Soils and Indicative Land Rehabilitation, Escarpment Mine Project, Denniston Plateau, Buller

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Summary

Project and Client

Soil resource information and indicative land rehabilitation techniques were requested by L& M Coal Ltd, via Resource and Environmental Management Nelson Ltd, for a prospective opencast coal mining operation in the former Escarpment/Plateau/Whareatea underground mining area on the south-eastern flank of the Denniston Plateau, Buller region.

Objective

To assess the soil resources over the Escarpment Project area for land and habitat rehabilitation planning.
To provide indicative land and habitat rehabilitation planning for prospective coal mining.

Methods

Soils were evaluated from transects across the landscape by auguring to a maximum of 120 cm depth using a Dutch clay auger. Profiles that typified the soils were described and photographed from excavated cuttings.

Soil fertility is described from published information for relevant soils sampled in the Upper Waimangaroa area.

Indicative land and habitat rehabilitation issues and techniques are described from experience of restoring indigenous ‘pakihi’ heathland and podocarp/beech forest vegetation on mine sites on the West Coast.

Soils

Vee Forty series (Rocky or Orthic Raw Soils) are the dominant soils (estimated 65% of the soil cover) over the project area. Minor soils (estimated 30%) are Trent series (Gley Soils) and Denniston series (estimated 5%; Humus Iron Podzols), which occur in a very complex, localised pattern on the pavement and hill slopes with the Vee Forty series. Vee Forty soils were the only soils found on the rocky escarpment faces and steep-sided stream gullies. The soils tend to be at or near saturation throughout the year and have very low fertility, plant nutrients being probably largely supplied from the organic regime rather than weathering of the mineral soil. This accounts for the very slow growth rates of native plants on the coal measures soils.

Only 50% (perhaps less) of the Escarpment Project area of about 148 ha has machine-salvageable soils. The areas where soil salvage is not practically possible are bare rock pavements; crevices in the pavement; areas where the soil has been stripped and eroded through tracking, prospect drilling, and underground mining operations; steep-sided rocky and bouldery escarpments and stream gullies; and perhaps areas where soils are less than about 50 mm depth, depending on the machinery used.

Indicative Land Rehabilitation Techniques

Land rehabilitation planning constitutes 4 phases: (1) initial mine development, (2) progressive rehabilitation, (3) mine closure, and (4) on-going maintenance. The goals of land rehabilitation are to develop indigenous ecosystems for conservation (including wildlife habitat) and recreational uses in accord with the objectives of the Conservation Estate.

New landforms and drainage systems that fit with the adjacent landscapes need to be developed from the overburden rock dumps. The drainage system within the area disturbed by mining will inevitably be altered as a consequence of mining and land rehabilitation operations. However, landscape and drainage design will need to link with the existing drainage systems (streams) to the Cascade Creek catchment to the east and Whareatea River catchment to the west.

Remedial techniques for management of potentially acid-forming materials (PAF) and reformation of drainage systems must be included in the land rehabilitation design.

A combination of revegetation techniques are recommended:

- Machinery direct transfer (translocation) of ‘pakihi’, manuka scrub, and podocarp/beech forest where practicable.
- Hand direct transfer of salvageable plants and small clumps of vegetation.
- Salvage and re-spread woody forest vegetation as slash from steep rocky and bouldery escarpments and stream gullies, preferably onto mixed topsoil and vegetation or overburden rock fines.
- Hydroseed engineered rocky faces and angle-of-repose overburden dump side-slopes with colonising plants (based on mosses) and seeds of appropriate native species.
- Fertilized plantings of nursery-raised plants into mixed soil and waste rock fines, with a roughened surface with microsites and scattered boulders, will be required to make up the short-fall in available soil and plant resources for land rehabilitation over the whole site.

Bare areas of sandstone pavement cannot be restored to their current natural forms. However, large rock boulders can be relocated onto rehabilitated waste rock dump surfaces using modern earthmoving machinery. So it is possible rehabilitation to rocky landforms is feasible and recommended.

Control of pest animals and weeds (undesirable plants) is a requirement of land rehabilitation, along with on-going maintenance.

A flexible closure plan needs to be developed for rehabilitating or leaving in a safe condition mining infrastructure, such as roads, building sites, coal storage bins, mining machinery, etc.

Monitoring rehabilitated areas and demonstration trials are recommended.

Opportunities for environmental offsets and post-mining recreational uses should be investigated by L&M Coal Ltd with the Department of Conservation.

1. Project and Client

A survey of soil resources on the Escarpment Project area, Denniston Plateau, Buller was conducted on 24−28 August 2008 for L & M Coal Ltd via Resource and Environmental Management Nelson Ltd.

The soils, other information on environmental resources on the Escarpment Project area, and experience of minesite rehabilitation from existing mining operations in the general Buller coal-field area were used to prepare an indicative land rehabilitation plan for prospective open-cast coal mining.

2. Previous Soils Information and Survey Methods

Soils on the Denniston Plateau were first mapped as Denniston soils and Denniston hill soils (Upland and High Country Podzolised Yellow-brown Earths and Podzols) in the 1:25 3440 'General Survey of the Soils of the South Island, New Zealand' (NZ Soil Bureau Bulletin 27, 1968).

The soils over the Escarpment Project area were later mapped at 1:50 000 scale in Mew and Ross (1991) as 30% Vee Forty series (moderately gleyed Lithosols from quartz sandstone), 30% Trent series (Gley soils from sandstone, mudstone and coal with related slope deposits, also colluvium and alluvium), 30% Koranui series (Yellow-brown earths from mixed colluvium of sandstone, mudstone and coal), and 10% inclusions of unspecified other soils.

A small area in the south corner was mapped as 35% Christmas series (Lithosols from bouldery sandstone, mudstone and coal colluvium), 30% Millerton series (strongly gleyed Humus Podzols from mixed sandstone, mudstone and coal colluvium and soil alluvium), 10% Trent series, and 25% undefined inclusions. 'Soils of the Upper Waimangaroa Area, Buller region' (Ross 1997), more recently characterized the soils of the area to the north of the Denniston Plateau in a confidential report to Solid Energy.

Soil resources over the Escarpment Project area (approximately 148 hectare) were assessed on 24−28 August 2008 by dutch-clay augering and probing to bed rock, and digging soil exposures for profile descriptions. Aerial-photo interpretation was used to differentiate the escarpments and steep-sided stream gullies that contained only Vee Forty soils. The soil pattern was too complex over short distances to be able to map separately the Vee Forty, Trent, and Millerton soils. However, areas dominated by rock pavement and areas disturbed by tracks, prospecting sites, and erosion were distinguished.

3. Soils

3.1 Description of Soils

Approximately (from aerial photography interpretation) 50% of the pavement surfaces have a soil cover, the other 50% are rock pavements. The escarpments and steep-sided gullies to the streams also have partial soil cover, the balance being rock outcrops and large boulders. However, the proportion of soils on the steep slopes was not able to be estimated because of the forest cover.

The soils over the Escarpment Project area are all developed from Brunner Coal Measures, which comprise predominantly hard, thick-bedded quartzose sandstone with subordinate carbonaceous mudstone and local coal seams (Nathan 1996), and related slope deposits, colluvium, and alluvium. A small area in the east corner of the project area was mapped (Nathan 1996) as Berlins Porphyry (microgranidiorite) but no granitic soils were found in this survey. The pre-Polynesian vegetation of the site was probably dominated by podocarp/beech forest with perhaps pockets of 'pakihi' and manuka scrubland on the pavement areas (Mew 1983, Williams et al. 1990). The site ranges in altitude from 640 to 800 m a.s.l. The environment is sub-alpine with a mean annual rainfall of approximately 6000 mm (range approx. 4400 mm to 8800 mm pa) , reasonably distributed throughout the year. Low cloud and fog are common and humidity is generally high, averaging 80−90%. The mean annual temperate on the Plateau is estimated to be about 8˚ C (Stockton is 8.6˚ C), with mean monthly temperatures ranging from about 13˚ C in January to about 4˚ C in July (Norton 1985). Frosts are common throughout the cooler months and snowfalls commonly occur in winter and early spring.

Soils over the rock pavement areas, escarpments and steep-sided (25−45˚ with shear rock faces and many surface large boulders) stream gullies are dominated by Vee Forty soil series (Fig. 1). Vee Forty soils are classified as Rocky or Orthic Raw Soils. Approximately 65% of the soil cover is estimated as Vee Forty soils. These soils generally have very thin (< 5 cm) very dusky red organic (L, F & H) horizons over dark brown humic sandy loam topsoils (Ah horizons) directly over Brunner Coal Measures rock (sandstone, argillitic mudstones, or coal). The organic horizons are generally thicker (up to10 cm) under podocarp/mountain beech forest than heathland 'pakihi' vegetation (dominated by prostrate manuka, coal measure tussocks, wire rush, Dracophyllum uniflorum and D. politum, Lycopodium laterale, Carpha alpina, pigmy pine, and hybrid yellow silver x pigmy pine).

The total depths of Vee Forty soils vary from 5 to 80 cm but average 20−30 cm on the rocky pavement areas. The deeper soils (> 50 cm) tend to be found mostly on pockets under podocarp/beech forest on the escarpments and steep gullies into streams. Vee Forty soils tend to be saturated or close to saturation all year because of the high humus content, low permeability, and evenly-distributed high rainfall (6000 mm pa), i.e. they never dry out. Vee Forty soils occur in a complex pattern on the pavement and hilly areas with Trent soils (and the occasional Denniston soil) that were too complex to separately map for this survey. Koranui soils were not identified in the project area, despite these more fertile soils being mapped as 30% of over much of the Denniston Plateau in the Mew and Ross (1991) survey.

Figure 1. Vee Forty soil profile (Ah / quartzose sandstone rock) − a Raw Soil. Scale in 10cm increments.

Trent soil series (Figs 2 & 3) are similar to Vee Forty soils but tend to be deeper (25−70 cm, av. 45 cm) and have gleyed light grey, sometimes mottled yellowish red, fine sandy loam to loamy sand Br or Bg subsoil horizons between the humic topsoil and the underlying coal measures rock. Trent soils comprise about 30% of the soil cover and are classified as Acid Gley Soils. Trent soils also tend to remain saturated throughout the year.

Figure 2. Trent soil profile (Ah1/Ah2/Br/R) with a gleyed subsoil over sandstone rock, a Gley Soil. Scale in 10 cm increments.

Figure 3. Deeper Trent soil profile (Ah/Br1/Br2/R) with a 36cm thick gleyed subsoil over quartzose sandstone rock. Scale in 10 cm increments.

Denniston soil series (Fig. 4) are deeper (40–> 120 cm) Humus Iron Podzols. An example profile has a 13 cm fine sandy loam dark brown topsoil (Ah), 27 cm thick light grey with coarse strong brown mottles loamy sand eluvial (E) horizon over 15 cm of humus enriched strong brown sandy loam (Bhw), a thin (5 mm) iron pan (Bfm), and a strong brown fine sandy loam lower subsoil (Bs) on quartzose sandstone rock (R). Denniston soils occur over about 5% of the soil cover on the site.

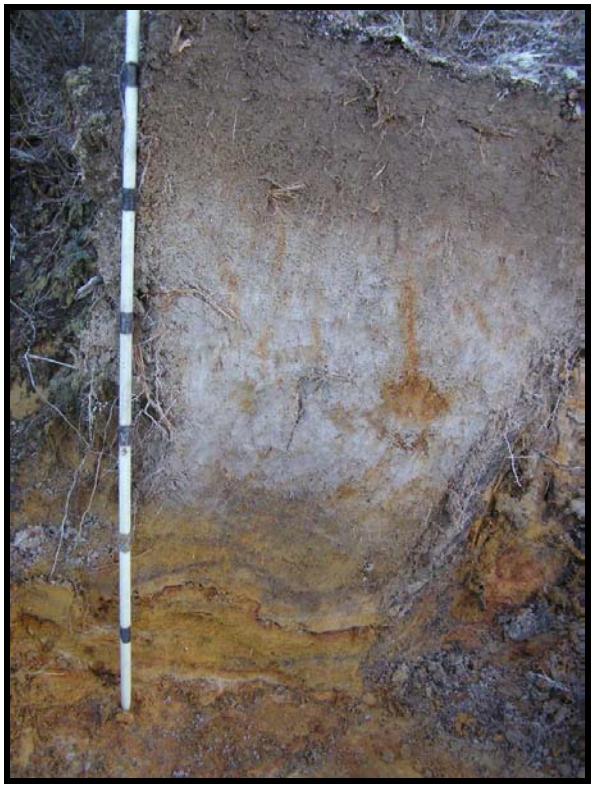

Figure 4. Denniston soil profile (Ah/E/Bhw/Bfm/Bs/R) of a Humus Iron Podzol. Scale in 10 cm increments.

3.2 Soil fertility

No soil sampling for analyses was undertaken during this survey. However, soil chemistry information is published (Ross 1997) for the Vee Forty and Trent series from the Upper Waimangaroa area. These soils have very low fertility, particularly limiting in phosphorus and exchangeable-Ca. This indicates that most of the plant nutrients are probably being recycled through the organic regime rather than coming from the mineral soil matter or weathering of the quartz-rich sandstone. This accounts for the very slow growth rates of native plants on the coal measures soils. The native flora and ecosystems in the project area are adapted to this acidic, wet, and relatively infertile environment.

Vee Forty soils are extremely acidic (pH(H2O) 3.9−4.5) with high carbon contents (total C 10.6−27.5%, except for an Eh horizon 1.2%) and C:N ratios (19−42). Bray 2-soluble phosphorus (P) is very low (0−7 mg/kg) and exchangeable cations (Ca, Mg, K) generally very low except for the surface horizon where cation content is medium to high.
Trent soils are also very acidic (pH 4.3−5.0) with medium carbon contents (6.1%) in the topsoil but low in the gleyed subsoil horizons (1.9% decreasing to 0.9% with depth). C:N ratios are very high (25−35) and Bray 2-soluble P very low (1−4 mg/kg). Exchangeable cations are very low.

There is no soil analytical information published for Denniston soils.

3.3 Salvageable Soils

Much of the surface area of the Escarpment Project site is bare of soil and vegetation. Bare rock pavement on the sloping plateau areas is devoid of machine salvageable soils and vegetation (Fig. 5). Hand salvage of individual plants or clumps of plants may be possible but will be labour intensive. Also, much of the area of the sloping plateau landscapes has been disturbed by access tracks, former prospect drilling sites (Fig. 6), and previous mining operations associated with the Whareatea, Plateau, and Escarpment underground mines. Soil erosion has exacerbated the effects of this disturbance.

Figure 5. Rock pavement with negligible salvageable soil or vegetation.

Figure 6. Disturbed ground from tracking and prospect drilling operations.

Salvage of soils on escarpment faces and steep-sided gullies with rock bluffs and many surface large boulders (Fig. 7) will be very limited because it is impractical for machinery to salvage these patches of soil. However, salvage of the vegetation as slash and woody material, with some soil attached, is feasible with excavating machinery.

Figure 7. Escarpment face with rock faces and large boulders with limited feasibility for salvaging soils.

Approximately 50% (perhaps less) of the surface area of the 148 ha site is estimated to have salvageable soils, at average depths of 20−30 cm. There will thus be an inevitable shortfall in soil for land rehabilitation over the whole site area, if soils are returned at average depths.

4. Indicative Land Rehabilitation

4.1 Landforms

Land rehabilitation planning is divided into 4 phases:
- The opening-up or initial mine development stage
- Progressive rehabilitation during mining operations
- Mine closure
- On-going maintenance.

A key part of land rehabilitation planning is setting the objectives and goals for the landscape that will be left after mining, closure criteria, and what the uses of the land are going to be. Re-instatement of wildlife habitat and a recovery plan for threatened species (Powelliphanta “patrickensis” snails, fernbirds, great spotted kiwi, and wekas) or environmental offsets to relocate the snails, kiwi, and weka outside the project area need to be considered. It is assumed that the Escarpment Project area will remain in the Conservation Estate after mine closure. The long-term goals are therefore to develop indigenous ecosystems for conservation and recreational uses. A key part of the land rehabilitation programme is planning the post-mining landscape/ landforms.

It is inevitable that the landforms of rocky pavement, escarpments, and incised streams of the site will be altered by opencast coal mining operations. Overburden waste rock dumps will need to be engineered to attempt to fit in with the adjacent tilted plateau landscape to the northwest and its drainage pattern into the Whareatea River catchment. Stable landforms that fit the environment are the primary goal of land rehabilitation.

Mining operations are not intended to affect the landscape of the steep-sloping forested mountainous landscape (and erosion scars below the former Escarpment Mine site) to the southeast i.e. into the Cascade Creek catchment; however, the southern extent of mining operations might impact on the edge of this landscape. Some drainage will continue to feed into V8 and V37 Creeks, subsidiary streams to Cascade Creek. The drainage systems need to be engineered to link where practicable with the existing streams, with a prerequisite requirement that acid rock drainage is mitigated upstream of any surface discharges into existing streams. The bouldery overburden dumps are also likely to be more porous than the existing rock pavement, although vehicle compaction of final flat tops and benches on overburden dumps and translocation of soil and vegetation can significantly reduce infiltration and permeability. The practicalities of recreating a similar ‘functionally’ impermeable surface as the sandstone pavement for restoring the low healthland ‘pakihi’ vegetation by compacting the surface veneer of overburden sandstone is uncertain and needs to be investigated.

Sediment control will be required because bare waste rock dumps and areas where the vegetation has been stripped off will generate considerable sediment in runoff. Note that non-impacted watercourses on the Plateau typically have low concentrations of suspended sediment solids, even under flood conditions. The coal measures sandstone fines, and silty subsoils (i.e. subsoils without a high root mass and with low humus contents) where they exist, are very erosive under the high rainfall regime of the Denniston Plateau.

The bouldery waste coal measures rock overburden dumps, comprising mostly quartzose sandstone and argillitic mudstone rocks, will include a swell factor. Long, steep angle-of-repose, side slopes to waste rock dumps (Fig. 8) should be avoided by either engineering a series of small dumps or by contouring the sides of dumps into a series of batters and benches. Both of these engineering options facilitate better revegetation techniques than large, steeply sided dumps, although they generally require a larger footprint. Local steepening of overburden dump slopes can be used to avoid covering or disturbing the most valued ecosystems or watercourses (e.g., heads of streams).

Figure 8. Angle-of-repose (about 35˚), long overburden coal measure sandstone rock dump slope that is erosive and very difficult (and dangerous for planters) to re-vegetate.

4.2 Acid Rock Drainage

The Brunner Coal Measures rocks contain facets of potentially acid-forming pyritic rocks (PAF) that produce acid rock drainage (ARD) when exposed to oxygen and percolating water. Acid leachate adversely affects water ecology and vegetation (where it emerges into the plant rooting zone). Plant survival at pHs below about 3.5 is limited to mosses and lichens and a small number of very slow growing and very acid tolerant species. PAF material at or near the surface in the uppermost rehabilitation layer generally take decades to revegetate, requiring the acid to leach out of the material and acid-producing potential to reduce significantly over time, allowing the pH to rise to > 3.5 before survival of higher plants will occur.

PAF rock will need to be identified and handled separately from the non-acid-producing overburden rocks, where practicable. The preferred option is to bury the PAF rock in ‘cells’ in the overburden dumps, which are covered with a relatively impermeable layer, where practicable. Crushed argillitic mudstone rock within the Brunner Coal Measures might provide a suitable impermeable barrier. Geotextiles or imported bentonite clays, which act as barriers to percolating water, are more expensive engineering options. If these options are impracticable or not economically feasible, then the ARD will need to be engineered to avoid contamination of rehabilitated and revegetated areas, and direct discharge into adjacent waterways. The ARD will require neutralization by either running it through a water treatment plant or through a passive limestone-lined wetland treatment system. International experiences of wetland ARD systems are that they need to be regenerated periodically because they become less efficient with time at neutralizing the acidic water as a consequence of bypass flow and the development of surface rinds on the limestone blocks.

4.3 Revegetation Techniques

A variety of revegetation techniques will be necessary for land rehabilitation/restoration over the project area, as follows. Progressive land rehabilitation during mining operations is strongly recommended given the special environmental sensitivities (especially the high rainfall and very slow plant growth rates) of the site. However, it is recognized that there will be an opening-up stage where soil and plants materials will need to be stockpiled and a closure phase where the remaining areas will need to be finally rehabilitated. Stockpiling needs to be carefully planned to avoid increasing the area of disturbed land, and hence should be restricted (as much as is practicable) to within existing disturbance or resource footprints, or naturally bare areas (e.g., rock pavements or eroded areas). Revegetated areas ideally should be designed to link with adjacent un-mined vegetation or in islands of reasonable size (several hectares), for wildlife ecological reasons, depending on the species present.

It is strongly recommended to salvage and recycle in land rehabilitation as much of the soils and vegetation as is practical and economically feasible. Burying soil and vegetation into large overburden dumps is wasteful of resources, causes settlement and gas (methane) problems, is ecologically disadvantageous, and will delay the revegetation process in this very slow-growing environment by several decades. It may take 20−50 years (during which bare areas are vulnerable to erosion and weed invasion) to reach a dense (> 75%) cover of 2−3 m height scrub or regenerating forest through planting or seeding techniques onto replaced mixed soil materials and almost certainly at the longer end of the spectrum for plant growth media of overburden fines.

Recommended re-vegetation techniques are:

- Direct transfer or translocation of the ‘pakihi’ heathland and manuka scrub vegetation with root plates attached (Figs 9 & 10) is the preferred method of revegetation onto compacted, flat topped or gently rolling overburden dumps and benches, i.e. like ‘instant lawn’ but with much deeper soil attached and no ‘rolling’ of the vegetation mat. Direct transfer of indigenous pakihi and manuka scrub vegetation has been successfully demonstrated and adopted on mine sites on the West Coast for over a decade (Ross et al. 1995a, 1996, 1997; Simcock & Ross 1995; Ross & Simcock 1997; Ross et al. 2000; Simcock et al., 1999, 2004).

Figure 9. Direct transferred clumps of 'pakihi' heathland vegetation after 2 years on a machinery-compacted overburden waste rock dump flat top.

'Pakihi' healthland and manuka scrub vegetation is resilient to salvage and replacement (Ross et al. 1997), as demonstrated in Figs 9 & 10, but not to trafficking. Hydraulic excavators and dump trucks have been successfully used to translocate 'pakihi' and manuka scrub onto rehabilitation sites at a number of mine sites on the West Coast. Operator skill is required to achieve a good result, especially given the soils are saturated throughout the year. Machinery must not be driven over the replaced patches of 'pakihi'.

Figure10. Close-up of direct transferred ‘pakihi’ heathland vegetation after 5 years on a machinery-compacted overburden waste rock dump flat top. Scale is 10 cm graduations.

Stockpiling the ‘pakihi’ vegetation, manuka scrub, and soil in traditional soil stockpiles several metres high is not recommended. The vegetation buried in the stockpile will die, the regeneration of the pakihi or manuka scrub vegetation is unlikely or at least will take decades to achieve. Rather, storage of salvaged ‘pakihi’ and manuka scrub with soil attached is recommended as thin veneers onto existing bare rock pavements or eroded areas (as exists naturally), for later retrieval and replacement onto rehabilitation sites.

- Direct transfer of patches of podocarp/beech forest (Ross et al. 1995, 1996, 2000; Simcock & Ross 1995; Simcock et al. 1999, 2004) is practically limited but still achievable on some sites (Figs 11−13), using the same equipment as applies to the ‘pakihi’ and manuka scrub. As much soil as practicable should be salvaged as root plates with the trees. Significant die-back and deaths of the trees are inevitable, particularly for the podocarp trees. However, some will survive and there is considerable regenerative capacity in the root plates and understory vegetation, as shown in Figures 12 and 13. The dead and living branches will be used as perches by birds that bring in seeds of many native species, and the dead and decaying vegetative materials (especially wood) provides refuges for insects, snails, lizards, and some birds, as well as nutrients from organic matter recycling. The varied microtopography of the ground surface created by this method is also more like the natural forest than planting onto flat engineered surfaces. It might look like a mess compared with traditional landscape plantings in ‘cultural’ environments but it more closely replicates natural forest and scrubland and provides better ecological outcomes than does traditionally 2 m x 2m spaced plantings onto bare flat surfaces (compare Figs 12 & 13 with Figs 17 & 18).

Figure11. Direct transfer of native shrub and tree vegetation.

Figure 12. Natural regeneration of direct transferred beech/podocarp/scrub vegetation,4 years after shifting onto the machinery-compacted overburden rock dumpflat top.

Figure13. Direct transferred beech/podocarp/manuka forest 3.5 years after shifting onto a vehicle-compacted overburden waste rock dump flat top.

- Direct transfer (salvage and replanting) by hand of individual plants and small clumps of vegetation onto rehabilitation surfaces with planting media (either soil or overburden fines) is a labour-intensive alternative to machinery direct transfer (Fig. 14; Ross & Simcock 1997; Ross et al. 2000; Simcock et al. 2004). This method is similar to planting nursery-grown plants, except that naturally growing plants already on the mine site are collected ahead of the mining front and replanted onto rehabilitation areas. Plant species known to be tolerant of shifting as individual plants are generally targeted.

Figure14. Hand-dug translocation of individual plants or small clumps of plants after 2 years, planted onto a mixture of soil and overburden rock material dumped onto the vehicle-compacted flat top of an overburden rock dump. Scale marker beside the sign is 120 cm long in 10cm graduations.

- Salvage and re-spreading vegetation (woody) material as a slash mulch without soil attached is recommended from the escarpment and steep stream gully rocky outcrop areas where direct transfer of vegetation with root plates attached is not practically feasible. The forest and scrub slash will provide a protective cover over the overburden rehabilitation surfaces for erosion control, as well as seed (if collected at the right time of the year), some vegetative regeneration, and nutrients from decomposition. Plantings into the slash will help the revegetation process, provided there is plant growth media (soil or overburden fines) underneath. The slash will provide habitat for insects, snails, and lizards.

- Hydroseeding (Fig. 15) is recommended for rocky faces and steep overburden dump batters or slopes where direct transfer or planting is impractical or dangerous.

Figure15. Hydroseeding mosses and other colonizing species onto a roadside rock face.

A technique for hydroseeding with colonizing mosses, lichens, Lycopodium sp. and ground cover herbs (e.g., Raoulia sp., Nertera depressa, Epilobium sp., Anaphalioides bellidioides), together with seeds of native plants (e.g., Phormium cookianum, Gahnia procera, Leptospermum scoparium, and Hebe salicifolia) has been developed by Landcare Research, HortResearch, and RST Environmental Solutions (Ross et al. 2003; Stanley et al. 2003). This technique has been successfully used for the relatively quick establishment (within 3−6 months) of a ground vegetation cover for rocky roadside faces (Fig. 16) and steep slopes or batters of overburden rock dumps (Fig. 17) on Stockton and Strongman Mines. The technique has also been successfully used to revegetate road batters, mine pit walls, and quarry walls at other South and North Island sites.

Figure16. Moss and other colonizing species hydroseeded (with some higher plant seeds)onto a rocky road cutting.

Figure 17. Bouldery angle-of-repose side-slope of an overburden waste rock dump, 2 years after hydroseeding with mosses and other colonizing plant fragments and native seeds.

Planting of nursery-grown native plants will be required to make up for the shortfall in salvageable soils and vegetation to rehabilitate the entire areas disturbed by mining (Ross et al. 1995a&b; Simcock & Ross 1995; Davis et al 1997; Mew et al. 1997; Langer et al. 1999; Theinhardt 2003; Simcock et al. 2004). Closely spaced (max. 1 m x 1 m) plantings are recommended using mostly native grasses, shrubs, and the more hardy trees (e.g., mountain beech) of local provenance. The plantings should be in a semi-random pattern and not in a traditionally evenly spaced design. The planting surface needs to be 'roughened' with different microsites (Fig. 19) rather than a smooth, compacted 'tabletop' (Fig. 18). Initially fertilized plantings of native shrubs into infertile overburden sandstone rock fines on a compacted, gently sloping, exposed surface were not successful for developing a vegetation cover after 11 years at a mine in the Plateau area (Fig. 18). More recent plantings (Fig. 19) into a mixture of waste rocks (boulders for shelter), rock fines, and soil or soil-like plant media with microsites were an improvement. However, vegetative ground cover was still not as good as direct transfer of vegetation clumps or where undiluted (with rocky materials) topsoil was spread.

Figure 18. Poor vegetation establishment 11 years after planting with native species, with some invasion of Juncus squarrosa, on quartzose coal measures sandstone overburden with no soil cover. Note toetoe plantings in the background.

Figure19. Plantings of native shrubs after 2 years into mixed overburden rock with some soil materials on the compacted flat top of a waste rock dump. Scale is 120 cm long with 10 cm graduations.

Exotic legumes and grasses, such as clovers, lotus, vetch, browntop, ryecorn, and ryegrasses, and nurse shrubs such as tree lucerne have not been very successful in the Denniston–Stockton Plateau environment and are not in keeping with the long-term Conservation Estate use of the site. Use of exotic 'cover crops' and nitrogen-fixing legumes are not recommended on this site. Slow-release fertilizer, with a small amount of fast release N & P fertilizer at planting, is recommended because of the extremely low fertility of the coal measures rock fines that result from mining operations. High rates of fast-release fertilizer are not recommended because they tend to encourage competitive weeds to the disadvantage of the native plants.

Combinations of all of these revegetation techniques potentially apply to the Escarpment coal mining project. The rehabilitation process needs to include record keeping, monitoring, and perhaps some demonstration or research trials to test the applicability of variations of the above techniques for the specific environmental issues of the Escarpment Project site. A programme of replacement ('blanking') planting and follow-up fertilizer applications for nursery-planted areas needs to be part of land rehabilitation planning.

Permanent photo points (of rehabilitation areas) are strongly recommended.

4.4 Pest and Weed Control

Pests, such as possums, red deer, goats, chamois, pigs, and hares that graze on and disturb (dig up) the rehabilitation re-vegetation require pest control measures.

The current main weed threats from species already present on the site are gorse (Ulex europaeus), exotic rushes (Juncus squarrosus, J. effuses) and montbretia (Crocosmia x crocosmiiflora). Other weeds may become threats following land disturbance by mining operations. Importation of weeds in materials (e.g. nursery potting media, roading gravels) needs attention to prevent invasion into the site, particularly onto disturbed areas. Areas on sites with weeds should be quarantined and the substrates and plants not mixed with non-weedy materials (gorse and Juncus seeds may remain viable for > 50 years). Weeds will need to be controlled either by spraying or cutting or hand removal or biological control (if appropriate biological control methods exist without threatening the native species).

Closure standards for revegetated areas need to be developed that include quantitative measures of native and non-native vegetation establishment and survival. When these standards are met, site maintenance can be reduced to normal Department of Conservation levels.

4.5 Closure plans for rehabilitating mining infrastructure sites

A closure plan needs to be developed for rehabilitating or leaving in a safe condition mining infrastructure, such as roads, building sites, coal storage bins, mining machinery, etc. Some mining infrastructure areas such as unwanted roadways and building sites can be rehabilitated back to indigenous vegetation. Other mining infrastructure such as roadways, coal bins and surface mining machinery may be desirable to leave as access roads, for cycling or tramping tracks, and mining relicts for tourism, provided they are left in a safe condition. Thus land rehabilitation planning must include a mine closure perspective, recognizing that this needs to be a flexible component of mine planning to take into account changes and developments during the mine life.

5. Environmental Offsets and Post-Mining Recreation Opportunities

Environmental offsets (restoring or improving environments at sites other than where the mine is) are often used internationally in the mining industry to compensate for the environmental impacts of mining (with the proviso that the site disturbance footprint has been minimised and acceptable site rehabilitation plans are in place).

Solid Energy has proposed controlling predators and developing alternative habitats for kiwi and Powelliphanta snails in the Upper Waimangaroa area as part-offsets for some mining impacts at Stockton. It is recommended that L & M Coal investigate with the Department of Conservation opportunities for developing an environmental offset programme that is cost-effective and realistic for the Escarpment Project. Offsets are most effective when implemented before any disturbance earthworks activities as most offsets have a lag phase.

Offsets also include social programmes (e.g., recreational lake construction outside of the mining area prior to mining at Martha Mine in Waihi and by development of tourist facilities). At the Escarpment project site, land rehabilitation planning needs to include development of potential recreational opportunities, in keeping with the objectives of the Department of Conservation. For example, reinstatement of mountain bike trails, nature walkways, perhaps canoeing if any small lakes are to be created through opencast mining, or mining relicts as tourist attractions (to become part of the Denniston historical mining theme).

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