MERG Report 2000-2

Assessment of Long-Term Vegetation and Site Conditions at Reclaimed Yukon Mineral and Coal Exploration Sites

By Mougeot Geoanalysis
and S.P. Withers Consulting Services

June 2000

MERG is a cooperative working group made up of the Federal and Yukon Governments, Yukon First Nations, mining companies, and non-government organizations for the promotion of research into mining and environmental issues in Yukon.

MERG (Mining Environment Research Group) reports are available at Geoscience Information and Sales, Yukon Geological Survey, Department of Energy, Mines and Resources, Room 102, Elijah Smith Building, Whitehorse, Yukon.

Mailing Address:
102-300 Main Street
Whitehorse, Yukon Y1A 2B5
Phone (867) 667-5200
toll free within the Yukon
1-800-661-0408 ext. 5200
Fax (867) 667-5150
E-mail geosales@gov.yk.ca

The reports are also available electronically at the MERG Website:

http://www.emr.gov.yk.ca/mining/merg/

Table of Contents

Assessment of Long-Term Vegetation and Site Conditions at Reclaimed Yukon Mineral Exploration Sites

Non-technical Summary

There have recently been many changes in the way mining exploration projects operate, including new technologies, new exploration targets and new environmental regulations. Following recent amendments to the Yukon Quartz and Placer Mining Acts, a significant new piece of legislation came into effect in December 1999. The Yukon Quartz Mining Land Use Regulations, administered by the Department of Indian Affairs and Northern Development, now requires the reclamation of disturbed land on mining claims. But what happens at these reclaimed sites several years after the work is finished? Is there more than one way to successfully reclaim such land? How do local conditions affect the regrowth of plants on these sites and how much preparation of the reclaimed surface is needed? This report may not provide answers to all these questions, but it presents data collected at several Yukon sites, each with different ages and having had different reclamation treatments. From these observations, patterns on the success or failure of revegetation programs emerge and provide information on the rate and extent of natural revegetation at reclaimed mining trenches.

Several types of reclamation sites were looked at in several different areas of Yukon, both above and below the treeline. Three of these were exploration trenches that were backfilled and revegetated as part of an experimental reclamation program in 1995. These reclaimed exploration sites included the Red Ridge trench, near Annie Lake in the Whitehorse area, the Nucleus trench west of Carmacks and the Hawk trench near Dawson City. Each of these reclaimed trenches were revegetated with different seed and fertilizer mixes. This report summarizes how these sites looked in 1999, four years after the reclamation work was done.

At Division Mountain, west of Braeburn, several coal trenches and drill pads were reclaimed by a mineral exploration company between 1995 and 1997. These sites were also looked at in 1999 in order to measure the success of the revegetation program. The last place visited in 1999 was Jason Knoll near Macmillan Pass where a number of exploration trenches and drill pads were reclaimed in the early 1980s. This site provides a look at the longer-term success rate of a revegetation program near the treeline.

Refilled and contoured trenches, with rough and loose surfaces seem to revegetate well. The replacement of original soil is most important and makes the most significant contribution to the revegetation process, particularly at high elevation sites or sites in extreme climatic conditions.

The replacement of tree debris significantly improves habitat conditions for small mammals by decreasing access and visibility for predators.

Seeded agronomic legumes are not surviving long and do not appear to contribute to surface coverage in a significant way at any stage. The use of sod-forming species such as red fescue can inhibit the natural invasion of colonizing plant species (the resultant litter from the thick vegetative mat further retards new growth). Meadow foxtail, fowl bluegrass and red top are not surviving on the two forested trench plots (Nucleus and Hawk trenches). From observations at all properties surveyed, agronomic species are not colonizing undisturbed sites. Results at the Nucleus and Hawk properties, located below treeline suggest that although an early dense coverage by agronomic species may be required to control soil erosion in areas with steep slopes, this dense seeding may not be necessary or desirable in most cases.

Observations at Division Mountain, also situated below tree line, reinforce these conclusions. Rough surfaces, with very loose and rugged micro-topography, foster the growth of seeded species, but the coverage is not dense. Native species, therefore, can invade pockets that act as seed traps and provide shade and moisture. This results in the rapid colonization of these surfaces. The use of the original top soil and vegetation debris definitely plays an important role in the return of native species. The replacement of tree debris creates an environment similar to burned over areas. In addition to preventing access by all-terrain vehicles to the corridors created by the trenches, it also avoids creating long corridors of high visibility for predators. Travel by ungulates is still possible across trenches. Small mammal habitat is probably enhanced by the numerous cavities, vegetation pockets and good cover created by the reclaimed trenches.

The Jason Knoll drill sites located below treeline are located in moisture-rich, nutrient-rich sites, and long-term impacts should be negligible. The ground-cover vegetation, as well as shrubs and seedlings, invading these sites 15 years after reclamation are dense, diverse and robust. The current seral stage of vegetation includes plants adapted to these wet conditions. Over the next 20 years, the vegetation on these disturbed areas will probably return to plant communities that resemble the surrounding forest.

Reclamation of disturbed land in alpine areas is the most problematic. The Red Ridge test plots and the highest reclaimed trenches at the Jason Knoll property are returning to natural conditions more slowly than lower elevation sites. In the lichen-moss alpine zone, the climate and soil conditions are often extreme and the growth of both agronomic and native plants is more difficult. At the Jason Knoll property, frost boils, evident both on both disturbed and undisturbed sites, are retarding plant colonization. This active process likely occurs at most high-elevation sites in the Yukon. Overall, from the sites visited during this project, we can conclude that refilling, recontouring and seeding trenches significantly reduces the long-term impact of exploration disturbances, and that changes in vegetation or habitat do not seem to extend beyond specific disturbances.

1 Introduction

1.1 Background

Recent amendments to the Yukon Quartz and Placer Mining Acts have brought into effect mining land use regulations. Since December 1999, the new federal Yukon Quartz Mining Land Use Regulations (MLUR) have been implemented. The MLUR has formulated operating conditions for exploration projects of various sizes regarding trench reclamation, archaeological and burial sites, camp cleanliness, fuel and chemical storage and handling, line cutting, drilling, use of vehicles on and off roads, stream crossings and the use of explosives. The reclamation requirements and procedures established by the MLUR are of specific interest to this project.

Previously there had been no reclamation requirements on quartz mining claims. As a result, few reclamation studies have been carried out and the revegetation capabilities of reclaimed mineral exploration sites have not been examined. There has been no verification of the **long-term** (5 to 15 years) success of revegetation at reclaimed exploration sites in the Yukon. There has been no long-term documentation of any of the following factors: soil erosion, the successful re-introduction of naturally colonizing plant species, the gradual disappearance or survival of agronomic grass species and the modification of habitat. In areas where permafrost is present, there has been no information on the behavior of permafrost at reclaimed sites. In addition, there has been no documentation of the long-term impact of agronomic species introduced to an area through trench reclamation or of site conditions after the long-term abandonment of reclaimed trenches or drill pads.

In many cases, it can take several years for the natural re-establishment of ground cover needed to control soil erosion. Agronomic grass species are usually seeded for the early control of erosion and to foster the colonization of the site by local plant species. Usually, it is desirable that the agronomic species do not survive or compete successfully with natural plant species, in order to reduce the risk of long-term changes to local ecosystems.

Between July 15th and 30th, 1999, the study team surveyed reclaimed sites at five different mineral exploration properties in the Yukon, each representing different lengths of time since

abandonment, different reclamation treatments and varying ecological conditions. The oldest reclamation site dates from 1982 and the most recent one from 1997.
The results of the vegetation, soil and site condition survey provide follow-up information on the regrowth conditions and vegetation community compositions several seasons after the abandonment of these exploration sites. Habitat values, the effects of erosion and gullying, the changes to soil and microsite conditions, the survival rates of agronomic species and the extent of natural invasion by pioneering plant species are documented. At some of the sites, permafrost behavior is also assessed.

1.2 <u>Project Objectives</u>

The objectives of this project are:

- To document the success of natural and assisted revegetation on reclaimed sites at five mineral exploration properties.

- To provide information on the long-term behavior of agronomic grasses, as well as colonizing grass, forb and shrub species at reclaimed sites at various altitudes and climatic zones in the Yukon.

- To document the site conditions of trenches reclaimed in a way similar way to those recommended by the Yukon Quartz Mining Land Use Regulations.

- To provide insights into habitat changes at reclaimed mineral exploration sites.

- To record changes in soil erosion patterns, micro-site conditions and if possible on permafrost conditions at reclaimed sites over several years.

- To provide insights into the cumulative environmental impacts at reclaimed mineral exploration sites.

- To formulate recommendations to improve the long-term success of reclamation practices in the Yukon, based on the observations taken at sites which have been reclaimed and left for several seasons.

1.3 Selected Mineral Exploration Sites

The mineral exploration sites investigated in this study are in the south-central Yukon (Figure 1-1).

The Jason Knoll property Yukon (Figure 1-1) is located 220 km north east of Ross River in the Macmillan Pass area (63°10’ N and 130°10’ W). In 1981 and 1983, Pan Ocean Oil Ltd. conducted a reclamation program on trenches located above the treeline and at drill pads located at lower elevation sites. The area was selected for this study because it provides regional insight into the reintegration of local plant species, the long-term behavior of imported species, the soil erosion conditions and the habitat value of disturbed and reclaimed sites that have been left for a period of more than 15 years. This is one of only a few sites in the Yukon that can provide insight into the long-term, cumulative results of reclamation efforts on mineral exploration trenches.

The Division Mountain coal property Yukon (Figure 1-1), located about 90 kilometres northwest of Whitehorse, is currently owned by Cash Resources Inc. The Division Mountain coal property is one of the few sites in the Yukon where trench and drill pad reclamation has been accomplished as part of the exploration program. This situation, therefore, provides a unique opportunity for monitoring the results of reclamation efforts as performed as an integral part of the exploration process, carried out within the cost, time and logistical constraints of an industrial exploration program.

The remaining three sites Yukon (Figure 1-1) are part of a reclamation study initiated in 1994 by the Mineral Resources Directorate of the Department of Indian Affairs and Northern Development. In 1994, investigations of natural revegetation processes were conducted by Mougeot GeoAnalysis (1996) in order to document the optimum abandonment conditions which foster natural regrowth on exploration features. These sites, located in the Dawson, Carmacks and Whitehorse areas, cover a range of locations, climates, elevations, as well as soil and bedrock conditions. In 1995, plots were prepared and seeded at these three locations by Craig and Associates (1998). Revegetation at these sites was documented after one and two seasons of growth (Craig *et al*. 1998). Each of these sites was revisited in order to follow up on vegetation growth and coverage at each plot.

Figure 1-1 Location map of the five exploration properties investigated.

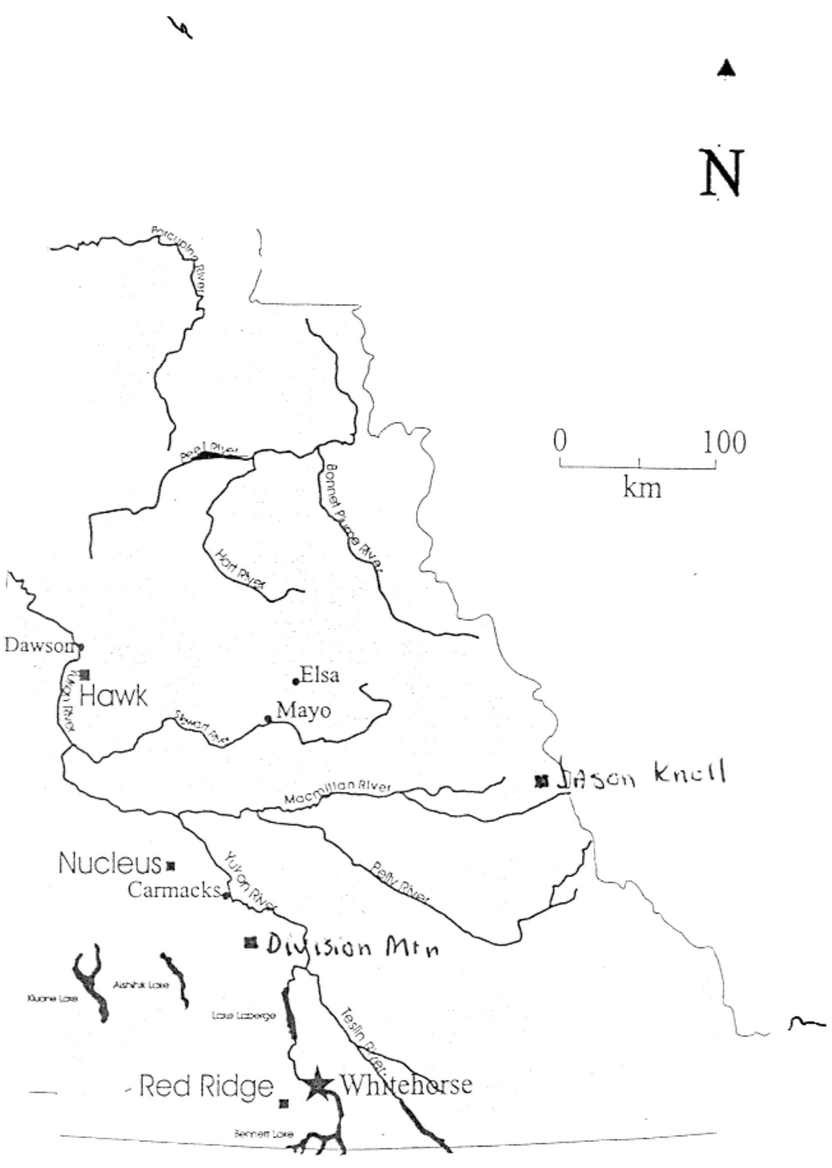


Table 1-1 Summary Table, Reclaimed Sites

Property Name	***RED RIDGE***	***NUCLEUS***	***HAWK***	***DIVISION MOUNTAIN***	***JASON KNOLL***
General Area	Wheaton River	West of Carmacks	Dawson	West of Braeburn	Macmillan Pass
Latitude N	60^{o} 21’	62^{o} 20’	63^{o} 54’	61^{o} 19’	63^{o} 10’
Elevation a.s.l.	1500 m	900 m	800 m	950 m	1140 m to 1400 m
Aspect	ridge top	east side	south side	variable	variable
Rock Type	hornblende diorite	rhyolite	schist	siltstone, sandstone, coal	shale and granite
Number of Sites	5 plots at 1 site	5 plots at 1 site	5 plots at 1 site	3 trenches, 1 drill pads	3 trenches 2 drill pads
Year Reclaimed	1995	1995	1995	1995	1981

1.4 Methods

Each reclaimed site included in the study is described in terms of:

- Physical setting (elevation, slope, aspect, drainage regime, etc.)
- Age and type of disturbance
- Soil conditions, processes and surface conditions for disturbed and undisturbed sites
- Reclamation treatments where possible
- Species diversity and cover-abundance of plant species within the disturbed site
- Species diversity and cover-abundance of revegetation outside the disturbed site

(Note that the common names of plant species are used in this report; the scientific names of all species are found in Appendix B).

In addition, the Macmillan Pass sites provide some indication on permafrost behavior at disturbed sites 15 years after site modification.

2 Reclamation Test Sites

2.1 <u>Red Ridge Reclaimed Trench</u>

This site is located south of Whitehorse, approximately five kilometres northwest of Annie Lake (Figure 2-1). It was part of the reclamation project by carried out by Craig *et al*. (1998) and by Mougeot GeoAnalysis (1996). Information from those earlier publications is summarized here.

2.1.1 Ecological Setting

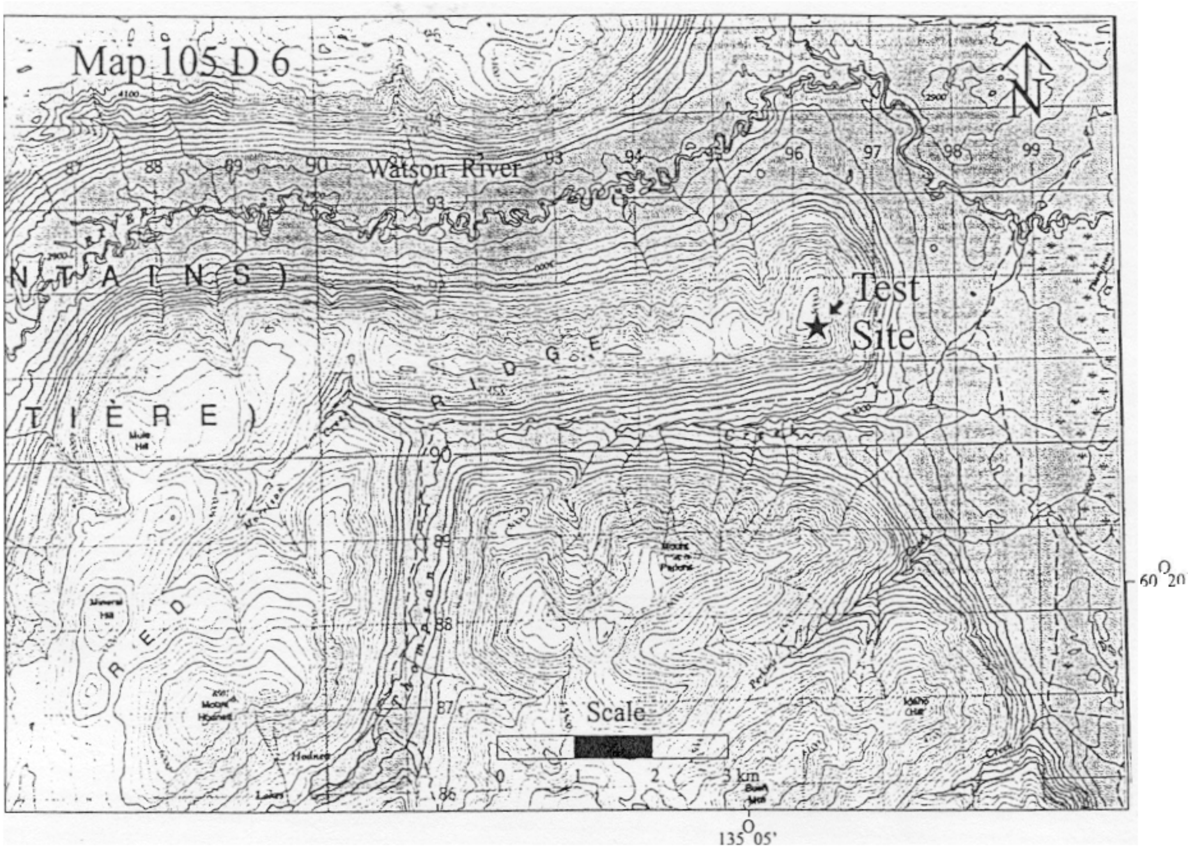
This reclaimed trench is located on Red Ridge, on the eastern edge of the Coast Mountains physiographic subdivision and in the Southern Lakes ecoregion. The trench is located on the top of the crest, at the east end of Red Ridge, at an elevation of approximately 1500 m. The reclaimed trench has a gentle slope, between two and four degrees and is exposed to the wind.

This area lies in the rainshadow of the St. Elias Coast Mountains; the climate can be classified as arid. Precipitation ranges from 200 to 325 mm annually. Mean annual temperatures are near -1°C. The mean January temperature is -19°C and is usually 5°C warmer over higher terrain due to thermal inversions. The July mean temperature is 14°C and is some 5°C cooler over higher terrain. Extreme temperatures have ranged from -55°C to plus 34°C. The average temperature from May to September is 11°C. Mean annual precipitation is 260 mm, with precipitation from June to August averaging 98 mm. This weather information is obtained from the closest weather station, at the Whitehorse Airport located at an elevation of 698 metres.

Winds are generally moderate, particularly in valleys with southeast to northwest orientation, due to the proximity of storm centres in the Gulf of Alaska. Strong winds, 30 to 50 km/hr, are common; winds can occasionally reach destructive force levels, with gusts over 100 km/hr, primarily from a southerly direction.

The Annie Lake area lies within the limits of the McConnell Glaciation (Bostock 1966) and within the scattered permafrost zone (Brown 1978). There were no visible signs of permafrost in the trenches described in this area, but it is possible that localized pockets of permafrost occur in sheltered sites with a thick organic cover.

Figure 2- Location map of the Red Ridge Property



2.1.2 Exploration History

Exploration history is reported in detail in Mougeot (1996) and in the Yukon Minfile (1997, 105D). The Annie Lake area is part of the Wheaton River mining district. This area has been an actively explored and mined for the last several decades.

The Red Ridge property was staked for the first time in 1970. Early exploration included soil sampling and geological mapping. The area has since been further explored through additional mapping, geochemical sampling, trenching and diamond drilling. The most recent activity in the area occurred in 1988, when soil sampling, geological mapping and diamond drilling projects were undertaken. Numerous trenches are easily identified at the crest of the ridge. Mineralization on the property includes copper, molybdenum, gold, silver and lead. The Red Ridge property is now inactive.

2.1.3 Reclamation History

The Red Ridge property was included in the 1994 exploration site study (Mougeot 1996). In 1995, five reclamation test plots were constructed (Craig *et al*. 1998). A trench was selected and refilled using a light bulldozer. Five plots were measured, staked and flagged. Each plot measures ten by four metres. Plot 1 was prepared using fertilizer, seed mix and an inoculant of nitrogen-fixing bacterial culture. Plot 2. was prepared the same way with a 2 cm-thick mulch blanket put over the plot and anchored with rocks. Plot 3 treatment included fertilizer, seed mix, inoculant and 8 cm of top soil. Plot 4 was the control plot without surface improvement. Plot 5 was treated with only fertilizer and seed mix. The composition of the seed mix included alsike clover, alpine bluegrass, creeping red fescue, sheep fescue, meadow foxtail and timothy.

The plots were revisited in 1996 and 1997 (for more detail see Craig *et al*. 1998). Plot 1 showed 15% coverage, with grasses being approximately 10 cm tall. In 1997, coverage was slightly greater and the grasses (timothy and bluegrass) were 25 cm tall. Plot 2 showed a 20% vegetative coverage in 1996 and 1997. Plot 3 showed a similar coverage as plot 2 in both years, with sparse colonization by native species. Plot 4 showed only a few bluegrass stems, while plot 5 showed growth similar to plot 1. In summary, the plot with topsoil showed slightly better growth than the plot with mulch, while the two treatment plots without mulch or topsoil were less productive.

2.1.4 1999 Field Observations

Undisturbed Site Conditions

Undisturbed site conditions are described in detail in Mougeot (1996). In summary, undisturbed surfaces consist of gently rounded crests and depressions. Exposed bedrock is visible in places and the parent material consists of weathered or shattered rock, with a very low percentage of fines or matrix. Soils are poorly developed and friable with a very thin to absent humic-rich horizon. The site is very dry, exposed to the wind, and poor in nutrients.

The site is above treeline and the natural vegetation is a typical alpine vegetation community (Mougeot 1996). The low shrub layer contains willow, mountain aven and low-bush cranberry. Moss campion, showy Jacob's ladder and red-stemmed saxifrage make up the forb layer. Naturally occurring grasses are very sparse. Mosses and lichens dominate the ground cover.

Soil and Site Conditions

All the plots shared a slightly convex surface and very gentle slope. Material is composed of angular rock fragments and matrix content is less than 20%. Surfaces were moderately compacted. Plot 1 and 5 showed significantly more fines than the control plot 4. Plot 3, with the top soil addition, showed that much of the top soil had been eroded by the wind. Less than 3 cm of top soil remained over most of the plot with pockets of thicker top soil around the edge of the plot showing good growth.

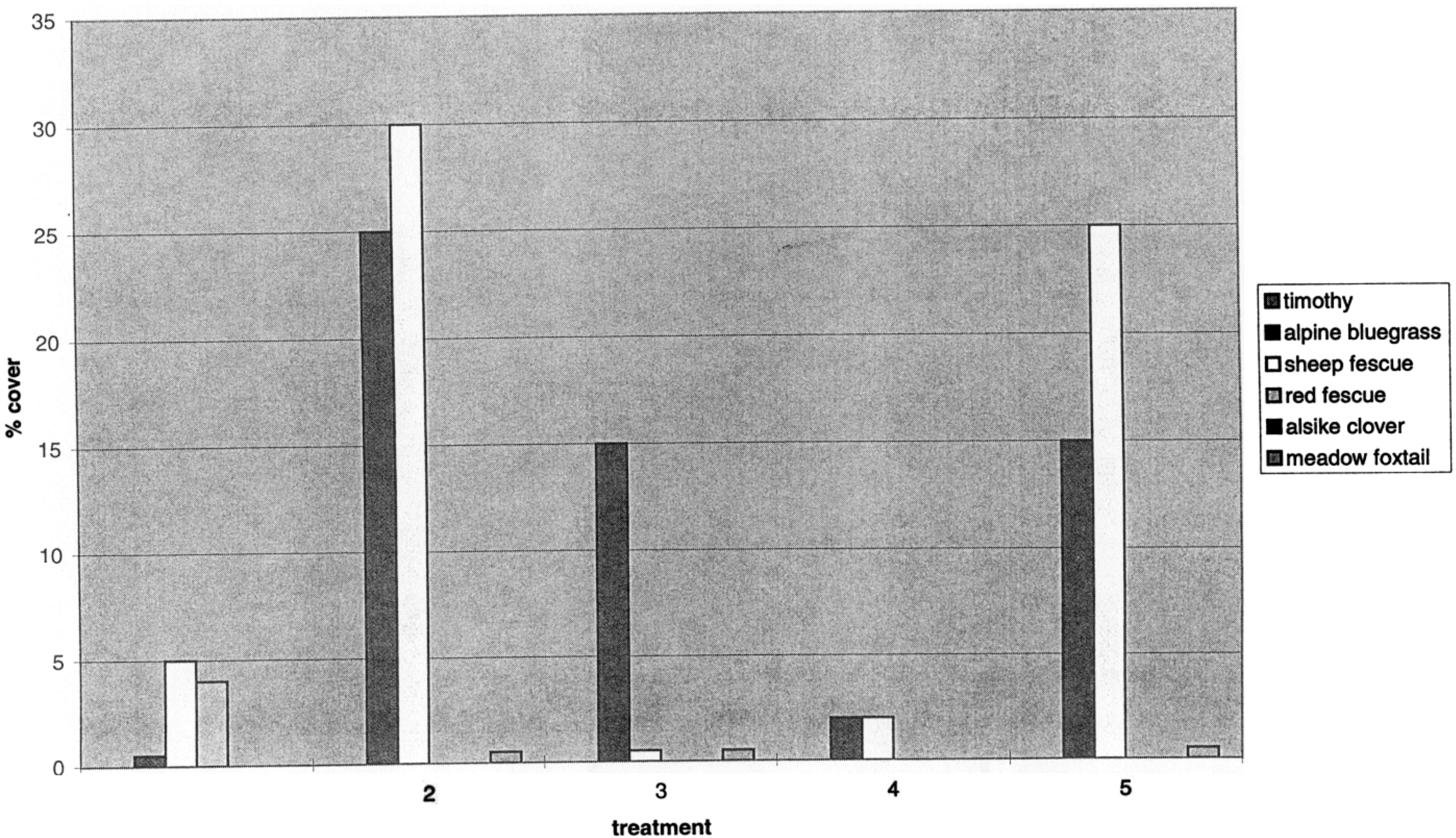
Vegetation

The vegetation occurring on this reclaimed trench was sparse, probably due to the harsh alpine environment. The seeded vegetation was dominated by alpine bluegrass and sheep fescue. Traces of meadow foxtail and red fescue occurred on some plots (Figure 2-2 and Appendix A).

- **Plot 1: Fertilizer, seed and inoculant.** Red fescue and sheep fescue dominated the seeded revegetation with covers of four and five percent, respectively. Colonization by native species was sparse. The only invading species were traces of Rocky Mountain fescue and alpine holygrass (Plate 2-1).

- **Plot 2: Fertilizer, seed, inoculant and straw mulch.** This test plot had the greatest vegetation cover, dominated by sheep fescue (30%) and alpine bluegrass (25%). Invasion

Figure 2.2: Red Ridge trench revegetation - 4 years after reclamation



by native species included only traces of northern rough fescue, Rocky Mountain fescue and chickweed (Plate 2-2).

- **Plot 3: Fertilizer, seed, inoculant and topsoil.** Alpine bluegrass was the only seeded species with a significant cover (15%). The greatest number of unseeded species were observed in this plot, including a 15% cover of Kentucky bluegrass. Some of these species may have been introduced with the topsoil (Plate 2-3).

- **Plot 4: Control (no enhancement).** This plot had the sparsest vegetation. The seeded species included alpine bluegrass and sheep fescue, each with two percent cover. The only colonizing native species were traces of Rocky Mountain fescue and Huddelson's locoweed (Plate 2-4).

- **Plot 5: Fertilizer, seed (no inoculant).** Sheep fescue and alpine bluegrass were the only seeded species with significant cover (25% and 15%, respectively). The only colonizing species were traces of Rocky Mountain fescue and Kentucky bluegrass (Plate 2-5).

Wildlife

Evidence of sheep (grazing sign and fecal pellets) was noted inside the reclamation plot. Two adult rams were observed nearby. Wolf scat was also observed close to the trench. The only other wildlife observed in the area were a few horned larks.

2.1.5 Summary

Four years after seeding, alpine bluegrass and sheep fescue appear to be the most successful species used for revegetation on the Red Ridge trench. Red fescue and meadow foxtail occurred in small amounts. Timothy and alsike clover are no longer found on any of the test plots.

Treatment two (seed, fertilizer, inoculant and mulch) and treatment five (fertilizer and seed) are the most effective reclamation practices used on this trench. The addition of topsoil does not appear to be a useful treatment. The top soil treatment has resulted in the occurrence of a number of plant species not found elsewhere in the area (these species were presumably introduced with the topsoil).

Colonization of the Red Ridge test plots by the surrounding native vegetation is occurring very slowly. In addition to the topsoil-introduced species, Rocky Mountain fescue, northern rough fescue, slender wheatgrass, alpine holy grass and wood blue grass have invaded the reclaimed trace in trace amounts.

It is interesting to note the clumps of native vegetation that are colonizing the disturbed but unseeded areas surrounding the test plots (Plate 2-6).

2.2 Nucleus Property Reclaimed Trench

The Nucleus property is located at the headwaters of Big Creek, approximately 90 km west of Carmacks on the Mt. Freegold Road (Figure 2-3).

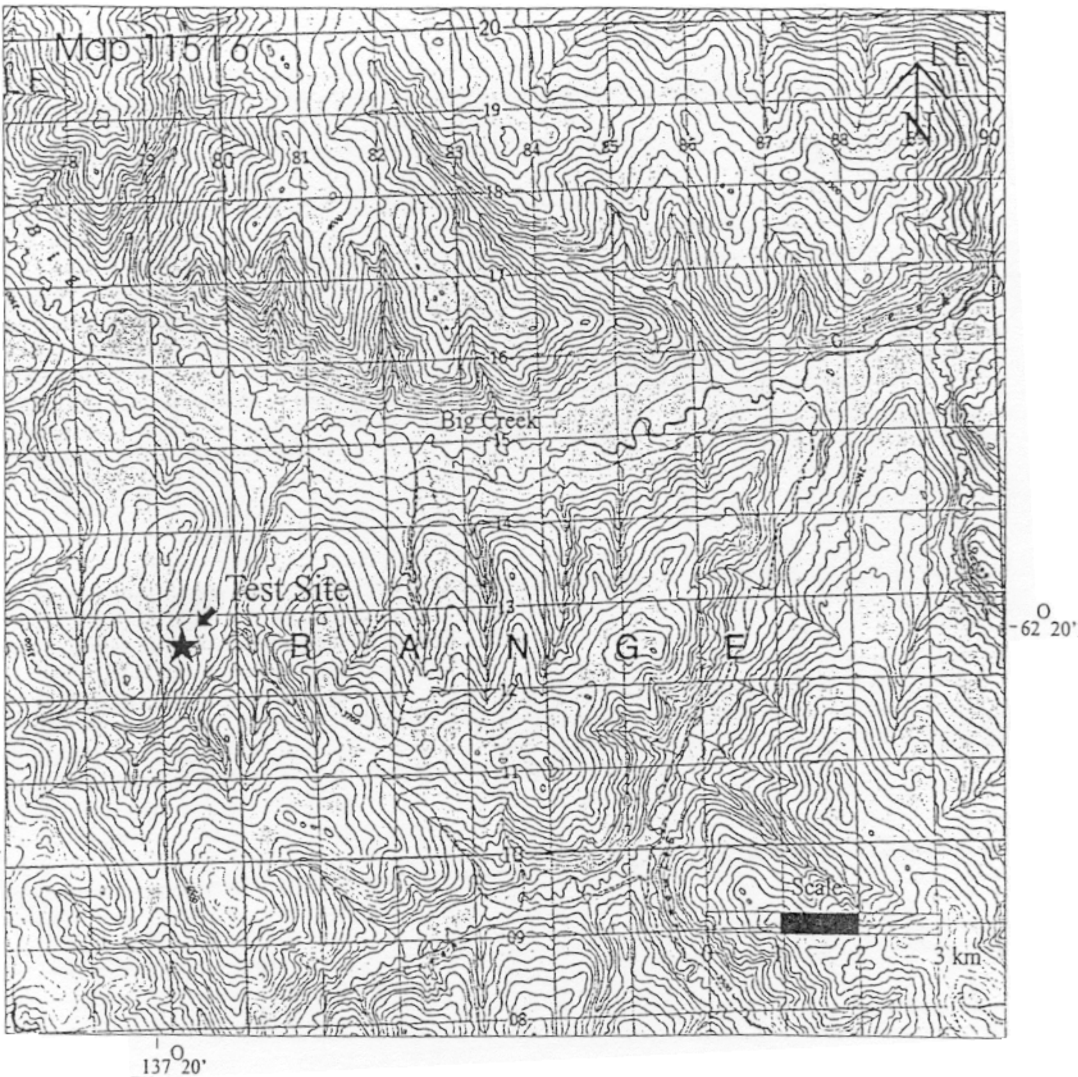
2.2.1 Ecological Setting

This site is located within the Central Yukon Plateau ecoregion. One trench was reclaimed at this property. It is located at an elevation of 900 metres and is located below treeline. It faces east and runs downhill and has a slope of 12 degrees.

The climate is sub-arctic continental and relatively dry with major temperature variability on both a daily and seasonal basis. Precipitation is relatively light ranging from 250 to 300 mm, two thirds of which falls during the summer months as rain, primarily showers. Mean annual temperatures are near -4^{0}C. Mean January temperatures range from -30^{0}C the lowest valleys to a more moderate -20^{0}C over the higher terrain due to the inversion effect. Mean July temperatures range from near 15^{0}C in the lowest valleys to 10^{0}C over the higher terrain. The most extreme daily temperatures will occur in the lowest valley floors and these can range from extreme minimums of -60^{0}C to -65^{0}C to extreme maximums near 35^{0}C. This weather information comes from the Carmacks weather station located at an elevation of 521 metres.

During the Quaternary time period, at least four major Cordilleran glaciations have affected southern and central Yukon Territory: the Nansen (oldest) and Klaza Glaciations which are collectively referred to as pre-Reid glaciations; the Reid (Illinoian) Glaciation; and the most recent McConnell (Wisconsin) Glaciation (Bostock 1966, Hughes *et al*. 1968).

Figure 2-3 Location map of the Nucleus Property.



The Nucleus property is believed to be located beyond the area covered by pre-Reid glaciation, but it is possible that pre-Reid glaciofluvial sand and gravel are present in creek and valley bottoms. The limit for the Reid glacial advance however is located a few kilometres east of Victoria Creek and proglacial deposits related to advancing and retreating glacial advance are found at lower elevations in the major valley floors of the study area. LeBarge (1993) discusses in detail the Quaternary geology of the area and its importance to placer deposits.

2.2.2 Exploration History

The Nucleus property is located in the Dawson Range. The Dawson Range occurs within the allochthonous and geologically complex crystalline belt known as the Yukon-Tanana Terrane. The geology of this part of the central Yukon is poorly known as the area was never glaciated and outcropping is therefore scarce. Copper mineralization is associated with both the potassium-rich granites of the Dawson Range Batholith and with the Prospector Mountain intrusions. The following information originates from Mougeot (1996) and Yukon Minfile (1997, 115I-Carmacks).

Claims were first staked on the Nucleus property in 1968. Records indicate that a variety of diamond and percussion drilling, geochemical surveys, soil sampling, trenching and VLF-EM, IP, magnetometre and other EM surveys have been carried out on the Revenue property between 1950 and the early 1990's. Soil geochemistry has outlined several anomalous zones, some of which have been followed up by drilling.

The Nucleus property has been subjected to extensive trenching, percussion and diamond drilling and geochemical sampling since it was first staked. A 1988 drilling program for which public information is available, indicated a high grade zone with reserves of 211,900 tonnes grading at 3.16 g/t gold. One drill hole intersected values of 34.9 g/t silver at over 13.7 m. During 1999 site visit, there was evidence of recent work being done on the property. The reclaimed trench was excavated in 1984 and was labeled as TR86NW4.

2.2.3 Reclamation History

The Nucleus property was also included in the 1994 exploration site study (Mougeot 1996). In 1995, five reclamation test plots were constructed by Craig *et al*. (1998). A trench was selected, refilled using a light bulldozer and the five plots were measured, staked and flagged.

As at Red Ridge, the plots measure 10 m by 4 m. Plot 1 was prepared using fertilizer, seed mix and an inoculant of nitrogen-fixing bacterial culture. Plot 2 was treated the same way with a 2 cm-thick mulch blanket placed over the plot and anchored with rocks. Plot 3 treatment included fertilizer, seed mix, the inoculant and 8 cm of top soil. Logs were placed perpendicular to the slope to help minimize soil erosion. Plot 4 was the control without surface improvement. Plot 5 was prepared with only fertilizer and seed mix. The composition of the seed mix is different from that at Red Ridge and included alsike clover, fowl bluegrass, creeping red fescue, red top, reed canary grass, slender wheatgrass, meadow foxtail and timothy.

The test plots were revisited in 1997. At that time, plot 1 had a cover of 80% grass. Clover was sparse (less than 1%). Plot 2 had a 90% vegetative coverage with timothy, red fescue and slender wheatgrass as high as 50 cm and a 20% clover coverage. Plot 3 showed similar results as plot 2 (90% coverage with traces of colonizing moss). Plot 4 had 10% of the surface covered by grasses, fireweed and rose. Plot 5 showed modest growth (80%). It was similar to plot 1 coverage without the clover but included a few fireweed plants. To summarize, in 1997 the plot with topsoil showed slightly better growth than the plot with mulch. Erosion channels were noted at the edge of the downhill side of the reclaimed surface. The two treated plots without topsoil or mulch had similar vegetative cover.

2.2.4 1999 Field Observations

Undisturbed Site Conditions

At the site itself, a metre of colluvial deposits rest over bedrock and there is evidence of some permafrost at the site. The undisturbed surface is gently hummocky and the slope is about 15%. The shallow soil rests on bedrock and is a moderately well to imperfectly drained orthic-turbic cryosol. The turbated soil horizons are an indication of shallow permafrost. The organic mat is 8 cm thick. Mineral soil has a pH value of 6.0 and is a fine to medium sand and sandy loam with 10% coarse fragments. Abundant micro to coarse roots are present between 0 and 8 cm. A few very fine roots reach 50 cm deep.

The undisturbed vegetation is a fairly dense black spruce/moss/lichen forest (Mougeot 1996). The tree layer is sparsely (10%) populated by small black spruce. The majority of the black spruce fall in the tall shrub category, with about 50% coverage. The low shrub layer is dominated by Labrador tea with some willow (3%) reaching up to 2 m in height, blueberry

(15%), and prickly rose with 1% coverage. Low-bush cranberry covers 20% of the dwarf shrub layer. The forb layer is very sparsely populated by coltsfoot (2%), and a clubmoss (1%). The graminoid layer is also very sparse (about 2% coverage). Two feather mosses, stepmoss and re-stemmed feather moss, dominate the moss/lichen layer with about 55% coverage. A brown sphagnum moss occurs here (2%), as does another common, unidentified moss. Eight species of lichens, dominated by green reindeer lichen (30%) combine to cover the rest of the forest floor.

Soil and Site Conditions

The reclaimed surface has slopes varying between 10 and 12%. The material is a cobbly, sandy loam with less than 30% fines in the matrix. Half the site is refilled trench; the other half is the scraped-off stockpiled overburden. The compaction is moderate to high.

Plots 1 and 5 were very similar, without noticeable traces of erosion or cryoturbation. Plot 2 (with the mulch blanket) is very effective at controlling erosion. The creation of a fibric mat may eventually happen but during this field visit, the thick mulch mat seemed to reduce light reaching the ground. Plot 3 is located at the downslope end of the trench and had five small gullies developing (5 to 18 cm deep). The logs placed at the end of the plot seemed to be effective in reducing erosion. The top soil thickness varied between 0 to 12 cm. Gullies had formed in Plot 4, next to Plot 5.

Vegetation

Each of the five ten-metre wide test plots on the Nucleus reclaimed trench spans the four-metre wide backfilled trench as well as a portion of the area where the excavated material had been stockpiled (Plate 2-7). The vegetation observed on the seeded test plots was noticeably different between these two zones (Figure 2-4 and Appendix A).

On the four treated plots, red fescue was clearly the dominant seeded species, with up to 85 % coverage. Red fescue formed most of the vegetative mat on all but the control (unseeded) plots, where timothy and alsike clover were the dominant seeded species.

- **Plot 1: Fertilizer, seed and inoculant.** Red fescue formed a 50% cover (average height about ten cm with little inflorescence in the current year) on the backfilled trench portion of the plot and 80% on the area where the overburden had been stockpiled. The only other seeded species with significant presence was timothy (average height about 30 cm), which

had a 15% cover on the backfilled trench and less than one percent on the remainder. Invasion by native species included traces of fireweed, arctic lupine and green alder. Previous years' vegetative litter (primarily from red fescue) dominated the ground cover, with about 5% bare ground (Plate 2-8).

- **Plot 2: Fertilizer, seed, inoculant and straw mulch.** Red fescue (average height 50 cm) dominated the vegetative mat with a 70% cover on both the backfilled trench and the excavated material storage area. Timothy (30 cm height) had a 15% cover on the backfilled trench and 1% on the remainder. Alsike clover covered 3% of the excavated material storage area. Shrub seedlings, including green alder, rose and willow were the most prominent colonizing native species. The straw mulch still covered 30% of the reclaimed surface and vegetative litter (primarily from red fescue) was very evident (Plate 2-9).

- **Plot 3: Fertilizer, seed, inoculant and topsoil.** This plot has the greatest cover by red fescue (85% on the backfilled trench and 80% on the remainder). The only other seeded species of significance was timothy, which has 7% cover on the backfilled trench but was not present on the remainder. A number of unseeded species, including squirrel's tail barley which covered 5% of the backfilled trench, were observed only on this plot and may have been brought in with the topsoil. Vegetative litter (red fescue) is prevalent (Plate 2-10).

- **Plot 4: Control (no enhancement).** Alsike clover covers 10% of the backfilled trench portion of the plot (the highest cover for this species on all of the plots). Timothy also covered 10% of the backfilled trench. Red fescue, by far the dominant species on the four treated plots, had not significantly colonized the control plot (less than 1% cover). Although this plot had much more bare ground without the red fescue vegetative litter, it has the highest number of colonizing species (17 species including eight graminoids) (Plate 2-11).

- **Plot 5: Fertilizer, seed (no inoculant).** As on the other treated plots, red fescue was the dominant seeded species (70% on the backfilled trench portion of the plot and 80% on the remainder), although very few plants had inflorescences in the current year. This was the only plot with a significant slender wheatgrass coverage (3% on the backfilled trench portion of the plot, although less than 1% on the remainder). Previous years' vegetative litter (primarily from red fescue) was very visible. Colonizing native species included traces of Rocky Mountain fescue, green alder, fireweed and arctic lupine (Plate 2-12).

Wildlife

Moose fecal pellets, tracks and browsing sign were noted nearby the Nucleus test plots. The only other evidence of wildlife at the site was that of varying hare and grouse.

2.2.5 Summary

In 1999 (four years after the Nucleus trench was reclaimed), red fescue is the most successful of the plant species seeded on the test plots, with up to 85% coverage. This species has clearly dominated the vegetation on all of the reclaimed trench except for the unseeded control plot. Less successful seeded species are timothy, slender wheatgrass, alsike clover and reed canarygrass. Fowl bluegrass, red top and reed meadow foxtail are no longer found on any of the test plots.

All of the four reclamation treatments were successful in establishing a high vegetative cover. The only visible benefit from the addition of inoculant was an increase in the presence of Kentucky bluegrass. Treatment with mulch showed no apparent advantage, while the addition of topsoil resulted only in a slight increase in the red fescue coverage. The topsoil treatment also resulted in a number of plant species not found elsewhere in the immediate area. These species were presumably introduced with the topsoil.

Invasion by the surrounding native vegetation was highest on the unseeded control plot. Colonizing shrubs found only on the control plot included black spruce, trembling aspen and willow. The colonization of the treated plots by native species was apparently retarded by the thick sod-forming seeded graminoids, particularly red fescue. The untreated control plot also had a higher coverage by the seeded legume, alsike clover.

A notable observation during the 1999 survey of the reclaimed Nucleus trench was the differing results found on the backfilled trench and the area where the excavated material had been stockpiled. The reclaimed backfilled trench generally had a higher vegetative cover than the reclaimed spoil pile, resulting from both the seeded species and the invasion by native species.

2.3 Hawk Property Reclaimed Trench

The Hawk property is located in the Klondike area (Figure 2-5), 25 km from Dawson City, on the north side of French Gulch, a tributary of Eldorado Creek. It is part of the Klondike Plateau. The trench is cut into a south-facing hillside.

2.3.1 Ecological Setting

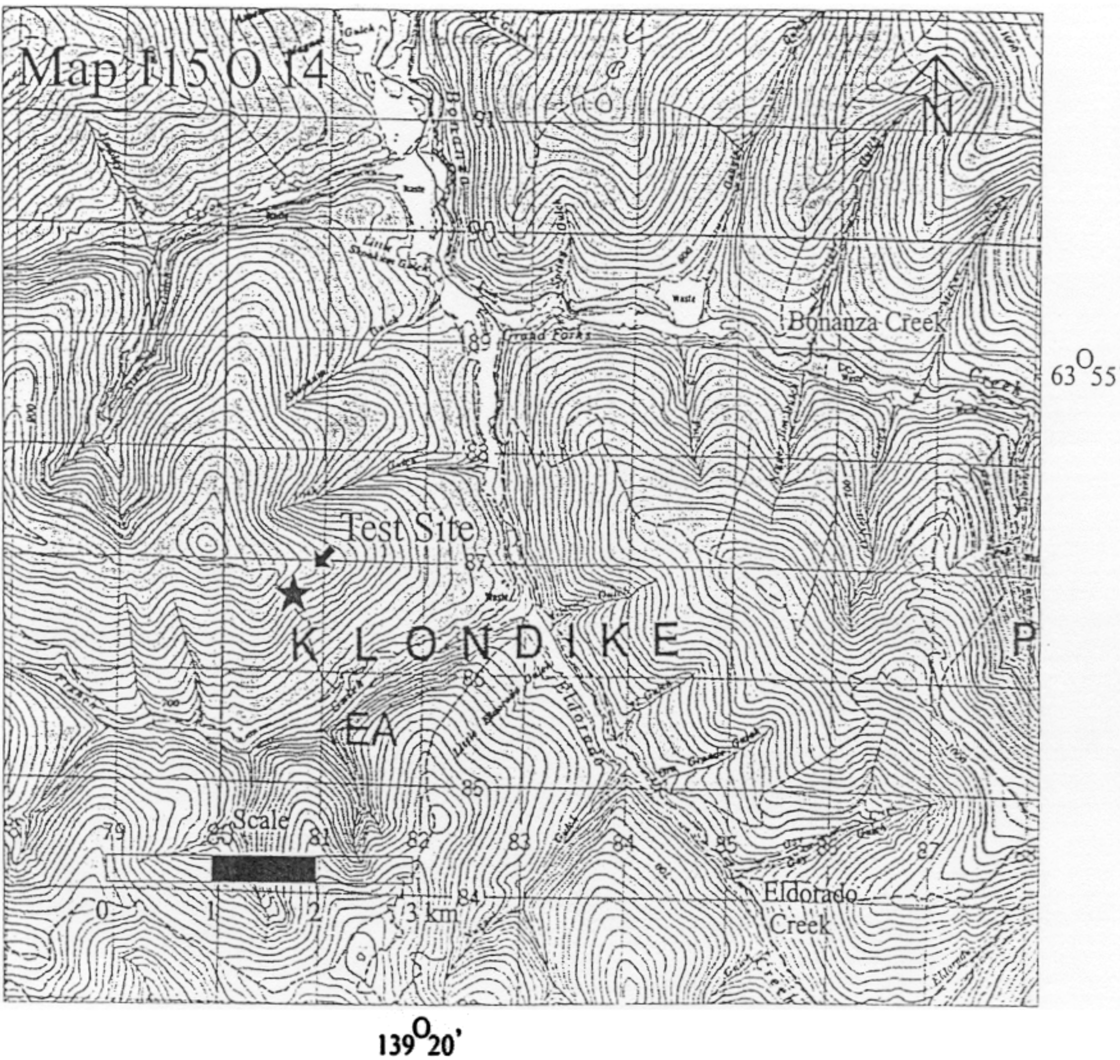
This property is located below the treeline at an elevation of approximately of 840 metres and at a latitude of 63°53'. It lies within is the Klondike Plateau ecoregion. The climate is sub-arctic continental and relatively dry with major temperature variability on both a daily and seasonal basis. Mean annual precipitation is about 325 mm and slightly more at higher elevations. Temperatures are extreme, with January means near -30°C and July means near 16°C. Mean annual temperature is about -5 °C. Mean temperatures during growth season (May to June) are approximately 11°C, and the average precipitation for the same period is 140 mm. This data is from the Dawson City airport weather station, located at an elevation of 324 metres (Oswald and Senyk, 1977).

This property lies in the unglaciated portion of the Western Yukon Plateau. The surficial geology consists mainly of colluvial blankets and residual bedrock. The colluvial material is a very angular, coarse gravel composed of fragments of grey, friable quartz-muscovite-chlorite schist and quartz cobbles. This schist weathers to a grey-green chlorite and mica-rich clay found in the matrix of the colluvium. This is the composition of the material used to refill the trench.

Permafrost is widespread in the area and is associated with processes such as solifluction, soil creep, nivation and cryoturbation. Permafrost was found along the forested edge of the reclaimed site.

Undisturbed vegetation consists of white spruce, birch and poplar. The understory includes tall and medium shrubs (willow, alder, high-bush cranberry and soapberry) and the ground cover is predominantly dwarf shrubs (bunchberry, low-bush cranberry, blueberry and kinnikinick). Thick moss covers the forest floor in places. The undisturbed soil consists of a humic-rich horizon (between 10 to 25 cm under the moss) and a loess blanket of irregular thickness (usually less than 5 cm) over colluviated or residual bedrock. The matrix content ranges between 50% to

Figure 2-5 Location map of the Hawk Property.



70% in the first 70 cm. Permafrost is present within 60 cm of the surface in the undisturbed area beyond the trench cut.

This site is well exposed, with a better growth medium and a more humid climate than that at the Red Ridge and Nucleus sites.

2.3.2 Exploration History

This property is located in the heart of the Klondike placer mining area. It is within the allochothonous and geologically complex crystalline belt known as the Yukon-Tanana Terrane, and is south and west of a major structural break, the Tintina Fault.

The rocks of the region are primarily quartz-feldspar schists with varying amounts of muscovite and hornblende. Minor lenses of carbonaceous quartzite and marble, and of chlorite-actinolite schists occur within the assemblage. Some foliated intrusive rocks also occur in the area.

The trench dates from a 1983 exploration program and the Hawk claims are now held by Arbor Resources Ltd.

2.3.3 Reclamation History

This property was also included in the 1994 exploration site study (Mougeot 1996). In 1995, the trench was modified by Craig *et al*. (1998) to form a more stable surface. The upper section has a slope of 21 degrees, the middle and lower sections less than 10 degrees. The reclamation treatment was similar to that applied to the Nucleus site. Five reclamation test plots were constructed. Plot 1 was prepared using fertilizer, seed mix and an inoculant of nitrogen- fixing bacterial culture. Plot 2 was prepared the same way with a 2 cm thick mulch blanket placed over the plot and anchored with rocks. Plot 3 treatment included fertilizer, seed mix, the inoculant and 8 cm of top soil. Logs were placed perpendicular to the slope to help minimize soil erosion. Plot 4 was the control plot without surface improvement. Plot 5 was treated with only fertilizer and seed mix. The composition of the seed mix is the same as the previous site and includes alsike clover, fowl bluegrass, creeping red fescue, red top, reed canary grass, slender wheatgrass, meadow foxtail and timothy.

The plots were revisited in 1996 and 1997. By 1997, plot 1 had a 90% ground coverage of timothy, fowl bluegrass, creeping red fescue and slender wheatgrass. Plot 2 was 100% covered with timothy, red fescue, wheatgrass and clover. Plot 3 was 85% covered with timothy, alsike clover and colonizing species such as strawberry blight, lamb's quarters and hawkweed. Plot 4, the control plot, had 50% of the surface covered with rose, willow, bluebell, Jacob's ladder, hawkweed, milk vetch and fireweed. The vegetative coverage of plot 5 was 95% with species similar to plot 1. In 1997, the results of the four treated test plots were similar; only the plot with topsoil showed a less vigorous growth. On all four seeded plots, a thick mat of grass litter had formed. The height of most grass species was between 90 to 100 cm.

2.3.4 1999 Field Observations

Soil and Site Conditions

The reclaimed site shows no significant erosion or permafrost related processes, except for some slumping at the uppermost slope, where the organic mat from the forested edge is sliding down.

The soil is composed of an angular, coarse gravel composed of fragments of grey, friable quartz-muscovite-chlorite schist and quartz cobbles with a micaceous silty loam to loamy sand matrix. Matrix content is usually greater than 65%. Surfaces are moderately to very compacted. All plots showed similar features, except for the plot enriched with top soil. Top soil thickness averaged 5 to 7 cm, an indication of the successful erosion control provided by rapid and extensive coverage of the surface by the seeded grasses.

A very notable feature of this site is the robust growth of shrubs and other colonizing native species on areas that were disturbed but not reseeded (Plate 2-13). The colluviated segment of the upper slope is also covered with a dense regrowth of native plant species. The natural revegetation of disturbed, but unreclaimed, areas was by far the most evident at this site.

Vegetation

Each of the eight-metre wide test plots are sloped from the less stable wall of the cut down to the more stable toe where the excavated material had been stockpiled. The depth of the backfilled material is therefore greatest at the higher side of each plot. The vegetation was observed to be generally more dense and robust on the high side of each plot next to the cut bank (Plate 2-13). The dominant seeded species on the four treated plots was slender wheatgrass with a 40% coverage on each. Other seeded species with significant coverage included red fescue, timothy and meadow foxtail. Traces of alsike clover were observed in three plots with inoculant treatment (Figure 2-6 and Appendix A).

- **Plot 1: Fertilizer, seed and inoculant.** Slender wheatgrass formed a 40% cover (average height about 60 cm). Other seeded species with significant cover included red fescue (50 cm) and reed canary grass (130 cm), each with 5% cover, and timothy (120 cm) with 3%. Invasion by native species was minimal. A 2 cm mat of vegetative litter covered 60% of the plot (Plate 2-14).

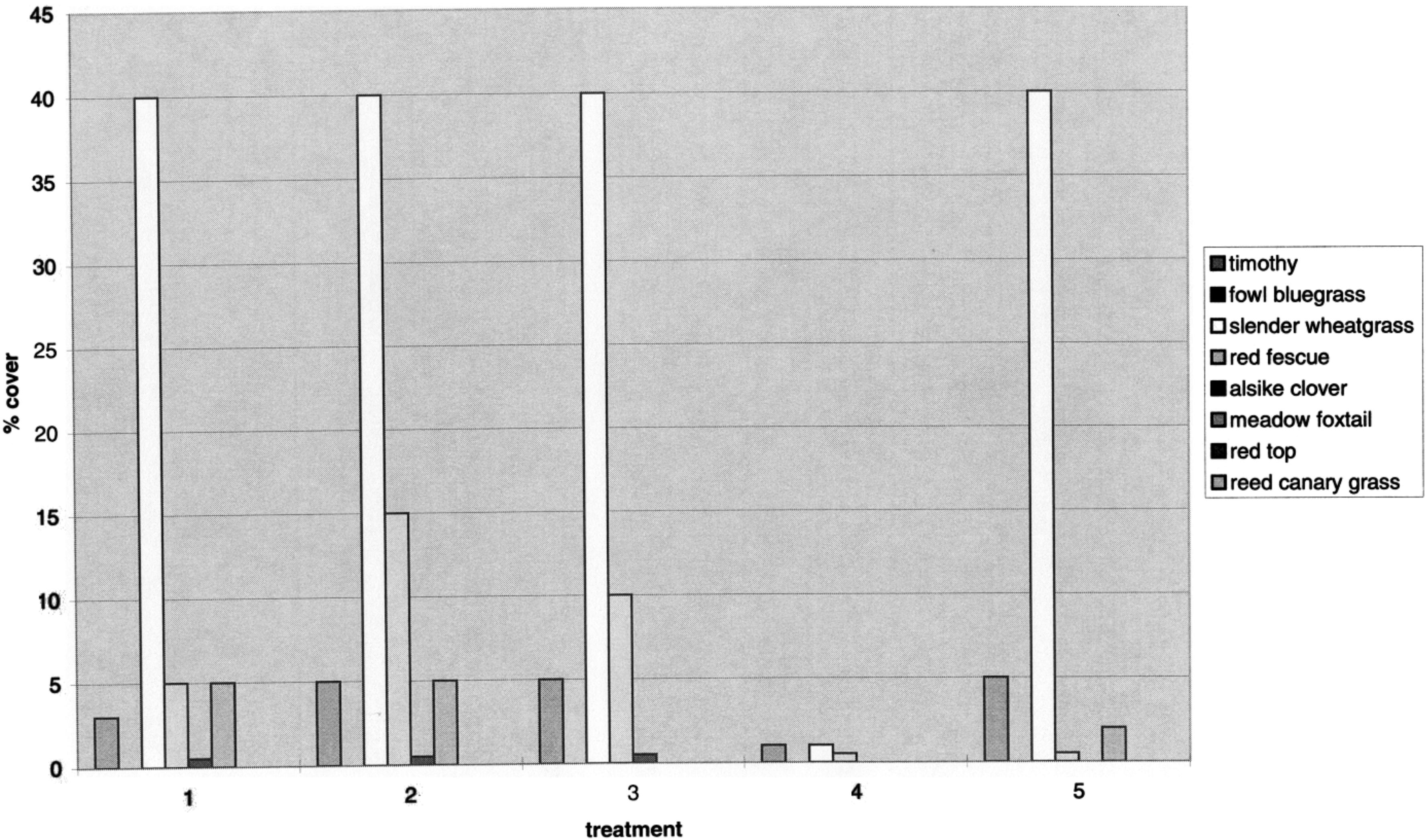
- **Plot 2: Fertilizer, seed, inoculant and straw mulch.** The seeded species growth was dominated by slender wheatgrass (40%) and red fescue (15%). Timothy and reed canary grass each had a 5% cover. Colonization by native species was minimal. A dense six cm mat of straw mulch and vegetative litter appeared to be retarding new growth (Plate 2-14).

- **Plot 3: Fertilizer, seed, inoculant and topsoil.** The vegetation was dominated by slender wheatgrass (40%) and red fescue (10%). The number of non-seeded species was higher than those on the two previous plots. Some of these species could have been imported with the topsoil. The mat of vegetative litter (primarily from slender wheatgrass) covered about 40% of the plot (Plate 2-15).

- **Plot 4: Control (no enhancement).** Little of the seeded vegetation had spread to the control plot. Colonization by native vegetation was significant, however, including four graminoid species, four forb species and six shrub species. Willow was the dominant shrub with a 15% cover (Plate 2-15).

- **Plot 5: Fertilizer, seed (no inoculant).** Slender wheatgrass and timothy dominated the seeded vegetation with covers of 40% and 5%, respectively. The most notable observation on this plot was the almost total absence of colonizing native species. Vegetative litter (primarily from slender wheatgrass) covered about 30% of the plot (Plate 2-16).

Figure 2.6: Hawk trench revegetation - 4 years after reclamation



Wildlife

Moose sign was abundant at the site, including tracks, fecal pellets, browsing and bedding. Varying hare sign was also common in the area.

2.3.5 Summary

Four years after the 1995 revegetation program, slender wheatgrass is the most successful of the seeded species on the reclaimed Hawk trench, with a 40% coverage on each of the four treated plots. Other seeded species with significant ground coverage include timothy, red fescue and reed canary grass. Trace amounts of alsike clover is still found on the plots with inoculant treatment. Fowl bluegrass, red top and reed canary grass no longer occur on the reclaimed trench.

Each of the four applied treatments resulted in a high vegetative cover, dominated by slender wheatgrass. The treatments that included inoculant produced higher percentages of red fescue. The addition of mulch and topsoil showed no apparent benefits. In all but the control plot, a dense mat of vegetation litter (primarily from slender wheatgrass) appeared to be retarding new growth.

2.3.6 Test Site Comparisons

Four years after the experimental reclamation treatments were applied, significant differences between the vegetative cover at the three test sites are obvious. These differences are presumably in response to the ecological variations between the three sites.

As expected, revegetation of the trench in the alpine zone at Red Ridge is taking longer than the other two sites in the boreal forest. A maximum of 55% cover by seeded species (treatment 2) was observed at Red Ridge, compared to covers of nearly 100% (seeded vegetation and vegetation litter) on reclaimed plots at the Nucleus and Hawk sites.

The treatment resulting in the highest vegetative cover at the Red Ridge and Hawk sites was treatment two (seed, fertilizer, inoculant and mulch), while treatment three (fertilizer, seed, inoculant and topsoil) induced a marginally higher cover at the Nucleus site.

The number of native plant species invading the Red Ridge reclaimed trench is also low compared to the other two sites. Only six species native to the area were observed on the Red

Ridge backfilled trench (not including those apparently brought in with the topsoil), compared to fifteen and ten native species colonizing the Nucleus and Hawk trenches, respectively. Treatment three (fertilizer, seed, inoculant and topsoil) encouraged the invasion of the most native species at the Red Ridge trench, while the unseeded control plot was most effective in attracting native species at the other two sites.

The most prolific species occurring on the Red Ridge trench four years after seeding is red alpine bluegrass (not used at the other two sites). Red fescue and slender wheatgrass were the most successful seeded species on the Nucleus and Hawk trenches, respectively. Like the unseeded control plot at the Nucleus trench, the control plot at the Hawk trench demonstrated a greater colonization by surrounding vegetation. A number of native shrub species, including white spruce, paper birch, willow, raspberry, prickly rose and kinnikinick had invaded only the control plot at the Hawk property site. It could be concluded that the high ground cover by graminoids on the four treated plots has retarded the invasion by native plant species. Control of wind erosion by rapid and extensive grass coverage is illustrated by the conservation of top soil on Plot 3 at the Hawk property compared to the two other sites.

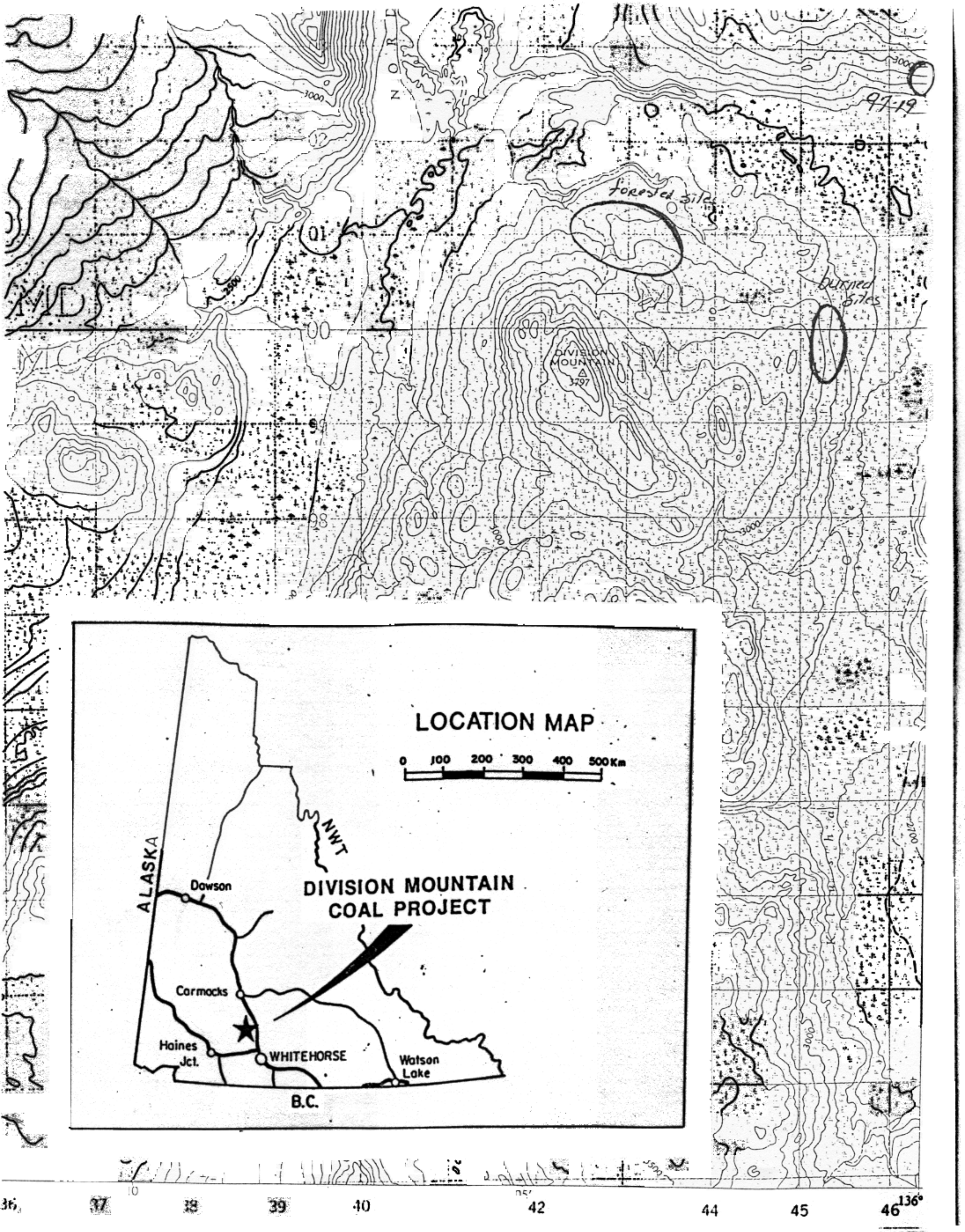
2.4 Division Mountain Coal Exploration Property

The Division Mountain coal property is located north of Whitehorse, approximately 22 km west of Braeburn (Figure 2-7). Coal exploration properties are administered under the Territorial Lands Act.

Under the Territorial Land Use Regulations, reclamation of exploration disturbances on coal leases is required. This coal exploration property is, therefore, one rare example of a location in the Yukon where land reclamation has taken place. It should be mentioned that extensive reclamation programs were carried out at several hard rock mining properties before MLUR were implemented. Several of these projects are discussed in Craig *et al*. (1998).

This site provides good examples of disturbances reclaimed by a mining company as part of their permitting requirement. All trenches and drill pads, several access roads and other disturbed areas were reclaimed and seeded. Several sites, three trenches and one drill pad were inspected and documented during this study. The team made additional notes on other sites of interest.

Figure 2-7 Location map of the Division Mountain Property.



2.4.1 Ecological Setting

The sites visited on this property are located below treeline at an approximate elevation of 950 metres and at a latitude of 61°19' N. It is in the Klondike Plateau Central ecoregion.

The climate is sub-arctic continental and relatively dry with major variability in temperature on both a daily and seasonal basis. Mean annual precipitation is about 280 mm and slightly more at higher elevations. Temperatures are extreme, with January means near -28°C and July means near 12°C. The mean annual temperature is about -3 °C. Mean temperatures during growth season (May to June) are approximately 9°C and the average precipitation for the same period is 130 mm (Oswald and Senyk 1977).

The Division Mountain area lies within the limits of the McConnell Glaciation (Bostock 1966). McConnell glacial ice was in the Division Mountain area between 14,000 and 35,000 years ago and reached an elevation of approximately 1830 metres a.s.l., and as a result covered the majority of the high elevation summits in this area. Most of the sites visited in the summer of 1999 were located on thin colluvium or on moraine and colluvium overlying bedrock. The parent material consists of a mixture of gravel, sand and silt with a thin silt veneer. In alpine areas, this surface material is usually less than 2 metres thick.

Permafrost is common on north- to northeast-facing slopes at mid to high elevations. Soils on these landforms consist mainly of Orthic Eutric or Dystric Brunisols depending on the pH levels, the drainage conditions and the physical characteristics of the parent material (e.g., well drained bouldery gravel). Matrix textures for these types of soils are typically loamy sand to sandy loam. They have a typically shallow profile with a weakly developed horizon over a well developed calcium-carbonate-rich C horizon (Cca) and a thin to non-existent organic-rich surfce (A) horizon. The upper horizons of the these soils are also mixed or interlayered with the White River Ash. Poorly drained areas also have the potential for ice-rich permafrost if there is a thick organic mat cover.

2.4.2 Exploration History

There has been interest in the coal this area since 1902, as several seams of the Tantalus Formation outcrop in many locations. The earliest documented exploration activities took place in 1970-72. Further work was done in 1990-91, and Cash Resources Ltd. acquired the lease in 1992. From 1992 until 1999, diamond drilling and excavator trenching have been carried out at the property.

2.4.3 Reclamation History

According to the summary provided in Craig *et al*. (1998), the trenches excavated during the 1970 exploration program were not reclaimed and now support only sparse vegetation. Since 1990, all trenches have been reclaimed. Cash Resources has performed site reclamation work since they acquired the property. Trenches have been excavated with bulldozers and, in recent years, excavators have stockpiled overburden on the sides of the trench with the uppermost material piled separately. While refilling the trenches, the organic-rich material was replaced at the surface and seeded with a northern seed mix designed for the region (seed mix components unavailable). Trees and shrubs were dragged back onto the surfaces. The surface of the reclaimed trenches have been left very rough and hummocky to provide micro-habitat and to discourage motorized traffic.

Where drill pads were built, sump ponds were excavated to contain drill fluids and to allow suspended particles to settle. Once the drilling was completed, the sump ponds were refilled, the sites was recontoured and seeded, and the tree and shrubs dragged back onto the surface. At some sites, local spruce seedlings were planted. Some side roads were also scarified and seeded.

2.4.4 1999 Field Observations

2.4.4.1 *Trench 95-29*

Undisturbed Conditions

This site is located in a burn area, the forest fire dating from 1958 (Plate 2-17). The undisturbed soil consists of a thin organic-rich horizon overlying a cobbly, gravely, sandy loam. The surrounding early seral stage vegetation is composed of willow, white spruce and aspen, with a shrub layer of soapberry, rose and kinnikinick. Common forbs include fireweed and goldenrod.

Purple reed-grass is the only native graminoid. The undisturbed surface is gently sloping at the base of a moderately steep hill with a northerly aspect.

Soil and Site Conditions

This trench, located in the burn area, is several hundred of metres long, with a moderately steep upper section (150 m long) with slopes ranging from 20% to 40%. The excavation itself was 1.5 m wide but the width of the reclaimed surface is between 5.5 and 6.5 m, because of the space required to stockpile the overburden and to operate the equipment.

Trees and shrub debris, along with organic-rich material were replaced. The overall impression of the trench now is that of a corridor, or a wide cut line, through the young colonizing forest (Plate 2-18). The debris has created shade for seedlings, and provides habitat for regenerating shrubs. It also prevents access by all motorized traffic.

On either side of the now-refilled excavation, the surface is hummocky and still supports a significant amount of natural forest floor with native species. Crests and ridges roughly 2 to 2.5 metres apart form an irregular pattern, with an average relief of 0.5 m. The middle part of the trench, where the excavation has been refilled, has a very hummocky, loose surface, with boulders, large rocks and lumps of organic mats forming a maze of ridges and depressions. This seems very effective in controlling erosion even on the steep segment of the trench. Shallow, short gullies have developed along that segment of the trench, but are not extensive. The very hummocky surface with as much as one metre relief provides catchment areas for seeds and shelters for seedlings (Plate 2-19).

Soil compaction over the stockpiled part of the disturbed area is similar to that of the undisturbed surface, and lower in the excavated section. There was no indication of frost churning, frost heaving or permafrost thawing.

Vegetation

In 1999, only limited evidence remained of the agronomic varieties used for reseeding the Division Mountain trenches and drill pads (Appendix A). The stockpiled portion of the trench has a coverage of 60 to 80% dominated by grasses, with a slightly lower coverage in the excavated part of the trench, possibly due to the rougher terrain. There the growth is concentrated in the depressions (Plate 2-19). The agronomic species have not appeared to invade the undisturbed forest.

Nine graminoid species were found in the 15 m X 1.5 m sample plot on this reclaimed trench. The most prevalent were Alaskan wheatgrass and Richardson's fescue, with covers of 20% and

15%, respectively. Sheep fescue had a cover of about 3%. Graminoids were less evident on the site where the overburden had been stockpiled (this area had also been reseeded), with only Richardson's fescue showing significant coverage (5%).

Nine species of shrubs were also noted on the reclaimed trench, but only blue-green willow had a significant cover (5%). Fireweed was the only notable forb species (5%) colonizing the trench.

Wildlife

There was abundant sign of browsing and grazing at this site. Moose and probably elk had recently frequented the trench. Moose browse was evident on the nearby willows. Varying hare sign was also evident.

2.4.4.2 Trench 97-17

This trench is several hundred metres long and is approximately 6 to 8 metres wide. The average slope of the reclaimed surface ranges between 2 and 5% sloping toward the road (northeast aspect)**.** Treatment of this trench was the same as at trench 95-29.

Undisturbed Site Conditions

This trench is located in a tall, mature white spruce forest with a moss/lichen ground cover. (Plate 2-20). The undisturbed soil has a thick organic layer (humic and mesic material 15 to 25 cm thick) overlying a poorly developed horizon. The parent material is a loamy gravel with 30 to 35% of the matrix composed of fine loamy sand to sandy loam. A thin loess veneer is present in places and the White River Ash is visible under the organic material. The undisturbed surface is gently undulating with minor micro-hummocks and faces north. No traces of agronomic species were found in the nearby undisturbed surfaces.

Soil and Site Conditions

As with trench 95-29, the surface of the disturbance can be separated into the refilled excavation and the surface used to stockpile and operate equipment during the reclamation process (Plate 2-21). This trench surface is very similar to trench 95-29, with very rough surfaces, pockets of organic mats, and replaced tree and shrub material. The material is composed of a bouldery gravel with 40 to 50% fines.   There was no sign of significant erosion at this site.

Vegetation

After two growth seasons, the overall surface (Plate 2-22) shows a 60% coverage dominantly by grasses. Rocky mountain fescue, with a 20% cover on the trench and a 25% cover on the site where the overburden had been stockpiled, was the most successful graminoid colonizing this reclaimed site. Perennial rye grass a seeded species, had a cover of less than 1%. Coverage by shrubs and forbs was negligible. The shrubs are regenerating from roots and branches replaced at the surface.

Wildlife

The only recent wildlife sign at the trench was the fecal pellets of varying hare.

2.4.4.3 Trench 97-19

The exploration footprint of this feature is approximately 10 m wide and 40 m long. It is located on a north-facing, gently convex surface with a slope of 8 to 10%. The excavation was refilled as was done at other sites, but not seeded. Tree and shrubs were dragged back onto the reclaimed surface.

Undisturbed Site Conditions

This site is located below treeline and is considered to be well drained at the upper portion of the site and moderately well drained at the lower, northern part. The undisturbed vegetation is a thick, mature white spruce / moss community.

Undisturbed soil consists of a thin organic layer, less than 8 cm thick, sitting on a thin loess veneer, and fine loamy sand approximately 10 cm thick. The parent material is a sandy to loamy gravel with 50 to 60% fine sandy loam matrix. Bedrock is very close to the surface along most of this trench.

Soil and Site Conditions

The reclaimed surface is very bouldery and very rough with the height between crest and ridge more than two metres in places. (Plate 2- 23). There are several large bedrock fragment, dominantly a hard sandstone, within the replaced material. The surface is moderately compacted . Erosion at this site was not significant.

Vegetation

This site's appearance was very different from other sites observed. Vegetation was very sparse on this backfilled (but not revegetated) trench (Plate 2-23). Total coverage was less than 2%. The only graminoid noted on the trench was northern rough fescue (a common native woodland species) with less than 1% coverage.

Wildlife

There was no evidence of wildlife at this recently reclaimed trench.

2.4.4.4 Drill pad DC-1

Undisturbed Conditions

This site is located below treeline in a dry, well drained location. Undisturbed soil and vegetation are very similar to those of Trench 97-17 located a few hundred of metres away. No traces of agronomic species were found in the nearby undisturbed surface.

Soil and Site Conditions

The drillpad was probably built and reclaimed in 1995. The moderately to well compacted surface is smooth and very gently sloping. The soil composition is the same as at trench 97-19 and 95-29. The original organic-rich material was replaced at the surface but is less continuous and thinner than the surrounding soil. The area where the sump pump was excavated and refilled is rougher, with hummocks and depressions, and there is significantly more moisture available there for plant growth.

Vegetation

A very high graminoid cover was noted on this drill pad (Plate 2-24). These graminoids included Rocky mountain fescue (80%) and the taller Alaskan wheatgrass (40%; note that the percent coverages total to greater than 100% since the canopy is estimated separately for each vertical layer). Coverage by native shrubs and forbs was negligible.

Several spruce seedlings had been planted at this site. On July 26, 1999, 17 seedlings were alive (Plate 2-24) with an average height of 60 cm and the tallest one being 90 cm.
Around the drill pad, scraped bedrock shows very little growth.

Wildlife

Old tracks of ungulates (possibly elk) were visible on the drill pad. Hare fecal pellets were also noted.

2.4.4.5 Trench TR-2

This feature is 5 to 7 m wide and 1.5 to 2 km long, possibly longer. It starts at road level, goes down into a poorly drained, permafrost-rich area and then climbs slowly uphill for several hundreds of metres. This trench was probably reclaimed in 1994. This very long trench was not surveyed in its entirety. Detailed information was collected at one site located approximately 400 m from the main access road. This site was selected because it is located in a permafrost-rich, poorly drained site quite different than the other reclaimed features visited during this study.

The general appearance of the trench, from the road and from most of the length walked during this survey, is that robust plant growth is occurring (Plate 2-25).

Undisturbed Site Conditions

This site is located in a gentle basin with a slight depression. The permafrost table is 40 to 60 cm below the surface. The soil is a Mesic Organic Cryosol, with an organic thickness ranging from 25 to 40 cm. By the end of July, water was visible in depressions and fractures. The undisturbed vegetation was very diverse and typical of such sites, with thick moss and shrubs, stunted spruce trees and a varied ground cover.

Soil and Site Conditions

The site was reclaimed as the other sites were, with material put back onto the surface and reseeded. The abundant supply of water from melting permafrost and the thickness of the original organic-rich material provides excellent growth medium for the site, which is slightly warmer than the surrounding undisturbed surface, as the permafrost table has receded for several tens of cm. This, and the proximity of a diverse source of seed and roots combined with moisture, seems to encourage the regrowth of native species.

Vegetation.

Dominant graminoids in the 15 m X 1.5 m sample plot were sheep fescue (20%), red fescue (15%) and Alaskan wheatgrass (5%). Graminoids were much less common on the site where the overburden had been stockpiled (this area had also been reseeded; Plate 2-26).

Bearberry was the only shrub with significant coverage (10%) colonizing the trench. On the reclaimed overburden stockpile site, shrubs such as bearberry, crowberry and Labrador tea, with coverages of 25%, 15% and 15%, respectively, were more evident.

Wildlife

Moose and possibly elk tracks werecommon on the reclaimed trench surface. Wolf scat was also observed.

Additional comments

As the trench climbs uphill, a cut bank as high a 2 to 2.5 m was left in places. Permafrost thawing is causing slumping and the entrainment of the forest floor mat onto the reclaimed surface and is fostering revegetation (Plate 2-26). Graminoids were growing here as at other sites. The rough topography is controlling erosion even on slopes at steep as 25%.

2.4.5 Summary

- The rough topography of the reclaimed trenches at this property provide pockets of moisture and shade for seeds and seedlings. The steep sides of some clumps of backfilled material do not revegetate as successfully and, therefore, the trenches will not be 100% covered by ground vegetation for many years.

- Native species are slowly colonizing the trenches, either as seeds from the surrounding areas or from the organic mats replaced at the surface. Shrub roots seems to regenerate from these organic rich clumps.

- This rough microtopography controls erosion successfully, even in the linear fractures parallel to the slopes observed in the excavated portion of some reclaimed trenches.

- A more uniform growth of agronomic species is more typical of the reclaimed flatter drill sites. Native species do not appear to be colonizing the drill pads to the extent they are on the reclaimed trenches.

- Additional moisture provided by the thawing of disturbed permafrost or in areas where the drilling sumps were excavated has had a significant positive impact on plant growth, as well as on the diversity of colonizing native plants.
- Agronomic species do not appear to be invading undisturbed surfaces, either in the mature spruce forests or in the areas burned in the 1958 fire. They do, however, propagate very successfully along roads and other surfaces where bare soil is present.

- The trees and shrubs replaced on the reclaimed trenches are very effective at impeding access, even by foot.

2.5 Jason Knoll Mineral Exploration Property

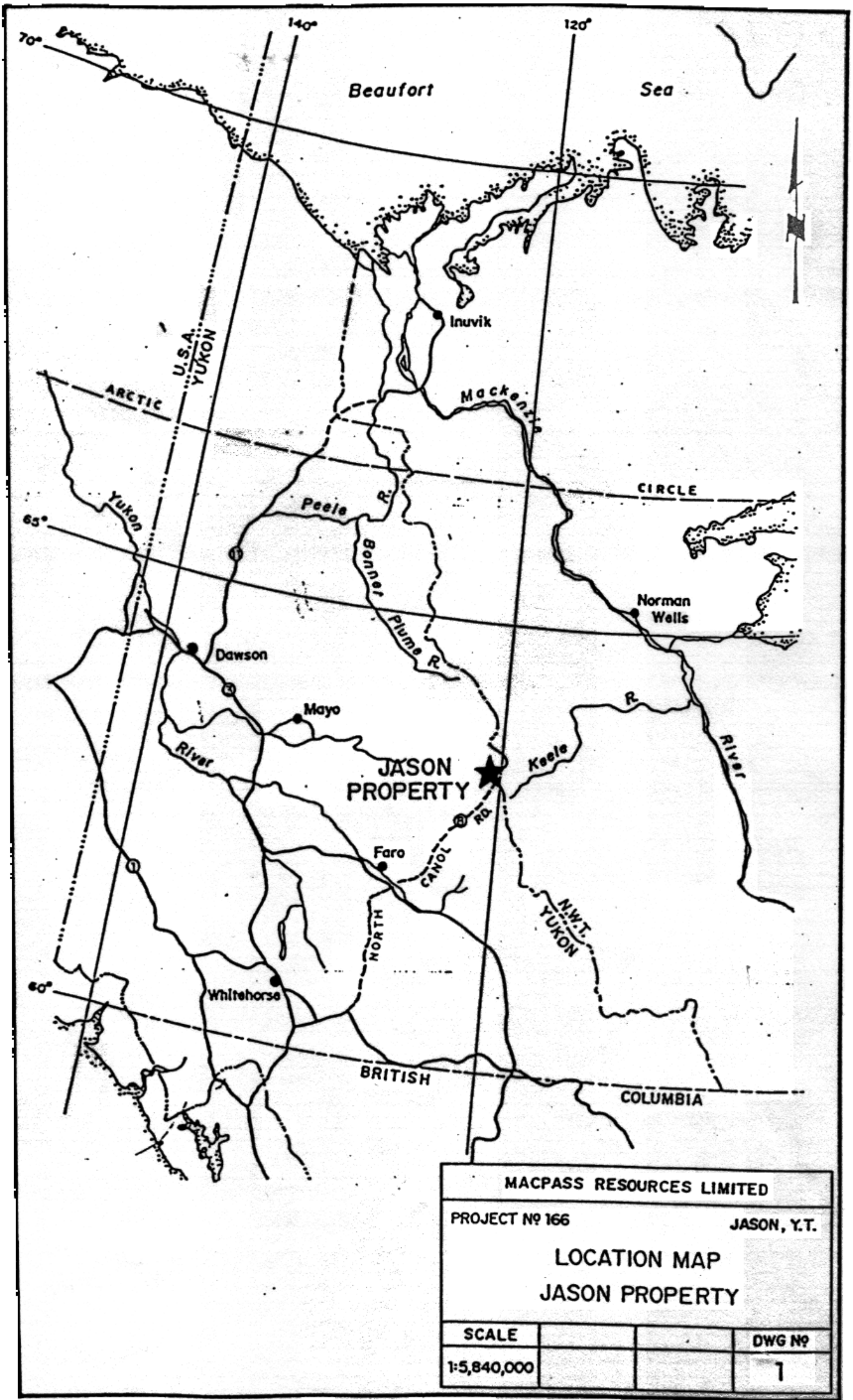
The Jason property is located in east central Yukon (Figure 2-8) at 63 10’N and 130 10’W. It is located approximately 220 km east of Ross River on the North Canol road. The property is accessible through a mining road running northwestward on the west side of the Canol Road near the Macmillan Pass (Plate 2-27). Three trenches and two drill pads are included in the study. This site was selected because reclamation activities took place in 1981, thus providing a unique opportunity to observe long-term conditions at a Yukon mining exploration site.

2.5.1 Ecological Setting

The Jason property is in the Mackenzie Mountain, in the South Macmillan River valley. The climate is sub-arctic continental, with major temperature variations on both a daily and seasonal basis. The mean annual precipitation is greater than 600 mm. Temperatures are extreme, with January means near -22^{o}C and July means near 10^{o}C. The mean annual temperature is about -7^{o}C. The mean temperatures during growth season (May to July) are approximately 9^{o}C and the average precipitation for the same period is 170 mm. This data is taken from Oswald and Senyk (1977).

The geology consists of rocks of the Lower Earn Group, mostly shales and coarse turbidites of the Devonian age. These sedimentary rocks were later intruded by mid-Cretaceous granite. Skarn development was widespread.

Figure 2-8 Location map of the Jason Knoll Property.



Elevations on the property range from 1140 m at the Macmillan River Valley, where the two drill sites surveyed are located, to 2016 m at the crest of Jason Knoll. Treeline occurs between 1300 to 1400 metres (Plate 2-28). The three trenches surveyed are located above treeline. Permafrost is widespread in the area.

2.5.2 Exploration History

This property was explored as early as 1951, when prospectors discovered the Tom deposit located 5 kilometres east of the Jason property. It was staked in 1974 with the exploration targets being lead, zinc, silver and barite. Drilling programs, as well as geochemical, gravity, EM, and IP surveys were conducted from 1974 to 1978 (Cameron 1991).

The property was optioned in 1979 by Ocean Oil. Drilling continued from 1979 to 1981. Later that year, Aberford Resources optioned the property from and continued exploration work with further mapping, geochemical sampling, drilling (9 holes), and of particular interest to this project, environmental and reclamation studies. Aberford Resources conducted feasibility and environmental studies jointly with Hudson Bay Exploration and Development on both the Jason property and the Tom property, located 5 km from the Jason exploration site.

There was no activity on the property from 1983 to 1989. In 1990, Phelps Dodge Corporation of Canada optioned the property and completed 12 drill holes and a magnetic survey.

2.5.3 Reclamation History

All the trenches encountered below the elevation of 1500 metres were refilled and contoured to blend in with the surrounding topography. Trenches located further above were not visited as the road leading uphill was badly washed out. Drill sites have been scarified and there was no evidence of buildings, fuel drums or other debris remaining on the property.

Three revegetation test plots were established in 1981: a trench in the in tundra above treeline and two in the boreal forest at lower elevations (Brown 1985). These sites were monitored until 1985. The studies and the results of five years' observations are described in a report submitted to Indian and Northern Affairs, Canada, in 1985. The summary page of the report is provided in Appendix C.

The objectives of the reclamation plots were to develop site specific revegetation techniques in the eventuality that a mine would be developed in the Macmillan Pass area. At each site, eight pairs of plots were seeded, with one set of plots being fertilized and the other not. The study screened a variety of both agronomic and native species. Although a map showing the configuration of the test plots is not available, a list of species used during the experiments is provided in Brown (1985).

The species seeded include: Engmo timothy, Durar hard fescue, Boreal red fescue, Arctared red fescue, Nugget Kentucky bluegrass, Fortress red fescue, violet wheatgrass, fowl bluegrass, Covar sheep fescue, meadow foxtail, annual ryegrass, Russian wild ryegrass and Sodar streambank wheatgrass. Native grass seeds were collected (five species) or purchased and seeded in 1982. Those species are ticklegrass, red fescue, alpine bluegrass, wood rush, northern rough fescue, red top, alpine holy grass and tufted hairgrass.

As of 1985, ticklegrass gave the best results and grew well at the alpine trench site as well as at the low elevation drill pads. The local species wood rush, alpine holy grass and northern rough fescue showed slow but persistent growth and good survival rates. Red fescue, alpine bluegrass and red top also showed potential. Agronomic species recommended were Boreal red fescue, Arctared red fescue, Nugget Kentucky bluegrass, Fortress red fescue, Engmo timothy and annual ryegrass. According to Brown (1985), the recommended and best performing species were ticklegrass and wood rush.

2.5.4 1999 Field Observations-Trenches

Three trenches were investigated in this survey. Trench JK-1 was refilled and leveled, with seeding plots established. Trench JK-2 was refilled and roughly leveled. These two trenches are located just above tree line and within the low shrub zone. Trench JK-3 was refilled and leveled and is located in a moss/lichen vegetation community. There is evidence of frost churning at all three sites but it is most noticeable at trench JK-3.

All three of these trenches (in fact all trenches observed on this property) had been refilled. When these trenches were refilled, the overburden was excavated and stockpiled, then returned and into the trench and roughly leveled. The total surface impact of each trench is approximately 6 to 7 metres wide and several tens of metres long.

At the surface some of the refilled trenches, there is evidence of the original vegetation mat being placed back at the surface, but not as a continuous cover. All trench surfaces now conform fairly closely to the existing topography. Stockpiling of the excavated material on one side of the trench required a belt approximately 3 to 4 metres parallel to the excavation. The lip, or elevation difference between the refilled excavation and undisturbed ground, is usually minimal.

2.5.4.1 Trench JK-1

Undisturbed Conditions

The surrounding topography is gently hummocky with slopes ranging from 5 to 10% (Plate 2-29). The parent material consists of colluvial and weathered rock overlying bedrock. It is dominantly coarse angular rock fragments with a loamy matrix. There is no evidence of ice-rich permafrost but frost churning and frost boils were present close to the trench. The soil is classified as an orthic brunisol-cryosolic phase, with a thin organic (fibric and mesic) layer ranging between 8 and 15 cm. An irregular, thin veneer of loess was present in some soil pits. This provides patches of soil with better moisture holding capacity. This mat of organic material and loess can provide rafts and pockets of growth media when replaced on the surface of disturbed sites.

The continuous vegetation cover dominated by moss and lichens, with clusters of shrub birch and willow up to 1.5 m tall, is occasionally interrupted by rock outcrops (Plate 2-29). The moss and lichen mat can be as thick as 20 cm and as thin as 3 cm. Alpine shrubs such as subalpine fir, Beauverd’s spiraea, shrub birch and white mountain heather are common.

Agronomic plant species do not appear to have invaded the undisturbed surroundings. Fifteen years after the reclamation work was completed, the seeded grasses have not propagated on the undisturbed ground cover of mosses and lichens.

Soil and Site Conditions

JK-1 is located near the crest of a knoll, on a gentle slope facing southeast, at an approximate elevation of 1450 m. The entire footprint of the trench, along with a drill pad located at the bottom end was surveyed (Plate 2-30). This includes a disturbed surface approximately 150 metres long and 6 to 7 metres wide.

Old wood markers were found at the edge of the trench and although there were no visible inscriptions on them. Their apparent 10 metre spacing was used to divide the trench into fifteen 10 metre long plots; one-half of each was the area where the overburden had been stockpiled, and one half was the excavated and refilled trench. Table JK1-1 summarizes the findings for each of the fifteen plots.

Vegetation

The vegetation observed on the reclaimed trenches and drill pads was almost exclusively that found colonizing any naturally disturbed sites in the area. Very little sign of the agronomic species used in the experimental revegetation of these sites in the early 1980s was evident (Appendix A) (Plate 2-30)

The diversity of shrub species colonizing this reclaimed alpine trench was notable (14 species). shrub birch and Beauverd's spiraea, with maximum coverages of 20 % and 10 %, respectively, were the most abundant. Shrub birch and diamond leaf willow specimens on this trench were aged at fourteen and twelve years, respectively. A number of ericaceous shrubs were also found on much of the trench.

Seven species of graminoids were found on the reclaimed site. The most prevalent were northern rough fescue, with a maximum coverage of 10%, and red fescue (possibly a seeded agronomic variety), with a maximum coverage of 20%(Plate 2-31).

Seven forb species were also noted on the reclaimed trench, although only Alaskan knotweed and bunchberry contributed significantly to the vegetative cover. No legumes were found on the site.

The invasion of the reclaimed site by the area's native plant species (Plate 2-31, 2-32 and 2-33), both woody and herbaceous, was more apparent on the southern (higher) end of the trench. Up to 70% cover was noted on the upper portions of the trench, while the lower end had a sparse vegetative cover of only about 3% (Plate 2-34).

Table 2-1: Trench JK-1 Plot Site Conditions Summary

Plot #	% Bare Ground	Slope	Compaction	Comments on surface conditions
1 B	5	3	mod	no rafting
1 S	10	3	mod-firm	no rafting
2 B	30	5	mod	
2 S	40	5	mod.	
3 B	20	4-5		
3 S	20	4-5		moss 20 cm thick in places, frost churning
4 B	30	5-6		rougher surface
4 S	25	5-6		organic mat rafts
5 B	30	8	loose	rockier, frost churning, moss mats
5 S	20	8	mod-firm	more cover, more shrubs and more variety
6 B		4-5	mod	more grass
6 S		4-5	firm	more shrubs
7 B	55	6	firm	rocky, irregular, microsite revegetation
7 S	35	6	firm	rocky, nearly hard
8 B	55	5	mod	microsite-depression reveg
8 S	45	5	mod-firm	microsite-depression reveg
9 B	40-45	4	mod.	higher microrelief, frost churning, salmon berry patch
9 S	40	4	mod.	smoother relief than 9B
10 B	50-55	5	mod	no organic clumps
10 S	50	5	mod	sparse organic clumps
11 B	80-85	4-6	mod	gullying, frost churning
11 S	80-85	4-6	mod	sparse organic clumps, frost churning, no gullying
12 B	85-90	3	mod	growth in bottom of gully
12 S	80-85	3	mod-high	no gullying
13 B	85	3	low mod	growth in gully
13 S	85	3	mod	no gullying, some organic mat in place
14 B	95	4-6	high	no difference from 14S, gravely
14 S	95	4-6	high	as 14B
15 B	95	5	high	well defined gully, gravely, old drilling pad?
15 S	95	5	high	well defined gully, gravely, old drilling pad?

The vegetation occurring on this reclaimed site also differed between that occurring on the backfilled trench and that found on the area where the excavated material had been stockpiled (Plate 2-30). Graminoids were more common on the backfilled trench, while moss (primarily polytrichum) was more prevalent on the area where the overburden had been stored. Colonization by shrubs (particularly shrub birch) was much more evident on the backfilled trench (Plate 2-32).

Wildlife

Grizzly bear scat and diggings were the only signs of wildlife at this reclaimed site.

2.5.4.2 Trench JK-2

Undisturbed Site Conditions

This site is located within several hundred metres from JK-1 and the undisturbed site conditions are very similar.

Soil and Site Conditions

This 1980 trench is located at an approximate elevation of 1430 metres and faces southeast (Plate 2-35). It runs generally north-south and is approximately 150 m long by 8 m wide. It was refilled in 1983 and contoured to fit the surrounding topography (Plate 2-36). Slopes averaged 5%. There is no evidence of revegetation test plots. The effects of the organic mat being replaced on the trench surface was very visible, as was the role of depressions left by equipment in creating seed and moisture traps.

The side of the trench used to stockpile overburden had a smoother topography with a fairly high coverage of the scraped, but still present, organic mat (Plate 2-36). A skilled equipment operator at this site had managed to leave a significant percentage of the original ground cover (mosses, lichens and shrub roots, as well as the fine-grained top soil horizons). The findings at this reclaimed, trench emphasizes the importance of replacing the organic material back onto the disturbed surface, and of leaving as much as much of the original ground cover vegetation as possible from the overburden stockpile. This is particularly significant considering the elevation and climate of the site. There was no evidence of erosion at this site.

Vegetation

The natural revegetation of this trench in the subalpine zone has resulted in a current vegetative cover of about 25%. The plant species that have colonized the site are similar to those on trench JK-1. The most common graminoid is northern rough fescue, with about 2% of the ground cover.

Wildlife

There were no signs of wildlife at this reclaimed trench.

2.5.4.3 Trench JK-3

This trench is saddled on the gently sloping crest of Jason Knoll. It is higher than JK-1 and JK-2 and is situated above tree line. It is approximately 180 m long by 6.5 to 7 m wide. Like the other trenches on this property, the excavated overburden was stockpiled, then replaced back in the excavation, and the surface contoured to fit the surrounding topography. There was no evidence of seeding at this trench.

Undisturbed Conditions

The surface is naturally smooth and convex, with little organic or humic material present. Frost-shattered and weathered rock outcrops are common. Frost churning, frost boils and frost stripes and ubiquitous (Plate 2-37), frequently interrupting the lichen cover. Lichens are the dominant ground cover.

Soil and Site Conditions

The trench surface is gently convex. Overburden and parent material are very similar in composition, both being a sandy, loamy gravel, with a fine matrix of 35%. Frost churning is evident, giving a freshly disturbed appearance at several places along the trench. There is evidence of replaced organic mat in a few areas on this trench, but noticeably less so than at JK-1 and JK-2 (Plate 2-38). This is partially explained by the gravely nature of the soil and the sparsity of organic or humic-rich material on the undisturbed surface.

Vegetation

The vegetation colonizing this longer reclaimed trench varies according to aspect. Moss (polytrichum) dominates the southern end of the trench (with a south aspect), while shrubs and graminoids are more common on the centre (with a neutral aspect) and the northern end (with a north aspect; Plate 2-39).

The only forb species with significant coverage was bunchberry with a cover of about a 2% on the centre and north end of the trench, and the only notable graminoid was Alaskan wood rush with a coverage of about 3%. Other graminoids observed include alpine holygrass, northern rough fescue and red fescue (possibly a seeded species).

Eight shrub species were noted on the trench, with shrub birch, Beauverd's spiraea and blueberry being the most prevalent.

Wildlife

Caribou tracks and fecal pellets were noted on the reclaimed trench. Ground squirrels were observed nearby.

2.5.4.4 Additional Observations - Trenches

- A rough or irregular microtopography helps revegetation. Depression perpendicular to the slope encourage regrowth and act as seed traps (JK-1 and JK-2).

- Grooves and depressions parallel to the slope, even on slopes lower than 10%, will foster some gullying. Minor gullying can create moisture channels and, if erosion is not severe, can encourage stream-like vegetation patterns. On a steeper slope, however, erosion results in unvegetated surfaces. The Macmillan Pass area is fairly dry so run-off is not a serious hazard.

- Organic mats are an effective medium for regrowth; shrubs, mosses, and lichens re-establish themselves fairly effectively if replaced on the surface. The re-establishment of the vegetative mat appears to occur more quickly on the overburden stockpile sides of trenches. The ripped, crushed, abraded and moved organic pads can be effectively replaced on disturbed surfaces.

- . Local conditions affect reclaimed surfaces just as they do undisturbed surfaces; frost churning and frost boils will create unvegetated patches on reclaimed surfaces, resulting in unvegetated areas, similar to those on undisturbed cryoturbated areas (JK-3). Wind erosion will affect reclaimed surfaces as it affects undisturbed surfaces.

- Generally, the excavated and refilled sides of the disturbed sites are slightly less compacted with a rougher micro-topography. Regrowth on the refilled side of trenches is dominated by colonizing grasses and forbs, and on the overburden stockpile side, by the re-establishment of plants that had been left in place during the excavation and backfilling.

- Shrubs seem to grow back indiscriminately. In general, the immediate surrounding vegetation influences shrub regrowth. Segments of the trench located within terrain without shrubs result in a lighter shrub regrowth on the reclaimed trench, and segments of the trench located within shrubs have a higher shrub regrowth on the trench. Roots, twigs and organic mat seem to play an important role in the re-establishment of shrubs.

- Shrub patches commonly become the site for revegetation by other species.

2.5.5 1999 Field Observations - Drill Pads

Two drill pads were surveyed. Both are located at approximately 1200 metres. They are on surfaces gently sloping toward the river in a dense boreal forest. Both drill pads were reclaimed and seeded. The access road to these sites was reclaimed as well. It is now overgrown by willows as tall as 8 metres, and access by vehicle was not possible because of the abundant growth.

Undisturbed Site Conditions

Both drill sites are located in a mature fir/birch/moss forest, on a south-facing slope by the Macmillan River (Plate 2-40). The undisturbed soil has an organic-rich horizon up to 20 cm thick, underlain by a thin loess blanket overlying the moraine. The gravely parent material has a fine-grained matrix as high as 80%. This site can be described as cool and moist. Permafrost is present at depth of 50 cm. The reclaimed drill pads are located at sites where water is moving from the upper slopes over the permafrost table towards the river. There is no evidence of agronomic plant species outside of the disturbed surface.

2.5.5.1 Drill pad 78-43

Site and Soil Conditions

The overall appearance of this site is very green (Plate 2-41), with abundant shrub and ground cover growth. The nearly level surface is approximately 14 m by 27 m with a slope of 9% towards the river. The site was excavated into the original slope of about 14%. The upper scarp, where the slope was excavated is actively slumping, with evidence of permafrost degradation and water seeping onto the reclaimed surface. This abundant water becomes available to the vegetation. Soil pits dug at the lower end of the site resulted in water seeping in and filling the pits within minutes. The surrounding vegetation however is characteristic of a moderately to well drained cool site, and not of a poorly drained site. It is assumed that the abundant moisture (from melting permafrost and run-off from the perched water table) is the result of the drilling activity. In this case, it is favourable to the site as natural revegetation is significant, both in surface coverage and species variety.

There is evidence of frost heaving and fracturing in places, but no evidence of gullying or subsidence. This drill pad was identified by a post and sign.

Vegetation

The vegetation on this lower elevation reclaimed drill pad consisted of a dense mat of mosses, lichens and wetland shrubs such as diamond leaf willow, crowberry and blueberry. Forbs and graminoids comprised only a minor component of the ground cover (Plate 2-42).

This drill pad was one of the sites seeded during the cover plot experimentation initiated in 1981. Eighteen years after the reclamation work was carried out, a trace of red fescue was the only seeded species noted in the drill pad area.

Wildlife

Moose track, fecal pellets and recent browsing sign were evident on this reclaimed drill pad.

2.5.5.2 Drill Pad West of 78-43

Site and Soil Conditions

This drill pad is probably 80-57A. No markers were found. The drill pad is a slightly raised surface approximately 15 m by 10 m. Like site 78-43, this site is now poorly to very poorly drained (Plate 2-43). It is also densely revegetated. The surface is gently sloping with the drill pad surface having a 4% slope, compare to a 8% slope in the surrounding area. Water seeps at the surface in may places and two shallow gullies frame the south and north side of the pad. There is evidence of degrading permafrost and seepage from the upper escarpment. There is no gullying on the reclaimed surface itself, but frost heaving and fracturing are visible.

The drill pad is constructed with gravely, loamy sand, with a 80% fine-grained matrix. This is the only site at Jason Knoll where a thin organic-rich horizon has been forming since the disturbance.

Vegetation

There were two distinct vegetation types found on this reclaimed drill pad. The high, dry centre had a diverse, but sparse, cover of shrubs and graminoids, while the low wet perimetre of the clearing was covered by a mat of wood horsetail, brownish sedge and moss (Plate 2-44). A substantial growth of diamond leaf willow was found on both the wet and dry parts of the drill pad.

Wildlife

Moose tracks, fecal pellets and recent browsing sign were evident on this reclaimed drill pad.

2.5.5.3 *Additional Observations - Drill Pads*

- All sites surveyed were located in ice-rich permafrost areas, or in areas where run off at the interface between permafrost and unfrozen ground is considerable. The water table was located at or near surface.

- Despite the increased moisture available to the sites, there is no significant erosion because of the near level surface of the drill pads.

- Areas immediately adjacent to drill holes do not show significant difference in revegetation patterns from peripheral areas from revegetation on the access roads.

- Moisture-loving plant species colonize the sites which are poorly to imperfectly drained. Because of the abundant moisture available to these sites after disturbance, revegetation is very successful, but the vegetation communities are different from the surrounding forest.

- These sites are revegetated predominantly by moss, lichens, sedges and dwarf shrubs. Trees from the surrounding white spruce forest have not yet colonized the drill pads.

2.5.6 Summary-Jason Knoll sites

Little evidence of the agronomic species used for revegetating these exploration sites remained in 1999. This is not surprising, considering the low yields for seeded species reported during the first four years after the reclamation work was carried out (Brown 1985). By 1985, the maximum cover observed on the revegetated trenches was 20 % and most species had reduced their flower production significantly.

Red fescue (varieties Arctared, Fortress and Boreal) was the most notable success during the third and fourth seasons (1984 and 1985), and was the only seeded species found on the reclaimed sites in 1999. Red fescue has been widely used for revegetation in the Yukon, but is difficult to distinguish from native species possibly present (Cody 1996).

Other graminoid species showing limited potential in 1985 were Kentucky blue grass (Nugget variety) and timothy (Engmo variety). There was no trace of these species in 1999.
Despite the harsh subalpine environment of the Jason Knoll area, recolonizing of the reclaimed trenches by native species, particularly shrubs, appears to be well underway. Shrub birch, blueberry and Beauverd's spiraea have become well established on these upland sites.

The natural revegetation of the lower elevation reclaimed drill pads also appears to be progressing well. These sites have been stabilized by vegetative mats of meadow sedge, horsetail and moss, along with shrubs such as diamond leaf willow.

The objective of using agronomic plant species is the rapid establishment of a vegetative cover in order to prevent erosion and to act as a nurse crop for native species. This goal may have been achieved at Jason Knoll. Natural succession appears to be occurring, although, because of the lack of data after 1985, the degree to which the use of agronomic species has contributed to this process cannot be certain. It is noteworthy, however, that agronomic species are not currently retarding the growth of native vegetation on the reclaimed sites, and that these species have not invaded the surrounding area.

3 Conclusions

The conclusions are organized in four categories and because of this, there may be some repetitions.

3.1 Surface conditions.

- Importing topsoil is an impractical treatment for reclaiming exploration trenches. Although it may have limited benefits as a growth medium in some situations, it would be prohibitively expensive in most areas and has the real potential for introducing noxious, invasive plant species.

- Refilled and contoured trenches, with rough and loose surfaces seem to revegetate well. The replacement of original soil is most important and makes the most significant contribution to the revegetation process, particularly at high elevation sites or sites in extreme climatic conditions.

- The replacement of tree debris significantly improves habitat conditions for small mammals by decreasing access and visibility for predators.

- The use of mulch may be an effective reclamation treatment in the harsh climate of most alpine areas or possibly in areas where slope are steep enough to warrant immediate erosion control.

- The use of inoculant (vesicular arbuscular mycorrhizae) on the experimental treatment plots appears to have had little benefit in enhancing vegetative growth.

- Backfilled trenches in forest situations may best be reclaimed by restoring the original vegetative mat and placing brush, logs, etc. loosely on the surface (seeding is not required if there are natural seed sources nearby and if there are no obvious potential erosion problems).

3.2 Plants

- The benefits of using of legumes for reclaiming exploration trenches are not obvious. Seeded agronomic legumes are not surviving long and do not appear to contribute to surface coverage in a significant way at any stage.

- The use of sod-forming species such as red fescue can inhibit the natural invasion of colonizing plant species (the resultant litter from the thick vegetative mat further retards new growth).

- The agronomic graminoid species, meadow foxtail, fowl bluegrass and red top are not surviving on the two forested trench plots (Nucleus and Hawk trenches).

3.3 Long-term impacts (15 years or more)

- From observations at all properties surveyed, there is no evidence that agronomic species are colonizing undisturbed sites. In areas with established ground cover (mosses, lichens, grasses, forbs or shrubs) agronomic grasses are not disseminating to undisturbed surfaces. Habitat changes are limited to the disturbed surfaces. In most cases, habitats for rodents and ungulates are improved by the addition of grasses.

- From the results at the Nucleus and Hawk properties, located below treeline, significant conclusions can be made. After five years, the seeded, nearly level plots are densely covered with vegetative litter or live agronomic grasses but with very little native vegetation. The unseeded test plots, nearly level and fairly compacted, have not revegetated successfully in terms of ground coverage, but have a higher diversity of native colonizing species than the seeded plots. By contrast, surrounding disturbed areas, with their rough and loose surfaces, are naturally revegetating both in terms of ground coverage and species diversity. This suggests that, although an early dense coverage by agronomic species may be required to control soil erosion in areas with steep slopes, this type of seeding may not be necessary or desirable in most cases.

- The addition of topsoil or bacterial inoculant does not appear to have any benefit.

- Observations at Division Mountain, also located below tree line, reinforce these conclusions. Rough surfaces, with very loose and rugged micro-topography, foster the growth of seeded species, but the coverage is not dense. Native species, therefore, can invade pockets that act as seed traps and provide shade and moisture. This results in the rapid colonization of these surfaces. The use of the original top soil and vegetation debris definitely plays an important role in the return of native species. The replacement of tree debris creates an environment similar to burned over areas. In addition to preventing access by all-terrain vehicles to the corridors created by the trenches, it also avoids creating long corridors of high visibility for predators. Travel by ungulates is still possible across trenches. Small mammal habitat is probably enhanced by the numerous cavities, vegetation pockets and good cover created by the reclaimed trenches.

- The Jason Knoll drill sites located below treeline are located in moisture-rich, nutrient-rich sites, and long-term impacts should be negligible. The ground-cover vegetation, as well as shrubs and seedlings, invading these sites 15 years after reclamation are dense, diverse and robust. The current seral stage of vegetation includes plants adapted to these wet conditions. Over the next 20 years, the vegetation on these disturbed areas will probably return to plant communities that resemble the surrounding forest.

- Reclamation of disturbed land in alpine areas is the most problematic. The Red Ridge test plots and the highest reclaimed trenches at the Jason Knoll property are returning to natural conditions more slowly than lower elevation sites.

- In the lichen-moss alpine zone, the climate and soil conditions are often extreme and the growth of both agronomic and native plants is more difficult. At these sites, the preservation and replacement of top soil and plant debris is critical. The creation of a loose and rough micro-topography is also important. At these sites, the use of fertilizers is probably beneficial, although this was not substantiated by the survey results at the Red Ridge property. The use of a mulch blanket significantly improved the survival of agronomic species at Red Ridge and created grazing habitat for sheep, in an area where grasses are very sparse.

- At the Jason Knoll property, frost boils, evident both on both disturbed and undisturbed sites, are retarding plant colonization. The churning of soil and rock disrupt plant growth on reclaimed surfaces. This active process likely occurs at most high-elevation sites in the Yukon. Soil erosion, however, was definitely not a problem in this alpine area.

- At the reclaimed trenches in the subalpine shrub zone, native plant species are invading well, particularly where mats of the original organic-rich soil have been replaced. The excavated (and subsequently backfilled) portions of these trenches have lower vegetative covers than the sides of the trenches where material had been stockpiled. The backfilled portions of the trenches do, however, have a high diversity of native colonizing plant species.

3.4 <u>Permafrost</u>

- The thawing of ice-rich permafrost following surface disturbance and vegetation removal generally create saturated and slightly warmer soil conditions and unstable surfaces. In the cases observed during this project, this has had a beneficial impact on growth. At most sites, moisture conditions are improved by permafrost melting, the soil becomes loose and warmer, and growth is more abundant and more diverse than the pioneering plant communities expected for these particular sites.

- The plant communities colonizing these saturated sites may be different, resulting in assemblages of plants that tolerate or thrive in poorly drained conditions. Seed mixes targeting such areas should include agronomic or native plants that will adapt to these conditions. However, evidence from field observations suggests that natural revegetation occurs rapidly and seeding may not be necessary unless slope stability or habitat improvement are issues.

- At nearly level to gently sloping sites, unstable slopes may stabilize fairly rapidly. As the sites visited during this project had been refilled (Nucleus and Hawk) or were nearly level (Jason Knoll drill sites), retrogressive slumping was not a serious problem, even at the 15 year-old sites at Jason Knoll property.

- The activity of cryoturbation, such as frost boils, was surprising. A significant percentage of the reclaimed high alpine trench at Jason Knoll shows freshly churned surfaces (unvegetated). Although undisturbed sites also show frost-churning, frost boils will definitely retard the revegetation of the alpine trenches.

4 References

Bostock, H.S., 1966. Notes on glaciation in central Yukon Territory. Geological Survey of Canada, Paper 65-36, 18 p.

Brown, G., 1985. Results of revegetation experiments 1981-85 Macmillan Pass, Yukon Territory. Indian and Northern Affairs Canada.

Brown, R.J.E., 1967a. Permafrost in Canada. Geological Survey of Canada, Map 1246A, (1:7,603,200 scale).

Cody, W.J., 1996. Flora of the Yukon Territory. NRC Press, Ottawa, Ontario, Canada.

Craig, D.B., J.E. Craig, K. Pelletier, D. Emond, and H. Copland. 1998. Reclamation practices and research on mineral exploration properties in the Yukon Territory. Mineral Directorate, Yukon Region, Indian and Northern Affairs Canada, 36 p.

LeBarge, W.P., 1993, Gravel sedimentology, Mt. Nansen, Yukon. Unpublished M.Sc. thesis, University of Calgary, Calgary, Alberta, 272 p.

Mougeot, C., 1996. Natural land reclamation for mineral exploration properties and placer mines in Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, 202 p.

Yukon Minfile. 1997. 105D - Whitehorse. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

Yukon Minfile. 1997. 115N/O - Stewart River. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

Yukon Minfile. 1997. 115I - Carmacks. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

5 Appendix A: Plant species distributions and densities at reclaimed trenches and drill pads (information will be posted in June 2001)

6 Appendix B: Botanical and common names of plant species referred to in this report

Botanical Name	Common Name
Abies lasiocarpa	subalpine fir
Achillea millefolium	common yarrow
Aconitum delphinifolium	monkshood
Agropyron riparium	streambank wheatgrass
Agrostis gigantea	red top
Agrostis scabra	ticklegrass
Alnus crispa	green alder
Alopecurus pratensis	meadow foxtail
Andromeda polifolia	bog rosemary
Arctostaphylos rubra	bearberry
Arctostaphylos uva-ursi	kinnikinick
Artemisia alaskana	Alaskan sagewort
Artemisia norvegica ssp. *saxatilis*	mountain sagewort
Aster sibiricus	Siberian aster
Astragalus agrestis	purple milk vetch
Astragalus sp.	milk vetch
Betula glandulosa	shrub birch
Betula papyrifera	paper birch
Calamagrostis canadensis	blue-joint
Calamagrostis purpurascens	purple reed-grass
Calamagrostis stricta ssp. *stricta*	slimstem reed-grass
Campanula lasiocarpa	harebell
Carex aurea	golden sedge
Carex brunnescens	brownish sedge
Carex canescens	short sedge
Carex concinna	woodland sedge
Carex filifolia	sedge
Carex media	Norway sedge
Cassiope tetragona	arctic white heather
Cerastium arvense	field chickweed
Chenopodium album	lamb’s quarters
Chenopodium capitatum	strawberry blite

Cladina mitis	reindeer lichen
Cladina rangiferina	reindeer lichen
Cornus canadensis	bunchberry
Crepis tectorum	hawksbeard
Cypripedium passerinum	sparrow-egg lady's slipper
Deschampsia caespitosa	tufted hairgrass
Dryas sp.	mountain aven
Elymus alaskanus	Alaskan ryegrass
Elymus junceus	Russian wild ryegrass
Elymus macrourus	ryegrass
Elymus trachycaulus ssp. *andinus*	ryegrass
Elymus trachycaulus spp. *trachycaulus*	slender wheatgrass
Elymus trachycaulus ssp. *subsecundus*	bearded wheatgrass
Elymus trachycaulus ssp. *violaceum*	violet wheatgrass
Empetrum nigrum	crowberry
Epilobium anagallifolium	alpine willowherb
Epilobium angustifolium	fireweed
Epilobium latifolium	broad-leaved willowherb
Equisetum arvense	common horsetail
Equisetum scirpoides	dwarf scouring rush
Equisetum sylvaticum	wood horsetail
Erigeron elatus	fleabane
Erigeron sp.	fleabane
Eriophorum brachyantherum	short-anthered cotton grass
Festuca altaica	northern rough fescue
Festuca brachyphylla	sheep fescue
Festuca ovina ssp. *duriuscula*	hard fescue
Festuca richardsonii	Richardson's fescue
Festuca rubra	red fescue
Festuca saximontana	Rocky Mountain fescue
Gentiana glauca	glaucus gentian
Gentianopsis detonsis ssp. *yukonensis*	fringed gentian
Gentianella propinqua ssp. *propinqua*	four-petalled gentian
Geocaulon lividum	northern comandra

Hedysarum alpinum	bear root
Hieraceum gracile	hawkweed
Hierochloe alpina ssp*. alpina*	alpine holygrass
Hordeum jubatum	squirrel's tail barley
Hylocomium splendens	stepmoss
Juncus biglumis	two-glumed bog rush
Juncus castaneus ssp*. castaneus*	bog rush
Ledum groenlandicum	Labrador tea
Ledum decumbens	Labrador tea
Linnaea borealis	twinflower
Lolium perenne ssp*. multiflorum*	perennial rye grass
Lupinus arcticus	arctic lupine
Luzula arcuata ssp*. unalaschkensis*	Alaskan wood rush
Luzula confusa	wood rush
Luzula parviflora	wood rush
Lycopodium clavatum ssp*. monostachyon*	running clubmoss
Mertensia paniculata	lungwort
Myosotis alpestris	mountain forget-me-not
Oxycoccus microcarpus	bog cranberry
Oxytropis campestris ssp*. jordalii*	field locoweed
Oxytropis huddelsonii	Huddellson's locoweed
Parnassia palustris	grass of Parnassus
Petasites frigidus ssp*. frigidus*	coltsfoot
Petasites saggitatus	arrow-leaved coltsfoot
Phalaris arundinaceae	reed canary grass
Phleum pratense	common timothy
Phyllodoce empetriformis	pink mountain heather
Picea glauca	white spruce
Picea mariana	black spruce
Pinus contorta	lodgepole pine
Pleurozium schreberi	red-stemmed feathermoss
Poa arctica	arctic bluegrass
Poa alpina	alpine bluegrass
Poa nemoralis	wood blue grass

Poa palustris spp. *pratensis*	fowl bluegrass
Poa pratensis ssp. *alpigena*	northern bluegrass
Poa pratensis	Kentucky blue grass
Polemonium pulcherrimum	showy Jacob's ladder
Polygonum alaskanum	Alaskan knotweed
Polytrichum spp.	polytrichum
Populus tremuloides	trembling aspen
Rosa acicularis	prickly rose
Potentilla anserina	silverweed
Potentilla fruticosa	shrubby cinquefoil
Potentilla uniflora	one-flowered cinquefoil
Pulsatilla ludoviciana	pasque flower
Pyrola asarifolia	pink wintergreen
Pyrola grandiflora	arctic wintergreen
Rubus chamaemorous	cloudberry
Rubus idaeus	raspberry
Salix arctica	arctic willow
Salix athabascensis	Athabascan willow
Salix glauca	blue-green willow
Salix myrtillofolia	blueberry willow
Salix planifolia	diamond-leaf willow
Salix reticulata	net-veined willow
Salix spp.	willow
Saxifraga lyallii spp. *hultenii*	red-stemmed saxifrage
Shepherdia canadensis	soapberry
Senecio triangularis	arrow-leaved groundsel
Senecio tundricola	tundra groundsel
Sibbaldia procumbens	sibbaldia
Silene acaulis	moss campion
Solidago capitata	northern goldenrod
Solidago simplex	spike goldenrod
Sphagnum spp.	sphagnum moss
Spiraea beauverdiana	Beauverd's spiraea
Spiranthes romanzoffiana	ladies' tresses

Stellaria longipes	chickweed
Trifolium hybridum	alsike clover
Trisetum spicatum	spike trisetum
Vaccinium uliginosum	blueberry
Vaccinium vitis-idaea	low-bush cranberry
Viburnum edule	high-bush cranberry

7 Appendix C: Summary of reclamation work at Jason Knoll

Information will be posted June 2001 (from Brown 1985)

8 Appendix D: Site photographs (Information will be posted June 2001)