

ECONOMICS AND APPLICATION OF VARIOUS RECLAMATION TECHNIQUES

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ABSTRACT

Various reclamation techniques are currently utilized to reclaim lands disturbed from mining. The cost effectiveness and success rate varies considerably between techniques. In order to determine which technique is most applicable to a specific reclamation program, it is necessary to review and compare the economics, constraints, and additional parameters for the various techniques.

Reclamation techniques currently utilized at various base metal mines in B.C. are reviewed. Cost comparison of various reclamation methods such as: aerial and ground application of seed and fertilizer, biogeoengineering, and planting seedlings are discussed. Factors, such as the size of the area to be reclaimed, which will determine the cost effectiveness of various techniques, are discussed. In addition, specific parameters and constraints of each technique is outlined. Examples of these reclamation techniques are given.

INTRODUCTION

Reclamation is a required part of the mining process. A number of various reclamation techniques are utilized to reclaim land disturbed by mining in order to reach the desired end land use. The end land use desired also determines which species of grass, legume or seedling is planted. Which technique to utilize often depends on which end land use is required, whether it be agriculture, grazing, wildlife, or forestry. In addition, certain techniques are applicable for certain reclamation sites. For example, some of the reclamation techniques applicable for level waste dumps are not applicable and/or cost effective for sloping waste dumps. The funds available for reclamation are often severely limited, therefore it is critical that the most cost effective reclamation techniques are utilized. In order to determine which technique to utilize, it is necessary to review and compare the economics, constraints and additional parameters for various techniques.

COMPARISON OF SEEDING & FERTILIZING TECHNIQUES

The costs vary greatly between different techniques used to seed lands disturbed by mining. The costs and associated constraints of each of these techniques must be examined in order to define which technique to use for which site. Five different techniques, that can be utilized in the application of seed and fertilizer over a uniform area of waste dump, are as follows:

- A 4W Drive tractor with a rear mounted cyclone seeder attached;
- A helicopter utilizing a remote applicator hopper slung below;
- A fixed wing aircraft that carries and applies seed and fertilizer from a compartment just in front of the pilot;
- Hydroseeding using a truck mounted hydroseeding unit; and
- Hand seeding by using manual applicators.

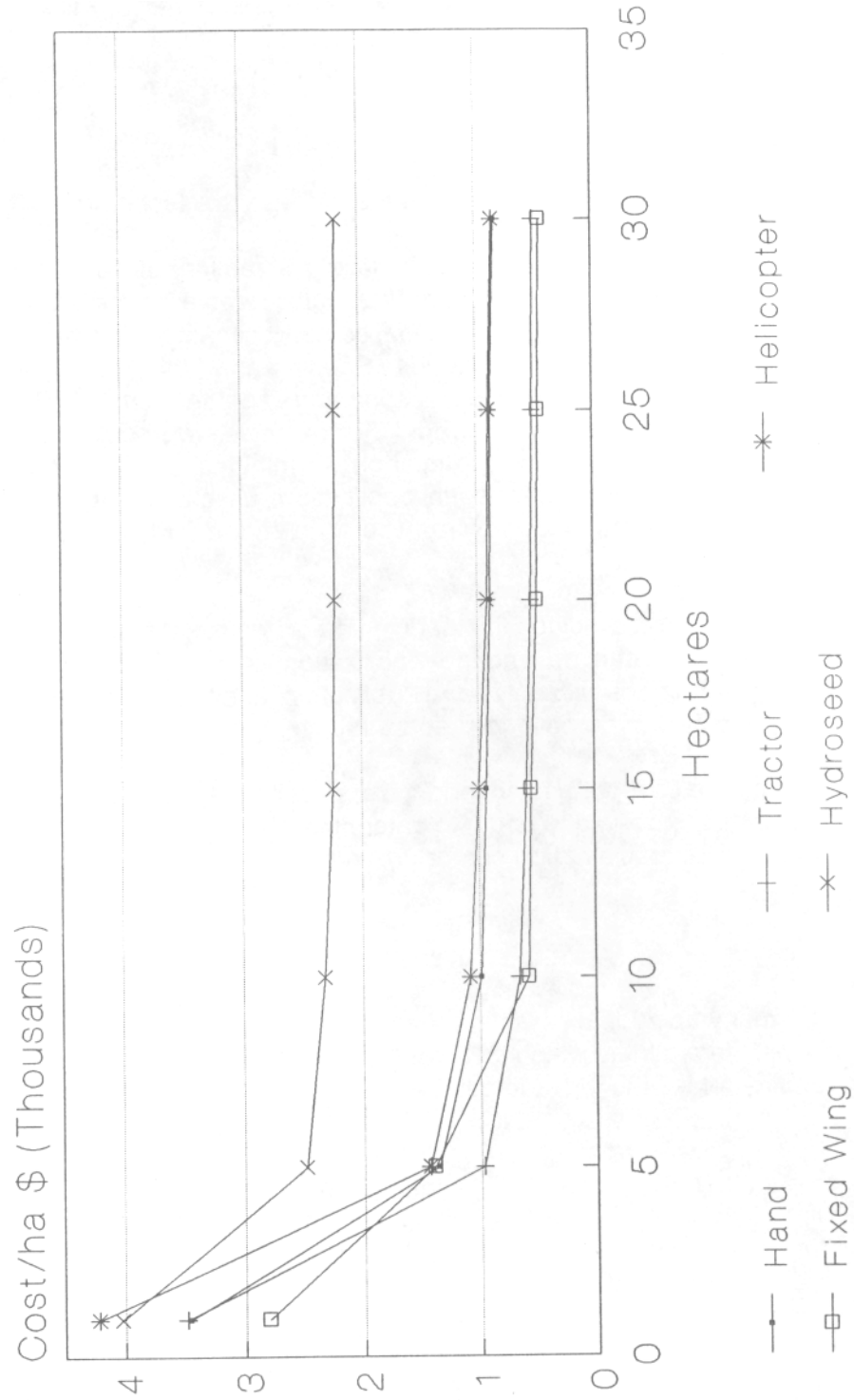
For comparative purposes, the cost figures are all inclusive of materials, equipment costs, transportation of equipment to and from site, operating labour, support vehicles, supervisory labour, and disbursements for sub-contractors.

The following discussion and comparisons are based on certain site conditions and requirements, and will vary depending on specific site conditions. Therefore, these comparisons are meant to exemplify these techniques and are not meant to indicate actual costs of reclaiming sites.

Cost Comparison

The cost comparison compares the techniques utilized to initially seed and fertilize a prepared level waste rock dump. Figure One compares the cost per hectare for the five different techniques over a range of area from 1 hectare to 30 hectares. As shown in this figure, all techniques are the most expensive for small areas and reduce at varying rates to level out at a consistent cost/ha. This dramatic cost per hectare reduction occurs because most of these techniques, with the exception of hand seeding and fertilizing, have high equipment, mobilization and set up costs that are best absorbed by the larger areas. Hand seeding, although not having high equipment costs, still shows a considerable higher rate for 1 hectare before levelling out at a lower cost per hectare. Hydroseeding also shows a decrease in the cost per hectare as the area increases, but does not drop down as dramatically or to a level close to other techniques.

FIGURE ONE - COST COMPARISON
Seed and Fertilize Level Waste Rock



This technique has high operational and additional (mulch & tackifier) material costs. By examining Figure One, it could be reasoned that one specific technique is the most appropriate to seed a certain sized area of waste rock. However, it is important to also look at the rate of application associated with each of these techniques.

Application Rate Comparison

Figure Two compares the application rates of these five techniques.

Hand seeding and fertilizing, although having a reasonable application cost, has an extremely low rate of application and would take a considerable amount of time to complete a large area. Hydroseeding, although not as slow as hand seeding, also has a slow application rate in comparison to the remaining techniques. Seeding and fertilizing utilizing the tractor and cyclone seeder has a reasonable rate of application and can often be utilized. Aerial application of seed and fertilizer by fixed wing is very rapid. For example, you could complete the seeding and fertilizing of five hectares by fixed wing in about 45 minutes, the same time as it would take to do a row or two by hand. Helicopter aerial application, while below the fixed wing rate is still fast enough to be a good technique to utilize when it is important to complete the site within a restricted time period.

These application rates include the loading time as well as the actual application time, but not mobilization, set up, clean up and de-mobilization times. This additional time is fairly consistent between techniques with only hand application being quick to prepare. Unfortunately, hand application is so slow, you have to prepare many times.

By examining the cost per hectare and the application rate per hectare for the application of seed and fertilizer, it is possible to begin to determine which technique is most applicable and cost effective to a specific reclamation site or program.

Additional Parameters

There are many additional parameters and constraints of each technique that must also be considered while determining which technique to use. Table One outlines the equipment and man power requirements, the advantages, and constraints of each of the five techniques reviewed.

Discussing the requirement for equipment for each technique, hand application as expected requires little in the way of equipment, although hand cyclone applicators are not reliable and frequently break and require replacement. The remaining techniques all have considerably greater equipment requirements, ranging from the tractor and cyclone spreader to the two aerial techniques which require a number of pieces of equipment. For helicopter application, the helicopter and application hopper, as well as a specialized loading truck and loading hopper is required. The fertilizer can be loaded straight into the application hopper, as long as you have a good number of strong backs! Fixed wing application, delivering the seed and fertilizer directly from the aircraft does not require an application hopper but requires a specialized loading truck. In this case, the loading truck is able to pick up the one ton mini - bulk fertilizer bags and drop the fertilizer directly into the plane. All equipment requirements correspond roughly with the rate of application, that is the more specialized the equipment utilized, the greater the average application rate in hectares per hour.

FIGURE TWO - RATE COMPARISON
Seed and Fertilize Level Waste Rock

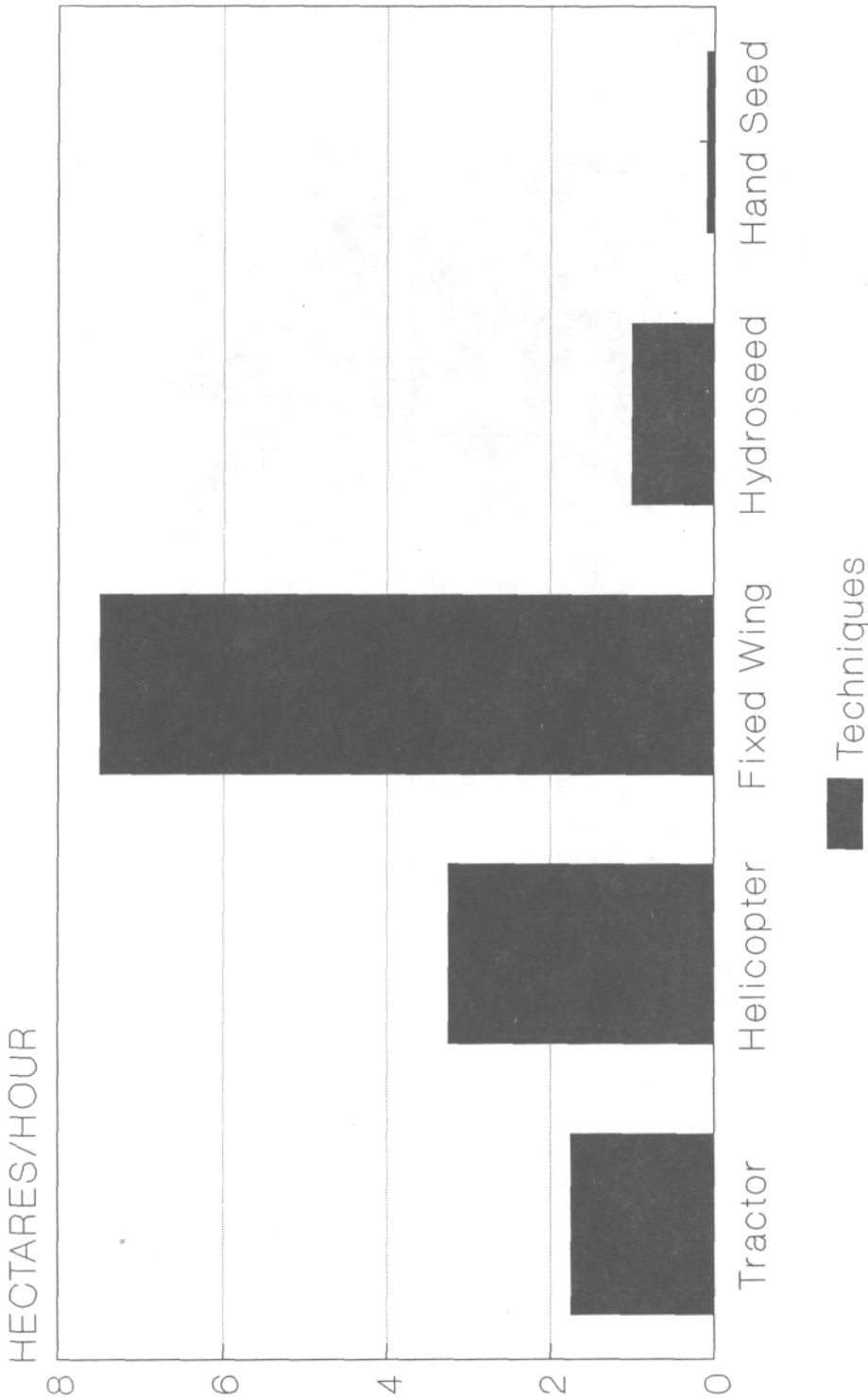


TABLE ONE
Reclamation Technique Summary

Technique	Equipment	Staff Required	Advantages	Constraints
Tractor & Cyclone	Tractor Cyclone Vehicle	2	-Excellent coverage -Modest amount of equip. required -Not weather dependent	-Relatively flat, surface required -Moderate rate -Hard on equipment
Helicopter	Helicopter Hopper-applic. Hopper-loading Equipment Vehicle	5	-Good coverage -High rate -Cover nearly any terrain	-Calm weather required -Ground crew & equip. required
Fixed Wing	Airplane Hopper-loading Equipment Vehicle	5	-Good coverage -Very high rate -Cover nearly any terrain	-Calm weather required -Ground crew and equip. required -Airstrip
Hand Applicator	Vehicle Hand seeders	5	-Low equipment required -Moderate costs for very small area -Not weather dependent	-Very slow rate -Large crew required -Relatively flat surface only -Poor, uneven coverage
Hydroseeder	Hydroseeder Vehicle	3	-Can do small, difficult areas -Excellent coverage	-High costs -Slow rate -Large water volume required -Large volume of material required

The advantages, and constraints or limiting parameters of each of these five techniques are also provided in Table One. By examining these factors in conjunction with the application costs and rates detailed previously, it is possible to determine which method of applying seed and fertilizer could be used for specific sites.

Seeding and fertilizing with the tractor mounted cyclone spreader unit is a cost effective technique for a moderate sized area. It does not require a major amount of equipment and it is not severely restricted by weather. It is however, definitely limited to relatively flat and smooth areas, and can be hard on equipment.

Small areas or disjointed parcels could be effectively completed by hand. This technique works well for numerous and very small areas that would not be feasible to do by any other technique. Hand application would require a large crew to complete the work within a reasonable time frame. It also can be limited to flat or gently sloping areas.

Hydroseeding is a technique that can be used to apply seed and fertilizer on small and extremely steep areas. It does require large volumes of water and additional material during application, and the total costs quickly rise as the area increases.

For larger areas, an aerial application is the most cost effective technique to utilize in many cases. The rate of application is far greater than other techniques and often at lower costs. The overall time of application is very short and an aerial application can apply seed and fertilizer on steep slopes and other hard to reach sites. Fixed wing costs are lower than helicopter costs, and fixed wing has a higher application rate. Both techniques can apply seed and fertilizer on rough or steep areas. However, the aerial techniques are dependant on calm weather in order to effectively spread the materials, and can tie up manpower and equipment waiting for good weather. In addition, a minimum area of approximately 10 hectares is often required to cover the mobilization and set up costs involved in these techniques.

Determination of the Most Viable Technique

The application cost and rate, the equipment and manpower requirements and the additional parameters and constraints have been reviewed. It is possible to put all this information together to obtain a guide to choosing the most cost effective and viable technique for the application of seed and fertilizer.

Figure Three lists a number of sites common to most mining operations that may require application of seed and fertilizer. For each of the sites, a recommended application technique is given, dependant of total area of the site. For example, on a steep waste rock slope you could use a hydroseeder for a two hectare area, and could use a fixed wing aircraft for larger areas. Also, for very small, visually important sites (eg. mine entrance) requiring landscaping, a hydroseeder could be utilized.

The suggested techniques provided in Figure Three are based on numerous variables and must be taken as a general recommendation only. To select the best application technique for a specific site, a review of all site requirements must be made.

FIGURE THREE

Determination of Reclamation Techniques

Site	Total Area in Hectares of Site						
	2	5	10	15	20	25	30
Waste Rock Dump Level	Hand	Tractor	Helicopter Fixed Wing				
Waste Rock Dump Slope	Hydroseed	Helicopter Fixed Wing					
Plant Site	Hand Hydroseed	Tractor	Helicopter Fixed Wing				
Pit	Helicopter Fixed Wing						
Dam Face	Hydroseed	Helicopter Fixed Wing					
Roads	Hand	Tractor	Helicopter Fixed Wing				
Linear Disturbances	Hand	Tractor	Helicopter Fixed Wing				
Clear Cuts	Hand	Helicopter Fixed Wing					

ADDITIONAL RECLAMATION TECHNIQUES

Drill Seeding

The reclamation of inactive tailings deposits often involves a seeding and fertilizing program. The most effective technique involves drill seeding the seed and fertilizer directly into the surface of the tailing deposit. By drilling, the seed and fertilizer is banded together at the right depth to ensure successful germination and growth. A drill seeding program has a higher cost per hectare than a broadcast seeding program but has a much greater success rate. If correctly done, a 100% coverage rate is not uncommon. The application rate averages one hectare an hour, and is only constrained by the requirement that the area be relatively uniform.

Surface Stabilization

Subsequent to drill seeding a tailings deposit, stabilization of the surface is often required to reduce erosional losses by wind or water. Stabilization is achieved by spraying the seeded tailing area with a surface binding material. There are a number of different binding or surface stabilization products available, each applied at different rates. The utilization of asphalt emulsion as a surface stabilizer is one of the most cost effective methods. This product requires a lower volume of water for application in comparison to other products. In addition, the black colour of the emulsion helps to warm the tailings and promote germination and growth; the emulsion breaks down naturally in one or two years. The other materials, although at higher costs, can be effective for use in jobs where only a small area requires stabilization.

Planting of Trees & Shrubs

In addition to the seeding of areas disturbed by mining, the planting of site-specific trees and shrubs is often essential to meet the productivity levels required for a specific end land use. The planting of trees and shrubs typically has a higher cost per hectare than the seeding of grass and legume species, but will likely become self sustainable and require little maintenance within a few years. The costs per hectare follow a decreasing curve, similar to other reclamation techniques, but level out at a high level reflecting the material costs of the plants and the high labour requirements. Tree and shrub species are planted in many different planting arrangements, depending on the end land use requirements.

Biogeoengineering Techniques

Biogeoengineering techniques are typically utilized for stabilization and revegetation of severely degraded and disturbed sites. Examples of sites include steep and rocky road fills and cuts, creek banks, and similar sites. Biogeoengineering often involves the highly labour intensive work of constructing hedge brush layers or wattle fencing, utilizing live plant material, to stabilize a slope. Additional planting, and seeding and fertilizing is done between the biogeoengineered structures. The cost of biogeoengineering, if examined only in context with the previously discussed techniques, appears very costly. However, if compared to traditional stabilization techniques, such as using erosion control materials, the costs are very reasonable.

Biogeoengineering also has the benefit of creating a more natural appearing site, as often

required in a sensitive location.

CONCLUSION

Many different reclamation techniques are feasible, and appropriate for the reclamation of disturbed areas requiring rehabilitation. With the severely limited funds that organizations are faced with, it is imperative that resource managers and reclamation staff choose the most cost effective technique available. All factors of each suitable technique must be reviewed and analyzed in detail. As well as examining the costs and rates of production, the advantages, disadvantages and constraints must be examined. Certain techniques that initially appear to be suitable for a specific reclamation program, may actually be much more expensive, and therefore unsuitable than an alternative technique.

By undertaking a careful review of the various reclamation techniques available, it is possible to reach the desired end land use for specific disturbed areas in the most cost effective manner.