range of potential environmental externalities. If these more expensive producers of coal are located in NSW, they will require some form of environmental assessment. Whether or not the environmental impacts of these mines are greater or less than cheaper coal producers currently seeking approval is not known but what is certain is that if the costs of production increase, with inelastic demand community welfare will diminish. Prices for coal will rise and this will be passed on through domestic electricity production and steel production and ultimately to consumers. There will be a reduction in returns to shareholders and payments to government. Given that NSW competes in a competitive global coal market if the next cheapest producers of coal are located overseas or interstate then there will be reduction in the state's share of the market.

APPENDIX 1

This appendix is based on Bennett (1991).

Figure 2: Conceptual Model of a Decrease in Supply of Coal Where Supply is Not Perfectly Elastic



The supply of coal, derived from a proposed mining operation in NSW (Mine A), as well as others sources is shown as the supply curve SS. Let the proposed production from Mine A be equal to XY Mtpa. That implies that coal production from the Mine A falls on the industry supply curve in the segment AB. If a decision is taken not allow mining at Mine A, then the AB segment of the industry supply curve is unavailable. The industry supply curve would therefore involve a discontinuity at output OX. Mines yielding coal in the industry supply curve segment BR would thus be called upon after production OX. The supply curve without mining of Mine A would therefore be SALS'.

Let the demand curve for coal be DD on Figure 1. The future industry production of coal with Mine A is therefore OQ, where supply SS is equal to demand DD. The prevailing average price is OP.

The withdrawal of the supply from Mine A would result in the formation of a new market equilibrium. The price would rise to OP' and the level of output would decline to OQ' because of the drop in supply.

It is possible to identify a number of costs and benefits of these changes in market conditions. With a higher price being charged and less product being purchased, consumers suffer a loss of surplus equal to the area P'MNP.

By not being permitted to market their coal output, the prospective producers of coal from Mine A also lose. The loss is equal to the producers' surplus that would have been earned from the Mine A: the area FGAB ((Price minus Cost) times quantity XY).

However, some gains are also evident. Producers of coal operating in the segment of the supply curve SA find that their producers' surplus has risen because they are now able to sell their output for a higher price. This gain is equal to the area P'JFP. Furthermore those producers who were located on the supply curve SS in the segment BR enjoy a gain. These producers are now located along the new supply curve in the segment LM. Previously their producer surplus was area BGN (higher cost producers in the segment NR were not even supplying the market) but now that has risen to the area LJM. The extent of this gain can be seen when it is recognised that the previous producers' surplus BGN is equal in area to the triangle LFT. Comparing the new producers' surplus LJM to LFT reveals that the gain is equal to the area JMTF. The total of the gains made by other coal producers is therefore the area P'MTP.

Consolidating all this information it is possible to consider the extent of the net costs arising from reducing the availability of low cost coal resource from Mine A. These are as follows:

- Consumers' surplus losses of P'MNP
- Mine A producer surplus losses of FGBA
- Other producers' surplus gains of P'MTP.

It is clear that the consumers' losses exceed the other producers' gains: there is a net loss equal to the area MNT. This can be added the producer surplus losses to Mine A to make up the net loss to the community of restricting production from Mine A, of FGBA and MNT.

References

ABARE (1991) *Supply Response In the Australian Black Coal Industry*, Technical Paper 91.1.

Bennett, J. (1991) *Alternative Natural Resource Management Options for Fraser Island*, Conservation, Management and Use of Fraser Island and The Great Sandy Region, Queensland Government, Brisbane, Appendix Vol. 1.

EMGA Mitchell McLennan (2010) *Australia – Africa Partnership*, Mining Scoping Study, AusAID.

Mitchell McCotter (1987) *Implications of NSW Government Policy on Mining and National Parks for the Western Coalfields*, NSW Coal Association.



Appendix H

Appendix H | Statement of Commitments

20 Revised Environmental Management and Commitments

20.1 Introduction

This chapter describes the revised commitments made by WML throughout the life of the proposed Warkworth Extension to manage potential impacts identified within the EA. Commitments include management, mitigation and/or monitoring measures.

Environmental management at Warkworth Mine has been discussed in general in **Chapter 4.10** which includes management under the ISO:14001 [2004] certified EMS. The EMS will continue to be implemented across Warkworth Mine and MTW. The relevant plans, procedures and monitoring programmes contained within the EMS will be reviewed and modified to incorporate the commitments outlined below and reflect the changes to operations resulting from the proposal. As such, existing management, mitigation and monitoring measures undertaken by WML to manage impacts identified in previous environmental assessments [such as the 2002 EIS] will still be maintained but reviewed and modified, if required.

Commitments are provided generally and for each environmental aspect considered in this EA.

20.2 General

WML will undertake the following general commitments:

- Should Project Approval be granted by the Minister for Planning for the proposal and subject to appropriate conditions, WML will surrender the current Warkworth development consent at the appropriate time as agreed between WML and DoP;
- WML will carry out the proposed Warkworth Extension generally in accordance with the systems, plans and mitigation measures identified throughout the EA, Response to Submissions and [the Preferred Project Report](#); and
- WML will obtain and maintain all permits, licences and approvals required throughout the life of the proposal, as required. These commitments do not replace any obligations WML has under statutory requirements.

20.3 Ecology

In addition to management and mitigation measures undertaken at Warkworth Mine for ecology as described in the EMS procedures, the following commitments specific to the proposal would be undertaken. Some commitments are already undertaken under the EMS. Furthermore:

- WML commits to an offset strategy to compensate for the disturbance of EECs consisting of the following:
 - Southern Biodiversity Area - long term protection of some 977.5ha of land including the re-establishment of 38.6 ha Warkworth Sands Woodland (WSW) and 277.9ha Central Hunter Grey box-Ironbark-Spotted Gum Communities. [State and Commonwealth];

- Northern Biodiversity Area – long term protection of some 342ha of land including re-establishment and enhancement of 195.8 ha WSW and 23.1 ha [Central Hunter Grey box-Ironbark-Spotted Gum Communities](#) [State];
 - Goulburn River Biodiversity Area – long term protection of some 1,299.3ha of land [State and Commonwealth];
 - Seven Oaks Biodiversity Area – long term protection of some 523ha of land with enhancement of 168.7ha of Cassinia/Acacia shrubland and derived native grassland [State and Commonwealth];
 - Putty Biodiversity Area – long term protection of some 379ha of land with enhancement of 12.2 ha of derived native grassland [State];
 - Bowditch Biodiversity Area – long term protection of some 520ha with enhancement of 2.3ha of derived native grassland [State];
 - Additional strategic offset properties (subject to commercial discussions) for long term protection of 750ha of woody vegetation to the acceptance of Office of Environment and Heritage [OEH] [within 12 months of project approval](#); and
 - Rehabilitation of mined lands – progressively establish some [2,114ha of](#) Central Hunter Grey Box-Ironbark-Spotted Gum woodland communities, 218.5ha of trees on grassland and the residual being rehabilitated to grassland [State and Commonwealth].
- The Warkworth Biodiversity Management Plan which will be updated following confirmation of the offset package and replace the existing Warkworth Coal Mine Green Offsets FFMP [2008], has been prepared which describes the management strategies, performance criteria and monitoring for the proposed biodiversity areas. The Warkworth BMP is intended to be a live document that would respond to site specific research [see below] and best practice;
 - Continue the existing five-year research programme being undertaken by the University of New England [UNE] on best practice for re-establishing the WSW community and the further commitment of an additional \$500,000 to the UNE for research into the re-establishment of WSW;
 - A commitment to contributing to and resourcing of a recovery plan for the WSW in consultation with the OEH;
 - Trials to rehabilitate an old quarry and revegetation of WSW on the old quarry site (approximately 1ha) within the Southern Biodiversity Area. The old quarry would be backfilled with material, including a sand layer, sourced from the extension area and the profile would be reconstructed and shaped with regard to the surrounding landscape. A revegetation trial of key WSW species would follow with guidance provided by University of New England;
 - A commitment contributing \$500,000 to research aimed at improving rehabilitation of ground stratum plant species of the Central Hunter Grey Box-Ironbark-Spotted Gum communities; and
 - Pre-clearance surveys would be conducted within areas to be cleared and where possible, threatened flora and fauna detected would be translocated into protected habitat.

20.4 Aboriginal Cultural Heritage

In addition to management and mitigation measures undertaken at Warkworth Mine for Aboriginal cultural heritage as described in the EMS procedures, the following commitments specific to the proposal would be undertaken. Some commitments are already undertaken under the EMS.

20.4.1 Management within Land Disturbed by Mining

- Aboriginal cultural heritage sites that would be directly disturbed by the proposal would be managed in accordance with an ACHMP;
- Double scarred tree Site MTW321 [WE16] would be excluded from the mining disturbance zone and incorporated into the Wollombi Brook Aboriginal Cultural Heritage Conservation Area;
- Mitigation salvage would be staged over time;
- Scarred trees at Sites MTW8, MTW70 and MTW80 would be managed in situ and where required removed in accordance with the Rio Tinto Coal Australia Scarred Tree Management Procedure and ACHMP protocols;
- Relocation of grinding grooves site PN10 as per the salvage requirements of AHIP s.90 consent #2801;
- Investigate feasibility of moving grinding grooves Site M including more detailed recording of site attributes, final management and salvage measures to be determined in consultation with CHWG and DECCW;
- Controlled collection [gridded collection] of artefact scatter Sites MTW60 & MTW65;
- Other artefact scatters and isolated finds would be mitigated by standard salvage collection measures in accordance with the ACHMP;
- All cultural materials collected would be stored in the temporary cultural heritage storage facility at Hunter Valley Services under an approved Care and Control Permit; and
- Develop a protocol for pre-disturbance testing of additional areas west of Wallaby Scrub Road that may comprise geomorphological features that are commonly described as the Warkworth Sands which may include Ground Penetrating Radar surveys and test auguring. Where areas are identified with potential to hold sub-surface stratified cultural deposits then further investigation activities would be developed in consultation with the CHWG and DECCW.

20.4.2 Wollombi Brook Aboriginal Cultural Heritage Conservation Area

- WML commits to establish the Wollombi Brook Aboriginal Cultural Heritage Conservation Area on WML owned lands within and adjacent to Warkworth Mine lease along the eastern side of Wollombi Brook which would include a significant portion [eastern] of the highly culturally significant Bulga Bora Ground area;
- The core Conservation Area would be protected permanently from mining and associated development disturbance;
- Provide for the protective management and cultural maintenance of the Bulga Bora Ground, associated cultural landscapes and sites situated within the Conservation Area;

- Sites in the proposed Conservation Area would be managed in situ in accordance with the management strategy that is currently under development for the Conservation Area with the CHWG and other stakeholders including DECCW and DoP;
- Support would be provided to assist active Aboriginal role in both cultural heritage and environmental management activities, including training and employment development opportunities;
- Establish strictly controlled non-access zones and protocols around culturally sensitive areas as determined in consultation with the CHWG;
- Establish areas for active cultural heritage and landscape management;
- Establish areas and protocols for use by Aboriginal people for cultural and community purposes;
- Implement a consultation process through the CHWG to develop an appropriate management agreement or accord for the co-management of the Conservation Area with the Aboriginal community;
- Engage with Wambo Coal Pty Limited to discuss options for developing a collaborative management protocol for the portion of the Bulga Bora Ground and associated cultural sites that are located on lands owned by Wambo Coal adjacent to the Conservation Area; and
- Rio Tinto Coal Australia and Coal & Allied would continue to resource the development of the management strategy for the Conservation Area.

20.4.3 Management of Other Lands within the Mining Leases

- Aboriginal Cultural heritage sites on land that is within the LOM plan that would be potentially disturbed by mining in the future would be managed for their protection in situ for long-term protective management and to minimise future disturbance for the foreseeable future in accordance with the Rio Tinto Coal Australia CHMS procedures until such time that an approval for mining in that area is granted;
- Sites that are assessed as vulnerable to damage due to proximity to roads and tracks or other operational infrastructure should be appropriately buffered and barricaded in accordance with existing site protection protocols;
- The scarred trees at sites MTW43 and MTW223 should be buffered and monitored regularly; and
- Where development activities cannot be conducted on an Aboriginal cultural heritage sites avoidance basis due to valid technical, safety or any other legitimate reasons, then alternative mitigation measures including cultural salvage of sites would be developed in consultation with the CHWG and DECCW.

20.5 Noise and Vibration

In addition to management and mitigation measures undertaken at Warkworth Mine for noise and vibration as described in the EMS procedures, the following commitments specific to the proposal would be undertaken.

- WML commit to managing operations in such a way that modelled noise levels at private receivers are not exceeded. Management of operations may include any combination of things such as:

- optimisation of mobile plant and equipment type, quantities and locations. This includes positioning of plant in less exposed areas, where practicable;
- investigation of attenuation of haul trucks. WML has been working with the suppliers of its haul fleet to develop a noise attenuation package. All new trucks, dozers, drills & excavators purchased for use across Warkworth and Mount Thorley Mines will be commissioned as suppressed units. A programme of fitting attenuation packages on some existing Warkworth and Mount Thorley Mines haul fleet has also been developed. Based on the above:
 - o 40% of truck fleet will be attenuated by end of Year 1 (nominally 2012 assuming approval 2011).
 - o 50% of truck fleet attenuated by end of Year 2 (nominally 2013).
 - o 60% of truck fleet attenuated by end of Year 5 (nominally 2016).
 - o 80% of truck fleet attenuated by end of Year 6 (nominally 2017).
- cladding or similar attenuation of the Warkworth CPP. The effect of this mitigation measure is a nominal 8dB reduction in noise from the CPP towards residences located to the east; and
- further use of real-time noise monitoring and investigation into correlation with real-time weather monitoring for use, where possible, to pre-emptively manage noise generated by mining operations [see below];
- The real time noise monitoring network would be expanded and improved such that the noise data can be correlated with real-time weather data and used to improve existing noise management techniques. This will be implemented as follows:
 - o Maintaining monitoring devices at suitable locations determined by an acoustic specialist. The suitability of locations will be reviewed by an acoustic specialist based on the project approval conditions. Preference, where practical, will be given to properties that ensure the minimisation and possible elimination of contaminated data from extraneous sources in the direction of the mine. The improvement of the monitoring network will allow for additional low pass frequency filtering to eliminate high frequency sounds such as insects and birds. The noise level from the direction of the site and other mines will be isolated to better understand the contributions from each area.
 - o Data will be communicated directly to Warkworth Mine via the Supervisory Control and Data Acquisition (SCADA) system.
- The system will include the use of Trigger Alarms from real-time noise monitors. An alarm will be set at an appropriate trigger level for receivers based on the project approval conditions. The trigger alarm system is currently being developed and trialled as a management tool and includes a two phase alarm based on the INP guidelines and incorporates real time meteorological and noise data. This system can assist management in making informed decisions to maintain noise levels within acceptable limits, for example:
 - o When noise levels reach the trigger level an alarm would be sent via SMS and/or email or similar to the supervisory site personnel at Warkworth Mine.
 - o In the event of an alarm, the supervisory site personnel will be notified and operational practices reviewed to minimise the potential for noise increasing beyond compliance levels or obtain suitable agreement from receivers.

- In the assessment of the need for the noise attenuation of equipment, WML commit to develop a noise trigger action response plan [TARP] that sets the operational noise level trigger for action. Action would include such things as analysis of real time monitoring, other monitoring, SPL testing and modelling of current operations if required. A hierarchy of actions will be developed and include such things as:
 - Where available meteorological data forecasts inversions and/or adverse winds are likely for the coming night period, where possible alternative operations will be identified in anticipation;
 - In the event of unfavourable meteorological conditions and where monitoring suggests noise levels are approaching limits, where possible alternative operations will be identified such as plant being relocated to lower areas of the mine and noise levels will continue to be monitored closely. The aim of this is to avoid noise exceedances during the more sensitive night time period;
 - Where noise limits are noncompliant with the project approval criteria limits, a protocol of identifying causes of the non compliance and offending sources/activities will be implemented with the view to modifying such activities to ensure noise levels return to within limits.
 - Where the pre-emptive noise modelling or monitoring identifies residents to be affected above acquisition criteria WML will investigate and consider reviewing equipment locations; or adopt pre-emptive acquisition.
 - Where the noise modelling or monitoring identifies residents to be affected below acquisition but above impact criteria, WML will investigate and consider reviewing equipment locations; or adopt pre-emptive mitigation measures at receiver.
- Pro-active mine planning, as informed by pre-emptive modelling, will also be implemented to plan for contingency events, such as during prevailing wind conditions that have the potential to increase noise beyond acceptable levels.
- Where agreement can be obtained from nearby landowners for predicted or actual exceedance of mine noise limits, changes to operations as outlined above would not be required.

20.6 Air Quality

In addition to management and mitigation measures undertaken at Warkworth Mine for air quality and dust as described in the EMS, the following commitments specific to the proposal may be undertaken. Some commitments are already undertaken under the EMS.

- WML will provide a copy of the NSW Health fact sheet entitled 'Mine Dust and You' to landowners and tenants in mine owned residences identified in the predictions in the EA that dust emissions generated from the project are likely to be greater than the relevant air quality criteria at any time during the life of the project;
- Tenancy agreements for WML owned residences will include acknowledgement of mining impacts, including dust and health impacts, in the terms of agreement. The agreements also facilitate the temporary vacation of WML owned residence if required due to mining impacts. WML will enable tenants to terminate their tenancy agreement without compensation based on mining impacts given reasonable notice;

- [WML will provide quarterly air quality monitoring reports on the Coal & Allied website and commit to providing the report to tenants where requested;](#)
- Disturb only the minimum area of land necessary for mining. Reshape, topsoil and rehabilitate completed overburden emplacement areas as soon as practicable after the completion of overburden tipping;
- Maintain coal handling areas and coal stockpiles in a condition that minimises wind-blown and traffic-generated dust;
- Undertake overburden emplacement on smallest area required for emplacement;
- Have available water sprays on ROM coal stockpiles and use sprays to reduce airborne dust, as required;
- All roads and trafficked areas would be watered as required using water trucks to minimise the generation of dust;
- All haul roads would have edges clearly defined with marker posts or equivalent to control their locations, especially when crossing large overburden emplacement areas;
- Development of minor roads would be limited and the locations of these would be clearly defined;
- Minor roads used regularly for access etc would be watered;
- Obsolete roads would be ripped and re-vegetated;
- Access tracks used by topsoil stripping equipment during their loading and unloading cycle would be watered;
- Long term topsoil stockpiles, not used for over three months would be re-vegetated;
- Dust aprons would be lowered during drilling;
- Drills would be equipped with dust extraction cyclones, or water injection systems;
- Water injection or dust suppression sprays would be used on drills when high levels of dust are being generated;
- Adequate stemming would be used at all times. Restriction of blasting during unfavourable weather conditions would occur, where practicable;
- Attach a PM10 monitoring head to the existing HVAS TSP monitor nominally at WML TSP3;
- Relocate Mount Thorley Industrial Estate PM10 HVAS monitor and WML-HV1 TSP monitor further north, away from any dust generating activities in the industrial estate, near Receiver 128; and
- Install a new HVAS with PM₁₀ monitoring head in the southern areas of Bulga village.

20.7 Greenhouse Gas

In addition to management and mitigation measures undertaken at Warkworth Mine for greenhouse gas, specific initiatives to be implemented include:

- Implementation of a detailed energy monitoring programme. This would include monitoring the electricity and diesel usage on-site to identify the main sources of greenhouse gas emissions and apply appropriate reduction mechanisms where possible;
- Regular maintenance of diesel powered equipment to ensure operation at peak efficiency; and
Funding of research programs to develop advanced technology focusing on reducing greenhouse gas emissions and carbon capture technologies.

20.8 Visual

The following commitments are specifically made in relation to visual amenity.

- A Visual Management Plan would be prepared to identify the privately-owned land that is likely to experience visual impacts during the proposed Warkworth Extension. It will describe the mitigation measures that could be implemented to reduce the visibility of the mine from these properties (including mitigation measures identified in Section 6 of Annex I of the EA Volume 4), as well as the timing for implementation of the strategies;
- The Visual Management Plan would also identify where planting could be undertaken on public land, including road reserves and other public spaces, to reduce visual impacts of the proposed Warkworth Extension, subject to the consent of the appropriate authority. These plantings on public land may also assist in screening Warkworth Mine from private properties. Any proposal to undertake planting on public land would be undertaken in consultation with Council, RTA and Bulga residents;
- WML commit to conducting site specific visual assessments for significantly affected landowners at elevated locations at Bulga;
- Where the site specific assessment confirms the potential for significant impact, develop on site mitigation on consultation with the landholder, which may include such measures as on site visual screening;
- Overburden will be rehabilitated with grasses and woodland. Woodland planting will be extended on the eastern face to achieve a similar mosaic to the existing rehabilitation on the landscape;
- The overburden heights will be maintained on average at current consent limits, which are RL 160m AHD for Warkworth Mine and RL 155m AHD for Mount Thorley Mine; and
- Annual survey of overburden heights and rehabilitation areas as part of the annual operating plan.

20.9 Groundwater

In addition to management and mitigation measures undertaken at Warkworth Mine for groundwater as described in the EMS, the following commitments specific to the proposal may be undertaken.

A comprehensive monitoring and mitigation program will be implemented to ensure that any unpredicted changes to groundwater quality and monitoring are responded to to minimise impacts.

Mitigation and potential responses include:

- The construction of monitoring bores at a further three sites in the Wollombi Brook alluvial aquifer and underlying Permian overburden to the west of the proposed Warkworth Extension to monitor the depressurisation of the shallow coal measures strata and subsequent drawdown in the overlying alluvial aquifers and any changes in groundwater quality as a result of depressurisation. The sites are shown in Figure 13.6 and were selected to complement the existing monitoring bore network,

including those operated by other mines, to enable comprehensive monitoring across the potentially impacted area. Water levels and salinity will be monitored electronically using data loggers installed in each bore to provide a record of changes. Field analysis of pH and electrical conductivity will be undertaken on a quarterly basis and samples collected from each bore on a six-monthly cycle for a full laboratory analysis;

- WML will liaise with adjacent mining operations, including Wambo Mine and HVO, regarding access to groundwater monitoring data to the north and north west of the proposed Warkworth Extension. Where provided, the data will be incorporated into groundwater assessment and reporting to ensure the regional impact of mining is understood;
- The continuation of the existing monitoring programme which includes 30 bores that have water level, and field measurements of pH and electrical conductivity on a quarterly basis and samples collected for a comprehensive laboratory analysis on an annual basis;
- The annual assessment of departures from identified monitoring data trends. If six consecutive monthly monitoring results depart from the established or predicted trend, then a detailed review of possible cause will be undertaken;
- Upon completion of the detailed review of possible cause suitable groundwater responses will be implemented where required. This may include more intensive monitoring and/or seeking professional advice in regards to model predictions and additional mitigation measures such as geotechnical investigations, structural assessments or consideration of changes to the mine plan if required;
- Formal review of measured depressurisation of coal measures and alluvial aquifers will be undertaken annually by a suitably qualified hydrogeologist. Every five years the model predictions will be re-assessed and if the data indicate significant divergence from the model predictions, an updated or new groundwater model will be constructed;
- Annual public reporting of all water level and water quality data as part of the AEMR process; and
- The predicted loss of water from the alluvial aquifer and from baseflow in Wollombi Brook will be offset by the purchase and retirement of an existing water licence from the appropriate water sharing plan that exceeds the maximum 73ML/year predicted to be lost from the system. WML would purchase and retire existing water licences from the Wollombi Brook Water Source Zone for the predicted loss of water from the alluvial aquifer and from baseflow in Wollombi Brook if required;
- WML would purchase and retire existing water licences from the Wollombi Brook Water Source Zone for the predicted loss of water from the alluvial aquifer and from baseflow in Wollombi Brook if required;
- A final void management plan [to be incorporated into the REMP] would be prepared, in consultation with the I&I NSW and other relevant agencies, which would outline the final design and future use of this void within five years of completion of mining ;
- Three new groundwater monitoring bores would be constructed in the Wollombi Brook alluvial aquifer to the west of the proposed operations to monitor the potential impact of depressurisation;
- Water levels and salinity would be monitored electronically using data loggers installed in each bore and provide a record of changes;
- If consecutive six monthly monitoring campaigns exhibit departure from the established or predicted trend, then such departures should initiate a detailed review of groundwater conditions. This may

include a need to conduct more intensive monitoring or to seek professional advice to compare against model predictions and/or instigate mitigation measures;

- Installation of a network of shallow monitoring bores to the base of the sand sheet at the western edge of the approved disturbance area to measure groundwater levels, hydraulic gradients, flow rates, and the permeability of the sands. This baseline information would be used to assess whether any mitigation is required. The network can also be used during mining operations to monitor groundwater levels in the sand sheet; and
- A formal review of the depressurisation of coal measures and alluvial aquifers would be undertaken annually by a suitably qualified hydrogeologist. Every five years the validity of the model predictions would be re-assessed and if the data indicate significant divergence from the model predictions, an updated or new groundwater model would be constructed for simulation of mining.

20.10 Traffic and Transportation

The following commitment specific to the proposal would be undertaken:

- WML commit to further discussion with SC regarding the closure of Wallaby Scrub Road. WML further commit to mitigation in the event of closure. Potential mitigation options may include [subject to negotiation with Council]:
 - The provision of development contributions [through a VPA] to fund community services or to conduct work in lieu under Part 4, Division 6 of the EP&A Act in consultation and agreement with SC;
 - Development of a road closure management plan in conjunction with relevant stakeholders such as the local community, emergency services, RFS and SC to develop strategies to minimise potential impacts;
 - Installation of speed advisory and curve warning signs on the approach and through the curve on Putty Road, just west of its intersection with Golden Highway;
 - Improvements to the channelisation at the Putty Road and Golden Highway southbound intersection; and
 - WML proposes to make a contribution (dollars at the time of payment) to the RTA of up to \$1,000,000 towards the upgrade of the Broke Road and Golden Highway Intersection in the event of closure of Wallaby Scrub Road without relocation.
- An option to relocate Wallaby Scrub Road has been assessed in **Annex Q** which the proponent would undertake if this is determined as the preferred option by the relevant administering authorities informed by community feedback. WML commit to undertake further consultation with the RTA and Council to discuss the configuration and design of the relocated road, should the project approval require the road to be relocated.
- Temporary road closures for blasting will continue to be managed in accordance with Coal & Allied's established protocols and procedures.
- All works will be undertaken, where relevant, in accordance with the RTA's Road Design Guide, Guide to Traffic Generating Developments, Austroads Guidelines and relevant Australian Standards.

20.11 Surface Water

In addition to management and mitigation measures undertaken at Warkworth Mine for surface water as described in the EMS, the following commitments specific to the proposal may be undertaken. Some commitments are already undertaken under the EMS.

- Dam 34N would be enlarged to 720ML;
- Sediment dams would be maintained or constructed as required and would be designed in accordance with relevant design standards [DECC 2008];
- Additional intake water of up to 700ML per annum may be required during extended dry periods. The demands on additional intake water would be mitigated through a combination of:
 - Water sharing between MTW and HVO;
 - Reduced HRSTS discharge which is supported by the additional out of pit water storage capacity that is currently under construction; or
 - Extraction of water via a bore from abandoned Lemington underground workings.
- Ongoing water balance modelling will be undertaken to enable the identification of water sharing efficiencies at MTW and HVO; and
- Additional water licences or water allocations will be sourced if required to ensure that MTW's water allocation is not exceeded.

20.12 Soils

In addition to management measures undertaken at Warkworth for soils as described in the EMS, WML commit to leading practise of soils, commitments apply generally to woodland and grassland areas and alternative strategies may be used for WSW depending on the outcomes of UNE research.

20.13 European Heritage

In relation to European heritage, all remaining elements of the former RAAF base would be recorded to NSW Heritage Office standards to record its historical significance and document the use and function of the kitchen building and demolished to its footings. Additionally, copies of the report would then be lodged with the Singleton Historical Society and the Australian War Memorial as a record of the site's history.

20.14 Community Consultation

Community and stakeholder consultation specific to the proposal may continue throughout the proposal timeframe from submission of this EA to the Minister for Planning's determination. Ongoing communication techniques utilised by Coal & Allied would be implemented as appropriate.

