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# Revegetation of the Stockton Coal Mine, Buller©

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## INTRODUCTION

Stockton Coal Mine is situated 25 km north-east of Westport and stretches from 1 km to 5 km from the coast. The 2,200-ha coal mining licence is located within the western sector of the Buller Coal Field on a plateau 400 to 1,100 m above the coastal plain. The opencast mine currently has a disturbed area of 750 ha and is expected to have a footprint of more than 900 ha at end of mine life.

Thick seams of generally high quality coal exported for use in thermal, coking, and specialised markets overlies a basement of weathered granite rock. This material is quarried for mine road aggregate and, due to its phosphate content, is capable of supporting vegetation. Overlying the coal is a thick layer of hard, massive quartz sandstone overburden, which is fragmented by blasting and stripped using 180-tonne excavators. It has poor plant-supporting characteristics, being low in fertility and having low water and nutrient-holding capacity. Remnants of the Kaiata mudstone exist on top of the sandstone and contribute to acid rock drainage through oxidation of sulphide-bearing minerals.

Stockton Mine experiences a moist (some would say very moist) temperate climate, which, combined with strong prevailing west/north westerly winds, means extreme weather conditions are common. Annual mean precipitation of 6,500 mm (predominantly as rain) and common, intense rainfall events (e.g., 140 mm in 6 h) produce extreme soil nutrient leaching and, along with severe winter frosts, causes high erosion rates of unprotected soil particles. High frequency of fog and clouds reduces light levels, resulting in decreased photosynthesis and growth rates.

The mine lies within the northern part of the Ngakawau Ecological District and exhibits distinct vegetation patterns, primarily the result of altitude and soil availability. Lower level pavement areas support only mosses, lichens, and herb species, while isolated pockets of podocarp/beech forest communities of mountain beech (*Nothofagus solanderi* var. *cliffortioides*), silver beech (*N. menziesii*), southern rata (*Metrosideros umbellata*), pink pine (*Halocarpus biformis*), and yellow silver pine (*Lepidothamnus intermedius*) exist in gullies where thicker and more fertile soils have developed. Stunted shrub and tussock fields exist at higher altitudes with manuka/tea tree (*Leptospermum scoparium*), wire rush (*Empodisma minus),* leatherwood (*Coprosma colensoi*), mountain flax (*Phormium cookianum*), and snow and red tussock (*Chionochloa conspicua* and *C. rubra*) predominating. Higher still, on the peaks and ridges of Mt. Augustus and Mt. Frederick at about 1000 m above sea level, subalpine herbs, grasses, and cushion plant associations are common [pink pine (*Celmisia* sp.) and wire rush (*Chionochloa* sp.)].

The podzol Pakihi soil is thin (commonly < 200 mm), nutrient deficient (low organic content and leached), acidic (3.5–5.6 pH), and poorly drained. Over many parts soil is naturally absent or has been removed by historic mining.

## REHABILITATION

The objective of the rehabilitation programme is to leave the site safe and geotechnically stable post-mining, incorporating landforms that are sympathetic to surrounding landscapes, and to encourage an indigenous, self sustaining, and diverse vegetation cover and ecosystem.

**Earthworks.** Rehabilitation begins with the bulk placement of overburden (waste rock) in engineered landforms (ELFs) or reshaping existing rock dumps. The process generally involves smoothing and flattening of steep (> 38°) angular features using bulldozers, hydraulic excavators, and dump trucks. Commonly, rock is removed from upper parts of the rock dumps and spread around the toe in contoured steps (lifts) to lower the height and reduce visual impact. However, in some cases increasing the footprint of the dump is undesirable (and therefore generally avoided) particularly if it requires impacting on natural ground and undisturbed vegetation. Once the overburden is shaped, benches are cut around the contour to provide drainage paths for runoff and access for subsequent rehabilitation operations. Drains are formed, and where steep gradients are encountered, they are lined with rocks to provide armouring against intermittent but large flows of runoff following intense rainfall events. The sloping portions of the ELFs (batters) are capped using up to 0.5-m layer of compacted, weathered granite to reduce oxygen and water entry to minimise oxidation of sulphide minerals (reduced acid mine drainage). Freshly stripped or stockpiled soil is then trucked in and spread 0.3–0.5 m deep by excavator. Alternatively mixed soil and vegetation (slash) is similarly spread.

**Revegetation.** When earthwork operations are completed, revegetation commences, with the method depending on what materials are available from other parts of the mine. Where possible, direct transfer is carried out, involving the precise removal and placement of soil, subsoil, and vegetation. It is a machinery intensive and therefore costly operation ($33,000–$55,000 per ha) requiring a minimum of two excavators and two trucks. Specialised machinery has been developed (flat extended truck decks and apron-type excavator buckets) that necessitate a high level of operator skill. While expensive, it is an ecologically superior method of vegetation establishment as entire ecosystems are transferred largely intact (soil, plants, mycorrhiza, insects, etc.).

Where direct transfer is not possible, hand transplanting is carried out using manual labour to transfer specimen plants using spades and trailers. It is obviously very labour intensive and is moderately beneficial ecologically through the introduction of mycorrhiza and nontarget piggy back plants, especially important ground covers such as wire rush (*E. minus*). It does have the shortcoming of there being a limited range of suitable species (tussocks, flaxes, cushion plants). The big advantage of this method is the significant visual effect of having larger and mixed aged plants incorporated into the rehabilitation area.

Hand planting of nursery-raised seedlings in spring and autumn is the final method of directly establishing vegetation cover. Up to 25 species are used, half of which are in large numbers. The aim is to plant 5,000 seedlings per ha, which, combined with 2,000 transplants, produces an inter-plant spacing of 1.3 m. Hand planting of seedlings, like transplanting, is labour intensive, with juvenile plants

**Table 1.** Common plant species used in the revegetation of Stockton Coal Mine and the method of establishment usually used (TP = transplant, NS = nursery seedling, DS = direct seeding).

| Botanical name | Common/Māori name | Establishment method |
|---|---|---|
| *Astelia nervosa* | | TP, NS |
| *Ozothamthus* (syn. *Cassinia*) *leptophyllus* | | TP, NS, DS |
| *Celmisia dallii* | | TP |
| *Celmisia lateralis* | | DS |
| *Chionochloa conspicua* | snow tussock | TP, NS, DS |
| *Chionochloa juncea* | coal measures tussock | TP, NS, DS |
| *Chionochloa rubra* | red tussock | TP, NS, DS |
| *Chionochloa flavescens* | snow tussock | TP, NS, DS |
| *Coprosma colensoi* | leatherwood | TP |
| *Coprosma foetidissima* | stinkwood | NS |
| *Cortaderia richardii* | toetoe | TP, NS, DS |
| *Dracophyllum uniflorum* | | TP |
| *Gahnia rigida* | tall mountain sedge | TP, DS |
| *Gaultheria rupestris* | bushy snowberry | NS |
| *Griselinia littoralis* | broadleaf | NS |
| *Hebe odora* | alpine hebe | TP, NS |
| *Hebe salicifolia* | koromiko | NS |
| *Isolepis reticularis* | | NS |
| *Leptospermum scoparium* | manuka | TP, NS, DS |
| *Metrosideros umbellata* | southern rata | TP, NS |
| *Nothofagus menziesii* | silver beech | TP, NS |
| *Nothofagus solanderi* | mountain beech | TP, NS |
| *Olearia arborescens* | | NS |
| *Olearia avicenniifolia* | | NS |
| *Phormium cookianum* | mountain flax | TP, NS |
| *Phyllocladus trichomanoides* var. *alpinus* | mountain toatoa | TP, NS |
| *Schoenoplectus lacustris* subsp. *tabernaemontani* | | NS |
| *Weinmannia racemosa* | kamahi | NS |

vulnerable to climatic events (e.g., heavy snow falls). "Carrot on stick" planting tools have been developed to allow planting in the rocky soil. A 10-g fertiliser pellet is applied at planting time to ease the stress of planting and to encourage root development from root ball into mine soil.

In addition to revegetation by direct introduction of plants, several methods of direct seeding are used depending on topography and access. Ground-based slurry application of seed and fertiliser is achieved through truck-mounted hydroseeding. If access is difficult, heli-hydroseeding and heli-seeding (dry application) methods are utilised. These methods are cost effective since large areas can be treated rapidly. For these bulk seeding methods large amounts (hundreds of kilograms) of coarsely processed seed are utilised. To date limited success has been achieved from direct seedling due to inferior seed quality, inadequate seed storage, and unstable substrates for seed germination.

The methods outlined above all require large inputs of labour, energy, and/or money. Despite the naturally harsh conditions at Stockton, there is ample evidence of natural vegetation establishment on favourable substrates (pH > 4 and not too coarse) and in sheltered sites, demonstrating nature's ability to repair itself after catastrophic disturbance (except where pH < 3.5 and very coarse substrates exist). Seed and plant fragments of a limited range of species contained in spread soil produce plants very readily, with mountain flax and wire rush being commonly present soon after soil is spread. In spite of young plants being used (nursery seedlings), seed is being produced and is germinating particularly for snow tussock, toetoe (*Cortaderia richardii*), koromiko (*Hebe salicifolia*) and snowberry (*Gaultheria rupestris*) within 2 to 4 years. As successful as seeding has been, the most astounding result has been the discovery of alpine hebe (*H. odora*) propagating itself through vegetative fragments knocked off the mother plant from rain and hail impact and establishing 2 to 3 m away.

## PLANT PROPAGATION

In order to revegetate a site experiencing conditions like Stockton using nursery-raised seedlings, a particular form of plant is required. Unlike most nursery stock, large, rapidly grown plants are not suitable, and so a number of specifications have been developed over many years. The two most important requirements are: plant height and stature; and the condition of the root ball.

Seedlings must be between 100 and 300 mm in height for woody species and 200 and 300 mm for grass/flax species. Plants exceeding these ranges are trimmed during the growing cycle to aid trunk development, leading to bushy, squat-stature plants that are less prone to wind damage. Tight root balls also result from trimming and are critical as multiple handling of plants from boxes to holding trays to buckets from which they are planted has the potential to cause major loss of potting material. Planting the resulting bare-root seedlings is undesirable given the poor soil conditions. The aim is to produce a plant of which one-third to half of the total height is root ball, which, if tight, produces a nutrient store for the first year after planting. From that time the seedlings have survived the shock of planting and are well stabilised in the soil substrate.

The provenance and type of propagating material has been found to have a significant effect on the success of seedlings. The use of propagating material from the Ngakawau Ecological District (NED) has been found to be too broad, as past experience has shown plants generated from lower altitude areas of the NED have struggled at higher altitudes. Therefore, material is collected only from the Stockton and Denniston plateaus to ensure plants are physiologically suitable (as well as genetically appropriate) for the highly exposed conditions, acidic soil, and low nutrient availability. Seedlings are generated from multiple material types to reduce risk and to utilise the advantages of each. Cuttings are commonly used, with ample supply generally available, and produce good plants relatively quickly. Better plants (stockier) often develop from seed that is mostly available in quantity, although viability is highly variable, leading to germination issues. Some species such as mountain flax and beech are mast seeders, which causes supply problems in some years. Natural seeding on road edges and historic mine tracks produces areas of almost unlimited seedlings (wildings) of a small range of species including broadleaf (*Griselinia littoralis*), tussock, and beech species. These wildings are very useful if additional plants of these species are required at short notice (6 months). The fourth source of propagating material is the use of divisions, which again is restricted to a limited number of species including tussocks and wetland species such as *Schoenoplectus validus.*

The choice of growing containers is governed by the type and size of the desired root ball, which in turn is determined by the soil conditions that are generally rocky and therefore restrict planting depth. Hiko™ V150 trays (Stuewe and Sons Inc., Oregon, U.S.A.) and pots of similar volume and depth have worked well, and are easy to handle in large numbers.

The period in transit is potentially the most stressful time for seedlings, and a number of lessons learned have eased the stress (not only for plants!). Excellent communication between propagator, transport operator, and rehabilitation staff is crucial to ensure plants are not left in conditions detrimental to living plants. Seedlings are delivered in growing trays or packed depotted in boxes in the month preceding planting. Boxed plants are unpacked into recycled plastic bread trays and placed in a semi-sheltered location to introduce them to ambient conditions of the plateau.

A number of species are still proving problematic for propagators, including *Gahnia rigida* (prevalent on site, producing abundant seed, but difficult to germinate), broadleaf (easy to propagate but coarse roots don't produce tight root balls), and manuka (principal species on site but suffers from dampening-off). In addition to propagation issues, seed quality and storage, plant holding facilities, and paucity of some species are issues requiring attention, particularly as anticipated plant numbers increase to approximately 250,000 to 300,000 per year.

## LESSONS LEARNED

Over a number of years some important lessons have been learned by various nurseries providing seedlings, in some cases too late to the detriment of a few. From a customers point of view rehabilitation-grade seedlings do not imply weak, substandard plants are acceptable, and similarly, large plant orders do not mean that poor quality plants are satisfactory. As plant numbers increase it is difficult to maintain quality control procedures but it is necessary to keep vigilant and provide feedback to growers. This reinforces the need for clear and accurate communication between propagator and customer, particularly regarding delivery details and seedling quality. With 100% survival rate set as the target it is crucial the propagator is familiar with the destination of their plants and the site conditions that influence the type of plant required. The most important aspect of propagating for harsh sites is the eco-sourcing of propagating material (particularly physiological) and a strict adherence to this axiom has resulted in a 98% survival rate of nursery raised seedlings.