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A Study of Plant Community Structure and a Reclamation Evaluation of Disturbed Subalpine Sites in Glacier National Park, British Columbia

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled A Study of Plant Community Structure and a Reclamation Evaluation of Disturbed Subalpine Sites in Glacier National Park, British Columbia submitted by Tamara Lamb in partial fulfillment of the requirements for the degree of Master of Science in Land Reclamation and Remediation

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Dedication

This thesis is dedicated to dear friends made during the course of writing this thesis: J.K., Darla and the cottagers - Dave, Darryl and Brian.

Quotation

All that we are is the result of what we have thought.
(Buddha)

ABSTRACT

A study was conducted in Glacier National Park, British Columbia in the biogeoclimatic zone, Interior Cedar Hemlock. The objectives of the study were to assess plant community structure in a subalpine forest ecosystem 10 years after disturbance, to assess the success of revegetation of disturbances based on the criteria agreed upon by Parks Canada and Canadian Pacific Railway and to discuss scientific and practical considerations for determining reclamation success. The layout (shape and size) of a disturbance will influence the species composition of the recovering plant community. The sites continue to be dominated by the agronomic species in the seed mix but native invasion is slowly taking place. Functional indicators of reclamation success are provided which would help determine whether the sites have achieved an acceptable level of ecosystem recovery.

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I. INTRODUCTION

1.1 Site Background

The Rogers Pass was discovered by Major A.B. Rogers in 1881 in his search for a railway route through the rugged Selkirk mountains of eastern British Columbia. Since its discovery, the pass has been used as a major transportation corridor linking British Columbia to the rest of Canada.

On March 9, 1982 Canadian Pacific Rail was granted approval by the Canadian Transport Commission to proceed with their proposed new track and tunnel project through the Rogers Pass in Glacier National Park. The new track alleviated the bottlenecks created because the westbound grades of the original track were in excess of 1%. In addition, it increased the operating capacity to meet projected traffic demands. The Rogers Pass Project involved the construction of 3 km of the new track on provincial Crown land and the construction of 34 km of track and tunnels through Glacier National Park bisecting it from east to west (Figure 1.1).

Glacier National Park (GNP) is noted for high snowfall and avalanche activity in the Rogers Pass and for containing more than 400 glaciers. Its ecological communities include the Columbia rainforest which is unique to the interior region of British Columbia. It provides important habitat for grizzly bears. Environment Canada - Parks has authority over GNP under the National Parks Act and is responsible for preserving the park for the benefit, education and enjoyment of present and future generations (Canadian Heritage Parks Canada, 1995). Because of their mandate and the unique qualities of GNP, Environment Canada - Parks participated in the design, construction and operation of the twinned railway, particularly the reclamation measures taken by CP Rail.

An Environmental Assessment Panel was formed in 1982 and it recommended stringent environmental guidelines be followed by CP Rail for water quality control, the operation of the work camps and reclamation. The reclamation criteria were detailed in the CP Rail/Parks Canada General Agreement on the Rogers Pass Development and resulted in an extensive reclamation plan by CP Rail.

1.2 Reclamation of the Disturbed Sites

In the past, attempts to reclaim sites in the park included a site above the twinned line at Mountain Creek in the Beaver Valley. In the report, " Initial Environmental Evaluation CP Rail Grade Improvement Rogers to Cougar Creek 1980 (LGL Limited, 1980)," the following assessment of the reclamation work at Mountain Creek was made:

> "At Mile 71 (Mountain Creek) extensive earthworks have been carried out to accommodate a new bridge built in 1977. The disturbed materials are largely

surface mineral deposits that contain very little organic matter. Long steep slopes (60 to 90 m at 40 degree angle) have been created as a result of cutting and filling. The vegetation cover includes introduced nurse crops of barley, white clover and creeping red fescue. Only the fescue appears to be thriving."

The poor establishment rates of vegetation at this site raised concerns about the potential difficulty of achieving satisfactory reclamation for the Rogers Pass Project and three major problems were identified. First, large cut and fill slopes would be a negative visual impact for travelers on the TransCanada Highway; second, exposed surfaces would contribute to erosion of soils into the streams and marshes of the valley floor; and third, water seepage could cause slumping and other drainage problems (Federal Environmental Assessment Review Office, 1982). Clearly, erosion was the predominant concern.

A moist grass/legume seed mix and a dry grass/legume seed mix were developed for revegetation of disturbed sites at the Rogers Pass. In 1980, LGL Limited recommended that locally occurring native plant species be used for revegetation. However, the required native seed was not commercially available in the necessary quantities in 1982. In addition, it was believed that compared to introduced species, native species are often slow to emerge and do not provide sufficient soil protection during the first year after sowing. The grass and legume seed mixes were designed as a temporary cover. The chosen species are generally short lived and the conditions which foster the growth of these species would be modified by other species which would subsequently invade or establish onto the sites (Polster Environmental Services, 1990). A sod mix was developed and seeded at Beaver Camp and Flat Creek Camp where picnic sites were proposed. The species and their proportions in the dry, moist and sod mixes are presented in Table 1.1.

The reclamation plan also involved the planting of native woody species. This was designed to mimic the successional processes associated with the natural revegetation of sites. It was expected that eventually the introduced grasses would be outcompeted and replaced by the native trees and shrubs replicating the primary stages in the natural succession of disturbed subalpine sites: an initial herbaceous phase, a woody shrub and brush phase, a pioneering conifer phase and a climax conifer phase. Planting native trees and shrubs would speed up the transition to later successional phases which would more closely simulate a natural subalpine ecosystem (Polster, 1988).

It was thought that since the seed mixes contained primarily bunch forming grass species, their widely spaced distribution would result in some open sites which would allow for the establishment of the woody vegetation. Woody shrubs and conifers were planted in most of the disturbed areas and included only native species of the area. Seeds and cuttings were collected within the park to preserve local germplasm. The species that were planted include *Populus balsamifera* (balsam poplar), *Cornus stolonifera* (red osier dogwood), *Rubus parviflorus* (thimbleberry), *Salix* spp. (willow), *Juniperus communis* (common juniper) *Sambucus racemosa* (elderberry), *Pseudotsuga menziesii* (Douglas fir) *Pinus contorta* (lodgepole pine), *Thuja plicata* (western red cedar), *Abies lasiocarpa* (subalpine fir) and *Tsuga heterophylla* (western hemlock).

Clearing limits were established 3 m beyond slope stakes for the particular cut and fill section as agreed upon by Parks Canada and CP Rail. Clearing limits were identified in the field with a combination of two colors of flagging tape. Grubbing occurred in the area between slope stakes which created a 3 m buffer between the slope stakes and the clearing limit. Material from the grubbing and all slash and stumps were burned on the site (Environment Canada, 1986).

The entire reclamation plan involved site preparation, seeding, fertilizing and planting. It was undertaken on an operational basis as disturbances occurred between 1984 and 1989 . Revegetation treatments were not applied equally for all sites. An 85 kg/ha seeding rate was chosen for both broadcast seeding and hydroseeding (Polster Environmental Services, 1988). Fertilizer application was targeted where it was believed to be most beneficial. Shrubs and trees were planted in patches to reflect natural landscape variation. No baseline data is available for the disturbances except the details of species composition and planting densities for each site which were provided on reclamation planning maps.

1.3 Ecological Characteristics of Glacier National Park

The biogeoclimatic ecosystem classification system of British Columbia is a hierarchical system that integrates ecosystem variation at regional and local levels and over time (Meidinger and Pojar, 1991; Bradfield and Scagel, 1984). Site units based on environmental characteristics such as moisture and nutrient status are identified at the local level and are used for forest management (Boyle, 1992). All of the sites within this study correspond to the Interior Cedar Hemlock (ICH) classification.

The ICH ecoregion has a mean annual temperature of less than 1°C. Temperatures range from a mean minima of -10 to -15°C to a mean maxima of 21 to 28°C (Achuff et al., 1984). The 30 year average for annual precipitation in the Rogers Pass is 1572 mm of which 612 mm occurs as rainfall and 960 mm occurs as snowfall (i.e. snow water equivalent). On average, the Rogers Pass receives precipitation on 230 days per year (Snow Research Avalanche Warning Service, 1996).

Soil parent materials in GNP generally are medium or coarse textured and noncalcareous. That, combined with the moist climate and predominance of coniferous forest at low elevations favors the development of podzols and strongly developed brunisols (Achuff et al., 1984).

The ICH occurs from 830 to 1450 m in GNP. It is dominated by *Tsuga heterophylla* and *Thuja plicata* (Habeck, 1968). Three sites, the Beaver Valley twinned railway, Beaver camp and the East Portal, correspond to the mw 1 subzone/variant of the

Interior Cedar Hemlock which is known as the Golden moist warm interior cedar hemlock variant (Achuff, 1984). The most typical undisturbed plant communities adjacent to the Beaver Valley, Beaver camp and East Portal sites were C49 and C52.

C49 occurs on mesic Interior Cedar Hemlock to lower Engelmann Spruce Subalpine Fir sites (870 to 2140 m) with moderate to very steep slopes and various aspects. Soils are Dystric Brunisols and Orthic Humo-Ferric Podzols on morainal and colluvial landforms (Achuff, 1984).

C52 occurs on mesic ICH sites (660-1530m) with moderate to steep, south facing slopes. Soils are well to rapidly drained Dystric Brunisols on colluvial and morainal landforms. This plant community is mature with stand ages of 90 to 300 years. In both C49 and C52 where mature forests exist with low occurrence of forest openings, understory vegetation is poorly developed (Achuff, 1984).

In a few instances in the Beaver Valley the fill slopes border wet subhygric communities. One common plant association found in these locations is C51 (*Thuja plicata/ Tsuga heterophylla/ Oplopanax horridum/ Gymnocarpium dryopteris*). C51 occurs on subhygric ICH (670 to 1420 m) sites on moderate slopes and various aspects in GNP. Soils are imperfectly to moderately well drained Brunisols which are often gleyed and have developed mostly on fluvial landforms (Achuff, 1984). See Table 1.2 for a common species list for C49, C51 and C52 and percentage composition within the tree, shrub or herbaceous/ dwarf shrub layers.

In the Beaver Valley native vegetation was catalogued in detail along the right-of-way before it was cleared because an important criterion in the reclamation requirements was to utilize native vegetation wherever possible; thus, it was necessary to know what was growing prior to disturbance. The frequency and relative abundance of plant species identified in sample plots along the new proposed railway right-of-way preclearing in June 1982 are presented in Table 1.3 (Maclaren Research, 1982).

The Ventilation Shaft, Glacier House and West Portal are on the west side of Glacier Park where conditions generally are wetter (Figure 1.1). According to the Biogeoclimatic Ecological Classification, these sites are in a transitional area from the ICH mw1 which covers the Beaver Valley sites to the wetter, ICH wk1 or Wells Gray Wet Cool Interior Cedar Hemlock variant (Braumandl and Curran, 1992). Compared to the ICH mw1, the ICH wk1 has less *Pinus contorta, Pinus monticola, Pseudotsuga menziesii* and *Dryopteris Assimilis*. Mesic sites in the ICH wk1 have *Oplopanax horridum* where none exists in mesic sites in the ICH mw1. The ICH wk1 contains more *Gymnopcarpium dryopteris* than the ICH mw1. *Juniperous communalis, Shepherdia canadensis* and *Arctostaphylis uva-ursi* are not found in the ICH wk1 whereas they occur on the dry sites of the ICH mw1 (Braumandl and Curran, 1992).

1.4 Disturbance and Recovery in Subalpine Ecosystems

By nature, Rocky Mountain forests are in some stage of recovery from prior disturbance creating a mosaic of stands of different ages and species compositions (Peet, 1978). Disturbances include any relatively discrete event in time that disrupts community or population structure and changes resource allocation or substrate availability and/or the physical environment (White and Pickett as cited in Rogers, 1996). The predominant types of natural disturbances in subalpine forests are single tree falls resulting from lightning strikes and wind. Blowdown on a larger scale often occurs in old growth areas which are susceptible because of rotting root systems (Baron, 1992; Rogers, 1996). The most destructive and extensive type of natural disturbance are snow avalanches (Johnson, 1987 as cited by Baron, 1992). Fire is infrequently but potentially an extensive type of disturbance to the subalpine forest. The fire rotation time is between 150 and 400 years. Epidemic attacks of insects can also be a contributing factor to forest disturbance (Baron, 1992; Rogers, 1996).

Toposequence and chronosequence studies spanning more than 45 years were used to study the long term natural recovery of disturbed subalpine plant communities in Colorado on abandoned mining sites. After 100 years, these disturbed plant communities remained distinct from similar surrounding undisturbed areas in species composition, species diversity, vegetation density, ground cover and biomass. An initial period of rapid vegetation colonization following disturbance occurs within the first 40 years and then the process of recovery appears to slow (Curtin, 1995). Abiotic factors such as microclimate or soil composition have important influences on the initial composition of disturbed plant communities but it is the effect of initial vegetation establishment that appears to guide subsequent compositional changes of the community (Curtin, 1995).

Succession is the continuum of change in vegetation composition within all plant communities resulting from the combined effects of invasion and competition as well as maintenance and decline (Peet, 1978, Johnstone, 1986). Secondary succession occurs on areas which were previously vegetated and where soils that have been modified by plants and microbes remain (Revel et al., 1984). Traditional successional theory supports the concept of relay sequential establishment of pioneer species followed by late successional or climax species which establish in the microenvironment created by the pioneer species (Veblen and Lorenz, 1986). However an alternative concept exists. Initial floristics suggest that species establish and grow in the disturbed area until one or more factors (e.g., light , moisture, nutrients, etc.) become limiting, after which new establishment and recruitment into the forest canopy decline dramatically for an extended time (Veblen and Lorenz, 1986). In Veblen and Lorenz's study of montane forests, the only stands in which pioneer species were clearly established earlier than late successional species were the most unfavorable sites. The two driving forces behind successional changes in plant community development are the presence of propagules either in the seed bank or provided through invasion and the competitive ability of the plants once they have established.

Plant establishment from a seed bank involves several factors: first, the storage of large quantities of dormant seeds in the soil in an undisturbed forest even when the species are absent from the existing community; second, triggering of seed germination by an environmental factor associated with disturbance of the canopy; third, rapid height growth dependent upon temporal nutrient enrichment of the soil; fourth, production of abundant amounts of seed after a short period; and fifth, the occurrence of short life spans for individuals (Bormann and Likens, 1981).

Invasion is caused by the removal of biotic or abiotic barriers that have previously excluded a plant species (Johnstone, 1986). Wind, animals, water and mass movements of the earth are seed dispersal mechanisms essential for the process of invasion.

The probability of seed being carried to a particular spot on a disturbed site where the species micro and macro environmental requirements will be met is reduced as the size of the disturbance and the distance downwind from a native seed source increases (Munshower, 1994). Species with light, highly mobile seeds often invade highly disturbed situations while species with heavier seeds, often animal disseminated, usually enter the ecosystem at a later stage of development (Salisbury, 1942 cited by Bormann, 1981).

Species invasion into established vegetation is very slow relative to invasion into disturbed communities. It appears that the intensity and size of a disturbance are critical determinants of invasion success (Reader and Bricker, 1994). For successful invasion an intermediate level of disturbance is optimal (Peet et al., 1983. Glenn-Lewin et al., 1980). On favorable or mesic sites, numerous species invade early but diversity drops later in succession as competitive interactions increase in importance (Peet, 1978).

The edges adjacent to undisturbed forests may provide the best opportunities for plant invasion. The forest edge is a zone of transition between the wide climatic fluctuations of a canopy opening and the relatively stable environment of the undisturbed forest (Matlack, 1994). The edge acts as both a separate microclimate and climatic mediator between a clearing and a forest (Chen et al., 1993). Wind influences temperature and moisture regimes at the edge. Relatively stable air exists as compared to a disturbance opening and allows for more extreme air temperatures and humidity. Biological features near the forest edge are related to the unique microclimatic conditions. Faster decomposition rates of litter near the edge are probably owing to more available soil moisture and higher temperatures (Chen et al., 1993). Forest edges tend to show a high density of saplings, greater shrub cover, production of adventitious limbs by canopy trees and invasion by species typical of open habitats.

Competition occurs where there is not enough of an environmental resource for two or more individuals and where the growth and survival of one or more of the individuals is affected by shortage of the resource (Whittaker, 1970 as cited by Revel et al, 1984). Disturbance temporarily reduces competition by providing bare ground which allows species to grow and have little influence on one another. The highest species diversities for Interior Cedar Hemlock forests in Glacier National Park were recorded during initial post fire establishment (Habeck, 1968).

In conditions immediately after a disturbance, shade intolerant colonizing species are able to attain local dominance due to a combination of reproductive, developmental and physiological growth attributes (Bormann and Likens, 1981). Eventually canopy closure and tree establishment during the earliest phase of forest development result in severe competitive inhibition of understory growth. The preemption of light and perhaps nutrient and water resources by canopy species (primarily trees and shrubs) results in temporary elimination of seedling establishment of intolerant tree species and most herbaceous plants (Peet, 1978).

Sites that are representative of the major early successional community types common to abandoned agricultural land and rights-of-way in New York state were examined. It was concluded that the net effect of intact vegetation on seedling survival in the study clearly depended on the shade tolerance of the target tree species (Berkowitz et al., 1995).

Although the processes of competition and invasion cannot be separated according to their relative influence, species diversity measures aid in understanding the combined effects of these processes and has prompted research to document changes in plant diversity across compositional and environmental gradients (Peet, 1978). Whittaker (1965) suggests three distinct levels of diversity: alpha diversity, beta-diversity and gamma diversity. The more precise term of alpha diversity refers to the within habitat or intracommunity diversity. It includes both species number or richness and the manner in which importance is proportioned among species (Chambers, 1983). Beta diversity describes between habitat or between patch diversity and gamma diversity is known as landscape or total diversity, the sum of the diversity of all the patches (Rey Benayas, 1995). Disturbance up to a point should have complementary effects of increasing alpha diversity while decreasing beta diversity (Peet, 1978).

1.5 Research Objectives

In 1996, fourteen years after the initiation of the Rogers Pass project and the subsequent implementation of the reclamation plan it was apparent that enough time had elapsed that an assessment of the vegetation would provide insight into the reclamation processes on subalpine sites and would confirm whether the reclamation criteria in the CP Rail/Parks Canada General Agreement on the Rogers Pass Development were met.

The purpose of this study was threefold:

1) To assess plant community structure in a subalpine forest ecosystem 10 years after disturbance,
2) To assess the success of revegetation of disturbed areas created by the Rogers Pass Project based on the criteria agreed upon by Parks Canada and CP Rail,
3) To discuss scientific and practical considerations for determining reclamation success of subalpine sites where the end goal is to restore to a natural functioning ecosystem.

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Table 1.1: Seed Mixes Used for the Establishment of Grasses and Legumes on the Project Sites

Species	Variety and Common Name	Percent by Species Composition	Percent by Weight
Dry Sites Mix			
Festuca rubra	Boreal Creeping Red Fescue	15	10.3
Festuca ovina	Durar Hard Fescue	10	7.3
Poa pratensis	Troy Kentucky Bluegrass	5	1.1
Agropyron riparium	Sodar Streambank Wheatgrass	10	27.2
Agropyron pectiniforme	Fairway Crested Wheatgrass	10	20.6
Dactylis glomerata	Chinook Orchardgrass	15	8.5
Phleum pratense	Climax Timothy	20	4.9
Trifolium hybridum	Aurora Alsike Clover	5	11.3
Medicago sativa	Rambler Alfalfa	10	8.8
Moist Sites Mix			
Festuca rubra	Boreal Creeping Red Fescue	15	11.4
Poa pratensis	Troy Kentucky Bluegrass	5	1.3
Dactylis glomerata	Chinook Orchardgrass	10	9.5
Phleum pratense	Climax Timothy	15	5.5
Agrostis alba	Redtop	10	0.9
Agropyron Trachycaulum	Revenue Slender Wheatgrass	10	29.9
Trifolium hybridum	Aurora Alsike Clover	20	12.5
Medicago sativa	Ramber Alfalfa	15	29.1
Sod Seed Mix			
Lolium perenne	Elka Perennial Ryegrass	15.3	40.0
Festuca rubra	Creeping Red Fescue	25.3	30.0
Festuca rubra var. *commutata*	Koket Chewing Fescue	8.4	10.0
Poa pratensis	Kentucky Bluegrass	25.5	10.0
Poa pratensis	Geronimo Kentucky Bluegrass	25.5	10.0

Adapted from Rogers Pass Project 1988 and 1989: Environmental Supervision, Monitoring and Reclamation Program, Polster Environmental Services.

Table 1.2:Common Plant Species in Plant Communities C49, C51 and C52 found in the Rogers Pass Project Sites and their Percentage in the Tree, Shrub or Herbaceous/ Dwarf Shrub Layer

Plant layer	C49	C51	C52
Tree	*Tsuga heterophylla* (15 to 35%) *Abies lasiocarpa* (5 to 20%) *Picea engelmannii* (3 to 5%) *Pseudotsuga menziesii* (2 to10%) *Pinus monticola* (1 to 5%)	*Thuja plicata* (10 to 40%) *Tsuga heterophylla* (10 to 40%) *Picea engelmannii* (5 to 15%)	*Tsuga heterophylla* (30 to 50%) *Thuja plicata* (10 to 20%) *Pseudotsuga menziesii* (5-15%) *Picea engelmannii* (less than 1%) *Pinus monticola* (less than 1%)
Shrub	*Rhododendron albiflorum* (10 to 40%) *Vaccinium membranaceum* (3 to 20%) *Abies lasiocarpa* (3 to 15%) *Tsuga* spp. (3 to 15%) *Menziesia glabella* (1 to 5%)	*Oplopanax horridum* (10 to 70%) *Thuja plicata* (3 to 10%) *Tsuga heterophylla* (1 to 5%) *Vaccinium membranaceum* (1 to 5%) *Vaccinium ovalifolium* (2 to 5%)	*Thuja plicata* (3-5%) *Tsuga heterophylla* (2 to 20%) *Pachystima myrsinites* (5 to 30%)
Herbaceous/ Dwarf Shrub	*Clintonia uniflora* (2 to 5%) *Cornus canadensis* (1 to 3%) *Gymnocarpium dryopertis* (1 to 5%) *Pyrola secunda* (less than 1%)	*Dryopteris assimilis* (3 to 10%) *Gymnocarpium dryopteris* (10 to 50%) *Athyrium felix-femina* (2 to 25%) *Tiarella unifoliata* (less than 3%) *Rubus pedatus* (less than 3%) *Clintonia uniflora* (less than 3%) *Cornus canadensis* (less than 3%) *Streptopus roseus* (less than 3%) *Streptopus amplexifolius* (less than 3%)	*Clintonia uniflora* (1 to 5%) *Chimaphila umbellata* (1 to 3%) *Goodyear oblongifolia* (less than 1%) *Pyrola secunda* (less than 1%)

Adapted from Achuff's Ecological Land Classification of Mount Revelstoke and Glacier National Park.

Table 1.3: Frequency and Relative Abundance of Plant Species Identified in Sample Plots Along the New Proposed Railway Right-of-Way, in Glacier National Park, June 1982

Plant Species	Occurrences (% of plots)	Mean Abundance
Equisetum pratense	4	4.0
Lycopodium annotinum	4	2.0
Lycopodium complanatum	4	1.5
Athyrium filix-femina	4	4.0
Dryopteris spp.	13	2.5
Gymnocarpium dryopteris	38	3.8
Thuja plicata	92	2.5
Abies lasiocarpa	79	1.7
Picea engelmannii	35	1.5
Pinus albicaulis ***	38	1.6
Pseudotsuga menziesii	6	1.0
Tsuga spp.	100	2.9
Taxus brevifolia	31	1.5
Acer glabrum	13	1.3
Aralia nudicaulus	19	3.0
Oplopanax horridus	13	3.3
Achillea millefolium	2	2.0
Arnica spp.	2	3.0
Asteraceae (unidentified)	2	1.0
Alnus spp.	6	2.3
Betula papyrifera	4	1.0
Linnaea borealis	33	3.4
Lonicera involucrata	8	1.5
Lonicera utahensis	25	1.9
Viburnum edule	2	1.0
Pachistima myrsinites	77	3.4
Cornus canadensis	50	3.7
Cornus stolonifera	19	3.2
Chimaphila umbellata	44	2.2
Menziesia ferruginea	42	2.9
Moneses uniflora	2	3.0
Pyrola asariflora	15	2.7
Pyrola spp.	25	2.8
Vaccinium membranaceum	50	2.8
Vaccinium ovalifolium	10	2.6
Vaccinium spp.	8	1.3
Ribes lacustre	6	3.0
Ribes laxiflorum	6	2.3
Clintonia uniflora	50	3.6
Smilacina racemosa	8	2.5
Smilacina stellata	29	2.0
Streptopus amplexifolius	8	2.3
Streptopus roseus	48	2.5
Epilobium angustifolium	8	1.5
Goodyera oblongifolia	33	2.4
Listera spp.	2	2.0
Poaceae (unidentified)	4	4.0
Actaea rubra	6	1.7
Amelanchier alnifolia	2	2.0

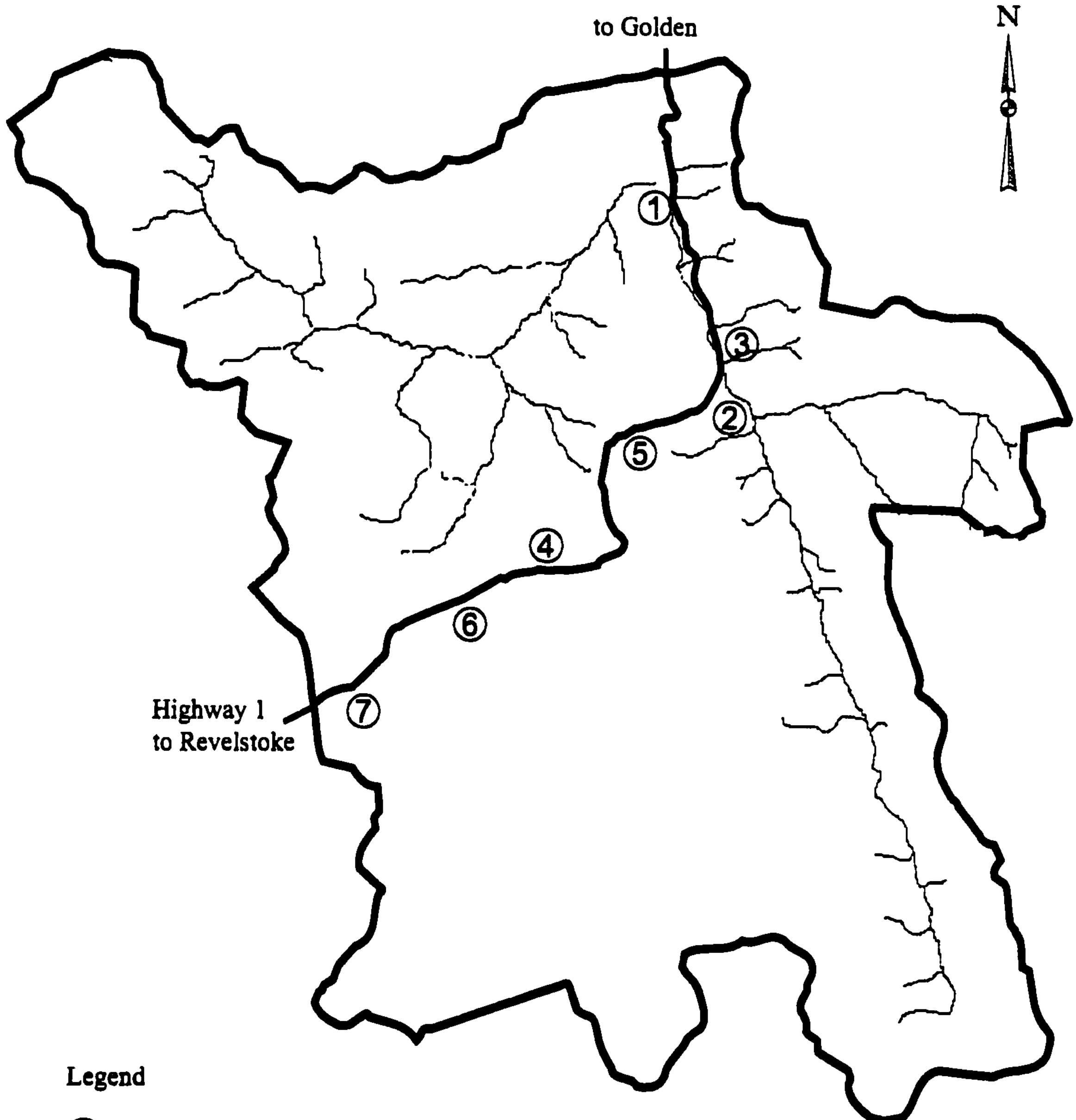
Table 1.3: Frequency and Relative Abundance of Plant Species Identified in Sample Plots Along the New Proposed Railway Right-of-Way, in Glacier National Park, June 1982 continued-

Plant Species	Occurrences (% of plots)	Mean Abundance
Aruncus sylvester	15	2.0
Rubus idaeus	4	1.5
Rubus parviflorus	29	2.5
Rubus pedatus	4	2.0
Spirea betulifolia	23	2.6
Spirea spp.	19	2.0
Galium triflorum	10	2.8
Salix spp.	6	1.7
Tiarella unifoliata	35	2.9
Pedicularis racemosa	6	2.3
Viola glabella	17	3.4

*** *Pinus monticola* was probably mistaken for *Pinus albicaulis*

Mean abundance is the average of abundance ratings in all occurrences where 1-3 plants = 1, 4-10 = 2, 11-20 = 3 and more than 20 = 4.

Adapted from MacLaren PlanSearch, Vegetation and Wildlife along Surface Route Prior to Clearing June 1982 Rogers Pass Project.



Legend

① Beaver Valley
② East Portal
③ Beaver Camp
④ Glacier Station
⑤ Ventilation Shaft
⑥ West Portal
⑦ Flat Creek Camp

Figure 1: Location of Study Sites in Glacier National Park, B.C.
Map is not to scale.

II. PLANT COMMUNITY STRUCTURE ON SUBALPINE SITES 10 YEARS AFTER RECLAMATION

2.1 Introduction

Few studies have documented the recovery phases of disturbed subalpine ecosystems particularly on reclaimed sites that used introduced or agronomic species where the final goal is for a native plant community to reestablish. The importance of such studies are clear given the land use conflicts apparent within national parks concerning conservation and development. Canada's National Parks Act (revised 1988) states that national parks must be managed on the basis of maintaining each park's ecological integrity (Canadian Heritage Parks Canada, 1995). Natural areas within national parks have assumed great importance as preserves for wild populations at the same time that human use and disturbance within parks has increased. Once predictions about the effects of human impacts are possible, they can be used to help prevent or mitigate the loss of ecological integrity (Baron, 1992).

Studies on the role of introduced species in the successional development of disturbed sites indicate a common conclusion. First, even if seeding mixtures contain only small proportions of introduced species, later plant communities can be dominated by those species (Depuit and Coenenberg, 1979). So if the purpose of the reclamation is to restore the land to a native plant community, then the planting of agronomic species that provide rapid competitive cover is not the best approach as it will inhibit the invasion of native species (Munshower, 1994).

Introduced species are often agronomic which are selected and bred for specific agricultural purposes such as forage, hay or cover crops (Bell and Meidinger, 1977 as cited in Van Zalingen, 1987). These species can compete vigorously with native plants as well as exploit anthropogenic disturbances because of their ease of establishment, their high above ground biomass production and their strong positive responses to fertilization. Where a plant canopy is removed high light intensity can favor the growth of introduced species over the original understory flora (Reader and Bricker, 1994; Parker et al., 1993).

Native species are those plants which occur naturally within a region and which are adapted to local climates and habitats (Bell and Meidinger, 1977 as cited in Van Zalingen, 1987). Native regeneration will be delayed by the presence of a herbaceous community (Hawk, 1973 as cited in Van Zalingen, 1987; Skousen et al., 1994) but eventually their invasion will occur on any site which was seeded to agronomic species. An established plant cover has an inhibitory effect on the invasion of a site by new plants and this is more strongly expressed if the disturbance has an arid climate (Munshower, 1994). In cool mountain climates growth of highly productive grass species creates a buildup of dead plant matter on the soil surface because the rate of decomposition of organic matter is slow. While some litter is beneficial, an excessive amount may hinder the invasion of native species (David Walker and Associates

Limited, 1983). Other factors which influence the invasion of native plants are coarse fragments, aspect, distance from the nearest upwind seed source, alfalfa cover and slope (Van Zalingen, 1987).

The reduction of native invasion by the introduced species on a disturbed site supports the inhibition theory of succession. It is a theory that emphasizes competition. No species is competitively superior to another. The site belongs to those species that become established first and are able to hold their position against invaders. As long as they live, they maintain their position. The ultimate winners are the long lived plants even though early successional species may suppress later stage species for a long time (Connell and Slayter, 1977).

2.2 Objectives

The objectives of this study were:

1) To examine the existing plant community composition on reclaimed sites and adjacent areas to determine the patterns of vegetation recovery 10 years after an anthropogenic disturbance.

2) To determine the amount of invasion that has occurred on and off the reclaimed sites.

2.3 Hypotheses

Understanding the recovery of a plant community following an anthropogenic disturbance is possible through detailed measurements. The following hypotheses will be tested:

Ha_1: The abundance of native vegetation will increase as one moves away from the center of a disturbance to the undisturbed edge.

Ha_2: The species richness of native vegetation will increase as one moves away from the center of a disturbance to the undisturbed edge.

The assumption for this study is that site conditions change from the center of the disturbance outward to the edge of the disturbance as a gradient. Along the environmental gradient the highest level of invasion will occur at the forest edge where microclimatic conditions are modified the most and where a relatively undisturbed seed bank existed at the time of disturbance. Since the area was seeded with a mix of non-native species, native plant invasion is defined as the proportion of naturalized species that have established on the site.

Assessments of revegetated sites over long periods of time will significantly increase the understanding of the processes which occur on reclaimed sites (Polster

Environmental Services, 1990). Detailed measurement of species composition in the study sites will satisfy the objectives of the study. It will provide an understanding of plant community development in a subalpine forest ecosystem 10 years after disturbance.

The value of analyzing the reclamation work of the Rogers Pass Project is that information was collected prior to and after disturbance. Analysis will provide information about the recovery processes as well as determine the effects of disturbance on adjacent undisturbed forest communities.

2.4 Materials and Methods

2.4.1 Description of Sites

An overview of the plant ecology, soils and climate is provided in Chapter 1 while specific site characteristics are provided in the following sections. See Figure 1.1 in Chapter 1 for the locations of the sites within Glacier National Park.

2.4.1.1 Site 1: The Beaver Valley

The Beaver Valley site involves the twinning of the railway from the northeast entrance of the park to the entrance of the Shaughnessy tunnel. The disturbed area is 11.4 km in length and is uniform in its environmental characteristics primarily because of the recontouring of the slopes for reclamation purposes. The railway cuts across the slopes of Mt. Hermit, Mt. Shaughnessy and Mt. Tupper and is continuously east facing. The slopes range from 30 to 70% and lie between 1000 to 1500 in elevation.

The cut and fill slopes largely border standing mature forest in the ICH C49 and C52 plant communities except for when they intercept eight creeks, several avalanche slopes and a forest fire site. These areas were omitted from the sampling to maintain a relative homogeneity across the sampled blocks.

The cut and fill slopes range from 3 to 200 metres in length. A number of trestles and retaining walls occur along the course of the rail line where it was too steep to try to cut and fill the slopes. In addition, 1 km of the rail line at the south end of the Beaver Valley was built upon a viaduct because at this point the disturbance comes within 500 m of the TransCanada highway and cuts and fills on the steep slopes would have been extremely visible.

2.4.1.2 Site 2: East Portal

The east portal lies south of the Shaughnessy Tunnel, north of the entrance to the Macdonald tunnel and immediately adjacent to the east entrance to the Rogers Pass. It involved the reclamation of an access road and cut and fill slopes for the 800 m of railway that occurs between the two tunnels. The slopes are primarily east facing with the slopes at the top of the access road being north facing. The slopes range in steepness from 15 to 70%.

2.4.1.3 Site 3: Beaver Camp

Beaver camp also occurs in the Beaver Valley and was the location of a work camp for over 400 individuals. One sampling block covered the entire area The site is flat with no aspect. Although CP Rail was required to reclaim it, it remains a helicopter staging site for Glacier Park operations and is in a state of ongoing disturbance. Thus, it would not be appropriate to apply the Parks/CP Rail reclamation criteria to the site. Nevertheless, it is important to be aware of the current vegetation growing on the site.

2.4.1.4 Site 4: Glacier Station

Glacier Station is at the west end of the Rogers Pass 4 km from the Parks compound. It is the past site of an old rail station and the present site of a permanent camp for CP Rail workers. Reclamation maps show the disturbance from the Rogers Pass project to extend for 400 m on either side of the entrance road from the TransCanada highway. Examination of the site shows continual disturbance particularly on the east side of the entrance road due to vehicular traffic in and out of the camp.

2.4.1.5 Site 5: Ventilation Shaft

The Ventilation Shaft facilitates the release of exhaust from trains within the Mt. Madonald tunnel. It occurs 1.5 km west of the Rogers Pass Compound off the TransCanada highway. The disturbance involved the upgrading of an access road up to the Ventilation Shaft. The distance from the start of the reclamation at the edge of the road to the undisturbed forest was an average of about 10 m. The slopes range in steepness from 25% to 40%.

2.4.1.6 Site 6: West Portal

The West Portal lies against the Illecillewaet River 7 km west of the Parks compound immediately adjacent to the TransCanada highway where the Macdonald tunnel ends on the west side of the Rogers Pass. The disturbance occurs on both north and south sides of the highway.

2.4.2 Experimental Design

A systematic random strip plot design was used to intensively sample each of the six sites (Petersen, 1985). This type of design was necessary in order to place the plots into locations along the disturbance that might potentially influence the plant community. With this design, confounding effects were eliminated. Further explanation is provided in section 2.4.3.

2.4.3 Field Sampling

Preliminary sampling was conducted July 10-30 1996 to develop appropriate field sampling methods. A walkthrough was conducted on each of the six disturbed sites (Beaver Valley, Beaver Camp, East Portal, Ventilation Shaft, Glacier Station and the West Portal) and general plant communities were mapped. The plant communities were measured in metric to determine the average size of intracommunity variation and to determine the amount of variation that typically occurred for species diversity. A botanist assisted with the initial plant identification. Flora of Alberta, Flora of the Pacific Northwest, Prairie Grasses Identified and Described by Vegetative Characteristics and Plants of Southern Interior British Columbia were used to classify unknown species (Moss, 1983; Hitchcock and Cronquist, 1973; Looman, 1982; Parish, Coupe and Lloyd, 1996).

As a result of this sampling the methods were developed. The six sites were divided into 200 m long blocks and one third of the blocks in each site were randomly selected and assumed to be representative of that site. The widths of the blocks varied because the shape of the disturbances varied. Highly variable areas with observable evidence of a factor with large influence on the site (creeks, avalanche tracks) were omitted from the sampling. The 200 m long blocks provide an appropriate size within which normal intracommunity variation could be expected between shrub dominant, shrub/herb codominant and the herb dominant microsites that were unmappable because they occur over small areas.

Within each block seven transects were laid perpendicular to the center line of the disturbance. The disturbances were primarily linear and included roads, areas around buildings, railways and camps. These transects were spaced 25 m apart. The transects started at the edge of the disturbance where reclamation begins. At this point a quadrat was taken at 0 m and then the subsequent quadrats were placed at 5 m intervals along the transect which spanned the width of the disturbance (Figure 2.1 and Figure 2.2). The long side of the quadrats were laid against the transect line to maintain sampling consistency. If an adjacent undisturbed area existed beyond the transect then one quadrat was sampled in this undisturbed area at the end of each transect. The six sites varied in steepness and aspect. This information was recorded for each transect measured (Table 2.1). Studies by Moran (1984) and Parkesit, Larson and Matthes-Sears (1994) influenced the sampling design.

The sampling was designed to include more replicates of smaller quadrats rather than fewer replicates of large quadrats. Replicates of smaller quadrats would give a more reliable community mean than a single quadrat three times the size because they average over large scale as well as small scale variation (Watkins and Wilson, 1993)

One tenth m^2 quadrats (20 x 50cm) were used to record the herbaceous layer and 0.5 m^2 quadrats (50 x 100cm) were used for the shrub and tree layer (Kent and Coker, 1992). The herbaceous and shrub quadrats were sampled at the same location on the transects.

Species composition was recorded for each quadrat. Both species abundance and species richness were measured. Within this study, species abundance refers to the number of individual plants that were counted for each species within a quadrat. Species richness refers to the total number of species within a quadrat. Despite the number of plants that occur for a given species, its appearance within a quadrat is valued as 1 whereas its absence is valued as zero for species richness.

Tillered plants were counted as an individual unit not as individual stems because the goal of the sampling was to provide a picture of relative dominance of species rather than to provide exact quantities of biomass. A plant must be rooted within the quadrat to be counted. Only vascular plants were recorded because of the difficulty of counting individual plants in the mosses and lichen families and because their occurrence on the disturbed sites was less than 1% as determined in the preliminary sampling. The canopy cover percentage estimations indicate whether moss and lichens were present within a quadrat.

Table 2.1 displays a comprehensive list of the plants found within sampled areas and the corresponding acronym that is derived from the first two letters of the genus and the first two letters of the species of the plant. The strata column identifies the groups that the species were placed in for the purposes of univariate analysis. 119 taxa were identified. Specimens not identified were listed by genus.

Initially, the distance perpendicular to the disturbance was to be measured to determine if there was a change in the plant community structure outwards from the disturbance; however, the disturbances vary in width. After the preliminary sampling it was determined that analysis done this way would be confounding because the transects were different lengths and so quadrats that were the same distance from the disturbance would be affected differently by features on the slope. Thus, distance was not used as a measure of variation.

The relative distances along the transect were identified as possibly having different site conditions which would produce variation in the plant community: 1) the reclamation edge which occurs adjacent to the main disturbance area, 2) the middle portion of the site that occurs between the edge of the forest and the starting edge of the undisturbed forest (this would be the mesic position on a slope), 3) the forest edge up to 5 m from the adjacent undisturbed forest 4) and the adjacent undisturbed forest (Figure 2.2). Since these locations occurred across transects the sampling design could be considered a strip plot design.

The influence of site conditions at the reclamation edge would come from ongoing disturbance on the site or from the drainage ditches built immediately adjacent to the road or railway. The effects of site conditions for this location were determined to have an influence up to 5 m away. Thus one quadrat on every transect was put into this category. The forest edge was believed to have a potential effect on the plant community since the microclimate would change due to the influence of mature standing timber. In addition, it may contain an undisturbed native seed bank. Observable plant changes occurred in the first 5 m from the undisturbed forest and so one quadrat on every transect was put into this category. Sampling the adjacent forested areas was limited to the understory vegetation and was limited to one quadrat because on an observational level it was clear that not much invasion had occurred. Although not part of the disturbed plant community, this sampling would provide quantitative data on how much invasion had occurred off the reclamation sites into undisturbed areas.

Species composition was conducted at every quadrat at every site. However, because the sites varied in the nature of their disturbance, the transects were laid out and sampled somewhat differently to maintain homogeneity among the sample sites (Table 2.2).

2.4.4 Data Analyses

Univariate statistical analysis was used to test two hypotheses: first, native species abundance varied among location categories along the transect which was placed perpendicular to the center of the disturbance and second, native species richness varied among the same location categories.

The species composition data were placed into 5 vegetation groups for the purposes of univariate analysis: Seed Mix, Introduced, Planted, Native and Natural. Seed Mix refers to the grass and legume species which were part of the original seed mix. Introduced refers to all plants that were not part of the seed mix which are not found naturally on the site. These plants may include weeds which invaded the site or were contaminants of the seed mix. Planted refers to the trees and shrub species which were planted on site. Since no permanent plots were set up at the time of reclamation it is recognized that some of the planted species found on the site established through other means. Native refers to the native herbaceous plants which have either invaded or been part of a seed bank. Natural refers to shrubs and trees that established naturally on the site and were not species that had been planted on the sites (i.e. invaded).

The data were analyzed with SPSS version 7.5 (SPSS Inc., 1997). While species richness was analyzed in its original form as counts, total counts for species abundance in each vegetation group were converted into a proportion or percentage of each quadrat. This standardized the measurement of a variety of plant types. Plots with no vegetation were eliminated from the analysis because they did not provide any data on relative plant abundance. Their elimination had no impact on the results since relative plant dominance was being examined. The exploratory analysis included normal probability plots, the Kolmogorov-Smirnov statistic and the Shapiro Wilk

Statistic. The Kolmogorov-Smirnov statistic with a Lilliefors significance level was used for the sites with greater than 50 quadrats. The Shapiro Wilk statistic was used for the sites with less than 50 quadrats. All of these tests indicated that the vegetation groups did not have normal distributions for any of the study sites. The Levene Test and residual plots indicated that in some cases homogeneity of variance did not occur.

Several different transformations including arcsin of the square root, log10 and loglinear were used to stabilize the variance of the dependent variables for all of the independent variables, to normalize the dependent variables so that observed values cluster around the expected values on the straight line of the normal probability plots and to improve the normal distribution of the dependent variables for all of the independent variables. The normality and homogeneity of variance tests indicate that no substantial improvements occurred except with the loglinear transformation. Although the loglinear transformation was powerful enough to normalize the distribution and improve the homogeneity of variance, it changed values of 0 into no values which severely limited the number of samples and in some cases prevented ANOVAs from being generated.

Comparison of ANOVAs for both transformed and untransformed data showed that overall the significance levels remained the same. Differences only occurred when pairwise comparisons were executed and then only cases which were border line significant or non significant were affected. Since the F-test is fairly robust, it is not largely affected by errors which are not normally distributed particularly where large sample sizes occur and the null hypothesis is false (Horton, 1978). Therefore, the data were analyzed in their untransformed form.

Initially, GLM General Factorial ANOVAs were run with a custom model which included Site, Block (Site), Transect (Block (Site)), Location and Location by Site. Block was nested within Site and Transect was nested within Block. Each location (start of reclamation, middle/mesic area, forest edge and undisturbed forest) was compared among sites to determine if there were differences in the vegetation groups. For example, the abundance of native herbaceous vegetation of location 1 was compared with each of the other sites.

All vegetation groups in all locations had significant differences for both abundance and richness among sites and consequently GLM General Factorial ANOVAs were run on a site by site basis. The model was altered slightly to: Block, Transect (Block), Location and Location by Block. Location was the variable tested and Location by Block was the error term. Because the design was unbalanced with more quadrats sampled in the middle/mesic location, Type III Sum of Squares was used.

Post hoc or multiple comparisons were used to determine which pairs of means were significantly different from one another. The Least Square Means method was performed wherever the significance level was 0.1 or less.

2.5 Results and Discussion

Table 2.4 provides the summary statistics on the observed means, standard error and significance of the species abundance of vegetation groups within and among locations for each site. Table 2.5 provides the summary statistics on the observed means, standard error and significance of the species richness of vegetation groups within and among locations for each site.

2.5.1 Site 1: Beaver Valley

Site 1 is an 11 km linear disturbance. Recontouring has given the site a uniformity which is rare in natural conditions.

2.5.1.1 Species Abundance

Aggressive agronomic species in the seed mix continued to dominate locations 1 and 2 which may have a microclimate suited to the establishment of these plants. In comparison to an adjacent forested area, clearings would be expected to recieve more direct solar radiation and precipitation, lose more outgoing long-wave radiation and show higher rates of evapotranspiration (Chen et al., 1993). Analyzing location effects on vegetation data within Site 1 with multiple comparisons indicated that significant differences for the abundance of the seed mix occur between each pair of locations except between location 1 and 3 (Table 2.6a).

Little invasion of introduced species occurred on the site in any location. Weed species, in particular, which are included in this category may have had higher abundance when the site was first disturbed but since that time have been outcompeted by the agronomic species in the seed mix. No introduced species were found in the undisturbed forest. Multiple comparisons indicate that the only significant differences occurred between locations 2 and 4. A comparison of means showed that the number of introduced species on the site was very low.

Both the original planting plan and subsequent survival rates affected the occurrence of the woody planted species along the transects. To minimize future maintenance, CP Rail did not plant woody species immediately adjacent to the rail line (Polster, 1996). However, a comparison of means showed that a large proportion of the vegetation in location 1 included planted woody species. These plants volunteered from adjacent areas which were planted. The properties of the area immediately adjacent to the rail line have to be identified to determine why it provides a good microsite for the establishment of woody species. Some possible factors include increased soil disturbance, submesic soil moisture conditions in adjacent railside drainages (Revel et al., 1984) and reduced competition from the seed mix.

There appears to be a relationship between the forest edge and the invasion of native herbaceous vegetation. Species abundance of native herbaceous vegetation was significantly different between location 3 and all other locations. In addition, the greatest proportional abundance for native herbaceous vegetation on the disturbance was in location 3 with a value of 0.1351 out of 1.

Natural invasion by native woody species may not occur as readily as that of native herbaceous vegetation onto a disturbed site. An ANOVA of species abundance for natural woody species indicated that significant differences only occurred between location 4 and all other locations. At the same time, a comparison of means may also explain why so little invasion occurred on the site. The means indicate that natural woody species do not comprise a large component of the abundance in any of the locations.

2.5.1.2 Species Richness

It appears that more seeded agronomic species established in locations 1 and 2 which would be influenced less by the microclimatic conditions derived from the undisturbed forest. The effect of the forest on most climatic parameters rarely extends more than two to three times the height of adjacent trees (Johnston et al. in Revel, 1984). Analyzing location effects on species richness of the seed mix on Site 1 indicated that significant differences occurred between each paired relationship except between location 1 and 2 (Table 2.6b). Comparison of means also indicated that the highest number of seeded species of the seed mix occurred in locations 1 and 2 (Table 2.5).

The number of introduced species on the site was extremely low and only 3% of the quadrats for the entire site contained species from this category. No species in this group were found in location 4. Similar to the situation with introduced species abundance, richness was not significantly different among the location categories except for location 4 versus locations 1 and 2.

The original planting plan, the ability of the planted woody species to compete with the species in the seed mix may help to explain the distribution of the planted woody species along the transect. A comparison of means indicated that the greatest number of planted species occurred within locations 1 and 3. Significant differences occur among all locations except locations 2 and 4 where competition with the seed mix was high and planting did not occur, respectively.

The greatest number of native herbaceous species in the disturbed area occurred on location 3 which suggests that the occurrence of a forest edge may improve the native biodiversity of a disturbed area. ANOVAs for native herbaceous species richness indicated that no significant differences occurred between locations 1 and 2 where the seed mix predominated.

Very little establishment of natural woody species occurred on the site. This could be a result of low proportions in the adjacent undisturbed forest. Significant differences occurred among all locations except 1 and 2 where the seed mix predominates. A comparison of means indicates that the greatest richness of natural woody species occurred in location 4 (0.6436) followed by location 3 (0.2938). On average only one species of natural shrub or tree might occur in these locations.

2.5.2 Site 2: East Portal

Site 2 is an irregularly shaped disturbance which included both a rail line and an access road onto the site. Lengthy transects (over 150 m) were sampled on the west side of the disturbance. A low ratio of forest edge to disturbed area occurred.

2.5.2.1 Species Abundance

Findings were similar to those in site 1 for abundance of seed mix, introduced species, native herbs and natural woody species.

Significant differences occurred between locations for seed mix abundance except between locations 1 and 2 and 3 and 4 (Table 2.7a). A comparison of means indicated that the seed mix dominates locations 1 (0.7155) and 2 (0.8964). A lower proportion of species from the seed mix occurred in locations 3 and 4.

No significant differences occurred among the locations for the abundance of introduced species. Weeds, which comprised the majority of the introduced species category, may have been more prevalent but have since been outcompeted by the agronomic species in the seed mix. The average abundance of introduced species for all the locations combined was 0.0018.

Survival rates appeared to be low at site 2 for planted woody species. No significant differences occurred among the locations for the abundance of planted species. At the same time, the relative mean abundance of locations in site 2 ranged from 0.0281 to 0.1263 which were lower than those for other sites.

Analysis of the existing plant community structure at site 2 supported the theory that invasion of native herbaceous vegetation will have a higher occurrence at the forest edge. Multiple comparisons indicated that significant differences for the abundance of native herbaceous vegetation occurred among most locations except between locations 1 and 2, and 3 and 4. The highest mean occurred at location 3 (0.5862).

Overall abundance of natural woody species was low for all locations. The only significant difference occurred between locations 2 and 3. Invasion into the disturbance may not be highly probable because of the low occurrence of natural woody species in the adjacent undisturbed area (0.0166).

2.5.2.2 Species Richness

The greatest number of species from the seed mix occured in location 2 (3.4206). ANOVAs indicated that significant differences occurred between location 4 and all of the other locations as well as between locations 1 and 2 (Table 2.7b).

Competition from the seed mix remained too high for species in the introduced group to establish on site 2. The means ranged from 0.0313 (location 3) to 0.2059 (location 1) and significant differences occurred only between these two locations. In addition, the higher value in location 1 could be related to the continual disturbance along the road within site 2.

A low number of planted woody species occurred in all locations in site 2. This could be a reflection of the original planting plan and the survival of the species. Although there are significant differences between locations 1 and 3 they are not noteworthy since a comparison of means showed that all the locations had a value of less than 1.

An examination of the species richness means for native herbaceous vegetation indicated that diversity was greatest in location 4 (2.1765) followed by location 3 (0.8437). A model where invasion occurred outward from the undisturbed forest suggested that after location 3 the next highest species diversity would occur in location 2. However a comparison of means showed that species richness was higher in location 1 than 2. This suggested that other factors in combination with location determine the invasion of native herbaceous vegetation. Significant differences occurred among all locations except between locations 1 and 2.

The occurrence of natural woody species was very low with the mean less than 1 for every location. Species within the natural woody species grouping do not occur frequently within and on the edges of undisturbed forests and this may reduce invasion. The only significant differences occurred between locations 2 and 4.

2.5.3 Site 3: Beaver Camp

Site 3 is a small disturbance which is a little over a hectare in size. It is continually being disturbed by human activity. Findings for Site 3 differ slightly from those of other sites. Summary statistics for abundance are in Table 2.4 and for richness in Table 2.5.

2.5.3.1 Species Abundance

A comparison of means suggested that the seed mix was less abundanct in Site 3 than other sites. This is likely due to the continual disturbance of the site. The only significant differences occurred between location 4 (in the undisturbed forest) and all other sites (Table 2.8a).

The ongoing disturbance of site 3 created an environment for the successful establishment of introduced species compared to sites 1 and 2. Locations 2 (0.2154) and 3 (0.3565) have supported large abundance. Significant differences occurred between locations 1 and 3, 2 and 4, and 3 and 4. The proportion of introduced species for location 4 was the lowest and this suggests invasion did not occur from the disturbed site into the adjacent undisturbed forest.

Only in location 4 do planted woody species occur in any large abundance and it is the only location which is significantly different from the others.

Continual disturbance and the low abundance of native herbaceous species in the adjacent undisturbed and forest edge may explain why little invasion occurred onto site 3. ANOVAs indicated that no significant differences for the abundance of native herbaceous vegetation occurred among the locations.

No invasion of natural woody species has occurred onto site 3. No natural woody species were found in locations 1, 2 and 3 and resulted in location 4 having significant differences from all other locations. Factors which may have affected the invasion of natural woody species is that the site continues to be disturbed and competition may be too high.

2.5.3.2 Species Richness

The ongoing disturbance of site 3 enabled species in the seed mix to establish in locations 1, 2 and 3 with no significant differences among these locations. Invasion of the seed mix into the undisturbed forest did not occur and so there were significant differences occur among location 4 and all other locations (Table 2.8b).

Introduced species grew vigorously on site 3 which was in a continual state of disturbance due to human activity. Significant differences only occurred between location 4 and all other sites.

Planted woody species had poor survival on site 3 probably due to the high competition from the seed mix and introduced groups. Significant differences occurred between locations 1 and 2 and locations 1 and 3. Location 1 had the highest mean for species richness. The edge of the reclamation possibly had less competition from the seed mix and thus the planted species were able to establish.

Species diversity of native herbaceous vegetation was low for all locations. The low mean richness for locations 3 (0.5714) and 4 (0.2857) may explain why native herbaceous species have not invaded onto the site. In addition, high competition from the seed mix and introduced species probably reduced the invasion rate of native herbaceous plants.

No invasion of natural woody species occurred on site 3 from location 4. No species were found in locations 1, 2 and 3 and so significant differences occur with location 4 and all the other locations. Since the mean of location 4 is less than 1 (0.5714), the biodiversity of natural woody species may have been naturally limited and so this would affect the number of species that could invade onto the disturbed site.

2.5.4 Site 4: Glacier Station

Portions of site 4 were continually disturbed by vehicular traffic. Since the site was not adjacent to an undisturbed area, only the start of the reclamation and the middle/mesic locations occur here as treatments.

2.5.4.1 Species Abundance

ANOVAs for all the vegetation groups showed no significant differences between locations 1 and 2. The most interesting element is that the proportion of native herbaceous vegetation was high for locations 1 (0.2470) and 2 (0.2580). Block 3 within site 4 differed dramatically in species composition, slope and aspect from blocks 1 and 2. A positive correlation between high native herbaceous abundance and northeast slopes needs further study.

2.5.4.2 Species Richness

Similar to species abundance no significant differences occurred between locations 1 and 2 for any of the vegetation groups. The absence of an undisturbed area immediately adjacent to site 4 may have made the diversity of species more uniform across the site because a source for invasion and the effects of a forest edge microclimate were both eliminated.

2.5.5 Site 5: Ventilation Shaft

Site 5 is a disturbance along the edge of an upgraded road. Transects were short and on average location 1 was never greater than 10 m from the undisturbed forest. The transects ran across drainage ditches which means that in many cases the moisture level was higher than for other sites. It is possible that these factors in combination with location may have influenced the plant community structure.

2.5.5.1 Species Abundance

The abundance of the seed mix was high for all locations in the disturbance and ANOVAs show significant differences only occurred among location 4 and the other locations (Table 2.9a).

No significant differences occurred for the abundance of introduced species for any of the locations and a comparison of the means showed that the proportion of introduced species that comprised the totals for the quadrats was extremely small.

The original planting plan as indicated on the reclamation maps and seedling survival influenced the abundance of planted woody species. No significant differences occurred among the locations.

The shortness of the transects and the hygric nature of the drainage areas appear to have affected the abundance of native herbaceous vegetation. Significant differences among location 4 and all other sites occurred as well as differences between locations 1 and 2. A comparison of means indicated that the highest abundance on the disturbed area was in location 2 (0.4036). The high edge to area ratio of the disturbed sited may have increased native herbaceous plant invasion. The plant community structure of site 5 appears to be the most advanced in the successional move towards a natural plant community.

Overall abundance of natural woody species was very low for site 5 and this may help explain why little invasion occurred on the site. Significant differences only occurred between location 4 and the other locations. There are no significant differences among the locations in the disturbed area.

2.5.5.2 Species Richness

Significant differences in the seeded species richness occurred between location 1 and all other locations and between location 4 and all other locations (Table 2.9b). It appears that the edge of the road where the reclamation started provides the best conditions for the continued survival of different seeded species.

The number of introduced species which occurred on any of the locations was low. The abundance means ranged from 0.000 to 0.1136 and no significant differences occurred among any of the locations.

The original planting plan and subsequent survival would affect the occurrence of planted woody species along the transects. The only significant differences occurred between locations 1 and 4.

The diversity of native herbaceous vegetation was not significantly different among any of the locations. However means were higher than for other sites which suggests that although no differences in invasion were occurring among locations, invasion was high overall for the site.

Species richness of natural woody species was low for all locations in site 5. The low mean for location 4 (0.5714) suggested that this site did not contain a high number of natural woody species prior to disturbance and so this would be a factor in the low invasion onto the site.

2.5.6 Site 6: West Portal

Site 6 is similar to site 4 in that only locations 1 and 2 occurred. No undisturbed area immediately adjacent to the site occurred and this simularity was reflected in the results of the ANOVAs for species abundance and species richness.

2.5.6.1 Species Abundance

The only significant differences for the vegetation groups was between the abundance of the seeded species on location 1 versus location 2. Part of this can be explained by the high survival of the planted species at the start of reclamation which reduced the ability of the seed mix to establish there. Location 1 occurs in a slight drainage ditch adjacent to a maintenance road in site 6 where high moisture accumulation could have allowed the native planted species to perform better against the seeded species.

2.5.6.2 Species Richness

Species diversity was uniform across locations 1 and 2 which may be partially due to the absence of an adjacent undisturbed area which would provide variations in microclimate and act as a seed source for native species. No significant differences occurred between locations 1 and 2 for the diversity of planted woody species and native herbaceous species. The original planting plan and the higher moisture level of location 1 could explain why these vegetation groups were able to compete with the seed mix. The higher number of native herbaceous plants which require moisture to establish such as *Equisetum pratense* and *Equisetum arvense* which were found in location 1 support this argument.

2.6 Overall Summary

Examination of species abundance and richness for the six sites indicated that overall the locations sampled on the disturbances were not significantly different. Significant differences were clear at Site 1 but not for the others (Figure 2.3). This can be attributed to the large differences in the types of disturbances examined. While Site 1 involved a right-of-way for a rail line, the other disturbances included roads and a former camp. In addition, it had a continuous and homogeneous slope throughout the area whereas the other sites had variable slopes. It is possible that if all sites tested had the same disturbance as Site 1 that the findings may have been more consistent. This is an important point since it emphasizes the need to tailor reclamation according to the type of disturbance involved. In addition, it is quite clear from the high standard errors relative to the means and trends in residual plots that other factors combined with location will influence the plant community composition. Location may be an important factor but it will be defined differently for every site depending upon its topographical and climatic characteristics.

The results support the hypothesis that native herbaceous invasion was higher at the forest edge in site 1. However site 3 had a higher relative abundance of native herbaceous vegetation across all the locations not just at the forest edge (Figure 2.4). Site 5 had the highest forest edge to disturbance area ratio and at the same time had the highest species abundance and richness means for native herbaceous vegetation for all sites (Figure 2.5). It appeared that at this site the microclimatic effects of the undisturbed forest would influence growth on all the locations because the transect lengths were so short. A broad literature survey of clearcutting concluded that the effect of the forest on most climatic parameters rarely extends horizontally more than two to three times the height of adjacent trees (Johnson et al., 1971 as cited in Revel et al., 1984) which may help to explain the differences in vegetation between long and short transects.

Species composition for abundance and richness of vegetation also provided an indication of the successional stage of the sites 10 years after disturbance. Abundance and richness means indicated that the agronomic species in the seed mix continued to dominate the present plant community. Introduced species including weeds are a small proportion of the overall plant communities in all of the sites apart from Site 3 which is being continually disturbed.

The density of planted woody species was greatest immediately adjacent to the rail line at some sites. Results indicated that the invasion of natural woody species was low for all sites. It is possible that different factors were involved in the invasion of natural woody species as compared to the invasion of native herbaceous species. Planting of some native woody species was successful in most areas and has facilitated the spread of these species on the site.

It is possible that low invasion from adjacent areas may be due to the nature of plant structure in those adjacent areas. Revel (1984) noted that in forested stands with heavy canopy cover competition, particularly for light, limits the number of understory plant species that can survive and hence the number of propagules that can potentially invade newly created seismic lines. The mature ICH forest is a classic example of a low light environment where ground cover is minimal or nonexistent and this type of forest bordered the majority of the study sites.

2.7 Recommendations

There is a common belief that the use of agronomic species to reclaim an area may be necessary because they are easily established, inexpensive and important in erosion control. If the end goal is to return the site to predisturbance conditions, several steps could be taken in the initial planning to increase the amount of native invasion that occurs on disturbed sites. The recommendations of this study support the findings of other research efforts.

Currently on the Rogers Pass sites the agronomic species, *Festuca rubra, Dactylis glomerata, Phleum pratense* and *Medicago sativa*, occurred most often in quadrats. Although believed to be short lived, these species are still thriving on the sites after 10 years. Further use of these species for reclamation of similar subalpine sites is not recommended.

Furthermore, to prevent agronomic species from dominating a site, alter the seed mix to include annuals which have low persistence as a cover crop. This would provide some immediate erosion control and would modify the microclimate to foster the establishment of native species. Aggressive and competitive species could be seeded at lower rates and this may increase the number of invading species because it reduces interspecific competition among plants by providing more open areas (Depuit et al., 1980). Lowering nitrogen rates in fertilizer and/or reducing the percentage of nitrogen fixing species in the seed mix such as *Medicago sativa* will reduce the vigor of the agronomic species and provide native species with a competitive edge since they have better establishment rates in nutrient deficient soils (Lovell, 1992).

The planting of native woody species onto a disturbed site may facilitate their establishment and spread in the face of competition from agronomic species. The shrubs *Alnus crispa, Populus balsamifera* and *Salix* spp. and the trees *Picea glauca* and *Thuja plicata* occurred most often in quadrats across the sites. These species should be targeted for planting projects in similar subalpine areas. In addition, planting islands of native vegetation may help to increase the rate of invasion for tree, shrub and herbaceous vegetation (Munshower, 1994).

A reclamation plan should be developed with ecoregional characteristics in mind but implemented on a site specific basis. This means that specific characteristics of a site may be used to encourage native plant establishment. For example, northeast aspects are cooler and more mesic than any other aspect and they may be a more suitable environment for the invasion of native species (Van Zalingen, 1987). Microclimatic differences on linear disturbances are most apparent on east-west lines. The northern edges of east-west lines are probably drier and warmer as a result of increased insolation than the southern edges (Revel, 1984).

A high forest edge to area ratio may influence native plant invasion particularly if an undisturbed area with suitable colonizing species is nearby. Prior to disturbance, layout of the disturbance area could maximize the edge to interior ratio which would increase native species invasion and diversity (Forman and Godron, 1981 as cited in Lovell, 1992). Some native herbaceous species which occurred most often in quadrats across the Rogers Pass sites may have a good competitive edge against agronomic species. *Anaphalis margaretaceae, Hieracium* spp., *Epilobium angustifolium* and

Equisetum spp. require further study of their competitive ability against introduced species on subalpine sites.

2.8 Conclusions

1) 10 years after reclamation the Rogers Pass Project sites continue to be dominated by the seeded agronomic species but native invasion is slowly taking place.

2) Native herbaceous vegetation is slowly invading onto the sites. On some sites this is occurring primarily at the forest edge. Areas with large edge to area ratio with adjacent undisturbed areas may have a higher component of native vegetation.

3) The higher proportion of planted woody species as opposed to natural woody species suggests that planting is a useful tool to establish woody species upon a site dominated by agronomic species.

4) An ongoing study of the sites, which should involve species composition sampling in five year intervals, would enable plant ecologists to understand the rate at which native species invasion occurs.

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Table 2.1: Vascular Plants Identified on the Rogers Pass Project Reclaimed Sites

Strata	Species	Acronym
Seed/Legume Mix	*Agropyron pectiniforme* R. and S.	AGPE
	Agropyron trachycaulum (Link) Malte	AGTR
	Agrostis gigantea Roth	AGAL
	Festuca rubra L.	FERU
	Festuca ovina L.	FEOV
	Medicago sativa L.	MESA
	Phleum pratense L.	PHPR
	Poa palustris L.	POPA
	Poa pratensis L.	POPR
	Trifolium hybridum L.	TRHY
Planted Trees/Shrubs	*Abies lasiocarpa* (Hook.) Nutt.	ABLA
	Alnus crispa (Ait.) Pursh	ALCR
	Cornus stolonifera Michx.	COST
	Picea glauca (Moench) Voss	PIGL
	Pinus contorta (Loudon)	PICO
	Populus balsamifera L.	POBA
	Pseudotsuga menziesii (Mirb.) Franco	PSME
	Rubus parviflorus Nutt.	RUPA
	Salix spp. L.	SALIX
	Thuja plicata Don ex d.	THPL
	Tsuga heterophylla (Raf.) Sarg.	TSHE
Introduced/Invaders	*Agoseris glauca* (Pursh) Raf.	AGGL
	Achillea millefolium L.	ACMI
	Cirsium arvense (L.) Scop.	CIAR
	Descurainia sophia Webb & Berthelot	DESO
	Leucantheum vulgare Lamarck	LEVU
	Chamomilla suaveolens (Pursh) Rydberg	MADI
	Melolitus alba Desr.	MEAL
	Medicago falcata L.	MEFA
	Plantago major L.	PLMA
	Stellaria media L. Cyrill	STME
	Stipa comata Trin. & Rupr.	STCO
	Taraxacum officianale Weber	TAOF
	Trifolium pratense L.	TRPR
	Trifolium repens L.	TRRE
	Urtica dioica L.	URDI
	weed spp. (unidentified)	weed spp.
	grass seedling (unidentified)	grass seedling
Native Herbaceous and Dwarf Shrub	*Actea rubra* L.	ACRU
	Agrostis scabra Willd.	AGSC
	Anaphalis margaretaceae (L.) Benth. & Hook.	ANMA
	Antenaria alpina (L.) Gaertn.	ANAL
	Aruncus dioicus (Walter) Fernald	ARDI
	Aralia nudicaulus L.	ARNU
	Aster spp. L. (unidentified)	*Aster* spp.
	Athyrium filix-femina (L.) Roth	ATFE
	Botychium virginianum L. Sw.	BOVI
	Bromus ciliatus L.	BRCI

Table 2.1: Species Sampled on the Rogers Pass Project Reclaimed Sites continued-

Strata	Species	Acronym
	Carex spp. L. (unidentified)	Carex spp.
	Castilleja miniata Dougl. ex Hook	CAMI
	Cerastium spp. L. (unidentified)	*Cerastium* spp.
	Chimaphila umbellata (L.) Bart.	CHUM
	Circaea alpina L.	CIAL
	Cornus canadensis L.	COCA
	Clintonia uniflora (Schult.) Kunth	CLUN
	Disporum hookerii (Torr.) Britt.	DIHO
	Elymus innovatus Beal	ELIN
	Epilobium angustifolium L.	EPAN
	Epilobium ciliatum Raf.	EPCI
	Equisetum arvense L.	EQAR
	Equisetum pratense Ehrh.	EQPR
	Erigeron speciosus (Lindl.) DC.	ERSP
	Fragaria virginiana Duchesne	FRVI
	Gaultheria ovatifolia A. Gray	GAOV
	Galium triflorum Michx.	GATR
	Geocaulon lividum Fern.	GELI
	Geum macrophyllum Willd.	GEMA
	Geum spp. L. (unidentified)	*Geum* spp.
	Goodyera oblongifolia Raf.	GOOB
	Gymnocarpium dryopteris (L.) Newm.	GYDR
	herb seedling (unidentified)	herb seedling
	Heracleum lanatum Michx.	HELA
	Hieracium albiflorum Hook.	HIAB
	Hieracium canadense Michx.	HICA
	Hieracium spp. L. (unidentified)	*Hieracium* spp.
	Koeleria macrantha (Ledeb.) J.A. Schultes f.	KOMA
	Linnaea borealis L.	LIBO
	Lolium perenne L.	LOPE
	Lycopodium selago L.	LYSE
	Lupinus arcticus S. Watson	LUPA
	Mimulus lewisii Pursh	MILE
	Mitella nuda L.	MINU
	Oplopanax horridum (Sm.) Miq.	OPHO
	Orthilia secunda (L.) House	ORSE
	Ozmorhiza chilensis Hook. & Arn.	OZCH
	Prunella vulgaris L.	PRVU
	Pyrola spp. L.	PYCI
	Rubus pedatus J.E. Smith	RUPE
	Senecio intergerrimus Nutt.	SEIN
	Senecio pseudareus Rydb.	SEPS
	Spirea betulifolia Pallas	SPBE
	Smilacina stellata (L.) Desf.	SMST
	Streptopus roseus Michx.	STRO
	Tiarella unifoliata Hook.	TIUN
	Vahlodea atropurpurea (Wahl.) Fries	VAAT
	Valeriana sitchensis Bong.	VASI
	Veronica americana (Raf.) Schw.	VEAM
	Vicea americana Muhl.	VIAM

Table 2.1: Species Sampled on the Rogers Pass Project Reclaimed Sites continued-

Strata	Species	Acronym
	Viola glabella Nutt.	VIGL
	Viola orbiculata Geyer ex Hook	VIOR
	Viola renifolia (A.Gray)	VIRE
	Viola spp. L.	*Viola* spp.
Native Trees/Shrubs	*Acer glabrum* Torr.	AGGL
	Amelanchier alnifolia Nutt.	AMAL
	Arctostaphylos uva-ursi (L.) Spreng	ARUV
	Lonicera involucrata (Richards.) Banks	LOIN
	Lonicera utahensis S. Wats.	LOUT
	Menziesii ferruginea J.E. Smith	MEFE
	Pachistima myrsinites (Pursh) Raf.	PAMY
	Pinus monticola Dougl. ex D. Don	PIMO
	Populus tremuloides Michx.	POTR
	Ribes lacustre (Persoon) Poiret	RILA
	Rubus idaeus L.	RUID
	Sambucus racemosa L.	SARA
	Sorbus scopulina Greene	SOSC
	Sorbus sitchensis Roemer	SOSI
	Taxus brevifolia Nutt.	TABR
	Vaccinium membranaceum Dougl. ex Hook.	VAME
	Vaccinium myrtilloides Michx.	VAMY
	Vaccinium ovalifolium J.E. Smith	VAOV
	Vaccinium spp. L. (unidentified)	*Vaccinium* spp.

This is a comprehensive list of the vascular plants found within sampled areas and the corresponding acronym that is derived from the first two letters of the genus and the species of the plant. The strata column identifies the group that the species was placed in for the purposes of data analysis. 119 taxa were identified.

Table 2.2: Specific Sampling Details on the Number of Blocks, the Total Number of Quadrats and the Quadrats Sampled at each Location for the Rogers Pass Project Sites

	Number of Blocks	Total Number of Quadrats	# Quadrats sampled in Location 1	# Quadrats sampled in Location 2	# Quadrats sampled in Location 3	# Quadrats sampled in Location 4
Beaver Valley	15	1081	188	580	163	149
East Portal	3	232	32	143	31	25
Beaver Camp	1	183	7	63	7	7
Glacier Station	3	110	22	89	not sampled	not sampled
Ventilation Shaft	3	79	21	18	20	21
West Portal	5	185	35	151	not sampled	not sampled

Location 1 is the start of reclamation.
Location 2 is the middle/mesic area.
Location 3 is the forest edge.
Location 4 is the undisturbed forest
Note that locations 3 and 4 were not sampled at Glacier Station and the West Portal because there was no undisturbed forest adjacent to the disturbances.

Table 2.3: Aspect and Slope Steepness for Sample Sites

Site	Block	Transect Position	Slope Angle	Slope Aspect
Beaver Valley	2	cut	22%	east
		fill	20%	west
	5	cut	75%	east
		fill	50%	west
	6	cut	0%	flat
		fill	0%	flat
	7	cut	0%	flat
		fill	40%	east
	8	cut	20%	flat
		fill	55%	east
	9	cut	70%	east
		fill	36%	east
	10	cut	85%	east
		fill	32%	east
	12	cut	50%	east
		fill	26%	east
	13	cut	85%	east
		fill	40%	east
	16	cut	100%	east
		fill	38%	east
	24	cut	100%	east
		fill	50%	east
	25	cut	55%	east
		fill	34%	east
	28	cut	0%	flat
		fill	40%	east
	41	n/a	80%	east
	46	n/a	80%	east
Beaver Camp	1	n/a	0%	flat
East Portal	2	above road	48%	northeast
		below road	18%	northeast
	3	above road	70%	west
			0%	flat
			60%	east
		below road	65%	east
	6	above road	48%	east
		below road	45%	northeast
Ventilation Shaft	1	n/a	22%	west
	4	n/a	55%	east
	8	n/a	40%	north
Glacier Station	1	n/a	0%	flat
	2	n/a	70%	south
	3	n/a	60%	north

Table 2.3: Aspect and Slope Steepness for Sample Sites continued-

Site	Block	Transect Position	Slope Angle	Slope Aspect
West Portal	2	n/a	18%	south
			0%	flat
	3	n/a	22%	south
			0%	flat
	4	n/a	22%	south
			0%	flat
	5	n/a	0%	flat
			75%	south
	9	n/a	60%	south
			20%	north

Table 2.4: Summary Statistics for Relative Plant Group Abundance for Sites 1 to 6 Including Proportional Means, Standard Error and Significance

Site 1 Beaver Valley	Location 1 Mean	Location 2 Mean	Location 3 Mean	Location 4 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	.7286	.8861	.6752	.0975	.028	.000
Introduced	.0031	.0061	.0016	.0000	.003	.087
Planted	.2506	.0742	.1567	.1444	.024	.000
Native	.0047	.0272	.1351	.6225	.027	.000
Natural	.0013	.0069	.0313	.1387	.024	.000

Site 2 East Portal	Location 1 Mean	Location 2 Mean	Location 3 Mean	Location 4 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	.7155	.8964	.2249	.3737	.088	.057
Introduced	.0348	.0159	.0147	.0064	.016	.348
Planted	.0727	.0736	.1263	.1542	.057	.454
Native	.1601	.0141	.5862	.4492	.091	.059
Natural	.0169	.0000	.0479	.0166	.021	.626

Site 3 Beaver Camp	Location 1 Mean	Location 2 Mean	Location 3 Mean	Location 4 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	.6995	.7200	.4438	.0952	.134	.001
Introduced	.0971	.2154	.3565	.0238	.070	.001
Planted	.0913	.0321	.0544	.4762	.113	.003
Native	.1120	.0326	.1452	.1429	.097	.630
Natural	.0000	.0000	.0000	.2619	.109	.294

Site 4 Glacier Station	Location 1 Mean	Location 2 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	.4599	.5095	.192	.121
Introduced	.2102	.1004	.230	.090
Planted	.0829	.0097	.164	.739
Native	.2470	.2580	.157	.897
Natural	.0000	.0323	.059	.423

Site 5 Ventilation Shaft	Location 1 Mean	Location 2 Mean	Location 3 Mean	Location 4 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	.6018	.4520	.5546	.1153	.105	.070
Introduced	.0060	.0078	.0192	.0000	.019	.499
Planted	.2104	.1321	.0569	.0514	.079	.058
Native	.1793	.4036	.3072	.6696	.086	.065
Natural	.0025	.0045	.0620	.1637	.057	.346

Site 6 West Portal	Location 1 Mean	Location 2 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	.4055	.7345	.257	.010
Introduced	.0366	.1267	.883	.054
Planted	.3060	.1183	.171	.853
Native	.2482	.0203	.235	.054
Natural	.0036	.0002	.014	.358

Location 1 is start of reclamation. Location 2 is the middle area. Location 3 is the forest edge. Location 4 is the undisturbed forest.

Σ of the proportional means for a given location = 1.00 or 100%

Table 2.5: Summary Statistics for Species Richness for Sites 1 to 6 including Mean Number of Species within a Plot, the Standard Error and Significance

Site 1 Beaver Valley	Location 1 Means	Location 2 Means	Location 3 Means	Location 4 Means	Std. Error For All Locations	Sig. For All Locations
Seed Mix	3.3351	3.3080	2.6289	0.3351	.123	.000
Introduced	0.0372	0.0422	0.0309	0.0000	.019	.069
Planted	1.6064	0.6718	1.1959	0.6170	.108	.000
Native	0.0487	0.1383	0.7474	2.1702	.112	.000
Natural	0.1649	0.0598	0.2938	0.6436	.055	.000

Site 2 East Portal	Location 1 Means	Location 2 Means	Location 3 Means	Location 4 Means	Std. Error For All Locations	Sig. For All Locations
Seed Mix	2.5294	3.4206	2.8750	0.4412	0.367	.000
Introduced	0.2059	0.0754	0.0313	0.0883	0.070	.179
Planted	0.4118	0.4428	0.9688	0.9118	0.261	.157
Native	0.3529	0.1283	0.8437	2.1765	0.229	.039
Natural	0.0588	0.0202	0.1250	0.1765	.079	.698

Site 3 Beaver Camp	Location 1 Mean	Location 2 Mean	Location 3 Mean	Location 4 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	2.4286	2.4719	2.1429	0.1429	0.523	0.001
Introduced	0.8571	0.9361	1.4286	0.1429	0.350	0.015
Planted	1.2857	0.3821	0.2857	0.8571	0.345	0.034
Native	0.5714	0.2578	0.5714	0.2857	0.298	0.577
Natural	0.0000	0.0000	0.0000	0.5714	0.210	0.031

Site 4 Glacier Station	Location 1 Mean	Location 2 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	1.4762	1.8330	0.710	0.158
Introduced	1.0714	0.5491	0.701	0.050
Planted	0.3810	0.3137	0.567	0.775
Native	0.8571	0.9592	0.672	0.055
Natural	0.0000	0.1429	0.196	0.423

Site 5 Ventilation Shaft	Location 1 Mean	Location 2 Mean	Location 3 Mean	Location 4 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	2.1905	1.4621	1.5500	0.3333	0.328	0.031
Introduced	0.0476	0.1136	0.0500	0.0000	0.083	0.353
Planted	0.9524	0.7879	0.5000	0.1905	0.317	0.159
Native	0.9524	1.8182	1.6000	1.7619	0.513	0.675
Natural	0.0476	0.0909	0.3500	0.5714	0.185	0.217

Site 6 West Portal	Location 1 Mean	Location 2 Mean	Std. Error For All Locations	Sig. For All Locations
Seed Mix	2.0078	2.9478	1.069	0.102
Introduced	0.2734	0.6888	0.391	0.099
Planted	1.5000	0.7821	0.692	0.004
Native	0.6094	0.1149	0.464	0.024
Natural	0.0625	0.0057	0.200	0.183

Location 1 is start of reclamation. Location 2 is the middle area. Location 3 is the forest edge. Location 4 is the undisturbed forest.

Σ of the proportional means for a given location = 1.00 or 100%

Table 2.6a: Multiple Comparisons of Locations for Plant Abundance Data for Site 1 The Beaver Valley

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.823	1	2	.787	1	2	.000	1	2	.411	1	2	.051
	3	.000		3	.735		3	.000		3	.000		3	.019
	4	.000		4	.048		4	.000		4	.000		4	.000
2	1	.823	2	1	.787	2	1	.000	2	1	.411	2	1	.051
	3	.000		3	.536		3	.000		3	.000		3	.000
	4	.000		4	.022		4	.603		4	.000		4	.000
3	1	.000	3	1	.735	3	1	.000	3	1	.000	3	1	.019
	2	.000		2	.536		2	.000		2	.000		2	.000
	4	.000		4	.097		4	.000		4	.000		4	.000
4	1	.000	4	1	.048	4	1	.000	4	1	.000	4	1	.000
	2	.000		2	.022		2	.603		2	.000		2	.000
	3	.000		3	.097		3	.000		3	.000		3	.000

Table 2.6b: Multiple Comparisons of Locations for Species Richness Data for Site 1 The Beaver Valley

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.000	1	2	.378	1	2	.000	1	2	.122	1	2	.038
	3	.000		3	.012		3	.000		3	.000		3	.000
	4	.002		4	.295		4	.351		4	.000		4	.000
2	1	.000	2	1	.378	2	1	.000	2	1	.122	2	1	.038
	3	.000		3	.054		3	.876		3	.000		3	.000
	4	.000		4	.699		4	.000		4	.000		4	.000
3	1	.000	3	1	.012	3	1	.000	3	1	.000	3	1	.000
	2	.000		2	.054		2	.876		2	.000		2	.000
	4	.000		4	.699		4	.000		4	.000		4	.000
4	1	.002	4	1	.295	4	1	.351	4	1	.000	4	1	.000
	2	.000		2	.699		2	.000		2	.000		2	.000
	3	.000		3	.191		3	.000		3	.000		3	.000

Table 2.7a: Multiple Comparisons of Locations for Plant Abundance Data for Site 2 The East Portal

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.050	1	2	.241	1	2	.987	1	2	.112	1	2	.427
	3	.000		3	.215		3	.354		3	.000		3	.150
	4	.000		4	.076		4	.155		4	.003		4	.985
2	1	.050	2	1	.241	2	1	.987	2	1	.112	2	1	.427
	3	.000		3	.945		3	.369		3	.000		3	.031
	4	.000		4	.555		4	.166		4	.000		4	.438
3	1	.000	3	1	.215	3	1	.354	3	1	.000	3	1	.150
	2	.000		2	.945		2	.369		2	.000		2	.031
	4	.105		4	.603		4	.627		4	.146		4	.146
4	1	.000	4	1	.076	4	1	.155	4	1	.003	4	1	.985
	2	.000		2	.555		2	.166		2	.000		2	.438
	3	.105		3	.603		3	.627		3	.146		3	.146

Table 2.7b: Multiple Comparisons of Locations for Species Richness Data for Site 1 The East Portal

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.018	1	2	.066	1	2	.905	1	2	.326	1	2	.472
	3	.344		3	.016		3	.037		3	.036		3	.402
	4	.000		4	.092		4	.056		4	.000		4	.134
2	1	.018	2	1	.066	2	1	.905	2	1	.326	2	1	.472
	3	.145		3	.533		3	.051		3	.003		3	.129
	4	.000		4	.854		4	.076		4	.000		4	.031
3	1	.344	3	1	.016	3	1	.037	3	1	.036	3	1	.402
	2	.145		2	.533		2	.051		2	.003		2	.129
	4	.000		4	.415		4	.826		4	.000		4	.514
4	1	.000	4	1	.092	4	1	.056	4	1	.000	4	1	.134
	2	.000		2	.854		2	.076		2	.000		2	.031
	3	.000		3	.415		3	.826		3	.000		3	.514

Table 2.8a: Multiple Comparisons of Locations for Plant Abundance Data for Site 3 The Beaver Camp

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.880	1	2	.110	1	2	.607	1	2	.423	1	2	1.00
	3	.072		3	.002		3	.748		3	.736		3	1.00
	4	.000		4	.311		4	.003		4	.754		4	.027
2	1	.880	2	1	.110	2	1	.607	2	1	.423	2	1	1.00
	3	.053		3	.060		3	.846		3	.261		3	1.00
	4	.000		4	.014		4	.001		4	.270		4	.027
3	1	.072	3	1	.002	3	1	.748	3	1	.736	3	1	1.00
	2	.053		2	.060		2	.846		2	.261		2	1.00
	4	.018		4	.000		4	.002		4	.981		4	.027
4	1	.000	4	1	.311	4	1	.003	4	1	.754	4	1	.027
	2	.000		2	.014		2	.001		2	.270		2	.027
	3	.018		3	.000		3	.002		3	.981		3	.027

Table 2.8b: Multiple Comparisons of Locations for Species Richness Data for Site 3 The Beaver Camp

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.935	1	2	.824	1	2	.017	1	2	.307	1	2	1.00
	3	.592		3	.120		3	.010		3	1.00		3	1.00
	4	.000		4	.056		4	.230		4	.350		4	.014
2	1	.935	2	1	.824	2	1	.017	2	1	.307	2	1	1.00
	3	.537		3	.177		3	.783		3	.307		3	1.00
	4	.000		4	.036		4	.185		4	.926		4	.014
3	1	.592	3	1	.120	3	1	.010	3	1	1.00	3	1	1.00
	2	.537		2	.177		2	.783		2	.307		2	1.00
	4	.001		4	.002		4	.115		4	.305		4	.014
4	1	.000	4	1	.056	4	1	.230	4	1	.350	4	1	.014
	2	.000		2	.036		2	.185		2	.926		2	.014
	3	.001		3	.002		3	.115		3	.350		3	.014

Table 2.9a: Multiple Comparisons of Locations for Plant Abundance Data for Site 5 The Ventilation Shaft

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.155	1	2	.923	1	2	.320	1	2	.010	1	2	.971
	3	.577		3	.391		3	.020		3	.068		3	.202
	4	.000		4	.704		4	.017		4	.000		4	.001
2	1	.155	2	1	.923	2	1	.320	2	1	.010	2	1	.971
	3	.330		3	.551		3	.343		3	.262		3	.318
	4	.003		4	.686		4	.314		4	.003		4	.008
3	1	.577	3	1	.391	3	1	.020	3	1	.068	3	1	.202
	2	.330		2	.551		2	.343		2	.262		2	.318
	4	.000		4	.228		4	.932		4	.000		4	.036
4	1	.000	4	1	.704	4	1	.017	4	1	.000	4	1	.001
	2	.003		2	.686		2	.314		2	.003		2	.008
	3	.000		3	.228		3	.932		3	.000		3	.036

Table 2.9b: Multiple Comparisons of Locations for Species Richness Data for Site 5 The Ventilation Shaft

Seed Mix			Introduced Species			Planted Woody Species			Native Herbaceous			Natural Woody Species		
Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.	Loc.	x Loc.	Sig.
1	2	.030	1	2	.429	1	2	.603	1	2	.096	1	2	.815
	3	.023		3	.973		3	.094		3	.137		3	.056
	4	.000		4	.491		4	.005		4	.062		4	.001
2	1	.030	2	1	.429	2	1	.603	2	1	.096	2	1	.815
	3	.790		3	.450		3	.369		3	.673		3	.169
	4	.001		4	.177		4	.064		4	.912		4	.012
3	1	.023	3	1	.973	3	1	.094	3	1	.137	3	1	.056
	2	.790		2	.450		2	.369		2	.673		2	.169
	4	.000		4	.475		4	.247		4	.706		4	.158
4	1	.000	4	1	.704	4	1	.017	4	1	.000	4	1	.001
	2	.003		2	.686		2	.314		2	.003		2	.008
	3	.000		3	.228		3	.932		3	.000		3	.036

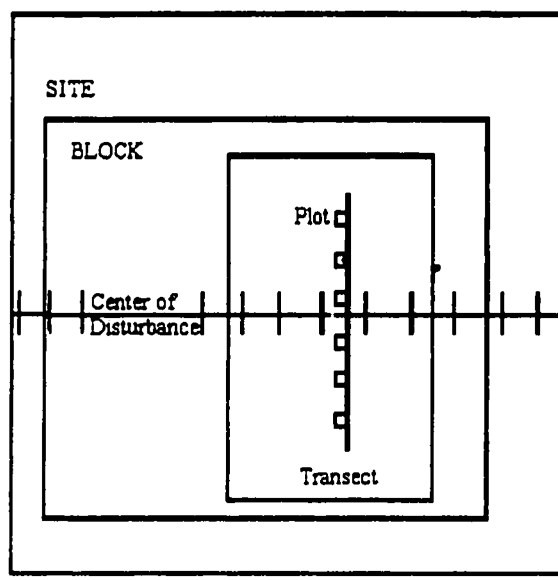

Figure 2.1 Sampling Design

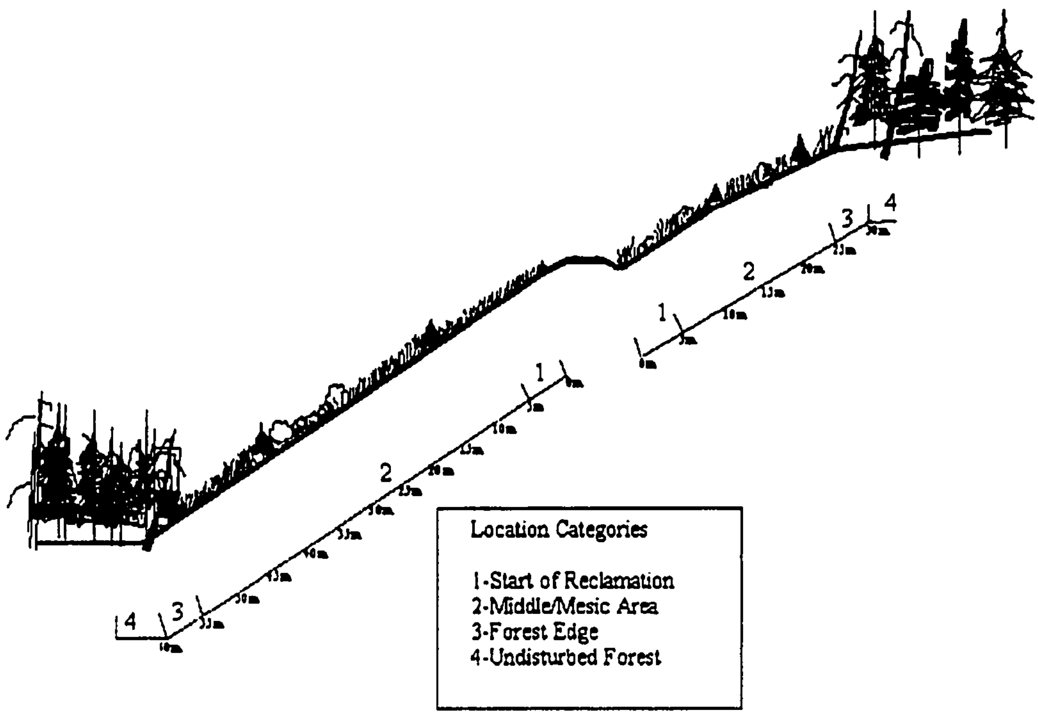

Figure 2.2: Transect Layout and Location Categories for Study Sites

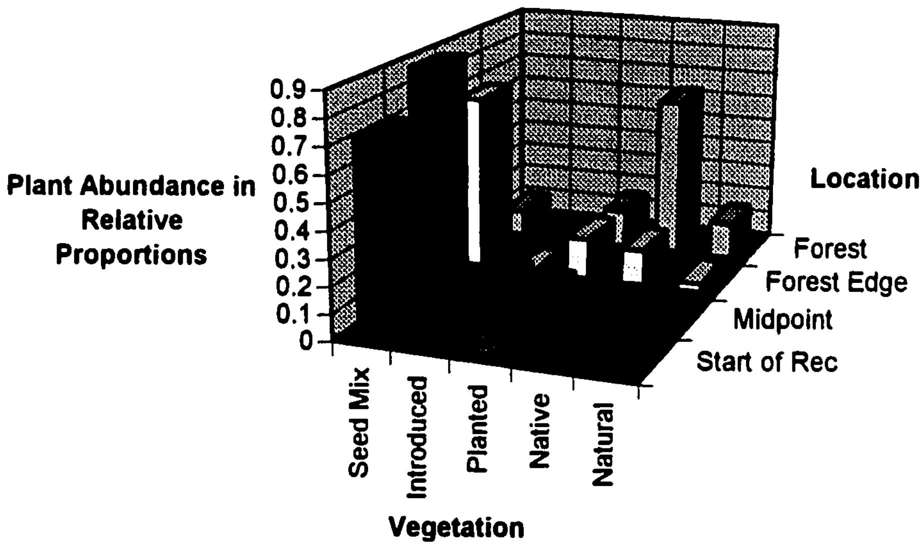

Figure 2.3: Plant Abundance in Site 1 Beaver Valley

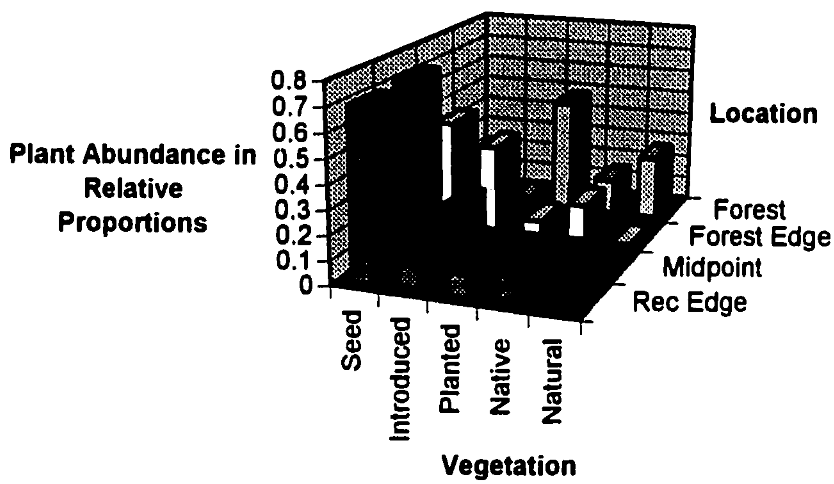

Figure 2.4: Plant Abundance in Site 3 Beaver Camp

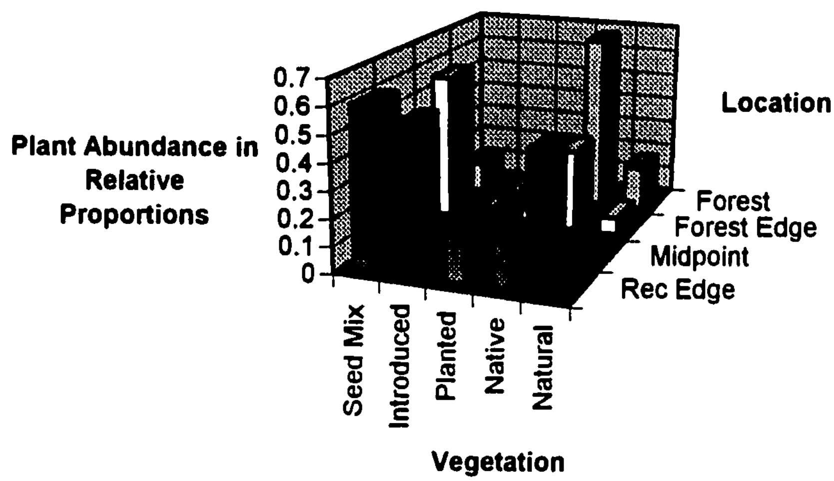

Figure 2.5: Plant Abundance at Site 5 Ventilation Shaft

III. RECLAMATION EVALUATION OF THE ROGERS PASS PROJECT SITES

3.1 Introduction

Following the Canadian Transport Commission hearings concerning the Rogers Pass Project in 1981, Environment Canada-Parks asked the Federal Environmental Assessment Review Office (FEARO) to form an Environmental Assessment Panel. The formation of this panel during the initial stages of the project resulted in the development of environmental guidelines within which the project was required to operate. Appendix F of The CP Rail/Parks Canada General Agreement outlines in detail the reclamation performance standards dealing with plant density, vegetative canopy cover, growth of woody species and erosion control.

3.2 Objective

The objective of this study was to evaluate the success of the reclamation according to the revegetation guidelines in Appendix F of the CP Rail/Parks Canada General Agreement for the Rogers Pass Project.

One post-project analysis, undertaken by W.A. Ross and G.D Tench (1989) for Environment Canada immediately after the final completion of the project in 1989, comments on the success of the reclamation. The report states that, "...the reclamation program seems to be quite successful although that may not be demonstrated convincingly for many years yet." Their preliminary evaluation involved a visual assessment and did not include intensive quantitative sampling.

To effectively evaluate the reclamation at the sites in the Rogers Pass Project, intensive sampling of each site by a third party would produce an objective quantitative evaluation. This study is an assessment of the current condition of the vegetation on the sites using the CP Rail and Parks Canada criteria 7 years after the reclamation was completely finished.

3.3 Reclamation Criteria

The following guidelines for site preparation, standards for grass cover and woody species establishment come from Appendix F of The CP Rail/Parks Canada General Agreement and concern an evaluation of the revegetation. These guidelines were used to develop the field sampling methods for this study.

3.3.1 Site Preparation

"The Company agreed to ensure that the final surface of all reclaimed areas as shown in the reclamation plan would be free of rocks larger than two feet in diameter and that the exposed surface would not be comprised of more than 40% rock, except where these materials are used as an integral part of the slope for slope stability reasons (Section 2.7, Appendix F, CP Rail/Parks Canada General Agreement)."

3.3.2 Standards for Grass Cover

The Company and Parks Canada agreed that the standards for a grass and legume cover would be as follows:

"Seeding and fertilizing shall result in a minimum of 10 healthy established plants per square yard averaged over 100 square yards, with an average canopy cover of not less than 80% including detritus, but excluding rock or other non-erosive surface, within any 10 yard by 10 yard area, except where by virtue of woody species growth the cover of seeded grasses and legumes is reduced and the cover provided by the woody species is equal to or greater than the amount of the reduction of grass and legume cover (Section 10.1, Appendix F, CP Rail/Parks Canada General Agreement)."

3.3.3 Standards for Woody Establishment

The Company and Parks Canada agreed that the standards for the establishment of woody species would be as follows:

1) Minimum survival rates for woody species shall be not less than 75% of the stocking rates that were planted as indicated on the Reclamation Plan.
2) Survival rate by percentage species composition shall not vary from the planted percentage species composition by more than 20%.
3) Growth rate of stock shall not be less than 20% of the growth rate of surrounding undisturbed native vegetation based on a method such as leader growth extension.
4) Parks Canada agreed to approve the woody species establishment if the above mentioned growth rate was achieved for two consecutive growing seasons without fertilization (Section 13.1, Appendix F, CP Rail/Parks Canada General Agreement)."

3.4 Materials and Methods

3.4.1 Site Descriptions

An overview of the plant ecology, soils and climate is provided in Chapter 1 while specific site characteristics are provided in the following sections.

3.4.1.1 Site 1:The Beaver Valley

The Beaver Valley site involves the twinning of the railway from the northeast entrance of the park to the entrance of the Shaughnessy tunnel (Figure 1.1). The disturbed area is 11.4 kilometers in length and is uniform in its environmental characteristics primarily because of the recontouring of the slopes for reclamation purposes. The railway cuts across the slopes of Mt. Hermit, Mt. Shaughnessy and Mt.

Tupper and is continuously east facing. The slopes range from 30 to 70% and stay within the 1000 to1500m range in elevation.

The cut and fill slopes largely border standing mature forest in the ICH C49 and C52 plant communities except for when they intercept eight creeks, several avalanche slopes and a forest fire site. These areas were omitted from the sampling to maintain a degree of homogeneity across the sampled blocks.

The cut and fill slopes range from 3 m in length where they meet with rock faces to over 200 metres in length. A number of trestles and retaining walls occur along the course of the railline where it was too steep to cut and fill the slopes. In addition, one kilometre of the railline at the south end of the Beaver Valley is built upon a viaduct because at this point the disturbance comes within 500 m of the TransCanada highway and cuts and fills on the steep slopes would have been extremely visible. Sampling in the Beaver Valley occurred in 15 randomly selected blocks. 15 blocks and 1081 quadrats were sampled at this site.

3.4.1.2 Site 2: East Portal

The east portal lies south of the Shaughnessy Tunnel, north of the entrance to the Macdonald tunnel and immediately adjacent to the east entrance to the Rogers Pass. It involved the reclamation of an access road and cut and fill slopes for the 800m of railway that occurs between the two tunnels. The slopes are primarily east facing with the slopes at the top of the access road being north facing. The slopes range in steepness from 15 to 70%. Three blocks and 232 quadrats were sampled at this site.

3.4.1.3 Site 3: Beaver Camp

Beaver camp also occurs in the Beaver Valley and was the location of a work camp for over 400 individuals. One sampling block covered the entire area and 183 quadrats were sampled. The site is flat with no aspect. Although CP Rail was required to reclaim it, it remains a helicopter staging site for Glacier Park operations and is in a state of ongoing disturbance. Thus, it would not be appropriate to apply the Parks/CP Rail reclamation criteria to the site. At the same time it is important to be aware of what is currently growing on the site so that appropriate courses of action can be taken.

3.4.1.4 Site 4: Glacier Station

Glacier Station is at the west end of the Rogers Pass 4 km from the Parks compound. It is the past site of an old rail station and the present site of a permanent camp for CP Rail workers. Reclamation maps show the disturbance from the Rogers Pass project to extend for 400 m on either side of the entrance road from the TransCanada highway. Examination of the site shows continual disturbance on the site particularly on the east side of the entrance road due to vehicular traffic in and out of the camp. Three blocks and 110 quadrats were sampled at this site.

3.4.1.5 Site 5: Ventilation Shaft

The Ventilation Shaft facilitates the release of exhaust from the trains within the Mt. Madonald tunnel. It occurs 1.5 km west of the Rogers Pass Compound off of the TransCanada highway. The disturbance involved the upgrading of an access road up to the Ventilation Shaft. The distance from the start of the reclamation at the edge of the road to the undisturbed forest was an average of about 10 m. Small drainage slopes were built on either side of the road and will be marginally affected by north and south aspects. The slopes range in steepness from 25 to 40%. Three blocks and 79 quadrats were sampled at this site.

3.4.1.6 Site 6:West Portal

The West Portal lies against the Illecillewaet River 7 km west of the Rogers Pass Parks compound immediately adjacent to the TransCanada highway where the Macdonald tunnel ends on the west side of the Rogers Pass. The disturbance occurs on both north and south sides of the highway.

No significant undisturbed area occurs at the West Portal because it is immediately adjacent to the TransCanada highway. Five blocks were measured on this site: four on the south side of the highway and one on the north side. One hundred eighty five quadrats were sampled here.

3.4.1.7 Site 7: Flat Creek Camp

Flat Creek camp is located approximately 15 km from the Rogers Pass Parks compound on the south side of the TransCanada highway. The disturbance was created by the establishment of a workers camp. Because the disturbance is long and narrow and the vegetation relatively uniform, three transects within one block were used to sample the vegetation. Twenty seven quadrats were sampled here.

3.4.2 Field Sampling

Preliminary sampling for this study was conducted July 10-30 1996 to develop appropriate field sampling methods. A reconnaissance survey was conducted on each of the seven disturbed sites (Beaver Valley, Beaver Camp, East Portal, Ventilation Shaft, Glacier Station, the West Portal and Flat Creek camp) and general plant communities were mapped. The plant communities were measured to determine the average size of intra-community variation and to determine the amount of species diversity that occurred. A botanist assisted with the initial plant identification.

As a result of this sampling the following methods were developed. The six sites were divided into 200 m blocks and one third of these blocks were randomly selected and assumed to be representative of the sites. Highly variable areas where observable evidence of a factor with large influence on the site (i.e. creeks, avalanche shoots) were omitted from the sampling. The 200 m long blocks provide an appropriate size, within which normal intracommunity variation could be expected between shrub dominant, shrub/herb codominant and the herb dominant microsites that were unmappable because they occur over small areas.

Within each block seven transects were laid perpendicular to the center of the disturbance. The disturbances were primarily linear and included roads, buildings and railways. These transects were spaced 25 m apart. The transects started at the edge of the disturbance where the reclamation began. At this point a quadrat is taken at 0 metres and then the subsequent quadrats are placed at 5 m intervals along the transect which spanned the width of the disturbance (Figure 2.1 in Chapter 2).

One tenth m^2 quadrats (50 x 20 cm) were used for the herbaceous layer and 1/2 m^2 quadrats (100 x 50 cm) were used to measure the shrub and tree layer. At each quadrat, species density, canopy cover, woody plant growth and plant vigor were measured and recorded.

3.4.2.1 Species Density

Species density was measured by total counts of plants for each species within the quadrat. Counts were necessary because one of the criteria of the grass cover standards is that, "...10 healthy plants must be established per square yard averaging over 100 square yards (Section 10.1, Appendix F, CP Rail/Parks Canada General Agreement)." Within this study, species abundance refers to the actual number of plants counted for each species within a quadrat. The CP Rail/Parks Canada criteria were converted into metric units which meant that in the case of species density, 1 healthy plant must be established within 0.1 m^2.

Tillered plants were counted as an individual unit not individual stems because the goal of the sampling was to provide a picture of relative dominance and richness of species rather than to provide exact quantities of biomass. A plant must be rooted within the quadrat in order to be counted. Unidentified plant species were placed within a genus category. Only vascular plants were recorded because of the difficulty of counting individual plants in the moss and lichen families and second, because their occurrence on the disturbed sites was less than 1% in the preliminary study. The canopy cover percentage estimations indicate whether mosses and lichens were present within a quadrat. A comprehensive list of vascular plant species found in sampled areas is provided (Table 2.1 in Chapter 2).

3.4.2.2 Canopy Cover

The criteria in Appendix F of The CP Rail/Parks Canada General Agreement require, "an average canopy cover of not less than 80% including detritus, but excluding rock or any other nonerosive surface, within any 10 by 10 yard area (Section 10.1, Appendix F, CP Rail/Parks Canada General Agreement)." To keep the measurements consistent, canopy cover was estimated for every 0.1 m^2 plot sampled. The 80% standard remained for the measurement of the areas in metric. The categories for canopy cover were live vegetation, litter, bare ground, rocks and moss/lichens. The measurements were made primarily to determine if the Parks/CP Rail criteria for erosion control were met.

3.4.2.3 Woody Species

Counts of woody species within each 0.5 m^2 quadrat were used to determine the survival rates of the planted trees. However, it was impossible to discern between naturally established and planted trees of the same species and so the assessment of survival was only a generalized one which included plants which invaded the site.

In addition, the criteria for woody species stipulates that the current percentage species composition of woody species should not vary from the original planting percentage by more than 20%. Ross and Tench (1989) propose that the standard for woody species should recognize that changes in the plant densities and species composition are a natural part of successional processes and that sites which are showing evidence of integration into the natural successional processes be considered acceptable even if the stocking densities and species composition differ from those set out in the reclamation plans (Ross and Tench, 1989). However wherever it was possible, data on woody species composition was noted.

Growth measurements of woody species were done according to Parks/CP Rail criteria. For each species found within the 0.5m^2, one sample tree or shrub was selected as average representative of the species within the immediate area. The growth of the woody species was estimated for 1995 and 1996 using the leader extension method which involves measuring the length of the dominant main stem. Since the sampling occurred in August and September, the measurements taken for the 1996 growing season were deemed representative since the majority of growth had occurred for most plants by that time. Leaf scars, branches and changes in the bark were used to distinguish one growing season from another to measure the growth that occurred.

To provide a picture of the current height of the vegetation, the height of shrubs and trees was measured from the base of the plant to the highest point of the dominant stem. Details of what seed mixes and specific tree and shrub species were used for areas sampled within each site are provided in Table 3.1.

3.4.2.4 Plant Vigor

Plant vigor was assessed for all plants within each quadrat. Within this study, plant vigor refers to the overall health of each plant as indicated by above ground visual signs including color, growth and damage. Two categories, healthy and unhealthy, describe the state of the vegetation. The unhealthy category included anything that was out of the ordinary and which may have an impact on plant survival (Table 3.2).

3.5 Data Analysis

Analysis of the samples taken at each site involved simple descriptive statistics including means, standard deviations and percentages. SPSS 7.0 was the statistical software used.

3.6 Results and Discussion

Several generalizations about the performance of the vegetation can be made across all the study sites. Plant density and canopy cover were relatively uniform among the sites and are summarized below (Table 3.3).

Overall, the plant density criteria were easily met. Each site had almost 100% of plots with a plant density of greater than 1. The average number of grasses and herbs in a plot ($0.1m^2$) ranged from 16 to 25 for all the sites. This density is due to the high seeding and fertilizer rates as well as the persistence and aggressive competitiveness of some of the agronomic species. The average number of shrubs and trees in a plot ranged from 1 to 3 ($0.5m^2$).

The average canopy cover met the 80% criteria in all the sites except Site 3 Beaver Camp and Site 4 Glacier Station which had 74% and 79% canopy cover, respectively. These lower numbers resulted from continued disturbance on both sites from vehicular activity. Bare ground ranged from 1 to 9%. The Beaver Valley (site 1) and West Portal (site 6) sites had the least bare ground at 1%. The Ventilation Shaft (site 5) had the most bare ground at 9%.

For most of the reclaimed sites, the surrounding undisturbed vegetation was a mature forest with very few juvenile trees and shrubs so the criterion that the growth rate of the planted stock was to be not less than 20% of the growth rate of surrounding undisturbed native vegetation could not be evaluated directly. Since the intent of the criteria was simply to assure that after three years on its own the transplanted stock was alive and growing satisfactorily, Ross and Tench suggest that where this is clear to a representative of Environment Canada-Parks the 20% growth rate need not be applied (Ross and Tench, 1987). The growth measurements were taken and could be used in comparison with the growth rates of shrubs and trees in other subclimax areas of the Interior Cedar Hemlock in the future.

For almost all of the species planted on every site there was some increase in numbers due to invasion and regeneration from the original planted stock (Table 3.4 and 3.5). Two exceptions occurred: stocking of *Picea glauca* decreased by 0.8 stems per 10 m^2 at Glacier Station and stocking of *Cornus stolonifera* decreased by 0.4 stems per 10 m^2 at the East Portal. In both cases the minimum survival rate of 75% was not met. *Salix* spp. and *Alnus crispa* consistently established well on all of the sites.

Tables 3.6 and 3.7 show the mean total height and growth increments for 1995 and 1996 and the standard deviations for these means. In most instances there was no adjacent native vegetation which could be compared since the adjacent areas were mature forest which do not supply the light requirements for this vegetation. A walkthrough of disturbed avalanche slopes and nearby cutblocks in the ICH ecozone within the Nelson Forest District suggest that the Rogers Pass Project sites are within acceptable range of growth for woody species. Although there may have been lower growth rates with the planted tree stock: primarily *Picea glauca*, *Pinus contorta*, *Tsuga heterophylla*, *Pseudotsuga menziesii* and *Thuja plicata*.

Revel (1984) found that growth rates for the initial 10 to 15 years of planted trees on seismic lines are much lower than those on clearcuts. Several factors may influence growth rates including the composition of the adjacent forest and human and animal use of the lines. A particularly important factor is the severe competition occurring between the trees and the grass species on the sites (Revel et al., 1984, Sherstabetoff et al., 1979). The high standard deviations for all species at each site imply that growth rates are more a function of microsite than an indication of generalized site factors.

Poor plant vigor was primarily due to the effects of natural pests and diseases and was not related to reclamation operations. The most significant damage occurred from ungulate and bear browse on *Amelanchier alnifolia*, *Vaccinium membranaceum*, *Pachistima myrsinites*, *Salix* spp., *Alnus crispa* and *Sorbus sitchensis*.

Some mechanical and vehicular damage occurred to the woody species along roads and rights- of-way. Revel et al.(1984) note that *Populus tremuloides* and *Populus balsamifera* were less susceptible to damage by either browsing or vehicular traffic than coniferous species. Overall, preferred woody forage species with high browse value should not be planted in operational areas to minimize injury to wildlife from vehicular traffic and reduce browsing stress on the recovering vegetation.

Woody species' measurements and plant vigor vary on a site by site basis and are summarized for each site in the following sections. Maps necessary for the woody species measurements were not available for the Ventilation Shaft or Beaver Camp so it is not known what quantities and where species were planted on the sites. However species planted and total quantities are listed in Table 3.8.

3.6.1 Site 1:The Beaver Valley

Ninety one percent of the plots sampled in site 1 had good plant vigor. Comments were made for each plot with poor plant vigor and these are summarized in Table 3.2 for all sites. The most common problems in the quadrats were the poor growth of some planted tree species: *Picea glauca*, *Abies lasiocarpa*, *Tsuga heterophylla* and *Thuja plicata*. This is probably due to competition from the dominant grass layer. Sign of browsing was also fairly prominent on the following species: *Amelanchier alnifolia*, *Vaccinium membranaceum*, *Pachistima myrsinites* and *Salix* spp.

All woody species had higher stocking levels than what was planted which suggests invasion occurred. *Pinus contorta* and *Tsuga heterophylla* had the lowest average increase of 0.2 stems per 10 m^2. Similarly *Alnus crispa*, *Populus balsamifera* and *Cornus stolonifera* were low with an average increase of 1, 1 and 1.4 stems per 10 m^2, respectively. *Rubus parviflorus* had an increase of 2 stems per 10 m^2, *Thuja plicata* of 3 stems per 10 m^2 and *Picea glauca* of 3.2 stems per 10 m^2. The greatest average increases were *Abies lasiocarpa* at 5.8 stems per 10 m^2, *Salix* spp. at 14 stems per 10 m^2 and *Pseudotsuga menziesii* at 16 stems per 10 m^2.

3.6.2. Site 2: East Portal

Plant growth and health was good on this site with 88% good plant vigor found in the plots. The most common problems found in plots judged unhealthy was browsing of *Pinus contorta*, *Tsuga heterophylla* and *Alnus crispa*. Spruce leader weevil damage also occurred on the *Picea glauca*. Alongside the road, snow removal damaged the shrubs, notably *Alnus crispa*.

The stocking of all woody species increased from the initial planting levels except for *Cornus stolonifera* which decreased by 0.4 stems per 10m^2. *Pinus contorta, Populus balsamifera, Salix* spp., *Abies lasiocarpa, Pseudotsuga menziesii, Thuja plicata* and *Tsuga heterophylla* all had increases under 0.2 stems per 10 m^2. *Alnus crispa, Picea glauca* and *Rubus parviflorus* had the greatest increases with 3.8, 5 and 10 stems per 10 m^2, respectively.

3.6.3 Site 3: Beaver Camp

Plant vigor on a site basis was poor, averaging 31%. This is most likely due to the continual disturbance occurring on the site by motorized vehicles. No information is available on the stocking levels of woody species which were planted at this site.

3.6.4 Site 4: Glacier Station

Plant condition at this site was good. Ninety two percent of plots had good plant vigor. Some common problems were vehicular disturbance because the site is adjacent to a CP Rail access road.

Initial stocking levels of woody species increased on the site except for *Picea glauca* which decreased by 0.8 stems per 10 m^2. *Abies lasiocarpa*, *Rubus parviflorus*, *Tsuga heterphylla* and *Cornus stolonifera* all had increases under 2 stems per 10 m^2. The largest increases in number were *Alnus crispa*, *Populus balsamifera* and *Salix* spp. with 6, 6.8 and 10.2 stems per 10 m^2, respectively.

3.6.5 Site 5: Ventilation Shaft

Ninety four percent of plots had good plant vigor. The main problem was caterpillar infestation on the *Alnus crispa*. No information is available on the stocking levels of woody species which were planted at this site. The species of caterpillar is unknown.

3.6.6 Site 6: West Portal

Seventy one percent of the plots sampled had good plant vigor. A severe caterpillar infestation attacked a large number of *Alnus crispa* and resulted in the lower number of plots with good plant vigor.

All woody species planted on the West Portal site increased in numbers on the site. *Pinus contorta*, *Pseudotsuga menziesii* and *Tsuga heterophylla* were not originally planted and sampling indicates that they have not invaded significantly onto the site at this time. *Picea glauca*, *Thuja plicata*, *Abies lasiocarpa* and *Rubus parviflorus* showed increases less than 2 stems per 10 m^2 from the original planting numbers. The greatest increases on the site were with *Alnus crispa*, *Cornus stolonifera*, *Populus balsamifera* and *Salix* spp. with 5, 5.6, 10.6 and 13.4 stems per 10 m^2, respectively.

3.6.7 Site 7: Flat Creek Camp

One hundred percent of the quadrats had good plant vigor. Flat Creek camp had the same type of disturbance as Beaver Camp. However, vehicular traffic has not occurred on the site and therefore the vegetation has been able to establish and grow vigorously.

3.7 Conclusions

Overall, the sites met the reclamation guidelines established in Appendix F of the CP Rail/Parks Canada General Agreement.

1) None of the sites had exposed surfaces comprising more than 40% rock.

2) Present plant density and canopy cover surpassed the requirements for 1 plant per 0.1 m^2.
3) The minimum survival rate of planted woody species was not less than 75% of the stocking rate for all species on all sites with the exception of *Picea glauca* at Glacier Station and *Cornus stolonifera* at the East Portal.
4) Plant vigor was exceptionally good and all sites continued to be productive 7 years after reclamation was completed.

The objective of the reclamation at the Rogers Pass was to seek to develop a self-sustaining vegetation cover which is compatible with the naturally occurring vegetation in the area (Polster Environmental Services, 1990). Compatibility has not been defined in detail but it suggests that ecosystem sustainability should be considered in an evaluation. The criteria used for evaluating the recovery of the Rogers Pass sites are effective measures of the structure of vegetation in the short term. Criteria which measure ecosystem function were absent from this reclamation evaluation.

3.8 Bibliography

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Table 3.1a: Seed Mixes, Tree and Shrub Species Used for the Beaver Valley

Site/Station	Block	Cut Slope	Seed mix/ shrub/tree code	Fill Slope	Seed mix/ shrub/tree code
Beaver Valley					
Stn 144-166	2	0-10m	1	0-10m	1
		10m+	1,4	10m+	1,4
Stn 144-164	5	0-15m	1	0-15m	1
		15m+	1,5	15m+	1,5
Stn 144-164	6	0m+	1	0m+	1
Stn 160-168	7	0-10m	1	0-10m	1
		10-20m *	1,6	10m+ *	1,6
		20m+ *	1,5	10m+ **	1,5
		10m+ **	1,5		
Stn 168-176	8	0-10m	2	0-10m	1 or 2
		10m+	2,7	10m+	1 or 2,8
Stn 176-184	9	0-10m	2	0-10m	2
		10m+	2,7	10m+	2,8
Stn 184-192	10	0-10m	2	0-10m	2
		10-30m	2,7	10m+	2,8
		30m+	8		
Stn 192-200	12	0-10m	2	0-10m	2
		10-20m	2,7	10m+	2,7
		20m+	2,8		
Stn 200-208	13	0-10m	2	0-10m	2
		10-20m	2,7	10m+	2,8
		20m+	2,8		
Stn 216-224	16	0-10m	2	0-10m	2
		10-20m	2,9	10-30m	2,11
		20m+	2,10	30m+	2,12
Stn 272-280	24	0-10m	1	0-10m	1
				10m+	1,13
Stn 312-320	25	0-10m	1	0-10m	1
				10m+	1,14
Stn 336-344	28	0-10m	1	0-10m	1
				10m+	1,14
Stn 456-480	41	0-10m	2	0-10m	2
		10m+	2,15	10m+	2,15
Stn 490	46	0m+ *	2	0m+ *	2
		0m+ **	2,15	0m+ **	2,15

Table 3.1a: Seed Mixes, Tree and Shrub Species Used for the Beaver Valley continued-

Site/Station	Block	Cut Slope	Seed mix/ shrub/tree code	Fill Slope	Seed mix/ shrub/tree code
East Portal					
Stn 758	2	0-10m	2	0-10m	2
		10-20m	2,16	10m+	2,17
		20m+	2,17		
Stn 766	3	0-10m	2	0-10m	2
		10m+	2,17	10m+	2,17
Stn 786	6	0-10m	2	0-10m	2
		10m+	2,16	10m+	2,17

See Table 3.1c for code information.
* Transects 1-3, **Transects 4-6

Table 3.1b: Seed Mixes, Tree and Shrub Species Used for Glacier Station, West Portal, the Ventilation Shaft and Beaver Camp

Site/Station	Block	Location on Transect	Seed mix/ shrub/tree code
Glacier Station			
	1	0m+	2,18
	2	0m+	2,18
	3	0m+	2,18
West Portal			
	2	0-10m	2
		10-20m	2,19
		20m+	2,20
	3	0-10m	2
		10-20m	2,19
		20m+	2,20
	4	0-10m	2
		10-20m	2,19
		20m+	2,20
	5	0-10m	2
		10m+	2,19
	9	0-10m	2
		10m+	2,19
Ventilation Shaft			
	1	0m+	2
	4	0m+	2
	8	0m+	2

Table 3.1b: Seed Mixes, Tree and Shrub Species Used for Glacier Station, West Portal, the Ventilation Shaft and Beaver Camp continued

Site/Station	Block	Location on Transect	Seed mix/ shrub/tree code
Beaver Camp			
	1	0m+	3

See Table 3.1c for code information.

Table 3.1c: Corresponding Seed Mix or Tree/Shrub Component for the Codes Used in Table 3.1a and Table 3.1b

Code Number	Seed Mix or Tree/Shrub Component	Stems per Hectare
1	Dry grass/legume seed mix	n/a
2	Moist grass/legume seed mix	n/a
3	Sod seed mix	n/a
4	PIGL 60%, ABLA 10%, THPL 30%	2964
	ALCR 90%, RUPA 10%	2964
5	PSME 50%, PICO 20%, PIGL 30%	2964
	ALCR 90%, RUPA 10%	2964
6	ALCR 80%, RUPA 10%, JUCO 10%	8645
7	ALCR 70%, COCA 10%, RUPA 10%, SALIX 10%	11115
8	PIGL 20%, TSHE 50%, THPL 10%, ABLA 20%	2964
	ALCR 80%, RUPA 20%	2223
9	ALCR 75%, COST 5%, SALIX 10%, JUCO 10%	8645
10	PIGL 20%, TSHE 50%, THPL 10%, ABLA 20%	3705
	ALCR 70%, COST 10%, RUPA 20%	2223
11	PIGL 30%, ABLA 20%, TSHE 20%, POBA 10%, THPL 20%	3705
	ALCR 70%, COST 20%, RUPA 10%	2470
12	PIGL 20%, TSHE 40%, POBA 30%, THPL 10%	3705
	ALCR 70%, COST 20%, RUPA 10%	2470
13	TSHE 50%, PIGL 20%, ABLA 20%, THPL 10%	3705
	ALCR 70%, COST 20%, RUPA 10%	2223
14	TSHE 50%, PSME 10%, PIGL 20%, ABLA 10%, THPL 10%	3705
	ALCR 70%, COST 20%, RUPA 10%	2223
15	TSHE 70%, PSME 5%, THPL 5%, PIGL 10%, ABLA 10%	3705
	ALCR 70%, RUPA 10%, COST 20%	2223
16	ALCR 80%, COST 15%, RUPA 5%	11115
17	TSHE 60%, PIGL 20%, ABLA 15%, THPL 5%	3705
	ALCR 80%, COST 15%, RUPA 5%	3705
18	PIGL 20%, TSHE 50%, THPL 10%, ABLA 20%	1976
	ALCR 80%, COST 10%, RUPA 10%	7410
19	ALCR 80%, COST 10%, RUPA 10%	11115
20	PIGL 50%, ABLA 20%, POBA 30%	2964
	ALCR 70%, COST 20%, RUPA 10%	5681

See Table 2.1 for the species that correspond to the acronyms. Stems per hectare are the planting densities used at specific locations.

TABLE 3.2: Details on the Occurrence of Quadrats with Poor Plant Vigor

Site	Block	Plant Species	Description (occurrence in one quadrat)
Beaver Valley	2	ABLA	chlorotic
		PIGL	brush competition
	5	ABLA	brush press
		conifer spp.	dead from brush press
	7	PIGL	brush press
	10	PIGL	brush press
		AMAL	heavily browsed
		VAME	bear browse
		PAMY	ungulate browse
		TSHE	brush press
	13	ALCR	caterpillar
		POBA	caterpillar
		THPL	brush press
		PIGL	frost kill
		PICO	snow press
	16	VAME	browsed
	25	PIGL	brush press
		PIGL	brush press
		all vegetation	bedding site
	28	SALIX	browsed
Beaver Camp	1	all vegetation	disturbed
East Portal	2	ALCR	snow removal damage
	3	PIGL	spruce leader weevil
		PICO	girdled, dead top
		TSHE	girdled
		ALCR	ungulate browse
	6	SOSI	browsed
West Portal	2	ALCR	70% caterpillar infestation
	3	ALCR	70% caterpillar infestation
	4	ALCR	70% caterpillar infestation
	5	ALCR	70% caterpillar infestation
Ventilation Shaft	8	ALCR	caterpillars

Table 3.3: Percentages and Averages of Plant Density, Canopy Cover, Plant Vigor for Sites 1-7

	Plant Density % plots> 1 plant	Mean # Grasses/ Herbs	Mean # Shrubs/ Trees	Mean % Canopy	Mean % Live Plants	Mean % Litter	Mean % Moss	Mean % Bare Ground	Mean % Rocks	% plots Good Plant Vigor
Site 1	98	17	3	96	76	14	6	1	3	91
Site 2	100	22	1	91	71	13	7	2	7	88
Site 3	100	18	1	74	43	20	11	7	19	31
Site 4	100	25	1	79	60	17	2	4	11	92
Site 5	96	16	3	81	54	11	16	9	9	94
Site 6	99	17	3	90	79	7	4	1	8	71
Site 7	100	33	0.1	96	71	14	7	2	3	100

Table 3.4a: Average Number of Woody Species per 0.5 m^2 for Site 1 Beaver Valley

Shrub/ Tree code		4	5	6	7	8	9	10	11	12	13	14	15
ALCR	1	0.13	0.13	0.35	0.39	0.09	0.32	0.08	0.09	0.04	0.08	0.08	0.07
	2	0.1	0.18	0.46	0.23	0.09	0.35	0.14	0.2	0	0.11	0.1	0.02
COST	1	0	0	0	0	0	0.02	0.01	0.02	0.02	0.02	0.02	0.02
	2	0	0	0	0.14	0.03	0.1	0	0	0.18	0.22	0.04	0.2
PIGL	1	0.09	0.04	0	0	0.03	0	0.04	0.06	0.04	0.04	0.04	0.02
	2	0.3	0.19	0.2	0.34	0.38	0.55	0	0.16	0.12	0	0.08	0
PICO	1	0	0.03	0	0	0	0	0	0	0	0	0	0
	2	0	0.02	0.06	0.05	0.05	0	0	0	0	0	0	0
POBA	1	0	0	0	0	0	0	0	0.02	0.06	0	0	0
	2	0.3	0.02	0	0.16	0.2	0	0	0	0	0	0.07	0
RUPA	1	0.01	0.01	0.004	0.06	0.02	0	0.02	0.01	0.01	0.01	0.01	0.01
	2	0.1	0.15	1.27	0.25	0.25	0	1	0.12	0.06	3.6	0.03	0
SALIX	1	0	0	0	0.06	0	0.04	0	0	0	0	0	0
	2	0	0.06	0	0.04	0.03	0.15	0	0	0	0.44	0.09	0
ABLA	1	0.01	0	0	0	0.03	0	0.04	0.04	0	0.04	0.02	0.02
	2	0.3	0.23	0	0.06	0.05	0.1	0	0.08	0	0.33	0.01	0
PSME	1	0	0.07	0	0	0	0	0	0	0	0	0.02	0.01
	2	0	0.13	0	0.15	0.13	0.5	0	0.08	0	0	0	0.02
THPL	1	0	0	0	0	0.01	0	0.02	0.04	0.02	0.02	0.02	0.01
	2	0	0	0	0.30	0.19	1.25	0	0	0	0.11	0.25	0
TSHE	1	0	0	0	0	0.07	0	0.09	0.04	0.7	0.09	0.09	0.13
	2	0	0.03	0	0.18	0.06	0.15	0	0.04	0	0.66	0.16	0

1 = Number of woody species planted per ½ m^2
2 = Number of existing woody species per ½ m^2
See 3.4b for code information.

Table 3.4b: Corresponding Shrub/Tree Component for Codes in Table 3.4a

Code	Shrub/Tree Component	Stems Per Hectare
4	PIGL 60%, ABLA 10%, THPL 30%	2964
	ALCR 90%, RUPA 10%	2964
5	PSME 50%, PICO 20%, PIGL 30%	2964
	ALCR 90%, RUPA 10%	2964
6	ALCR 80%, RUPA 10%, JUCO 10%	8645
7	ALCR 70%, COCA 10%, RUPA 10%, SALIX 10%	11115
8	PIGL 20%, TSHE 50%, THPL 10%, ABLA 20%	2964
	ALCR 80%, RUPA 20%	2223
9	ALCR 75%, COST 5%, SALIX 10%, JUCO 10%	8645
10	PIGL 20%, TSHE 50%, THPL 10%, ABLA 20%	3705
	ALCR 70%, COST 10%, RUPA 20%	2223

Table 3.4b: Corresponding Shrub/Tree Component for Codes in Table 3.4a continued-

Code	Shrub/Tree Component	Stems Per Hectare
11	PIGL 30%, ABLA 20%, TSHE 20%, POBA 10%, THPL 20%	3705
	ALCR 70%, COST 20%, RUPA 10%	2470
12	PIGL 20%, TSHE 40%, POBA 30%, THPL 10%	3705
	ALCR 70%, COST 20%, RUPA 10%	2470
13	TSHE 50%, PIGL 20%, ABLA 20%, THPL 10%	3705
	ALCR 70%, COST 20%, RUPA 10%	2223
14	TSHE 50%, PSME 10%, PIGL 20%, ABLA 10%, THPL 10%	3705
	ALCR 70%, COST 20%, RUPA 10%	2223
15	TSHE 70%, PSME 5%, THPL 5%, PIGL 10%, ABLA 10%	3705
	ALCR 70%, RUPA 10%, COST 20%	2223

See Table 2.1 in Chapter 2 for list of plant species that correspond to the acronyms.

Table 3.5a: Average Number of Woody Species per 0.5 m^2 for Site 2 East Portal, Site 4 Glacier Station and Site 6 West Portal

Shrub/ Tree code		Site 2 16	Site 2 17	Site 4 18	Site 6 19	Site 6 20
ALCR	1	0.44	0.09	0.3	0.44	0.2
	2	0.71	0.19	0	0.62	0.52
COST	1	0.08	0.02	0.04	0.06	0.06
	2	0	0.06	0.1	0.15	0.41
PIGL	1	0.03	0.04	0.04	0	0.07
	2	0	0.07	0	0.1	0.11
PICO	1	0	0	0	0	0
	2	0	0.02	0	0	0
POBA	1	0	0	0.02	0	0.04
	2	0	0.14	0.38	0.34	0.75
RUPA	1	0	0.01	0.04	0.06	0.03
	2	0.78	0.28	0.05	0.04	0
SALIX	1	0	0	0	0	0
	2	0	0.04	0.51	0.46	0.89
ABLA	1	0	0.03	0.04	0	0.03
	2	0	0.01	0	0	0
PSME	1	0	0	0	0	0
	2	0	0.03	0	0	0
THPL	1	0	0.01	0	0	0
	2	0.07	0.03	0	0	0.02
TSHE	1	0	0.11	0	0	0
	2	0	0	0.01	0	0

1 = Number of woody species planted per ½ m^2
2 = Number of existing woody species per ½ m^2
See Table 3.5b for code information.

Table 3.5b: Corresponding Shrub/Tree Component for Codes in Table 3.5a

Code	Shrub/Tree Component	Stems per Hectare
16	ALCR 80%, COST 15%, RUPA 5%	11115
	TSHE 60%, PIGL 20%, ABLA 15%, THPL 5%	3705
17	ALCR 80%, COST 15%, RUPA 5%	2223
	PIGL 40%, ABLA 40%, POBA 20%	1976
18	ALCR 80%, COST 10%, RUPA 10%	7410
	ALCR 80%, COST 10%, RUPA 10%	11115
19	PIGL 50%, ABLA 20%, POBA 30%	2964
	ALCR 70%, COST 20%, RUPA 10%	5681

See Table 2.1 in Chapter 2 for the plant species list which corresponds to the acronyms.

Table 3.6: Mean and Standard Deviation of Total Height and 1995 and 1996 Growth for Planted Woody Species on Rogers Pass Project Sites 1, 2 and 3.

	Site 1 Mean			Standard Deviation			Site 2 Mean			Standard Deviation			Site 3 Mean			Standard Deviation		
	TH	1	2	TH	1	2	TH	1	2	TH	1	2	TH	1	2	TH	1	2
ALCR	135.5	11.6	17.4	97.3	8.3	8.3	158.5	10.3	13.5	87.2	6.8	8.4	N/A	N/A	N/A	N/A	N/A	N/A
COST	92.7	13.2	18	60.3	10.9	9.1	42	7.4	10.2	31.3	4.7	11	N/A	N/A	N/A	20.8	1.7	1.7
PICO	106.8	14.6	15.4	57.6	10.3	9.6	101.7	11.7	8	36.1	11.1	7	N/A	N/A	N/A	N/A	N/A	N/A
PIGL	49.5	8.4	4.9	49.2	7.8	5.7	36.1	6	4	37.1	5.6	4.8	77.6	12.6	10	63.9	10.2	6.7
POBA	48.7	8.7	12.3	32.8	7.1	7.9	18.7	7.1	7.5	22.5	8	9.1	13.9	7.8	4.2	12	9.8	3.5
RUPA	44.1	37.1	5.8	28.1	27.9	11.7	43.6	21.1	22.6	17.9	20.6	21.1	53	0	0	N/A	N/A	N/A
Salix	57.6	13	12.9	43.3	12.1	10.4	60.4	12.3	13.1	32.3	9.6	8.8	22.8	8.5	8.5	22.3	5.9	9.3
ABLA	29.1	3.4	4.1	31.9	2.5	3.0	N/A	N/A	N/A	N/A	N/A	N/A	27	6	5	N/A	N/A	N/A
PSME	42.3	5.8	5.2	51.1	5.8	5.5	46.6	7.4	7.3	43.4	7.5	7.4	89	4.5	4.5	118.8	4.9	0.7
THPL	28.3	6.1	4.6	46	5.5	6.8	22.9	4.3	2.3	39.5	3.6	3.6	96	31	11	N/A	N/A	N/A
TSHE	47.2	7.9	6.5	72.5	7.2	7.1	48.9	4.8	3.7	53.8	3.1	4.4	123.3	17.7	19.7	10.1	19.4	18

TH: total height in cm.
1 is growth in cm for 1996.
2 is growth in cm for 1995.
N/A: site was not planted with this species

Table 3.7: Mean and Standard Deviation of Total Height and 1995 and 1996 Growth for Planted Woody Species on Rogers Pass Project Sites 4,5 and 6

	Site 4						Site 5						Site 6					
	Mean			Standard Deviation			Mean			Standard Deviation			Mean			Standard Deviation		
	TH	1	2	TH	1	2	TH	1	2	TH	1	2	TH	1	2	TH	1	2
ALCR	N/A	N/A	N/A	N/A	N/A	N/A	94.1	10.7	12.8	49.0	8.2	6.9	123.3	6.8	14.1	69.4	7.9	7.2
COST	73.5	3	4	53	0	1.4	89.6	10	19.8	76.0	13.9	10.2	45.2	11.7	7.4	22.7	6.6	6.7
PICO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PIGL	N/A	N/A	N/A	N/A	N/A	N/A	40	6.3	8.0	39.1	4.9	7.6	72.6	11.4	7.4	39.5	7.2	4.8
POBA	67.5	6.4	6.4	45.6	4.8	5.9	4.4	2.7	1.7	4.14	3.1	3.3	41.5	8.6	9.4	46.6	8.1	7.1
RUPA	77	42	35	N/A	N/A	N/A	19	13	6	N/A	N/A	N/A	21.7	0	21.7	15.6	0	15.6
Salix	122.7	13.8	14	32.7	8.0	4.6	56.6	13	11.6	66.6	9.9	11.9	47.9	9.6	11.3	35.2	6.7	8.7
ABLA	N/A	N/A	N/A	N/A	N/A	N/A	1	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PSME	N/A	N/A	N/A	N/A	N/A	N/A	52	32	4.8	40.4	32.5	5.6	N/A	N/A	N/A	N/A	N/A	N/A
THPL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	54.3	5.7	4.7	35.2	2.5	1.5
TSHE	89	10	9	N/A	N/A	N/A	17.2	5.5	7.2	16.5	3.9	7.1	N/A	N/A	N/A	N/A	N/A	N/A

TH: total height in cm.
1 is growth in cm for 1996.
2 is growth in cm for 1995.
N/A: site was not planted with this species

Table 3.8: Shrub and Tree Species Planted at the Ventilation Shaft and Beaver Camp

	ALCR	COST	RUPA	PSME	PICO	SALIX	PIGL	THPL
Ventilation Shaft	5300	1060	880	0	0	900	3000	0
Flat Creek Camp	3880	1240	954	1400	0	0	0	1050
Beaver Camp	3150	300	0	1140	500	0	1200	735

See Table 2.1 in Chapter 2 for the plant species list which corresponds to the acronyms. No planting densities are available.

IV. DIRECTIONS FOR DEVELOPING RECLAMATION EVALUATION CRITERIA

4.1 Introduction

Criteria for evaluating reclamation success must be well defined and clearly address the end goals of a reclamation project. The term reclamation is often used as a generalization for three different end goals of ecosystem re-construction. These are rehabilitation, restoration and reclamation and are defined as follows:

1) Rehabilitation involves the return of a disturbed area to a condition and level of productivity in conformity with a land use plan (Powter, 1995). Or, an alternative ecosystem is developed which falls within the existing land uses of the area such as replacing native ecosystem with a pasture (Chambers and Wade, 1992).

2) Restoration is the recreation of conditions and the ecosystem which are identical to those before disturbance (Powter, 1995; Chambers and Wade, 1992).

3) Reclamation is an attempt to create an ecosystem similar to the original or predisturbance ecosystem. This should ensure stable, non-hazardous, non erodible, favourably drained soil conditions, equivalent land capability, the decontamination of land or water, and the stabilization, contouring, maintenance, conditioning or reconstruction of the land surface (Powter, 1995). It can, for example, include introduced species that respond similarly to the native species which they replace (Chambers and Wade, 1992).

Despite the difference in the goals of each, rehabilitation, restoration and reclamation all aspire towards a stable ecosystem (Chambers and Wade, 1992). In this paper, stability is defined as the ability of an ecosystem to continue to function within certain biogeochemical parameters despite the incursion of a perturbance.

The goals of the Rogers Pass Project reclamation plan were: 1) to revegetate exposed erodible materials, to minimize erosion and subsequent water quality degradation; 2) to ameliorate the visual impacts of cuts and fills through revegetation; 3) to develop a self-sustaining vegetation cover which is compatible with the naturally occurring vegetation in the area; 4) and to use native species for revegetation where this does not compromise the other objectives of the program (Polster Environmental Services, 1990). Although it is not directly stated in any related documents, these goals suggest that the aim of the project was for the reclamation of the disturbed ecosystems or the creation of an ecosystem similar to the original or predisturbance one.

4.2 Types of Evaluation Criteria

Evaluation criteria provide insight into which reclamation methods are effective in the recovery of a specific ecosystem. The criteria can be distinguished as structural or functional. Analysis of both structural and functional criteria is essential in evaluating the reclamation of projects like the Rogers Pass.

Structural criteria include the distribution and abundance of organisms. Functional criteria include all aspects of the growth and interactions of the biotic and abiotic elements of the environment including competition, predation, parasitism, mutualism, transfers of nutrients, etc. (Odum, 1971). These functional characteristics are often process oriented.

Most reclamation evaluations stress structural criteria because of the expediency of the assessment. For example, the minimum legal standard for reclamation success in British Columbia is the Health, Safety and Reclamation Code for Mines in British Columbia. Section 10.6.6 states that land shall be revegetated to a self sustaining state using appropriate plant species (Regional Operations, Health and Safety Branch, 1997).

By these standards, if a site looks verdant and lush then no further evaluation is done to determine if a site has recovered. However, a high cover of green vegetation does not provide the entire story on the current and future state of an ecosystem. In other words, it does not address the functional aspects of reclamation. For example, the high density of introduced grasses currently established on the Rogers Pass sites meets the evaluation criteria agreed upon by CP Rail and Parks Canada (chapter 3). But at the same time, this vegetation has limited native plant invasion and slowed the development of a native plant community (chapter 2), minimizing restoration potential.

Both structural and functional reclamation criteria can be assessed in the short and long term. Short term criteria concentrate on erosion control and aesthetics. Long term criteria focus on returning a disturbed site to an ecosystem that reflects the landscape or ecology of a region. They are often overlooked because of the length of time involved. However, a more comprehensive ecological evaluation of reclamation could provide important information to the science of reclamation and could provide a more objective basis for determining the success of reclamation projects (Chambers, MacMahon and Wade, 1992).

4.3 Objectives

This chapter has the following objectives:

1) To provide evidence from current academic research on ecosystem management that functional characteristics of an ecosystem including populations and community interactions of fauna, soil structure and function, and biogeochemical processes are all potential measures of ecological recovery.

2) To suggest how a reclamation evaluation for the Rogers Pass Project could be improved.

4.4 Review of Functional Indicators of Ecosystem Recovery

Trying to incorporate ecosystem functions into a reclamation evaluation requires an underlying assumption that ecosystem processes are determined primarily by the functional characteristics of component organisms rather than just their numbers (Grime, 1997).

An ecological indicator should suggest or describe a given condition of an ecosystem. It should be sensitive to change, accurately reflect the functioning of the system, and be universal, yet illustrate temporal or spatial patterns (Kennedy and Papendick, 1995). Vegetation, fauna, soils and ecosystem processes are potential functional indicators of the state of recovery of a disturbed ecosystem.

4.4.1 Vegetation

Some problems exist with the current use of vegetation for evaluation criteria. Two communities that have the same numbers of species can exhibit very different relationships of species dominance. Species interactions are just as important are total numbers. Comparing species richness among communities may be invalid unless it is assumed that the contributions of individual species to community function are similar (Chambers, 1983).

Several ecological concepts which are seldom used in evaluating reclamation success could be used in evaluating the function of vegetation: beta and gama diversity, rare species, keystone species, phennology and plant vigor (Bach Allen, 1992).

Species diversity refers to the number of species (richness) and their distribution. Alpha, beta and gamma diversity are different scales of species diversity. High diversity of species may help to maintain year to year and site to site productivity as each species has different responses to environmental conditions and will maximize resource use at different times during the growing season (Frank and McNaughton, 1991).

Alpha diversity is measured by enumerating species richness and uniformity within a habitat, patch or homogeneous land unit. Beta and gamma diversity incorporate concepts of species and structural diversity. While beta diversity refers to between habitat or between patch diversity, gamma diversity is known as landscape or total diversity or the sum of the diversity of all the patches. Studying vegetation patterns at this level shows that natural landscapes contain heterogeneous patches of vegetation (Bach Allen, 1992).

Beta and gamma diversity indices could be created for ecoregions and used as a measure for a reclaimed site. The amount of variation would be relative to the size of the disturbed area. The simulation of natural plant patchiness is important in the

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Beta and gamma diversity indices could be created for ecoregions and used as a measure for a reclaimed site. The amount of variation would be relative to the size of the disturbed area. The simulation of natural plant patchiness is important in the reclamation of productive communities and islands of fertility (West 1989, Garner and Steinberger, 1989 as cited by Bach Allen, 1992) and making this a requirement of reclamation evaluation would reflect the reality of the recovery so that in areas where erosional concerns such as increased siltation were minimal, patches of vegetation would be seen as acceptable and desirable since it would encourage plant invasion.

If the goal of reclamation is to return a site to a predisturbance natural community then a minimum rate of invasion for natural species should be included in the evaluation of reclamation success. Alpha diversity indices such as the Shannon-Weiner (Smith, 1996) could be used with guidelines for a particular ecosystem to measure the level of plant diversity on a site.

Specific plants may be targeted as important indicators of ecological recovery. Many rare plants are important components of plant communities. However, rare species are seldom used in reclamation plans (Bach Allen, 1992). Four categories of rarity are sometimes used: R1 is for single or few populations; R2 is for several populations, locally common; R3 is for widespread or scattered distribution; and R4 is for restricted distribution, large populations (Straley et al., 1985).

Other plant types to target as indicators of ecological recovery are keystone species or species that affect the integrity of an ecosystem. Not all species are equal within an ecosystem. Some species with particular functional traits may have a great impact on a particular ecosystem process. Examples of floral keystone species are shrubs which create microsites for establishment of other species and plants with nitrogen fixing symbionts. For example, in the ICH ecozone, *Alnus crispa* is a nitrogen fixing shrub that is an important early colonizer of avalanche paths. At the same time, certain plants could be considered negative indicators of ecological recovery. A high abundance of weeds might suggest that a site is still at an early successional stage.

Another measurement of reclamation success is plant vigor which refers to the overall health of the vegetation as indicated by above ground visual signs including color, growth, turgor and damage. The concept of plant vigor could be broadened to include flowering frequency and analysis of below ground vigor by examining the root architecture for size, number of branches, health and growth patterns.

4.4.2 Fauna

Recolonization of a disturbance by animals and microorganisms can be an indicator of successful reclamation since the lifecycles of fauna integrate a wide variety of abiotic and biotic variables. Both individual organisms and populations have definite functions within the ecosystem: driving ecosystem processes and promoting ecosystem development.

Animals require habitats that provide food, shelter and reproduction sites. A major component of animal habitat is the vertical and horizontal architecture of the vegetation. Animals also influence the plant community through herbivory, granivory, pollination and seed dispersal. Diversity of fauna (species richness and evenness) and their biomass are properties of ecosystems that could be measured and used to determine ecological recovery.

Studies of vertebrate community structure on disturbed sites can yield insights into successional processes but often suffer from the logistical difficulties of obtaining a large enough sample size to be statistically suitable. Studies of invertebrates can be more useful because extensive data sets can be acquired from which to evaluate reclamation success. Studies of the successional development of insect communities on disturbed sites show that initial colonization and dominance is generally accomplished by scavenging and omnivorous species and that the species populations change as a function of vegetation diversity and abundance (Parmenter and MacMahon, 1992).

Bacteria and fungi are particularly important in the development of soil structure and nutrient cycling (Chambers and Wade, 1992). Microbial species abundance distributions enable short and long term recovery rates and community stability to be assessed. The ratio of microbial respiration to microbial biomass, termed the metabolic quotient, links the microbial activity and organic matter production and could be a good indicator of overall system recovery and stability (Zak, Fresquez and Visser, 1992). Although Wardle and Ghani (1995) suggest that it has limitations because it can fail to distinguish between the effects of disturbance and stress.

In view of the importance of invertebrate, vertebrate and microbial fauna to ecosystem function (pollination, herbivory, soil aeration, litter decomposition, seed predation and dispersal) an analysis of faunal community development could be used as an evaluation method for successful reclamation if enough is known of an organism's role within an ecosystem. (Parmenter and MacMahon, 1992).

4.4.3 Soils

A serious omission in many current evaluations of reclamation success is the assessment of soil properties. Soil quality is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health (Kennedy and Papendick, 1995).

Soil quality criteria that can be used in reclamation evaluations are particle size distribution, salinity, sodicity, pH, cation exchange capacity, total nitrogen and total carbon. Macronutrient analyses are useful in assessing the availability and mobility of some nutrients. Extractable aluminum and manganese analyses are useful on low pH soils to aid in the assessment of toxicities (Soil Quality Criteria Working Group, 1987).

Alberta Agriculture (Soil Quality Criteria Working Group, 1987) has criteria for evaluating suitability of topsoil and surface materials for different regions of Alberta. For example, guidelines are provided for rating a soil as good, fair, poor and unsuitable for the following properties: pH, salinity, sodicity, stoniness or rockiness of an area, texture, soil moisture and $CaCO_3$ equivalent.

4.4.4 Ecosystem Functioning and Community Processes

An assessment of functional processes such as nutrient cycling, mineralization, immobilization, infiltration and decomposition will help to limit the subjectiveness of solely evaluating the qualities of a recovering ecosystem on a purely visual level. Because of the complexity of these systems, a tremendous amount of research needs to be done for individual biomes.

Rowell and Florence (1993) found that a combination of biological and conventional measurements may determine which industrially disturbed sites have responded to remediation. The biological measurements were related to nutrient cycling (alkaline phosphatase, arylsulfatase, protease, arginine deaminase, mineralizable N and nitrification potential), microbial activity (dehydrogenase, invertase, biomass C and basal respiration rate) and organic matter content (extractable organic C and colorimetry). Conventional measurements included pH, electrical conductivity, organic C, cation exchange capacity (CEC), mineral N, $SO^2{}_4$-, P, saturation percentage and particle size distribution. Electrical conductivity, extractable organic C, alkaline phosphatase, P, CEC, colorimetry and arginine deaminase may be indicators of the level of soil recovery.

4.5 Alternative Reclamation Evaluation for the Rogers Pass Project

When the end goal of a reclamation plan is reclamation or restoration, current research suggests functional properties of an ecosystem could be important criteria. However, at this point in time there are few practical examples of how this could be incorporated into a reclamation evaluation. To integrate function into an evaluation of reclamation, a much better understanding of natural systems is required. In addition, the measures of function must be practical enough that they will be acceptable and easily applied to industry and government.

The criteria in the CP Rail/Parks Canada General Agreement for evaluating reclamation success for the Rogers Pass Project reflect standards currently accepted according to the Health, Safety and Reclamation Code for Mines in British Columbia. They primarily involve an assessment of short term structural features (Section 3.3 of Chapter 3) and include standards for grass cover, woody species and site preparation.

Even though the end goal of the reclamation plan for the Rogers Pass Project was to return the site to a state similar to that of predisturbance, the reclamation criteria deal primarily with aesthetics, protection, erosion and time limits for companies. This serves as an example of how difficult it is to incorporate functional characteristics into a reclamation evaluation and to evaluate a site over a long term basis. At the same time, it indicates where the current focus is.

One particular difficulty in assessing reclamation lies in the time frame of ecosystem recovery for subalpine sites. Disturbances like those in the biogeoclimatic ecozone ICH mw1 and wk1 at the Rogers Pass Project, are often considered the easiest to reclaim because of an abundance of propagules and rapid plant establishment. However, because of the length of time required for succession to occur in forests, it may never be possible to reclaim a forest so that it resembles a late successional stage within a reasonable human time scale and have it as a legal requirement for a company.

Late seral forest species (such as *Picea engelmanii* in the ICH) frequently exhibit slow growth rates and are slow to reach reproductive maturity so the structural complexity of the forest is slow to develop (Chambers, MacMahon and Wade, 1992). Development can take anywhere from 100 years or more. However, in forested areas the reclamation success must be evaluated when the recovery stage is at the early to mid seral point due to legislative requirements. Since it is not practical to reclaim to a mature forest stand in less than 100 years, the site must be assessed to determine whether it is moving in the right direction at an earlier point in time.

The British Columbia Ministry of Forests has established a minimum density of trees which would result in a satisfactory restocked condition on logged areas. The criteria assess juvenile trees of species which are designated as suitable for the particular biogeoclimatic zone the site is found in. Only trees with acceptable form that are free of pest and disease are used to determine whether a site has met the stocking criteria. Since the end goal of these criteria is to harvest these sites again, the densities could not be directly applied to recovering natural systems. But the general premise of determining an adequate number of trees on a site with acceptable growth and form and using this as reclamation criteria when the trees are in a juvenile phase at 10-20 years of age is something that could be developed for recovering natural subalpine systems.

Structural measurements are preferable because they are usually simpler, quicker and more economical to take than measurements of ecosystem function. But because of the slow structural development of disturbances in the Rogers Pass, functional criteria may provide more immediate and comprehensive insight into the state of recovery.

Some functional features could be used as early indicators of ecosystem recovery for the Rogers Pass project sites. As indicated in the previous discussion, there are numerous potential characteristics of vegetation, fauna, soil and ecosystem processes that could be measured. In the study of the current plant community at the Rogers Pass sites (chapter 2) the process of native invasion was the only criterion that was examined.

Measurement of plant abundance and species richness indicate that the plant communities on the Rogers Pass sites continue to be dominated by the agronomic species in the seed mix. It is also apparent that the planted woody species have established and regenerated on the sites and that native herbaceous and woody species invasion is slowly taking place.

No quantitative guidelines presently exist that could serve as criterion for the invasion of native species on the site. Curtin (1995) did a chronological study of recovery on disturbed subalpine communities and determined the changes in species diversity over 45 years. Changes in species diversity could be used as a measure of native species invasion. Fire history can determine the age of the vegetation in an area, so that a rate of native species invasion could be determined at sites in the same ecoregion which have been disturbed by fire at different points in time. Habeck (1968) has derived a set of importance values for vegetation in climax, seral and climax communities for cedar hemlock forests which were disturbed by fire. It is not clear how far results from these studies could be extrapolated to the Rogers Pass project. This would require a detailed study. But given current examination of the site it is safe to say that native species will eventually dominate the sites.

Comparison of the lists species found on Site 1 the Beaver Valley predisturbance (Table 1.3) and 10 years postdisturbance (Table 2.1) suggests that successional recovery will eventually result in a plant community similar to adjacent undisturbed areas. *Picea engelmanii* and *Thuja plicata* which are dominant members of the tree canopy in this biogeoclimatic zone have the highest occurrence of all tree species on the recovering sites. These species may serve as early indicators that succession is on the right track.

To develop new criteria for reclamation evaluations, it is crucial that the definition of successful reclamation includes change. In other words, an ecosystem should be considered dynamic rather than static and so flexible parameters for evaluation criteria are necessary.

Permanent plots may aid in the long term assessment of function because rates of turnover can be measured. Collecting plant community composition data on a disturbed ecosystem at different points in time will provide guidelines for the recovery rates of both structural and functional characteristics. As more knowledge is gained about disturbances, their reclamation and recovery in subalpine environments then these functional criteria will have more useful and measurable applications in reclamation evaluations.

4.6 Conclusions

4.6.1 General Conclusions Derived from the Literature Review

1) Criteria for evaluating reclamation success must be well defined and clearly address the end goals of a reclamation project.

2) The criteria can be distinguished as structural or functional and can be assessed in the short term or long term.

3) Vegetation, fauna, soils and ecosystem processes are potential functional indicators of the state of recovery of a disturbed ecosystem.

4) Few practical examples exist of how functional criteria of ecosystem recovery could be incorporated into a reclamation evaluation.

5) Reclamation evaluation must be adapted to a particular ecoregion and to a certain degree must be site specific.

6) No parameters exist for acceptable native invasion rates on subalpine sites. Flexible guidelines should be developed in the recognition that ecosystems are dynamic in nature.

4.6.2 Conclusion Applied to the Rogers Pass Project

7) Measurement of plant abundance and species richness indicate that native invasion is slowly taking place on the Rogers Pass sites.

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V. Conclusion

Disturbances include any relatively discrete event in time that disrupts ecosystems, community or population structure and changes resources, substrate availability, or the physical environment (White and Pickett as cited by Rogers, 1996). The nature of the disturbance is an important part of succession in that the disturbance will influence all the changes that follow (MacMahon, 1983).

For the six Rogers Pass Project sites, examination of species abundance and richness for the locations on the disturbances indicated no significant differences. Location may be an important factor but it will be defined differently for every site. This may explain the large differences of plant community composition for the locations when compared among sites.

The results support the hypothesis that native herbaceous invasion is higher at the forest edge on some of the sites. The layout (shape and size) of a disturbance will influence the species composition of the recovering plant community. Areas with large edge to area ratio with adjacent undisturbed areas may have a higher component of native vegetation. This requires further study.

Invasion of natural woody species is low for all sites. It is possible that different factors are involved in the invasion of natural woody species as compared to the invasion of native herbaceous species. Planting of some native woody species was successful in most areas and facilitated the spread of these species on the site.

Low invasion from adjacent areas may be due to the nature of the plant structure in those adjacent areas. Forested stands with heavy canopy cover competition have a limited number of understory plant species that can survive particularly because of reduced irradiation. Therefore the number of propagules that can potentially invade newly created seismic lines is limited (Revel et al., 1984). The mature ICH forest is a classic example of a low light environment where ground cover is minimal if not nonexistent and this type of forest bordered the majority of the study sites.

Presently, agronomic species in the seed mix continue to dominate the plant community. There is a common belief that the use of agronomic species to reclaim an area may be necessary because they are easily established, inexpensive and important in erosion control. The effect of initial vegetation establishment appears to guide subsequent compositional changes of the community (Curtin, 1995).

Several steps could be taken to increase the amount of native invasion that occurs on disturbed sites particularly if the end goal is to return the site to a native plant community. These include actions taken at the time of disturbance as well as during implementation of the reclamation plan. For example, layout of a disturbance area could maximize the edge to interior ratio which would increase native species invasion and diversity or increasing aspect variation when recontouring a disturbed area could increase the number of microsites

According to the reclamation guidelines established in Appendix F of the CP Rail/Parks Canada General Agreement, reclamation success was achieved for the Rogers Pass Project. However, the goal of the reclamation was to develop a self sustaining vegetation cover which is compatible with the naturally occurring vegetation in the area and it is debatable as to whether these criteria measure this or not.

In many instances, reclamation success is more a human perception than an ecological reality. Successful reconstruction of a disturbed ecosystem often depends on the achievement of certain predetermined anthropogenic goals such as the development of a prescribed flora and fauna or the replacement of the original predisturbance biotic community (Parmenter and MacMahon in Chambers and Wade, 1992). This is evaluated with criteria which involve a visual assessment of plant cover, vigor and species composition.

These criteria assume that an equilibrium condition exists. However, each combination of species, environment, and topography is in some way unique in both space and time (Tausch, Wigand and Burkhardt, 1993). One hypothetical community as the "correct" community for a site is a misnomer. Species composition may be different between communities but they still may be functionally and structurally similar. Management strategies should be developed around two critical points: first, ecosystem processes as evaluation criteria may provide better insight into the recovery of an ecosystem and second, ecosystems should be perceived as being dynamic as opposed to stable.

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IMAGE EVALUATION
TEST TARGET (QA-3)

150mm

6"

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