

MINE RECLAMATION STRATEGIES IN BRITISH COLUMBIA

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David F. Polster, B.Sc., M.Sc., R.P.Bio.
Polster Environmental Services Ltd.
5953 Deuchars Drive
Duncan, B.C.
V9L 1L5
d.polster@telus.net

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Reclamation has been an integral part of the mining process in British Columbia since the late 1960's when reclamation legislation was introduced. A variety of reclamation strategies have been applied to lands disturbed by mining. Some reclamation programs have followed traditional forestry practices while other programs have used agricultural systems to develop vegetation covers on the reclamation sites. Poor results have been experienced on sites where high elevations, adverse climatic conditions and poor substrates have limited growth. Ecologically based reclamation systems have had greater success and have been able to return pre-mining productivity to the mining disturbances in some cases. The diversity of ecological and geological conditions in British Columbia requires adaptable reclamation strategies. This paper explores the wide variety of reclamation strategies that have been used in British Columbia over the past 40 years. By looking back at previous successes and failures in light of current knowledge, key features of effective reclamation strategies can be determined. A summary of effective reclamation strategies is provided from this evaluation.

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INTRODUCTION

Reclamation is an integral part of mining in British Columbia. Reclamation research and work has been undertaken in the Province since the 1960's and a significant body of information has been collected (TRCR 2003). Early reclamation academic leaders provided reclamation strategies based on their background. Forestry (Jack Thirgood), agriculture/soils (Art Bomke & Les Lavkulich) and ecology (Marc Bell) provided the foundations of the approaches to reclamation that have been applied in the Province. In addition, reclamation practitioners at the various mines provided their personal stamp on the reclamation strategies that were emerging. Sharing reclamation ideas at conferences held by the Technical and Research Committee on Reclamation and the Canadian Land Reclamation Association has resulted in a blending and modification of strategies. Continued improvements in reclamation performance are part of the progressive mining community in British Columbia.

Mine reclamation in British Columbia is particularly challenging. Steep mountainous terrain and adverse climatic conditions coupled with high wildlife and fisheries values in many minesite areas create conditions that test the skills of reclamation practitioners. The massive size of many B.C. mines also creates difficulties. Elements such as acid rock drainage (ARD), selenium, neutral pH metal leaching and molybdenum toxicity provide particular challenges at specific mines. Innovative mine and reclamation strategies such as wrap-around dumps (Milligan and Berdusco 1978; Milligan 1988) have been developed to meet these challenges.

Strategies for mine reclamation in B.C. can be grouped into three major classes; forestry, agriculture and soils; and ecological. Standard tree planting as a revegetation approach would fall into the forestry category while application of a till capping or biosolids to enhance soil fertility would be assigned to the agriculture and soils category. Successional reclamation (Polster 1989) as well

as the use of native species islands (Bittman 1995) belongs in the ecological class of mine reclamation strategies. This paper is organized around these three main classes of reclamation strategies with discussions of the pros and cons of each included with the discussion of the strategy. Conclusions are provided following the section on the strategies.

FORESTRY BASED STRATEGIES

Forestry is a dominant player in the economy of B.C. so it is not surprising that when faced with reclaiming mining disturbances many practitioners turned to forestry and notably silviculture as a model for mine reclamation. Tree planting, including the use of fertilizer tablets to enhance the nutrient content of the substrates the trees were planted in is a standard approach for revegetation at some mines (Gardiner et al 1992). Tree planting coupled with planting of legumes has also been employed to enhance nutrient characteristics of mine wastes to improve tree growth (Gardiner et al 1992; Polster and DuBois 2007). Other tree establishment approaches fall more appropriately into the ecological category of mine reclamation strategies.

Standard silvicultural methods may fail to achieve acceptable growth when applied on mine wastes. The major reason for this is that mine wastes, unlike normal forest soils, lack many of the elements that will ensure the success of tree planting. In most cases, mine wastes lack significant organic components and thus elements such as soil micro-organisms that are important in the development of nutrient cycling are lacking. Even when fertilizers are applied at the time of planting, the inability of the freshly planted tree roots to be colonized by appropriate soil organisms limits their growth. Standard silvicultural methods typically fail to achieve satisfactory tree growth on mining wastes.

Compaction can be a significant issue in establishing forest vegetation on mining wastes. Traditional ripping with bulldozers or graders does not loosen the soil

sufficiently to allow tree roots to penetrate deeply enough to obtain moisture and nutrients needed for optimal growth. Free dumping, where loose truck-loads of waste rock is dumped in a close configuration on the top of dump platforms shows promise in addressing the problems of compaction. However, free dumping is generally only effective where wastes do not need to be covered with some form of suitable growth media. Reactive waste rocks with the potential to generate acidic drainage will require an appropriate cover and free dumping will not provide a benefit for tree growth in these cases. Waste dump re-sloping can also serve to loosen compacted dump platforms. Where wrap-around dumps have been built with sufficient regularity to allow re-sloping to reach from one to the next and provide a reasonable slope for vegetation compaction problems can be avoided and forest growth is a reasonable expectation.

AGRICULTURAL STRATEGIES

Many of the roots of reclamation in Canada come from agriculture. Standard agricultural treatments such as the establishment of grass and legume forage species, applications of fertilizer and/or bio-solids as well as the use of agricultural equipment are common practices in reclamation. Early studies of tailings reclamation employed many techniques from agriculture, including liming and fertilization (Gardiner 1977). Drill seeding, another agricultural technique has been used at a number of mines (Jones 1989) while dry broadcast seeding followed by harrowing with a chain link harrow has been used at other mines (Horton and Kempe 2001). Early studies of fertility and the suitability of mining wastes for vegetation drew heavily on standard agricultural tests (Ames 1980). Reclamation practices at the time followed agricultural treatments to address deficiencies.

Many of the agricultural strategies that have been applied to mines throughout the Province have been effective in the establishment of agronomic grasses and legumes. Excellent stands of forage species have been established at a number

of mines in British Columbia. These are often favoured by wildlife and large populations of ungulates have established around some mines. Studies of the metals uptake by plants and subsequently by animals have been framed in an agricultural context (Gardner et al 1996)

Establishment of productive grass and legume stands can create problems in establishing woody species (Green 1982). High populations of rodents can girdle woody plant stems while direct competition for moisture and nutrients can result in the death of planted woody stock (Polster 1991). Successional stagnation (Kimmins 1987) can occur where dense stands of agronomic grasses and legumes have been established. Bio-solids, the name applied to treated sewage sludge, may be applied to mine wastes to ameliorate the adverse conditions of the wastes. However, in combination with agronomic grasses and legumes, bio-solids treated sites may significantly slow the re-establishment of natural successional trajectories while doing little to ameliorate the adverse conditions of the wastes over the long term.

ECOLOGICALLY BASED STRATEGIES

Ecologically based reclamation strategies are founded on the belief that natural processes of succession and vegetation establishment on adverse sites provide the most effective model for reclamation of mining disturbances. Studies of the colonization by vegetation of talus slopes, natural loose rock slopes that form from the weathering of cliffs, can provide clues to the effective reclamation of waste rock dumps (Polster and Bell 1980). Similarly, knowledge of the dynamics of native vegetation colonization of barren expanses has been applied to the development of native species islands (Bittman 1995). Application of ecological principles to the reclamation of difficult sites promises to provide solutions that have been missing in the use of forestry or agricultural models for reclamation (Walker et al 2007).

Successional reclamation is the term applied to the use of successional models for reclamation of disturbed sites (Polster 1989). The key to successional reclamation is to create the conditions that allow natural successional processes to take over the work of reclaiming the site. This may involve a wide variety of treatments such as re-sloping, amelioration of adverse substrate conditions such as ARD or dark, heat absorbing colours and de-compaction of compacted sites. Once the vegetation limiting factors are addressed, establishment of early successional species can provide the start of a successional trajectory that will provide an effective vegetation cover into the future (Polster 1991).

Replacement of critical ecological elements such as large woody debris that initiate nutrient cycling and provide substrate diversity (Lawrence 1983) or planting keystone vegetation species such as alder or early seral willows and poplars (Polster 1991) can be an important part of ecologically based reclamation programs. Seeking natural remedies to elements such as erosion rather than establishing dense stands of seeded agronomic grasses and legumes can result in the re-establishment of natural successional trajectories earlier in the reclamation process. Large woody debris and other organic detritus can help prevent erosion. Similarly, creating a rough and loose substrate can reduce erosion by as much as 50 percent over smooth compacted soil slopes (Wischmeier and Smith 1965). Determining the vegetation limiting factors associated with the site and ameliorating these conditions allows natural successional forces to re-establish vegetation on most sites.

Ecologically based reclamation programs are often significantly less expensive than other approaches as the natural processes of vegetation re-establishment are harnessed to provide an appropriate vegetation cover on the disturbed site. Natural seed rain can provide pioneering species on disturbed sites that are appropriately prepared. Similarly, the seed of later successional species such as forest trees can travel large distances and can result in tree establishment where early pioneering species have prepared the site. Application of ecologically

based seed harvesting strategies such as the establishment of puddles for willow and poplar establishment can result in the development of an appropriate vegetation cover at a fraction of the cost of traditional tree planting.

Natural ecological processes such as colonization and population expansion in bare areas can be enhanced by planting native legumes (Smyth 1984). Native species islands can serve as colonization centres for the establishment of appropriate vegetation across much larger areas (Bittman 1995). Care must be taken however, to include enough islands so that the entire disturbed area is suitably vegetated within a reasonable time frame. In addition, the creation of suitable micro-sites for seeds to lodge in and germinate can greatly assist in the spread of native species from the original islands. Similarly, protection from browsing may be needed to allow the vegetation in the islands to reach maturity and start producing seed.

Ecological reclamation strategies can be effective in developing a vegetation cover on mine areas. Establishment of pioneering species can encourage invasion by later successional species. Alder, a keystone species in many ecosystems in British Columbia, often provides this service and can be a valuable species for planting within the context of an ecological reclamation program. Similarly, willows and poplars can be easily established from cuttings and can provide an initial cover for later successional species to invade.

CONCLUSIONS

Three major reclamation strategies are found at mines in British Columbia; forestry based strategies; agricultural / soils based strategies and ecologically based strategies. Of these, with the exception of sites that are to be reclaimed to an active agricultural use, ecologically based strategies offer the most effective model for reclaiming lands. Mine sites are rarely covered with good forest soils or good agricultural soils, so approaches that follow forestry or agricultural

strategies often fail to perform adequately. However, natural ecosystem processes have been “reclaiming” significant disturbances since the dawn of time. Applying these methods to mine reclamation can provide effective solutions to vexing problems.

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