VEGETATIVE REHABILITATION OF WHITEHORSE COPPER MINE TAILINGS

REPORT NUMBER 3

BY

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1. INTRODUCTION

Whitehorse Copper Mine, 10 kilometers south of the main part of Whitehorse, but still within city limits, on the west side of the Yukon River Valley, is a property of Hudson Bay Mining and Smelting Company Limited. The mine ceased operation in 1982 after almost 15 years of production, and since that time the site has been a matter of environmental concern. The geological setting is a metamorphic contact between Lewes River limestone and Cretaceous granodiorite of the Whitehorse stock. Some ten million tons of finely ground material - limestone, granodiorite and calc-silicate metamorphic rocks has been pumped into three tailings areas following the extraction of the valuable copper sulphides and gold. The largest of these areas, adjacent to the Little Chief Mine and the mill site, called the Old Pond, is 55 hectares in extent, and contains tailings ranging from 0 to 20 meters in depth, depending on the topography onto which the tailings were pumped. The tailings are confined by dykes of crushed and broken rock.

The tailings material is fairly benign compared with that from many other base metal mines. There are no specific, toxic chemicals present. Manganese, being slightly high, is mentioned in the Hudson Bay Mining and Smelting Company abandonment plans, presumably because it is the only metal which is moderately above the concentration in the normal geological environment. Snow melt ponds, right on the tailings, present from May until late July are drunk from by humans, including the writer, and animals, without apparent ill effects. The tailings are, however, extremely alkaline, having a pH in excess of 9.0 due to the presence of finely ground limestone. This alkalinity is one of several factors, perhaps the most important one, which inhibits vegetative growth on the site. This evaporite material has a high electrical conductivity (E.C.) lab reading. The salinity registered by the E.C. readings are high enough to be toxic to plants.

The material, fine sand or silt sized particles (minus 150 screen mesh or about minus 0.1 mm) is subject to wind erosion and deposition. On the windward side of a barrier fence, fine sand collected to a depth of 20 centimeters in three months. The site also includes alkaline evaporite deposits where rain and snow melt percolate downward into the tailings, dissolve salts, then rise by capillary action, evaporate and leave the salt precipitated as white to grey encrustations on the surface.

There had been negligible re-growth on these tailings after a minimum of 12 years even though other disturbed portions of the mine property, especially the dykes of crushed rock, gravel and mineral soil, support an impressive floral display of yarrow, fireweed, kinnikinnick, dandelions, rumex, arabis, shepherdia, etc as well as willow and small conifers. Wind blown tailings build up as cones of sand or silt dunes around dandelion clumps - and the plants seem to thrive. Such hardly suggests these particular tailings to be toxic. Further, where the original topographic surface is present, or is covered with only a thin skin of tailings, there is growth of aspen, willow and other plants.

A 0.9 hectare area on the east side of the Old Pond was selected in 1994 and isolated by a wind barrier fence constructed of plastic film over metal or plastic chain link fencing. This area was identified in the Hudson Bay reports as being subject to wind erosion with transport of tailings dust, as well as formation of evaporite deposits. The site was divided into plots (Figure 1) and each treated with a different application of organic material (compost) and commercial fertilizer. It was then rototilled to 15 - 20 cm depth and seeded with a recommended mixture of grasses. Details of this project are provided in the 1994 and 1995 reports entitled Vegetative Rehabilitation of Whitehorse Copper Mine Tailings.

A total of 75 trees, representing 11 species, ranging up to four meters in height, were transplanted by a tractor mounted, hydraulic tree spade from the forested area at the margin of the tailings to immediately inside the barrier fence. Trees were set at three meter intervals. The intention is that these trees, once established, will take over the wind barrier duties from the plastic fence, partly sheltering the enclosed, revegetated area from prevailing winds and their burden of blowing tailings.

2. PURPOSE OF PROJECT

The purpose of the project is to revegetate a portion of the Old Pond to make it a more attractive and productive site, especially for wildlife, even though deer, moose and bear presently use or cross the area. The specific site was deliberately chosen based on the Hudson Bay Abandonment Plan which identified it as an area subject to wind erosion.

We regard the project as reflecting in a tangible way some of the goals of the Yukon Conservation Strategy prepared by the Government of the Yukon in 1988 and 1989, which states (page 38) "... establish well defined, site specific approaches for effective clean-up and reclamation of depleted or abandoned mining sites". A key aspect is to identify and evaluate the various parameters or conditions which inhibit vegetative growth - pH, electical conductivity (E.C.) or salinity, moisture, texture, nutrients and wind - and to overcome these.

Optimistically, the project could serve as a model for the reclamation of other tailings areas in the Yukon or other sub-arctic settings. However, at present, the project is intended to stand on its own merits. For chemical/mineralogical reasons Whitehorse Copper Mine tailings represent a less formidable problem than some other mine sites. Anvil and Elsa tailings produce acid waters when leached by rain and snow melt and Venus tailings contain highly toxic arsenic as a basic part of the mineral assemblage (arsenopyrite).

3. ACTION PLAN IMPLEMENTATION

Of the various aspects, factors or conditions which inhibit plant growth, the following are considered the most important:

a. pH:

As referred to, unlike the spoil or waste from many base metal mines, which produce acid water, the pH of these tailings is approximately 9.3 (highly alkaline), too high for the growth of all but the most alkaline tolerant plants.

b. Electrical conductivity (E.C):

The E.C. is a measure of the salinity of the tailings. Below 2.0 is acceptable for plant growth. An E.C. of 2 to 4 is acceptable but the analyses suggest "caution" for a growing medium. Above 4 is regarded as excessive salinity and is considered toxic to plants.

c. Soil Nutrients:

Since the tailings consist of finely ground rock, nitrogen, a major essential plant nutrient, is lacking and growth would not be expected. However, phosphorus, potassium and sulphur are all present in adequate amounts, although they may not be available to the plants for other reasons such as the high pH inhibiting the uptake of potassium. The tailings are lacking in organic material and normal soil organisms such as bacteria, moulds, fungi, worms, mites, insects, etc.

d. Evaporites:

On some parts of the tailings, water, having moved downward, dissolves soluble constituents and then percolates upwards to the surface by capillary action and evaporates, leaving a light grey to white, hard encrustation, largely calcium carbonate. This material, both texturally and compositionally, is a poor growth medium, having an extremely high salinity.

e. Texture:

The tailings, thought of as a soil, consist of fine sand to silt sized particles (0.1 mm), are dense, tightly packed and non cohesive. In their usual state of packing they do not contain air.

f. Wind Erosion:

The wind removes silt from some areas and deposits it in others, in some places, to almost one meter depth. Either removal or deposition at any given site would inhibit plant growth. Flying, sharp mineral fragments could damage germinating plants at a vulnerable stage.

g. Water:

Water is deficient in the top few centimeters. The tailings are moist at greater depth. Movement of water may not be satisfactory due to weak permeability between pores and excessive permeability along fractures. However, genuine lack of water is probably not a strongly inhibitory factor in this setting.

Measures taken to cope with each of the factors listed are as follows:

a. pH:

Most of the effort has gone towards amelioration of what is seen as a crippling pH. All of the organic material - bark, shavings and sawdust, as well as more conventional compost material - garden waste, grass cuttings and horse manure, are acidic upon decomposition. This material should shift the pH towards neutral, hopefully by an amount adequate to allow plant growth. Further, ammonium sulphate commercial fertilizer was applied to improve the pH in the short term.

Of the suite of grass seeds sown, Bering Sea hairgrass (*Deschampsia caespitosa*) , an alkaline tolerant species, was included as part of the seed mixture.

b. Electrical Conductivity (E.C.):

The salinity responds to about the same efforts or additives as does the pH. On well composted areas which has deep rototilling, both pH and E.C. readings are reduced to acceptable levels and vegetation flourishes.

c. Soil Nutrients:

These are contributed by the compost and wood waste, as well as the commercial fertilizer at 150 kg/ha of 34-0-0 + 11% sulphur and 150 kg/ha 0-0-60.

d. and e. Evaporites and Texture:

Rototilling to introduce air and reduce compaction should reduce evaporation. Also, the organic material added should both absorb water, reduce evaporation, and improve the friability and other textural characteristics.

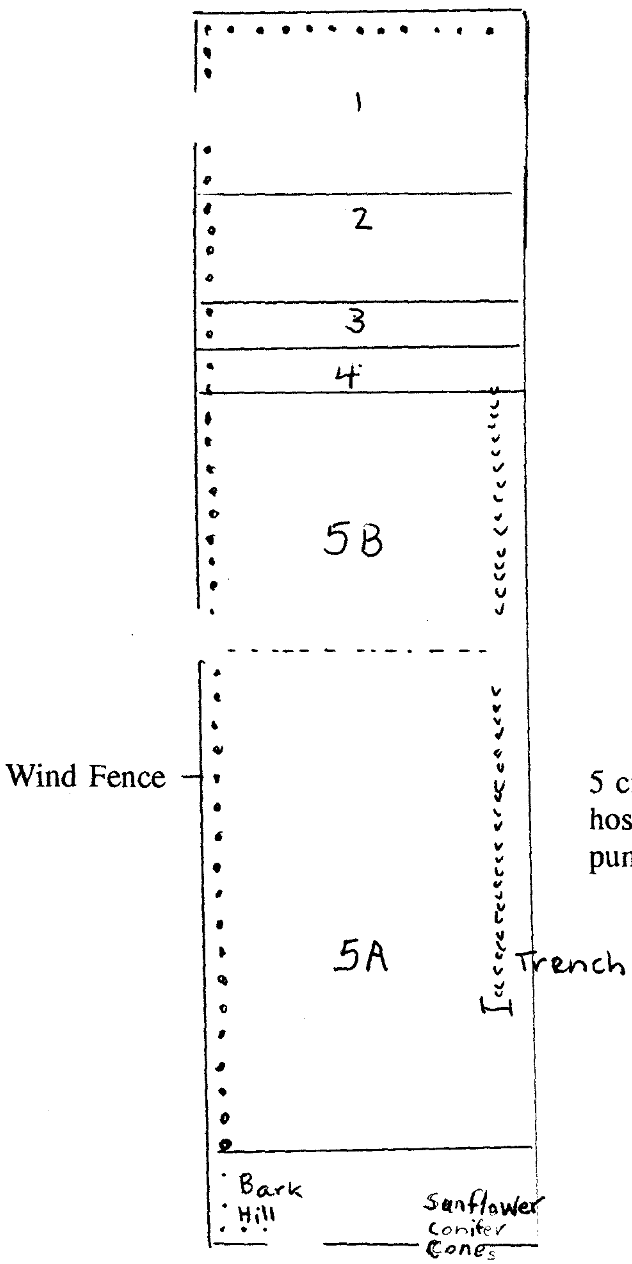
f. Wind Erosion:

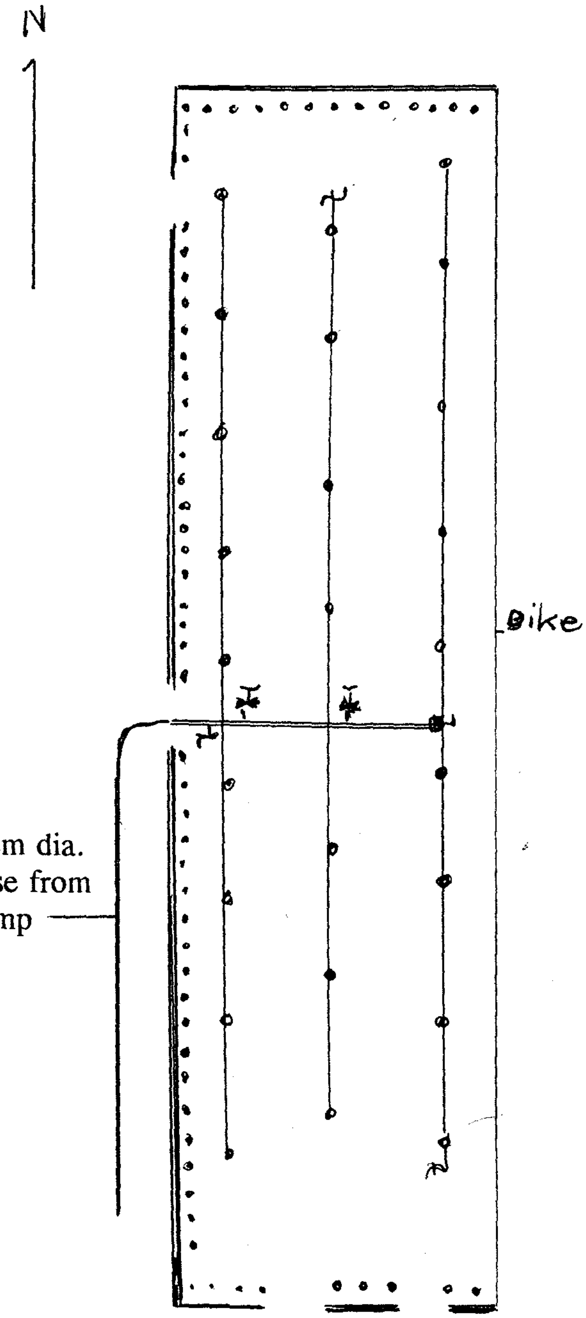
The 1.2 meter high fence, consisting of chain link with 6 mil construction plastic folded over the fencing blocks the wind, especially on the west side of the area. During the first three months the fence was in place, some 10 - 25 cm of sand and silt accumulated on the windward side, blocked from the test area by the fence, and indicative of the rate of wind transport of unanchored tailings.

g. Water:

A 1300 liter water tank was placed on a seven meter tower on the outer dyke. Water was pumped into this during 1994 and used to dampen the compost windrows. Once the sprinkler system was installed in 1995, the tank and 45 gallon drums were removed from the site.

The 1995 mine tailings revegetation program consisted of assembling and operating a sprinkler irrigation system. (Figure 2) The specifications for the water line, spacing of lateral lines and spacing of sprinklers along the lines were based on advice from International Plastics Limited, irrigation specialists from Kelowna, British Columbia. System components were purchased from the Kelowna firm and from several Yukon industrial supply firms. Totaltrac of Whitehorse supplied the pump.





Scale: 1 cm = 12 m

Figure 1:
Test Plots:

Figure 2:
Irrigation System

Equipment consisted of a Kubota KVP - 20 S high pressure pump (65 meters head) having a four centimeter discharge expanded to five centimeters diameter, connected to 450 meters of five centimeter diameter delivery hose extending from the water source, a snow melt pond, to the reclamation site. At the site the delivery hose was connected to the irrigation system (Figure 2). This system consists of rigid plastic pipe five centimeters in diameter arranged with a transverse feeder line connected to three parallel sprinkler lines 17 meters apart. Each sprinkler line is arranged with a Tee and gate valve such that each line can be operated independently, the usual mode of operation. The plastic pipe is buried 10 to 15 centimeters deep with 30 centimeter risers, 20 millimeters in diameter set at 20 meter intervals. Bering Sea hairgrass (*Deschampsia caespitosa*) an alkaline tolerant species, was planted on the surface, above the buried pipe. Prior to installation of this system, the trees were watered by hand.

Irrigation was typically 0.5 to 0.75 hours per day for each lateral line or approximately two pumping hours per day at 300 liters per minute. In 1995, the site was irrigated for 34 of the 45 days from June 9 to July 25 when the water supply was exhausted, providing abundant water for the main growing season, a total of roughly one million liters. During 1996, the site was irrigated for 22 of the 57 days from May 15 to July 11, at two or three day intervals, a total of 600,000 liters. The pond was exhausted two weeks earlier in 1996 than in 1995. The pump was brought to the site, operated and removed each day of use. Garden hoses, 20 millimeters in diameter, were connected to the irrigation system and used to water the perimeter trees. Additionally in 1996, material for further compost production, largely grass cuttings and yard waste, were added to the east side of the site, as available, to act as a wind break and snow catchment ridge.

Spruce and pine seedlings, 10 to 30 centimeters in height, were planted along the compost windrows and the perimeter fence, to augment the large one to four meter tree spade transplants in forming the future wind break.

At the end of the irrigation period the delivery hoses were taken up and stored for the winter. The risers and sprinkler heads of the irrigation system were removed, the pipes drained and plastic plugs placed in the lateral lines at the sprinkler sites. The plugs prevent the entry of either snow or dirt which could freeze and damage the pipes. The buried distribution system remains in the ground for the next year's irrigation program.

4. RESULTS and LAB TEST OBSERVATIONS

Norwest Lab results given in Appendix B.

Soil samples, taken on August 2, 1996 were sent to Norwest Labs of Edmonton. Soils samples were tested for soil quality - pH (acidity), E.C. (salinity) - and nutrient analysis (ppm) - nitrogen, phosphate, potassium and sulphate.

Plot 1

Three samples were taken from plot 1.
Sample # 1 was taken 1.5 m from a Shepherdia shrub.
Sample # 2 was taken west of sample # 1 (3 meters), 1.5 m from a pine.
Sample # 3 was taken from the 0.5 sq m clipped area.

#1	pH 8.0	E.C. 2.6	N 4	P 80	K 526	S 80
#2	pH 8.6	E.C. 2.0	N 4	P 30	K 458	S 80
#3	pH 9.4	E.C. 2.5	N 22	P 53	K 385	S 80

Dried grasses clipped from 0.5 sq m on Sample #1 area is 118 grams; (2360 kg/ha). The dried sample was chosen beside the Shepherdia shrub and the 0.5 sq m clipped area.
The other dried grasses sample clipped from a randomly chosen 0.5 sq m on Sample #3 area is 29 grams; (580 kg/ha).

Plot 2

One sample, #4, was taken on this control panel. There was not enough growth to clip for a weighed sample.

#4	pH 9.4	E.C. 1.3	N 4	P 27	K 179	S 80

Plot 3

One sample was taken on this sawdust only addition of organic material.

#5	pH 9.3	E.C. 5.9	N 4	P 22	K 502	S 80

Dry weight of grass from the 0.5 sq m clipped area is 3.0 grams; (60 kg/ha).

Plot 4

One sample #6 was taken on this sawdust plus green grass lawn cuttings.

#6	pH 8.7	E.C. 3.8	N 4	P 25	K 497	S80

Dried weight of grass from the 0.5 sq m clipped area is 22 grams; (440 kg/ha).

Plot 5

Plot 5 was treated with compost. The sample from the 2 - 4 cm layer of compost was #7. Two 0.5 sq m were clipped and averaged.

#7	pH 8.6	E.C. 7.8	N 52	P 44	K 919	S 80

Dry weight of grass from two areas is (6 grams, 9 grams); (150 kg/ha).

Plot 5 treated with the thick layer of compost was clipped in three areas - marginal, average and heavy growth. Sample #8 was taken from the average clipped area. Sample # 9 was taken from the area of heavy growth.

#8	pH 8.7	E.C. 1.2	N 20	P 49	K 409	S 80
#9	pH 9.0	E.C. 1.2	N 58	P 120	K 887	S 80

Dry weight of marginal grass growth is 420 gm; 1060 kg/ha.
Dry weight of average grass growth is 2390 gm; 7410 kg/ha.
Dry weight of heavy grass growth is 4100 gm; 12980 kg/ha.

Bark Hill

On the south west corner a steep hill was covered with ten year old conifer bark. Sample #10 is taken from this area. No areas were clipped.

#10	pH 8.9	E.C. 1.0	N 4	P30	K 151	S 80

No grass mix was planted on this site because of the steep slope. Some sweet clover seed was dormant in the bark and that has germinated. Conifer seedlings planted in deep holes filled with local gravel pit soil also grew, as did fireweed and dandelion seedlings.

South end on the hectare site was under a snow melt pond during May. Sample #11 was taken on barren ground. Sample #12 was taken on ground covered with conifer cones, needles and sunflower husks from birdseed.

#11	pH 9.2	E.C. 2.9	N 4	P 20	K 417	S 80
#12	pH 9.2	E.C. 1.0	N 126	P 32	K 162	S 80

5. INTERPRETATION

The differences in growth characteristics of the suite of grasses on the five different plots were striking. All were treated with commercial fertilizers (150 kg/ha 34 -0 -0 + 11% S, 150 kg/ha 0 - 0 -60), rototilled and planted with the same grasses (See Appendix E). Irrigation was the same on all plots. There is some variation within the tailings themselves, particularly between silty areas of wind deposition and areas of crusty, alkaline evaporites. These areas of evaporites show the higher E.C. readings. The site is now largely protected from wind deposition as evidenced by a ridge of fine sand, up to 25 centimeters deep, outside the fence, formed since the fence was erected in July 1994. Further, a belt of crusted evaporites did extend through the reclamation site, and is prominent just to the north of the site. Treatment and response for each plot follow.

The response during the 1996 growing season was similar to that of 1995 except for taller, denser grasses on the thick layer of the well composted plots. In-filling of some bare spots from 1995 occurred. Areas of good 1995 growth was largely alkali grass (*Puccinella nuttaliana*) but in 1996 this was being displaced by the wheatgrasses, bluegrass and fescue, a normal succession, in which the alkali grass acts as a nurse crop for the other species.

The composted additions to the tailings have reduced the high level pH. The compost also raised the E.C. readings in Plots 1, 4, and 5. Much of the compost was made from well fertilized grass cuttings. Soil additions of old bark or lawn thatchings with assorted cones, needles and seeds did not raise the E.C. level.
Where the organic matter was thick enough to be rototilled well into the tailings, the E.C. readings on Plot 5 were acceptable for good growth. On thin layer additions of compost or only partly made and dry organic matter, the rototilling did not incorporate the organic matter into the soil in a satisfactory manner.

Test plot distribution is shown on Figure 1. Plant species distribution map is given in Figure 3 in Appendix C. Detailed range survey of plants (10 meter transects) observed adjacent to 0.5 sq m clipped area of each plot is given in Appendix D.

Plot 1:

Grass cuttings and landscaping wastes were partially composted early in the 1994 season. These were distributed and rototilled into the upper 15 centimeters of the tailings. There is non uniform, modest growth on this plot. Striking is the abundant growth around the buffalo berry (*Shepherdia canadensis*) and pine trees, transplanted by the tree spade. Plot 1 has a pH of 8.0 (good) and E.C. of 2.6 (acceptable - "caution"). However, this abundant growth persists in the tailings one to two meters from the transplants which is well beyond the soil brought in by the root ball. Nitrogen fixing bacterial nodules are identified on the shepherdia rootlets. The leachate from the original location of the composting pile may have improved the growing soil medium as well. The original windrow of landscaping waste was on this area; the windrow was damped several times until the snow melt pond dried up in June, 1994.

Plot 2:

This plot is regarded as the control plot with respect to organic material. No organic enhancement was provided. In spite of tilling, fertilizing, seeding and irrigating there was zero growth on this plot. By spring 1995, compaction was such that these tailings appeared to be the same as in the spring of 1994, before any reclamation efforts had been started. Crusted evaporites developed, (possibly exacerbated by irrigation), gullies on the slope and cracks, many centimeters in length, formed similar to those in evaporite zones outside the reclamation site. Irrigation water drained down the cracks. (Photograph 1) pH was 9.4 (very high) although E.C. was still acceptable at 1.3.

Plot 3:

A five centimeter layer of spruce and pine sawdust rototilled into the upper 12 centimeters of tailings produced some but poor growth. Perhaps five percent germination producing stunted grasses to 12 centimeters height would be a reasonable description. However, that a textural change was brought about is apparent from the more friable, less caked character of this plot, (Photograph 2), in contrast with that of the control plot. Also notable was the lack of cracks and presumably more water was retained in the upper few centimeters where it would be available to plants. There was not a significant difference in this plot after the 1996 growing season than after the 1995 season. pH was 9.3 (no improvement) and E.C. was 5.9 (toxic)

Plot 4:

Here five centimeters of spruce and pine sawdust and ten centimeters of lawn grass cuttings were rototilled into the tailings. This grew reasonably well, showing sporadic but locally robust growth to 25 centimeters height. Texture of the growth medium, although hardly a soil, was much more like a soil in terms of friability than are the barren tailings. pH was 8.7 (acceptable), E.C. was 3.8 (caution). Growth was 440 kg/ha - suitable for wildlife grazing.

Plot 5:

Horse manure, grass cuttings, vegetable waste, coffee grounds from government offices, bark, wood shavings, and landscaping wastes were stacked in windrows and carefully put through the composting process by moistening and restacking or turning several times over several weeks. In this process various bacterial strains multiply and raise the temperature of the windrow 20° to 50° Celsius above ambient temperature. The process converts the source material into a nutrient rich soil conditioner. The compost was spread over most of the plot in a 10 to 15 centimeter layer, largely by front end loader. Missed patches were completed by hand, and the complete layer rototilled into the tailings.

This plot, representing 70 percent of the site, experienced luxuriant growth over 80 percent of the plot. The poor growth on the northern end of this plot was directly related to the thinner layer of compost that was tilled into the tailings there. The plot is divided into Plot 5A with 12 centimeters of compost, and Plot 5B on the north part with 2 to 4 centimeters compost. Lab reports show that the nutrient level of nitrogen was higher on Plot 5; the nitrogen has enhanced plant growth. (Photograph 3).

Plot 5A planted grass seed produced dense growth to 80 centimeters height and a mixture of seeds, brought in with the landscaping wastes and not killed by the compost processing temperatures, also germinated and complemented the grasses with fireweed, dandelions, lamb's quarters, clover, poppies, daisies, etc. Of the planted grasses, in 1995 alkali grass (*Puccinella nuttaliana*) 35% of the seed mix, dominated as expected. In 1996 alkali grass was being succeeded by the wheatgrass species (*Agropyron species*). The 1995 alkali grass stalks, matted down to help form a litter sod, retaining moisture and providing nutrients for the successor plants. Root sampling revealed a dense, robust root mass roughly 12 centimeters thick from Plot 5A. (Photograph 4)

pH on Plot 5A was 8.7 (acceptable) and E.C. was 1.2. Heaviest growth sampled was 12,980 kg/ha - comparable to modest forage crops on agricultural land.

In Plot 5B the grasses showed a higher percentage of alkali grass than in Plot 5A and sparser growth. The lab E.C. readings were toxic to plant growth; the randomly selected test site had stunted grass growth and some white evaporite patches nearby.

The perimeter trees on the south end, west side and north end, planted as a wind break, suffered some losses but 70 of the 75 survived through to midsummer of 1996, putting out new growth. The aspen and willow were not as fully leafed out or as robust appearing as those off the tailings which were not disturbed, but such is expected after a transplant. The trees show some stress apparently due to shortage of water and to wind desiccation. Still, the conifers put out leaders and developed cones. Rose plants had flowers and set small rose hips. Also notable is what is here called "by-catch". When the tree spade extracts a tree with a 70 centimeter diameter rootball, it also moves the grasses, forbs, small shrubs and seedling trees living around the base of the tree. Hundreds of plants representing 20 species, were also transplanted, but with their own soil environment. Thus each transplanted tree and smaller plants associated with it form an oasis on the tailings. The plants in these oases have flourished and are extending gingerly out from the root ball perimeter to start the vegetative colonization of the tailings.

On the east side of the site, adjacent to the retaining dyke, a trench was dug about 30 centimeters wide and 40 centimeters deep. This was backfilled to 20 centimeters with partially composted organic material mixed with the tailings. The tailings from the trench were cast on the west (windward) side and a windrow of grass clippings and yard wastes was also placed there (Photograph 5). Thus plantings of domestic raspberries, willows, dandelions, yarrow, and grasses are protected from the wind and grow in the 20 centimeter deep trench. The plants received negligible irrigation water, being just beyond the range of the sprinklers. Nevertheless, growth has been impressive with water supplied by rain alone. The raspberries, while not as luxuriant as those in a home garden, have still set fruit each year. (Photograph 6) A number of willow cuttings, planted in the trench, survived and now have developed branches and leaves.

At the south end of the site on the barren tailings between Plot 5 and the wind fence, yard waste in the form of conifer needles and cones were spread to help reduce gullying and to make the surface less slippery. Sunflower seeds from a bird feeder area happened to be in this material as well. These germinated and experienced considerable growth. (Photograph 7)

Finally, if the efforts to date have concentrated on the flora, the fauna are not far behind. Lapland longspurs, Canada geese and ducks stop by on the spring migration (Photograph 8). Bluebirds, killdeer and swallows frequent the area. Tracks or sightings of bear, moose and mule deer are recorded. Field mice are nesting in the grass sod. Insects are represented by lady bugs, aphids, grasshoppers, wasps, bees, moths, butterflies and others too small to identify.

6. CONCLUSIONS

Based on the evidence to date, the project has been a success. A portion of the Whitehorse Copper Mine tailings has been revegetated. The preferential growth on the test plots is clearly the result of differential amounts and quality of organic material applied to each test plot, with the plots receiving abundant, well composted material showing by far the most abundant growth. The role or function of the organic material is at least five fold:

a. Bark, shavings, sawdust and vegetable compost are all acidic upon decomposition. Such material should move the pH from the present highly alkaline condition towards an only slightly alkaline state.

b. This material also reduces electrical conductivity (E.C.) which has been directly correlated with salt content and osmotic pressure. The degree of salinity is shown by the electrical conductivity. Areas where evaporites are present register high E.C. readings as in samples #5, #6 and # 7. Plot 1, plot 4 and plot 5 have a large amount of lawn grass cuttings or compost that was only partially composted and contained a large amount of lawn grass. The E.C. is 2.5 + and has caution warnings. With more mature, denser compost and a thicker layer of compost, the rototiller can cultivate into the tailings soil to a deeper layer so possibly dilutes the E.C. to lower levels. Immature compost is less heavy and tends to float up when rototilled.

c. It will foster a better tilth or texture than the finely ground, rock texture of the tailings, which have no fibre or organic material.

d. Sponge like, it enhances the retention of snow melt, rain and irrigation water.

e. The compost provides plant nutrients, especially nitrogen, which is totally lacking in barren tailings. Further, the organic material is less vulnerable to rapid leaching of nutrients than is commercial inorganic fertilizer.

f. Compost provides a habitat for soil organisms to develop in. Soil bacteria, actinomycetes, fungi, moulds, mites, insects, worms and other micro and macro-organisms assist in soil building and soil health. Indigenous floral species and organisms listed above, many from the immediately surrounding natural habitat, are well represented in the revegetation suite. It is reasonable to expect that such will continue to grow on the site and may well come to dominate in a few years.

The animal population, modest at present, will be in a symbiotic relationship with the flora. The mice will eat the plants; their burrows will enhance soil aeration and faecal material will provide plant nutrients. The grasses will provide wildlife forage. The mammals leave hoof prints to catch water and drop nutrient rich faecal material.

Two growing seasons, however successful, represents too short a time on which to predict long term results. Succeeding seasons, especially 1997 should validate (or negate) the promising results of 1995 and 1996.

7. RECOMMENDATIONS

It is recommended that:

a. The reclamation site described in this report be irrigated during the 1997 growing season from mid May to late July by the same system and technique installed and applied during the 1995 and 1996 seasons. Snow melt appears to be an adequate water source for this area. It is hoped that by the end of 1997, plants will be well enough established that irrigation of the site will no longer be required.

b. The site be used for field trips in 1997, as it was in 1994, 1995 and 1996, for environmental education benefits of having a mine tailings area and test reclamation project readily accessible within the city.

c. Since the plot receiving compost exhibited by far the most abundant growth, an effort be made to continue gathering of organic material, composting and applying such to other parts of the site. It is here acknowledged that gathering and preparing compost is labour intensive. Further effort should be made to identify the minimum organic matter application which will support sustainable plant growth. Once started, the view is that plant growth and decay will provide the necessary soil nutrients for the continuation of growth. Thus the first growth is critical. Plot 4 - Grass and Sawdust - is the most cost effective.

d. Further, although some effort is being made towards a municipal compost facility, both household wastes and contractors' grubbings, still go to the city landfill. It is here suggested that an effort be made to re-direct a part of this stream to Whitehorse Copper Mine site reclamation.

e. Since a determined interest is being taken in Canada to reduce total greenhouse gases, especially carbon dioxide, and that one such technique is to put carbon back into the environment by enhanced vegetative growth, it is suggested that Whitehorse Copper Mine tailings be identified as a suitable site for a local carbon sink.

f. Some consideration should be given to expansion of the revegetation efforts to other parts of the tailings. This effort should capitalize on the experience gained thus far. The use of small floral oases rather than a single block should be attempted.

g. A trench system, both for wind protection, snow catchment and ground moisture should be tried.

h. Food scraps should probably be avoided as any inadvertent fat, meat or dairy products may lure bears or other wild animals, an illegal activity. Bear have been seen nearby on occasions but have not scavenged at this site. Animals, both microscopic to large mammals, are an important part of this revegetation project.

i. A reliable water source be established to further revegetation efforts.

APPENDIX A

PHOTOGRAPHS

Ph #1: Cracks in Plot 2 (Control) and fewer cracks in Plot #3 (Sawdust).

Ph #2: Evaporite on Plot #3 (Sawdust) shows zero growth. Modest growth on part of plot.

Ph #3: Plot 5A dense growth to 80 centimeters.

Ph #4: Plot 5A robust root system.

Ph #5: Sign and windrow.

Ph #6: Plant growth in trench.

Ph #7: Sunflower germination in springtime lawn rakings.

Ph #8: Waterfowl tracks.

Photograph # 1: Cracks in Plot 2 (Control) and fewer cracks in Plot 3 (Sawdust)

Photograph # 2: Evaporites on Plot 3 shows zero growth.
Modest growth on part of plot.

Photgraph # 3: Plot 5A dense growth to 80 centimeters.

Photograph # 4: Plot 5A robust root system.

Photograph # 5: Sign and windrow.

Photograph # 6: Plant growth in trench.

Photograph # 7: Sunflower germination in springtime rakings.

Photograph # 8: Waterfowl tracks.

APPENDIX B

FLORAL LIST
INCLUDING DISTRIBUTION MAP

Plants at Whitehorse Copper Mines Tailings Revegetation Site

September 20, 1995 Joan Craig

Seeded in September 1995

Violet wheatgrass	*Agropyron violaceum*
Slender wheatgrass	*Agropyron pauciflorum*
Awned wheatgrass	*Agropyron subsecundum*
Alkali grass	*Puccinella nuttaliana*
Bluegrass	*Poa glauca*
Fescue	*Festuca saximontana*
Hair grass	*Deschampsia caespitosa*

Planted by tree spade in September 1995

Trembling aspen	*Populus tremuloides*
Balsam poplar	*Populus balsamifera*
Willow	*Salix*
Willow	*Salix*
White spruce	*Picea glauca*
Lodgepole pine	*Pinus contorta*
Wild rose	*Rosa acicularis*
Canadian buffalo-berry	*Shepherdia canadensis*
Common juniper	*Juniperus communis*
Alder	*Alnus crispa*

Growing on rootball of transplanted trees

High bush cranberry	*Viburnum edula*
Low bush cranberry	*Vaccininium vitis-idaea*
Kinnikinnick	*Arctostaphylos uva-ursi*
Dandelion	*Taxacum officiale*
Groundsel	*Senecio lugens*
Yarrow	*Achillea millifolium*
Fireweed	*Epilobium angustifolium*
Goldenrod	*Solidago multiradiata*
Raspberry	*Ribes idaeus*
Lupin	*Lupinus kuschei*
Graceful silverweed	*Potentilla gracilus*
Yellow locoweed	*Oxytropis spicata*
Hawkweed	*Hieracium umbellatum*
Lungwort	*Mertensia paniculata*
Twin-flower	*Linnaea borealis*

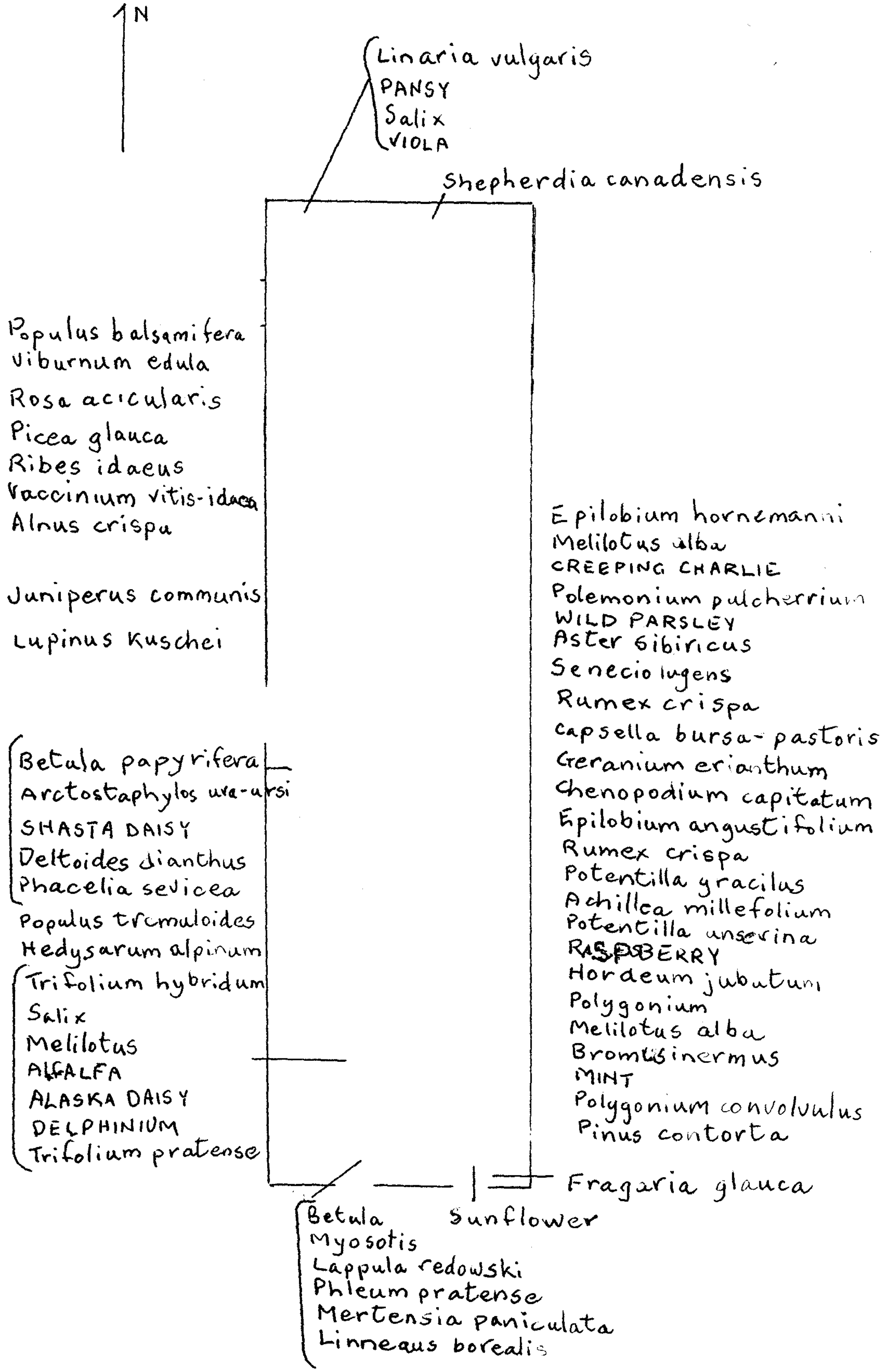
Plants on the reclamation site, September 1995.

Sticky cranesbill	*Geranium erianthum*
Filaree, crane's bill	*Erodium cicutarium*
Hedysarum	*edysarum alpinum*
Small fireweed	*Epilobium hornemanni*
*Bindweed	*Polygonium convolvulus*
Jacob's ladder	*Polemonium pulcherrimun*
Wild rhubarb, curly dock	*Rumex crispa*
Strawberry blite	*Chenopodium capitatum*
Raspberry	Domestic - Boyne
Stickweed	*Lappula redowski*
Pineapple plant	Camomile ?
Rock cress	*Arabis drummondii*
Pinks	*Diathus deltoides*
Red clover	*Trifolium pratense*
Yellow sweet clover	*Melilotus*
White sweet clover	*Melilotus alba*
Alsike clover	*Trifolium hybridum*
Silverweed	*Potentilla diversifolia*
Alfalfa	*Trifolium*
Lamb's quarters	*Chenopodium alba*
Knotweed	*Polygonium*
*Dogwood red osier	*Cornus stolonifera*
Chickweed	*Cerastium alpinum*
Shepherd's purse	*Capsella bursa-pastoris*
Butter and eggs	*Linaria vulgaris*
Pumpelly brome	*Bromus inermus*
Timothy	*Phleum pratense*
*Stinkweed	*Thlapsi arvense*
Biscuit root, mustard tansy	*Lomatius*
*Bladder campion	*Melandrium*
Barley foxtail	*Hordeum jubatum*
Antennaria	*Antennaria subviscosa*
Viola	
Pansy	
Alaska daisy	
*Swan River daisy	
Iceland poppy	
Delphinium	
Creeping Charlie	
*Snap dragon	

Plants found in August 1996 (all the above except those *)

Birch	*Betula papyrifera*
Wild strawberry	*Fragaria glauca*
Felwort	*Gentiana arctophila*
Forget me not	*Myosotis alpestris*
Scorpion-weed	*Phacelia sevicea*
Alaska aster	*Aster sibiricus*
Sunflower	

Figure 3: Location of stakes which mark plant growing sites.



APPENDIX C

NORWEST LAB RESULTS

9938-67 Avenue
Edmonton,AB
T6E 0P5

NORWEST LABS

(403)438-5522
(403)438-0396fax

W.O. NUMBER:	1 117023
PAGE:	1 of 14
LAB NUMBER:	223731

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

YUKON RENEWABLE
SAMPLE: 96044/#1

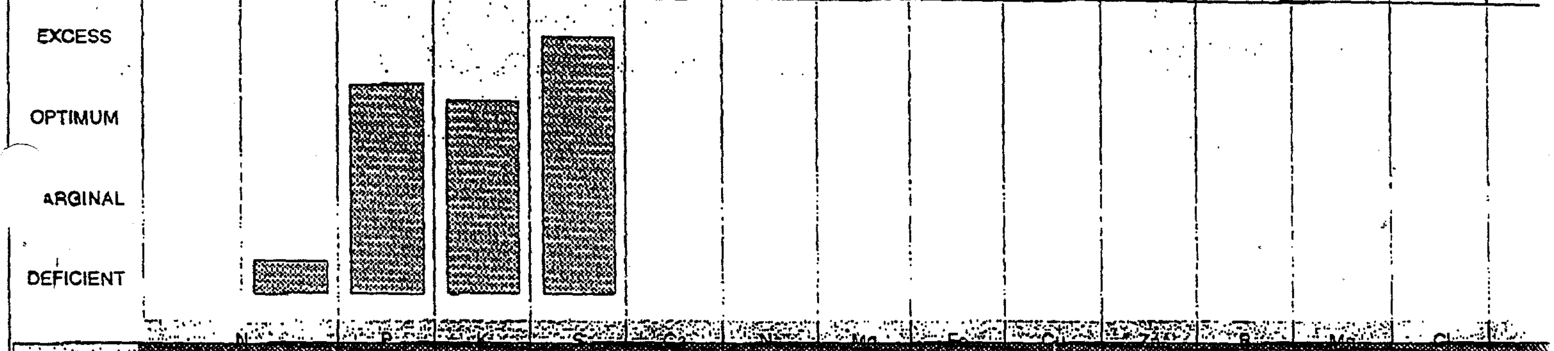
FIELD:

SAMPLE RECEIVED:	13 AUG 96
ANALYSIS COMPLETED:	15 AUG 96 08:48
SAMPLE RETAINED UNTIL:	15 SEP 96
FOR INFORMATION CALL:	Doug Keyes
AT:	1-800-661-7645
	or 403-438-5522

client number: 30577 fax:FAX4036836722 phone:

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM-N	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATE-S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0-6"		1	40	263	>20									
TOTAL LBS/ACRE		2	79	526	>40									
ESTIMATED AVAILABLE LBS/ACRE		4	80	526	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0- 6"	8.0	(Alkaline)	2.6	(Caution)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Soil is Slightly Saline.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

9938-67 Avenue
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T6E 0P5

NORWEST LABS
(403)438-5522
(403)438-0396fax

W.O. NUMBER: 1 117023

LAB NUMBER: 223732

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

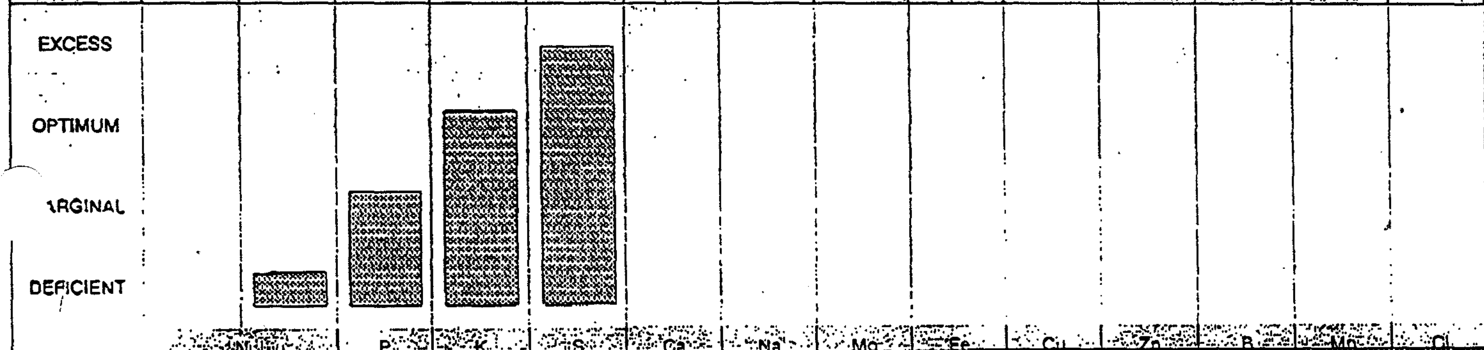
YUKON RENEWABLE
SAMPLE: 96045/#2

FIELD: PLOT 1

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30677 fax:FAX4033936222 phone:

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)													
	AMMONIUM-N	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATE-S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0- 6"		<1	15	229	>20									
TOTAL LBS./ACRE		<2	29	458	>40									
ESTIMATED AVAILABLE LBS./ACRE		4	30	458	80									



SAMPLE DEPTH	SOIL QUALITY							MICRONUTRIENTS
	pH (ACIDITY)	E.C.(SALINITY)	ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE	No micronutrient analysis requested.
0- 6"	8.6 (Alkaline)	2.0 (Caution)						

RECOMMENDATIONS

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Soil is Slightly Saline.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

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NORWEST LABS

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W.O. NUMBER: 1 117023

LAB NUMBER: 223733

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

YUKON RENEWABLE
SAMPLE: 96046/#3

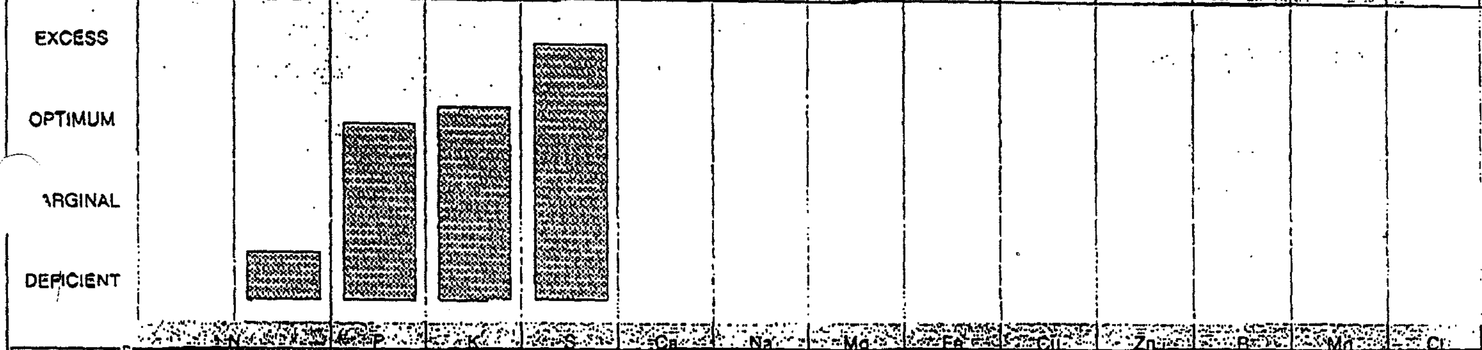
FIELD: PLOT 1

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30677 fax: FAX4033936222 phone:

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM-N	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATE-S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0-6"		6	27	193	>20									
TOTAL LBS/ACRE		11	53	385	>40									
ESTIMATED AVAILABLE LBS/ACRE		22	53	385	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0-6"	9.4	(Alkaline)	2.5	(Caution)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----lbs/ac----			
Excellent	83	36	20	0
Average	64	25	20	0
Poor	45	15	20	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Soil is Slightly Saline.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

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NORWEST LABS
(403)438-5522
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W.O. NUMBER: 1 117023

LAB NUMBER: 223734

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

YUKON RENEWABLE
SAMPLE: 96047/#4

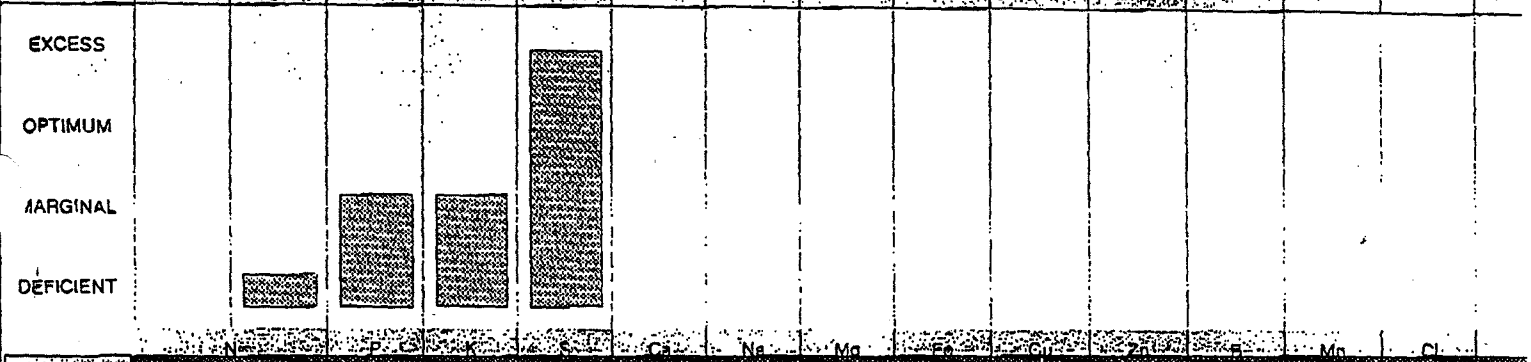
FIELD: PLOT 2

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30577 fax:FAX4033936222 phone:

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM-N	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATES	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0-6		<1	14	90	>20									
TOTAL LBS/ACRE		<2	27	179	>40									
ESTIMATED AVAILABLE LBS/ACRE		4	27	179	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C.(SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0-6"	9.4	(Alkaline)	1.3	(O.K.)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----lbs/ac----			
Excellent	101	60	59	0
Average	82	49	51	0
Poor	63	38	42	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

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W.O. NUMBER: 1 117023
PAGE: 5 of 14
LAB NUMBER: 223735

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

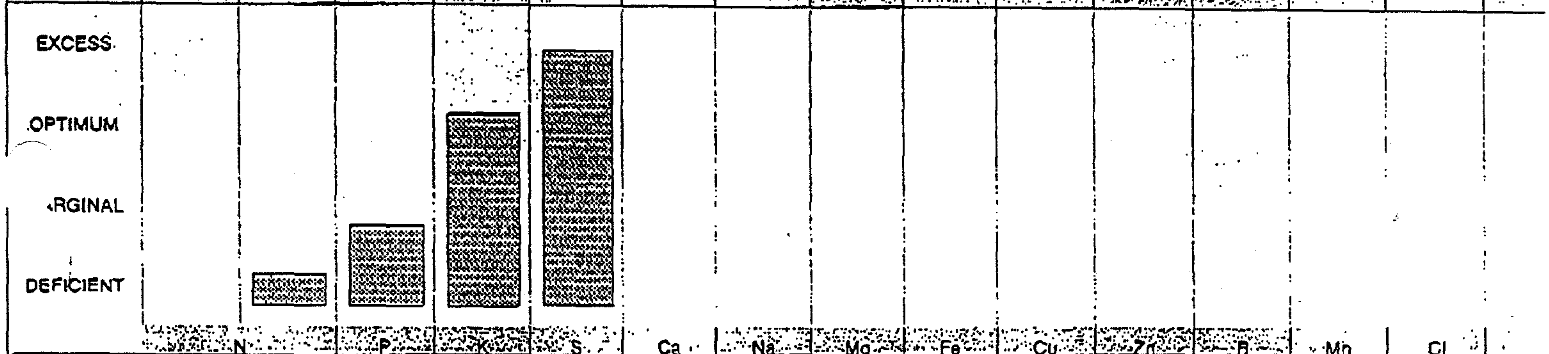
YUKON RENEWABLE
SAMPLE: 96048/#5

FIELD: PLOT 3

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30677 fax:FAX4033938222 phone:

SAMPLE DEPTH	AMMONIUM-N	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATE-S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0-6"		<1	11	251	>20									
TOTAL LBS/ACRE		<2	22	502	>40									
ESTIMATED AVAILABLE LBS/ACRE		4	22	502	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0-6"	9.3	(Alkaline)	5.9	(Toxic)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----lbs/ac----			
Excellent	101	64	0	0
Average	82	53	0	0
Poor	63	42	0	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Soil is Moderately Saline. Yield of many crops may be reduced.
On high K soils, crops may respond to 0-0-60 due to chloride or to decreased root disease.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

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NORWEST LABS
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W.O. NUMBER: 1 117023

LAB NUMBER: 223736

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

client number: 30677 fax:FAX4036930222 phone:

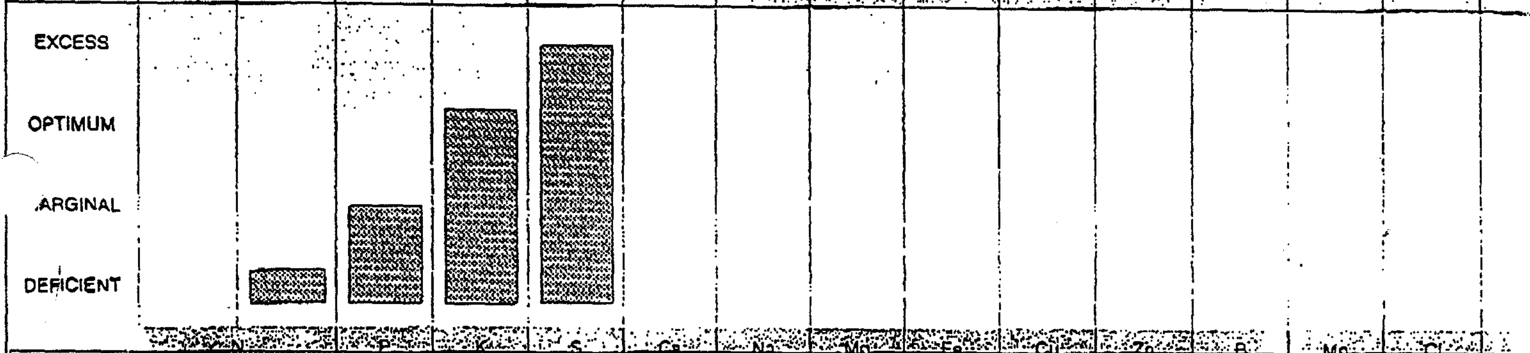
YUKON RENEWABLE
SAMPLE: 96049/#6

FIELD: PLOT 4

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATES	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0-6"		<1	13	249	>20									
TOTAL LBS/ACRE		<2	25	497	>40									
ESTIMATED AVAILABLE LBS/ACRE		4	25	497	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0- 6"	8.7	(Alkaline)	3.8	(Caution)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----	lbs/ac	----	
Excellent	101	62	0	0
Average	82	50	0	0
Poor	63	39	0	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Soil is Moderately Saline.Yield of many crops may be reduced.
On high K soils, crops may respond to 0-0-60 due to chloride or to decreased root disease.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

08/16/96 11:14 ☎403 438 0396 NWL CLIENT SERV. 007/014

9938-67 Avenue
Edmonton, AB
T6E 0P5

NORWEST LABS
(403)438-5522
(403)438-0396fax

W.O. NUMBER: 1 117023

LAB NUMBER: 223737

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

YUKON RENEWABLE
SAMPLE: 96050/#7

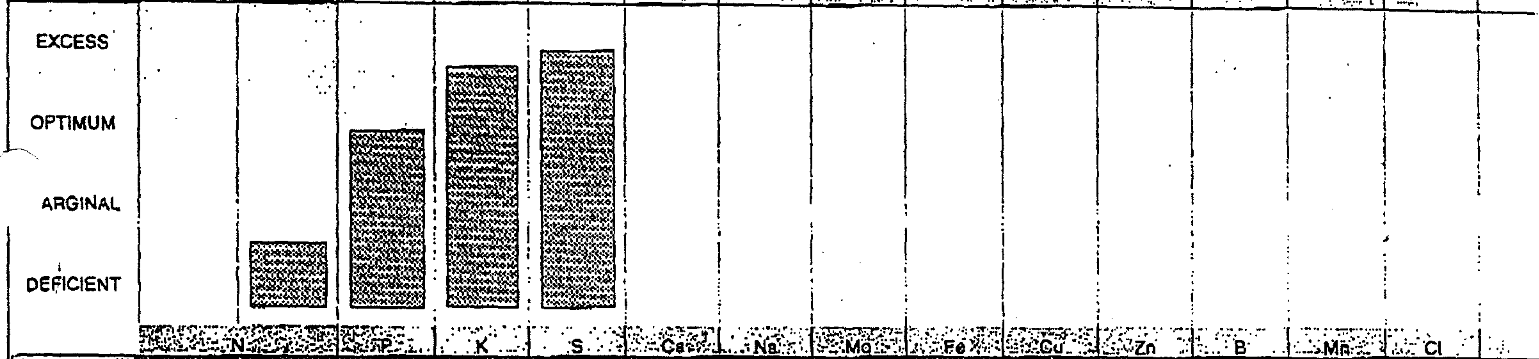
FIELD: PL. 5B

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30677 fax:FAX4033836222 phone:

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM	NITRATE N	PHOSPHATE	POTASSIUM	SULPHATE S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0- 6"		13	22	460	>20									
TOTAL LBS/ACRE		26	44	919	>40									
ESTIMATED AVAILABLE LBS/ACRE		52	44	919	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0- 6"	8.6	(Alkaline)	7.8	(Toxic)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----lbs/ac----			
Excellent	53	45	0	0
Average	34	33	0	0
Poor	15	22	0	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Soil is Severely Saline. Yield of most crops will be reduced.
On high K soils, crops may respond to 0-0-60 due to chloride or to decreased root disease.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

08/16/96 11:15 403 438 0396 NWL CLIENT SERV. 008/014

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Edmonton,AB
T6E 0P5

NORWEST LABS
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W.O. NUMBER: 1 117023
PAGE: 8 of 14
LAB NUMBER: 223738

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

YUKON RENEWABLE
SAMPLE: 96051/#8

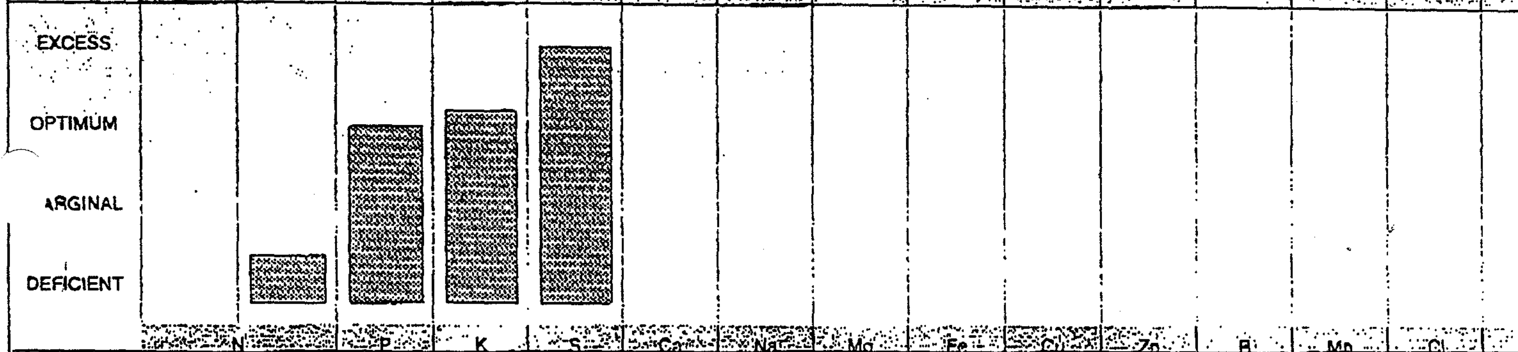
FIELD: PL. 5A

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30077 fax: FAX4033936222 phone:

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM N	NITRATE N	PHOSPHATE	POTASSIUM	SULPHATE S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0-6"		5	25	205	>20									
TOTAL LBS/ACRE		10	49	409	>40									
ESTIMATED AVAILABLE LBS/ACRE		20	49	409	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)	E.C.(SALINITY)	ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0- 6"	8.7 (Alkaline)	1.2 (O.K.)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----	lbs/ac	----	
Excellent	85	40	0	0
Average	66	29	0	0
Poor	47	18	0	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
On high K soils, crops may respond to 0-0-60 due to chloride or to decreased root disease.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

9938-67 Avenue
Edmonton, AB
T6E 0P5

NORWEST LABS
(403)438-5522
(403)438-0396fax

W.O. NUMBER:	1 117023
PAGE:	9 of 14
LAB NUMBER:	223739

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

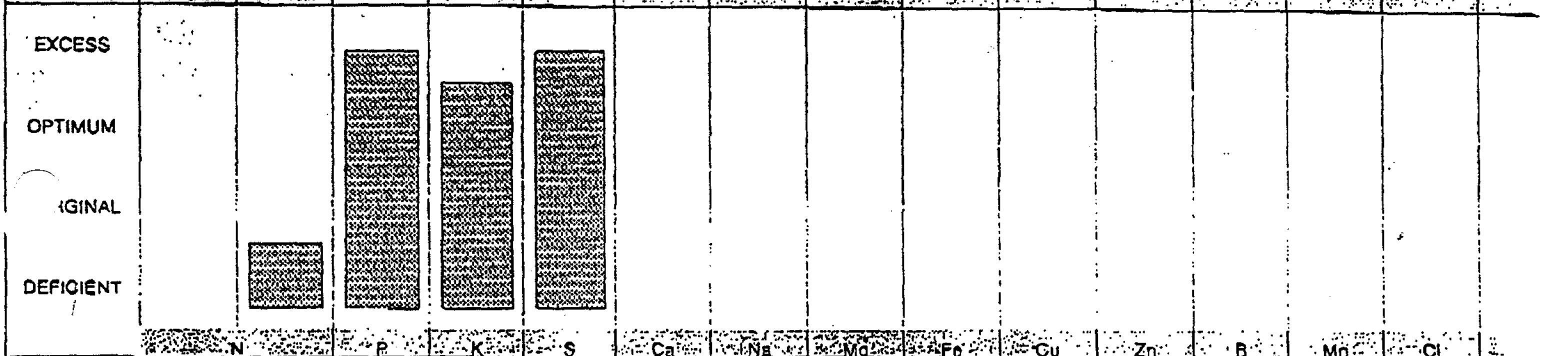
client number: 30677 fax:FAX4033936222 phone:

YUKON RENEWABLE
SAMPLE: 96052/#9

SAMPLE RECEIVED:	13 AUG 96
ANALYSIS COMPLETED:	15 AUG 96 08:48
SAMPLE RETAINED UNTIL:	15 SEP 96
FOR INFORMATION CALL:	Doug Keyes
AT:	1-800-661-7645
	or 403-438-5522

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATE-S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0-6"		15	>60	444	>20									
TOTAL LBS/ACRE		29	>120	887	>40									
ESTIMATED AVAILABLE LBS/ACRE		58	120	887	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0-6"	9.0	(Alkaline)	1.2	(O.K.)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----lbs/ac----			
Excellent	47	0	0	0
Average	28	0	0	0
Poor	10	0	0	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
On high K soils, crops may respond to 0-0-60 due to chloride or to decreased root disease.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

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NORWEST LABS

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W.O. NUMBER: 1 117023

LAB NUMBER: 223740

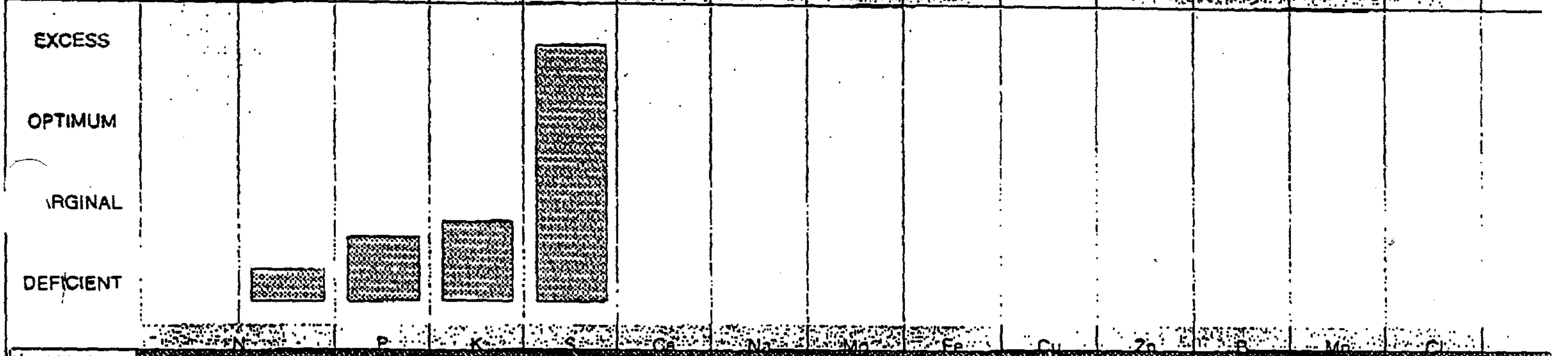
YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

YUKON RENEWABLE
SAMPLE: 96053/10

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30877 fax:FAX4033836222 phone:

SAMPLE DEPTH	NUTRIENT ANALYSIS (P.P.M.)														
	AMMONIUM-N	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATE-S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE	
0- 6"		1	10	73	>20										
TOTAL LBS/ACRE		2	19	145	>40										
ESTIMATED AVAILABLE LBS/ACRE		4	19	145	80										



SAMPLE DEPTH	SOIL QUALITY									MICRONUTRIENTS
	pH (ACIDITY)		E.C.(SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE	No micronutrient analysis requested.
0- 6"	8.9	(Alkaline)	1.0	(O.K.)						

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----lbs/ac----			
Excellent	101	67	72	0
Average	82	56	64	0
Poor	63	45	55	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

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W.O. NUMBER: 1 117023
PAGE: 11 of 14
LAB NUMBER: 223741

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

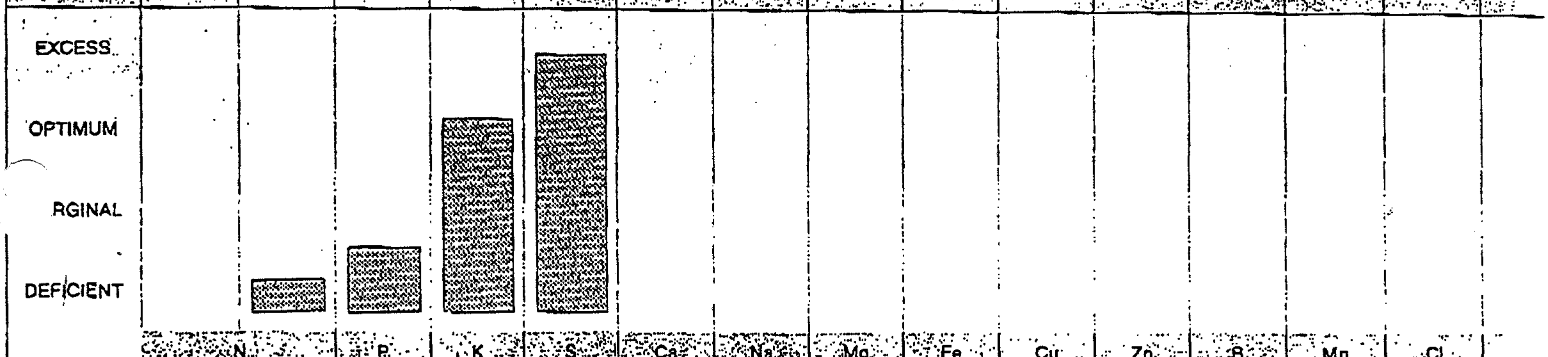
YUKON RENEWABLE
SAMPLE: 96054/11

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

client number: 30677 fax:FAX4033938222 phone:

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM-N	NITRATE-N	PHOSPHATE	POTASSIUM	SULPHATE-S	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE
0- 6"		<1	10	209	>20									
TOTAL LBS/ACRE		<2	19	417	>40									
ESTIMATED AVAILABLE LBS/ACRE		4	20	417	80									



SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C.(SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0- 6"	9.2	(Alkaline)	2.9	(Caution)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----	lbs/ac	----	
Excellent	101	66	0	0
Average	82	55	0	0
Poor	63	44	0	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Soil is Slightly Saline.
On high K soils, crops may respond to 0-0-60 due to chloride or to decreased root disease.
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment

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W.O. NUMBER: 1 117023
PAGE: 12 of 14
LAB NUMBER: 223742

YUKON RENEWABLE RESOURCE
2131 - 2 AVENUE
BOX 2703
WHITEHORSE, YK
Y1A 2C6

client number: 30077 fax:FAX4033936222 phone:

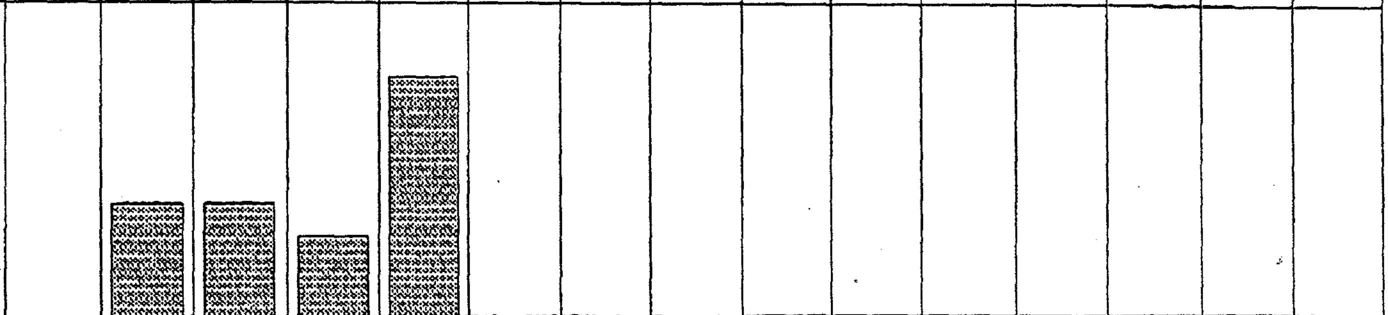
YUKON RENEWABLE
SAMPLE: 96055/12

SAMPLE RECEIVED: 13 AUG 96
ANALYSIS COMPLETED: 15 AUG 96 08:48
SAMPLE RETAINED UNTIL: 15 SEP 96
FOR INFORMATION CALL: Doug Keyes
AT: 1-800-661-7645
or 403-438-5522

NUTRIENT ANALYSIS (P.P.M.)

SAMPLE DEPTH	AMMONIUM	NITRATE	PHOSPHATE	POTASSIUM	SULPHATE	CALCIUM	SODIUM	MAGNESIUM	IRON	COPPER	ZINC	BORON	MANGANESE	CHLORIDE	
0- 6"		32	16	81	>20										
TOTAL LBS./ACRE		63	32	162	>40										
ESTIMATED AVAILABLE LBS./ACRE		126	32	162	80										

EXCESS
OPTIMUM
MARGINAL
DEFICIENT



	N		P	K	S	Ca	Na	Mg	Fe	Cu	Zn	B	Mn	Cl	

SOIL QUALITY

SAMPLE DEPTH	pH (ACIDITY)		E.C. (SALINITY)		ORGANIC MATTER %	Sand %	Silt %	Clay %	TEXTURE
0- 6"	9.2	(Alkaline)	1.0	(O.K.)					

MICRONUTRIENTS

No micronutrient analysis requested.

RECOMMENDATIONS

PASTURE

GROWING CONDITION	N	P_2O_5	K_2O	S
	----lbs/ac----			
Excellent	10	55	66	0
Average	10	44	57	0
Poor	10	33	49	0

You may reduce the amount of N added in proportion to the amount of legume (clover, alfalfa, etc.) in the stand.
These rates are based on broadcast application. Consider additional nitrogen mid-summer for top production.

COMMENTS

This recommendation is made for soil: Peace
The previous crop was UNKNOWN
Recommended application rates are based on seed placed or banded fertilizer efficiencies unless otherwise indicated.
The method of application, however, is left to your discretion. The total amount can not necessarily be placed with the seed!

These recommendations are given as a management tool based on general research consensus. They should not replace prudent and responsible judgment.

APPENDIX D

DETAILED RANGE SURVEYS

CRAIG VEGETATIVE SURVEY DETAILED RANGE SURVEY

Yr. 1996 Mo. 7 Day 29
Examiner Joan Craig Location Whitehorse Copper Mines Tailings
Plot # 1 ~~landscaping~~ Landscaping Waste Position from west waterline, near rainbird
Comment Partially composted Scattered patches of vegetation. Sweet clover in nearby vicinity. Along irrigation ditch → variety: spruce, willow, festuc

10 meter line from clipped area toward eastward
Iceland poppies, dianthus, dandelion, shepherd's purse, potentilla

---Microplots-cover (%)---

SPECIES	1	2	3	4	5	6	Average
Grass mix: Puccinella nuttaliana					80%		
Festuca saximontana					5%		
1. Barley foxtail Hordeum jubatum					T		
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							

Bare Ground 50%

Litter 5%

Lichen

CRAIG VEGETATIVE SURVEY

DETAILED RANGE SURVEY

Yr. 1996 Mo. 7 Day 29

Examiner Joan Craig

Location Whitehorse Copper Mines Tailings

Plot # 1

Position Northend, near Shepherdia (5 Trees from dike)

Comment Growth around shepherdia was abundant. The original compost pile from the landscapers wastes was located on this area. Samples of soil was taken and grasses clipped for drying & weigh.

---Microplots-cover (%)---

SPECIES	1	2	3	4	5	6	Average
Grass mix: Puccinella nuttaliana 80%							
Festuca saximontana 5%							
Agropyron sp 10%							
1. Barley foxtail (Hordeum jubatum)						T	
2. Dandelion (Taxacum officinale)						T	
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							

Bare Ground 99% only bare spot can be attributed to a strip of cellephane

Litter 1%

Lichen

CRAIG VEGETATIVE SURVEY

DETAILED RANGE SURVEY

Yr. 1996 Mo. 7 Day 29

Examiner Joan Craig Location Whitehorse Copper Mines Tailings

Plot # 2 Control Position

Comment Vegetation limited to a sparse growth on irrigation line.

---Microplots-cover (%)---

SPECIES	1	2	3	4	5	6	Average
1. Puccinella nuttaliana - small 5cm sprouts							T
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							

Bare Ground 99% dry & cracked, gullying

Litter 1%

Lichen

CRAIG VEGETATIVE SURVEY   DETAILED RANGE SURVEY

Yr. 1996 Mo. 7 Day 29
Examiner Joan Craig Location Whitehorse Copper Mines Tailings
Plot # 3 - Sawdust Position Center Waterline, near rainbird sprinkler
Comment Growth very little
Evaporites patches, cracks noted, gullying on slopes

---Microplots-cover (%)---

SPECIES	1	2	3	4	5	6	Average
Puccinella nuttaliana germinated 5-10 cm high.							
1. Puccinella nuttaliana 10							
2. Barley foxtail (Hordeum jubatum) T							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							

Bare Ground 80%

Litter 5%

Lichen

CRAIG VEGETATIVE SURVEY

DETAILED RANGE SURVEY

Yr. 1996 Mo. 7 Day 29

Examiner Joan Craig Location Whitehorse

Plot # 4 Grass + sawdust Position East waterline

Comment Location is right beside irrigation rainbird sprinkler. On sod near rainbird - potentilla, chickweed, lamb's quarters, danlelion, pineapple plant, shepherd's purse, deltoides dianthus. 10 meter line from clipped area to west.

---Microplots-cover (%)---

SPECIES	1	2	3	4	5	6	Average
Grass Mix: Puccinella nuttaliana 80%							
Agropyron violaceum							
Agropyron sp							
1. Puccinella nuttaliana			13				
2. Fir from Adorna			1				
3. Hordeum jubatum			2				
4. Yarrow (Achillea millefolium)			3				
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							

Bare Ground 35%

Litter 10%

Lichen

CRAIG VEGETATIVE SURVEY — DETAILED RANGE SURVEY

Yr. 1996 Mo. 7 Day 3
Examiner Randy Lamb Location Whitehorse Copper Mines Tailings
Plot # 5A - Compost Position Average growth - South half
Comment Three areas in Plot 5A were clipped (0.5 sq. meters each), sparse, average and heavy growth.
Plot # 5A had 8 cm cover of compost, rototilled into top 10cm tailings.
Vegetation was observed along a 10 meters tape. Chosen area to clip was randomly chosen by throwing a rock over back shoulder.

---Microplots-cover (%)---

SPECIES	1	2	3	4	5	6	Average
Grass mix: Puccinella nuttaliana 35%							
Agropyron sp 35% Agropyron violaceum 5%							
Poa glauca 5%							
Festuca saximontana T							
1. Grass mix 80% cover							
2. Dock (Rumex crispus) T							
3. Pineapple plant (Camomile) T							
4. Potentilla T							
5. Knotweed (Polygonium) 10							
6. Lamb's quarters (Chenopodium alba) 2							
7. Tanzy mustard T							
8. Red clover (Trifolium pratense) T							
9. Alfalfa - purple T							
10. Dandelion (Taxacum officinale) T							
11.							
12.							

Grass Cover 80%

Bare Ground 5-10%

Litter 5%

Lichen

Grasses clipped - dry weight 2390 kg/ha

CRAIG VEGETATIVE SURVEY

DETAILED RANGE SURVEY

Yr. 1996 Mo. 7 Day 28-29

Examiner Joan Craig Location Whitehorse Copper Mines Tailings

Plot # 5B - Compost Position 4 m. West of centre (N-S) pipeline

Comment Compost 2 cm, growth spotty, ground cracking in some area
some evaporites area nearby
10 meter line from clipped area toward west.

---Microplots-cover (%)---

SPECIES	1	2	3	4	5	6	Average
Grass mix: Puccinella nuttaliana						50%	
Agropyron sp						40%	
Festuca saximontana						5	
1. Barley foxtail (Hordeum jubatum)						T	
2. Knotweed (Polygonium						T	
3. Bluegrass (Poa gluuca)						T	
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							

Bare Ground 60%

Litter 5%

Lichen

APPENDIX E

SEED MIXTURE

The 0.9 hectare plot was seeded with the following:

50 pounds seed prepared by Arctic Alpine Seed Ltd. of Whitehorse for reclamation of disturbed sites in the sub arctic. Species and proportions are:

Violet Wheatgrass	(*Agropyron violaceum*)	20%
Slender Wheatgrass	(*Agropyron pauciflorum*)	20%
Awned Wheatgrass	(*Agropyron subsecundum*)	10%
Alkali grass	(*Puccinella nuttaliana*)	35%
Bluegrass	(*Poa glauca*)	10%
Fescue	(*Festuca saximontana*)	5%

Additionally, 5 pounds of hair grass, (*Deschampsia caespitosa*) seed was obtained in Alaska, specially selected for tolerance to alkaline conditions.

Locally collected seed of lupin, dandelion, fireweed and balsam poplar were also sown.

APPENDIX F

ACKNOWLEDGEMENTS

Financial sponsorship, making the carrying out of this project possible, was provided by:

Hudson Bay Mining and Smelting Company Limited
Shell Environmental Fund
Canada/Yukon Economic Development Agreement, Project 4181-245
Arctic Environment Strategy

Corporate sponsorship :
1994 - Yukon Chamber of Mines
1995 and 1996 - Rotary Club of Whitehorse

As well as nine paid part time employees, many volunteer contributions were made by individuals and firms, largely in the collection of grass and other compostable materials and the collection of local seed for the revegetion. Among these are:

<u>Landscapers</u>

Decora
Adorna
Iditarod
Sourdough Sodbusters
Hotte Landscaping

<u>Horse Owners</u>

L. Mitchell
J. Mackinnon
A. Wiens
J. Scott
D. Richardson
G. MacKenzie-Grieve

Kelly Douglas Company, food wholesalers, provided several tons of wilted fruit and vegetables during the early months of 1994.

The Slough Mill (Gunnar Nilsson) provided 24 cubic meters of sawdust.

The Department of Economic Development, Yukon Territorial Government, saved lunch scraps and coffee grounds for two years. The pail of scraps was picked up periodically.

Barbara Robertson and Diana Mulloy frequently walked out and gave valuable encouragement. They also photographed the work at the reclamation site.

University students working on their own research or courses co-operated with us for their studies.

Jeanne Burke, Ph. D. studies
Ian Oostendie, Masters studies
Diana Watson, Masters studies
Malcohm Taggart, Course work paper
Alison Black, Course work paper

Students from grade five, junior high school and grade eleven also came out with their class teachers.

Members of the Whitehorse Garden Club, the Rotary Club of Whitehorse, officials from the City of Whitehorse, Association of Yukon Communities and the Yukon Territorial Government visited.

Ms. Audrey Mac Laughlin, M. P. (Yukon), and Mr. Jack Cable, MLA toured the site.

Officers of Yukon Agriculture assisted with their encouragement and professional assistance, lab tests on grasses and financial contribution for soil tests.

The Yukon Chamber of Mines permitted gardeners to drop off bags of suitable yard wastes.

The City of Whitehorse provided generous use of their photo copying facilities.

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