Brown McDade Waste Rock Pile
Mount Nansen Mine Site, Yukon

Ecological Restoration Strategy

Prepared for:

Assessment and Abandoned Mines Branch
Energy, Mines and Resources
Government of Yukon

Altura Environmental Consulting

March 2009

Table of Contents

List of Tables

List of Figures

1.0 Introduction

1.1 Purpose of Document

This document presents a conceptual-level restoration strategy and plan for the Brown McDade waste rock pile located at the closed Mount Nansen mine site in central Yukon. Relevant site conditions and background information to support development this plan are also provided.

1.2 Overview

As mentioned above, the Mount Nansen mine site is located in central Yukon (Figure 1.1), approximately 60 km west of the community of Carmacks and within the traditional territory of the Little Salmon Carmacks First Nation. The mine site is permanently closed and is under care and maintenance, while studies are underway to support development of a comprehensive site closure plan, slated to be underway in 2009.

Figure 1.1 Location of Mount Nansen Mine Site (from Conor Pacific, 2000)

The Brown McDade deposit was mined via open pit from 1996 to early 1999, and during this period an estimated 1.5 to 2 million tonnes (Mt) of waste rock was placed in piles immediately to the west of the Brown McDade pit. Numerous operational and permit-related issues resulted in the closure of the mine in February 1999. The site was placed in receivership and reverted to the responsibility of the Water Resources Division of Indian and Northern Affairs Canada, and then to the Assessment and Abandoned Mines Branch of the Ministry of Energy and Mines of the Government of Yukon. These agencies have taken responsibility for the care of the remaining facilities of the site, and ensuring that water discharge from the site meets effluent quality standards.

The Assessment and Abandoned Mines Branch has worked extensively with the local community and the Little Salmon Carmacks First Nation in disseminating information about the site, and seeking input on concerns and suggestions for future use of the site.

1.3 Objectives and Scope

1.3.1 Mount Nansen Closure Objectives

As previously mentioned, input from the local community and First Nation has been sought, and Closure Objectives for the Mount Nansen site were derived which form the basis for the next phase of site closure planning. The following is an excerpt from the Closure Objectives circular (Mount Nansen Closure Objectives):

These objectives were gathered through traditional knowledge interviews, community meetings and mine site tours.

A complete review of the closure options by workers from Little Salmon Carmacks First Nation, Yukon and federal governments will happen before final options are chosen.

The closure options will be measured against the closure objectives to help the governments come up with the best option for cleaning up the mine site.

Protect human health and safety

- *People using the area will be safe from remaining mine hazards.*
- *Animals, plants and berries around the mine site are safe to harvest and will stay that way.*
- *Water at mine site and downstream will be clean and safe for people to use.*
- *Mine metals in dust will not be able to build up more on plants and soils in years to come around the mine site.*

Protect the environment including land, air, water, fish and wildlife

- *Animals using the area will be safe from remaining mine hazards.*
- *Water at the mine site, in the ground, and downstream will be as clean and safe as possible for the health of animals, plants and bugs.*
- *Mine metals in dust will not continue to build up on plants and soils around the mine site. This will help protect and improve the health of plants, animals and soils.*
- *Restore the land and water so that plants and animals can live there in the way they did before the mine.*

Return Mine Site to an acceptable state of use that reflects original use where possible

- *Quality of water at the mine site and downstream will be clean and safe so it will not limit traditional use.*
- *The opportunity for traditional uses of the area will be restored and as close to before mining use as possible.*

- *Make the clean up so that, as the years go by, there will not have to be much work at the mine site to keep it clean and safe.*

Maximize local, Yukon and First Nation benefits

- *Local people will be hired to help clean up at the mine.*

Community Closure Planning Core Values:

The community and the knowledge of local people will always be recognized and a part of decisions made about the Mount Nansen mine site.

The safety of the plants, animals, fish, and water will continue to be checked on and people will know how safe they are.

People will be kept up to date about what it is like at the mine site.

The LSFN [Little Salmon First Nation] Final Agreement will be followed.

1.3.2 Scope of this Project

The author was approached by the Assessment and Abandoned Mines Branch of the Government of Yukon to perform a detailed assessment of the Brown McDade waste rock pile site. Study aspects include both: i) assessing existing conditions of and potential for acid rock drainage and metal leaching, and ii) determining a revegetation strategy for the site. Specific study tasks relevant to ecological restoration of the waste rock pile are:

- An assessment of types of native vegetation currently growing on portions of the dump and factors promoting growth in those areas; and
- Conceptual proposal for reclamation (resloping and revegetation) of the waste rock piles.

The following are key underlying assumptions in the ecological restoration approach:

- Closure Plan Objectives: the ecological restoration approach will be aligned to meet the Mount Nansen Closure Plan Objectives stated in section 1.3.1
- Restoration Plan: the conceptual ecological restoration plan is committed to be developed assuming:
    - exclusive use of native species
    - provenance of source plants within 5 kilometres of site
    - propagation by either seed or vegetative methods (eg. no transplants)
    - establishment of 'native species islands' as nuclei for self-propagation of species and encouragement of wildlife use

It is important to note that closure planning for the Mount Nansen Mine site is in the early stages, and during subsequent phases it will be determined whether a part of or all of the Brown McDade waste rock will be backfilled into the open pit, or left in place. As a result, the strategy discussed in this report focuses on over-riding aspects of ecological restoration of this site such as identifying successional sequence, potential restoration barriers, and target trajectory. In all, these factors are independent of any given earthworks plan for the site. Altura suggests that it is important to begin considering vegetation strategies at this early stage of closure planning in order to focus the ongoing site-specific research and revegetation activities. In addition, consideration of revegetation approaches at this stage will allow participation of local stakeholders in developing both this restoration strategy, and their own internal capacities so that they may assume many of the responsibilities for the future closure work.

2.0 Local Setting

The Mount Nansen property is located within the Dawson Range, with the terrain consisting of rounded ridges and shallow valleys with a light cover of vegetation and small trees. Elevations range from 945 metres to 1525 metres above sea level. The Nisling River drains the area to the west, which ultimately drains into the Yukon River via the Donjek and White Rivers. Drainage from the property flows in two moderate sized tributaries to the Nisling River: Nansen Creek to the west and Victoria Creek to the east (Figure 2.1). Back Creek and Dome Creek are tributaries of Victoria Creek on the east side of the property, where the workings of the Mount Nansen mine are located.

Many historic prospects and minor hard rock mine workings are located in the region; in addition placer operations, both historical and active, are located along Back Creek and other higher tributaries to Victoria Creek. Dome Creek is directly impacted by the Mount Nansen mine site, primarily by the historical Heustis underground mine workings, the mill facility, and the tailings impoundment. Pony Creek is a tributary of Back Creek that is potentially impacted by the historic Brown McDade underground workings, and the Brown-McDade open pit. The Brown McDade waste rock pile straddles the divide between the Back Creek and Dome Creek drainages.

2.1 Climate

Average monthly temperatures in the Mount Nansen area range from about 15°C in July to -15°C in January. Annual precipitation averages about 270 mm occurring mostly as rain in summer months. Average annual potential evaporation is approximately 350 to 400 mm. Accumulated snowpack is in the order of 50 to 70 mm water equivalent.

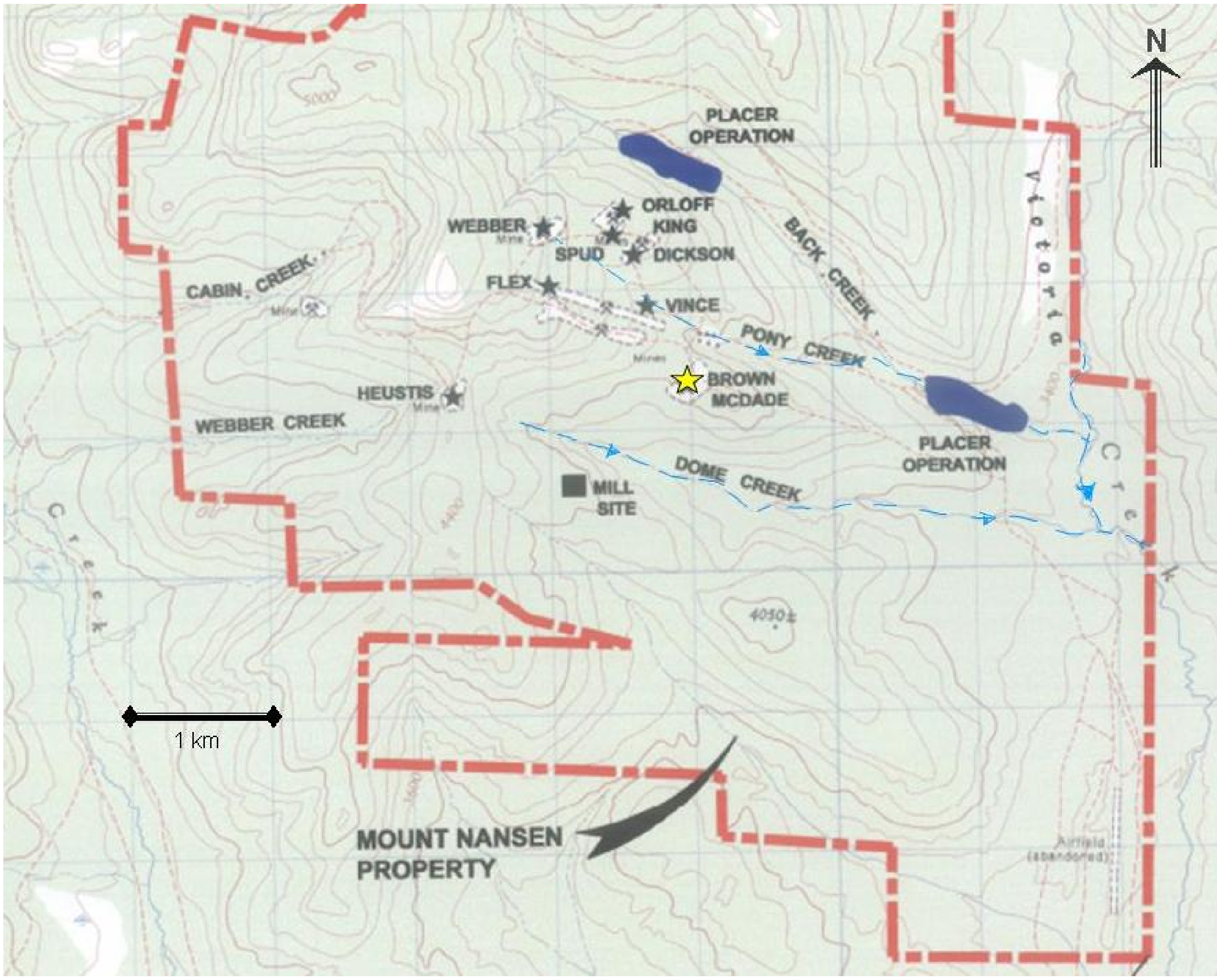


Figure 2.1 Mount Nansen Property and Local Drainages and Workings (adapted from Conor Pacific, 2000)

2.2 Physiography and Soil Conditions

The Mount Nansen area lies within the Yukon Central Plateau of the Boreal Cordillera Ecozone (Government of Yukon, 2008), and has similar characteristics to the Spruce-Willow-Birch biogeoclimatic zone (SWB) in British Columbia.

Local host rocks are metamorphic rocks of Mississipian in age (approximately 356 million years), and in the immediate area of the Brown McDade deposit, plutonic rocks of granodioritic composition of Late Triassic to Mid Jurassic age (105 to 224 million years ago). A volcanic quartz feldspar porphyry complex intrudes the granodiorite at the Brown McDade deposit, and hosts the gold-silver enriched mineralization that was mined from 1996 to 1999.

As previously mentioned, local terrain consists of gently rounded hills and shallow valleys. Pemafrost is discontinuous, but is evident at shallow depths (0.4 metres) in east and north facing slopes valleys and benchlands where surficial sediments and bedrock have a thick organic or moss cover (Figure 2.2).

Figure 2.2 View of Mount Nansen area in vicinity of Brown McDade pit and waste rock pile, looking south (from EDI, 2007).

This area is one of the few areas of North America to have been ice-free during the last glaciation period (approximately 10,000 to 26,000 years before present). Hence, surface weathering tends to be deep, with rock demonstrating pervasive surface oxidation (or supergene alteration) to depths of 10 metres or more.

Soil development is generally poor across the property; typically represented by several centimeters of organics overlying a layer of volcanic tephra, which itself overlies decomposed bedrock. Unconsolidated alluvium has been mapped on the property, principally occurring in the Victoria and Nansen Creek Valley bottoms. Loess and volcanic ash have been observed in scattered patches throughout the property. The loess occurs as fine sand mantling some of the lower slopes. White ash appears as a few centimeters of soil exposed in road cuts, and is postulated to be from a recent eruption (1,230 years ago) in the Wrangell Mountains to the northwest. North facing slopes are typically permafrost-bound, as evidenced by thick moss cover and stunted conifers. The south facing slopes are well-drained and can be grassy to barren of vegetation.

2.3 Vegetation

To date, a systematic inventory of vegetation in undisturbed sites has not been documented for the Mount Nansen area. The list of species given in Table 2.1, below, is derived from vegetation test work performed by EDI Environmental Dynamics Inc. (2007), and from the author's own reconnaissance in the project area.

Table 2.1 Preliminary inventory of plant species in undisturbed sites in the Mount Nansen area

Common Name	Scientific Name
Scrub Birch	*Betula glandulosa*
Blueberry / Bilberry	*Vaccinium spp.*
Mossberry or Crowberry	*Empetrum nigrum*
Kinnikinnick	*Arctostaphylos uva-ursi*
Labrador tea	*Ledum groenlandicum and/or L. decumbens*
Crowberry	*Empetrum nigrum*
Lowbush cranberry	*Vaccinium vitis-idaea*
Bolete mushroom	*Leccinum sp.*
Prickly Rose	*Rosa acicularis*
Caribou horn (Tumble) lichen	*Masonhalea richardsonii*
Willow	*Salix spp.*
Spruce, black /white	*Picea spp.*
Trembling aspen	*Populus tremuloides*
Wheatgrass	*Agropyron sp.*
Sphagnum moss	*Sphagnum sp.*

2.4 Wildlife

The Mount Nansen area is utilized by a variety of wildlife, including large mammals such as the woodland caribou (*Rangifer tarandus*), moose (*Alces alces*), wood bison (*Bison bison*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), and a number of furbearers and small game. Low snow packs and the open grassland valleys provide important winter habitat for big game species, particularly to the west of the mine site.

2.5 Socioeconomic and Cultural Values

The Mount Nansen area lies within the traditional territory of the Little Salmon Carmacks First Nation (LSCFN). Both the LSFN and the general Yukon community use the area for subsistence and recreational purposes.

The area sees gold placer mining activity in many of the small drainages, and exploration works for gold have been ongoing in the region for decades.

2.6 Relevant Natural Processes

2.6.1 Natural Disturbance Processes

No large scale natural disturbance processes have been identified. Given its sub-alpine location, the Mount Nansen area is not subject to fire-generated disturbances. Landforms tend to be physically stable, and no erosive or active talus areas are noted within the zone.

Wildlife browsing appears to be an important disturbance mechanism for the zone, and primarily stimulates localized growth patterns in shrub species.

2.6.2 Anthropogenic Disturbance Processes

The local ecosystem has responded to man-made disturbances through voluntary colonization processes. Figures 2.3 and 2.4 show examples of voluntary colonization of linear disturbances approximately 50 and 30 years in age.

Willow along with minor grass species (foxtail barley [*Hordeum jubatum*], among others) and occasional spruce are observed to be some of the first colonizers of a disturbed area. In the 10 metre wide fringe between undisturbed vegetation and the the Brown McDade pit, yarrow (*Achilla sp.*), foxtail barley and fireweed are also noted. Other vegetation such as kinnikinnick, lichens, and crowberry appear to establish as a much later phase and encroach inward from the undisturbed edges.

Figure 2.3 Voluntary Colonization of Old Road (circa 1950?) by Kinnikinnick, White Spruce, and Willow. A dark "biological" or cryptogamic crust is visible on the soil surface. Approximately 10 km from Mount Nansen mine site.

Figure 2.4 Voluntary Colonization in a 6 metre-wide old exploration trench in Heustis Zone (circa 1970?), approximately 1 km to west of Brown McDade zone. Willow is primary species, along with unidentified grass species (possibly Festuca altaica [Polster, pers. comm., 2008]) and occasional white spruce. Rare scrub birch, laborador tea and mossberry observed. Soil surface is darkened in some patches, potentially indicating early-stage development of a biological crust.

2.7 Reference Ecosystem

Two potential reference climax ecosystem sites in the immediate area of the project site were documented during the preliminary field work. The vegetation assemblage appears to be controlled by available moisture and/or drainage, soil development, and aspect.

2.7.1 Poorly Drained / Moist Regime

This site, designated as SP-1, is located approximately 100 metres to the west of the Brown McDade area. Aspect is south and slope is approximately 5 percent.

Soil profile excavated to 0.3 metres shows a dark, high organic horizon to 0.25 metres depth. Encountered below this horizon is a layer of tan-coloured sand with minor lenses of either dark grey silt or dark brown organics. Soil sample results are given in Appendix A and indicate a potential excess of S and Ca, and low levels of available N, P, K and B. in the order of 50% organic material in the upper horizon. The organic layer consists of approximately 50 percent organic matter.

Moss cover is notably thick and compresses substantially under the foot.

Vegetation in order of relative abundance includes:

Understory (<0.25 metres): sphagnum moss, lichen, mossberry/crowberry

Mid-Story (0.25 to 2 metres): willow, labrador tea, scrub birch, unidentified potentilla species

Canopy: black and white spruce

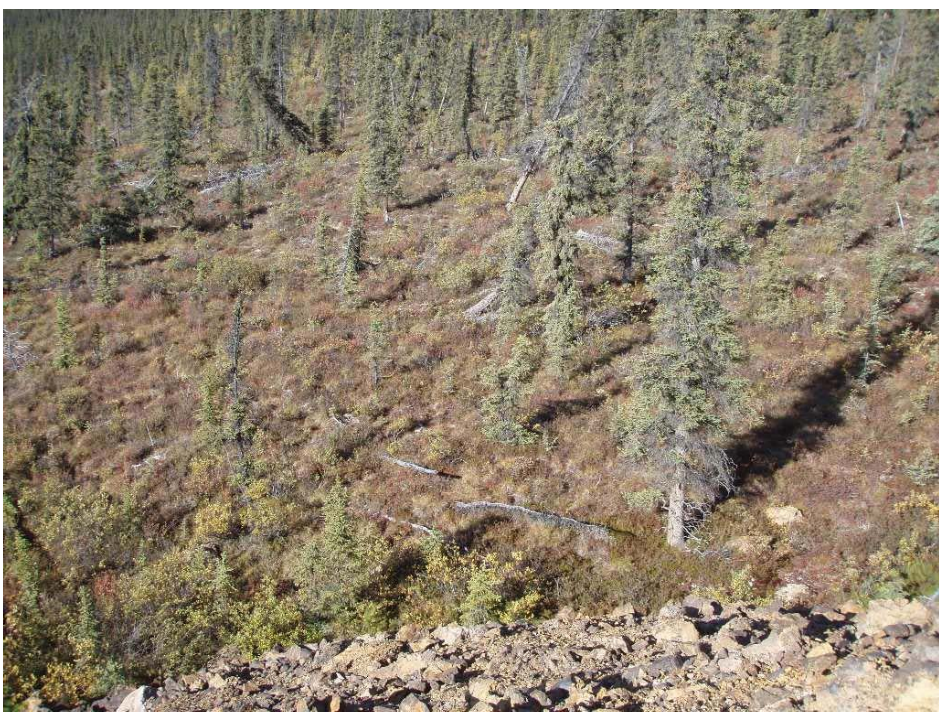


Figure 2.5 Vegetation typical of poorly drained regime ecological reference site, SP-1.

2.7.2 **Well-Drained / Dry Regime**

This site designated as SP-2, is located approximately 100 metres to the southeast of the Brown McDade area. Aspect is southwest and slope is approximately 10 percent.

Soil profile excavated to 0.25 metres shows a thin dark, high organic horizon to 0.07 metres depth. Encountered below this horizon is a layer of grey brown sandy-textured soil with rock fragments. Soil sample results are given in Appendix A and indicate no parameters in potential excess, and low levels of available N, P, and B. Similar to site SP-1, the organic layer, albeit much thinner, also consists of approximately 50 percent organic matter.

Lichen and moss coverage is firm and does not compress appreciably underfoot (Figure 2.5)

Vegetation in order of relative abundance includes:

Understory (<0.25 metres): lichen, sphagnum moss, kinnikinnick, mossberry/crowberry

Mid-Story (0.25 to 2 metres): willow, scrub birch, labrador tea

Canopy: white spruce

Figure 2.6 Vegetation at well-drained regime ecological reference site, SP-2.

3.0 Description of Project Site

3.1 Layout and Geometry

The Brown McDade waste rock pile is comprised of 1.5 to 2 Mt of waste rock, and covers an approximately 10 hectare area, located at an elevation of 1220 to 1230 metres above sea level.

Figure 3.1 shows a sketch layout of the Brown McDade Waste Rock pile; oblique aerial photos are given both on the cover of this report and in Figure 3.2. The waste pile is actually composed of several separate piles, with maximum height from original ground in the order of 10 metres. More than 85 percent of the pile is flat to slightly inclined platform areas, with the remainder being angle of repose slopes in the order of 32 degrees (shown as cross-hatched areas in Figure 3.1). Overall angle from the toe of the pile to the uppermost sections is shallow, in the order of 13 to 16 degrees.

As can be seen in Figure 3.1, the majority of the slopes have a west to southwest aspect, and only a minor fraction of the slopes are east to north-facing.

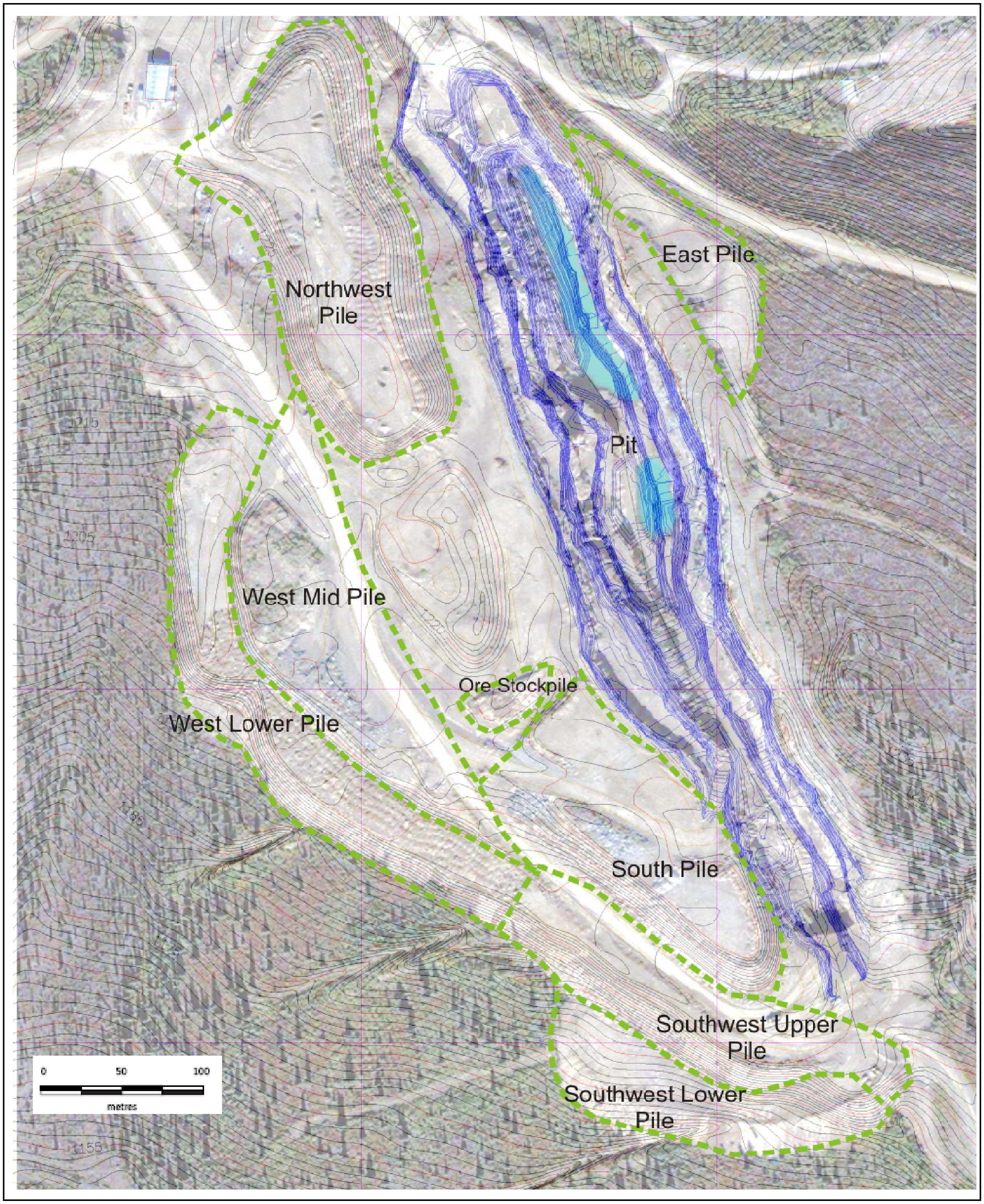


Figure 3.1 Brown McDade waste rock pile and pit

Figure 3.2 Aerial view of Brown McDade waste rock pile looking east. Pit is immediately behind waste rock area. Local natural vegetation can be seen.

3.2 Rock and Soil Characterization

3.2.1 Physical Characteristics

Being comprised of relatively recently deposited rock, there is no discernable soil horizon development on the waste rock pile. The material is comprised of rock extracted from the nearby pit during mining operations from 1996 to early 1999, and is primarily composed of variably altered granodiorite and porphyry, with occasional lenses and pods of sulphidic and vein material.

Figure 3.3 shows a wall of a 1.0 metre deep test pit excavated in the waste rock pile. Despite the obvious abundance of cobble-sized fragments, the matrix of much of the waste rock pile material is fine and "clayey-silt" in texture. The rock is well-drained and there is no evidence of saturated zones within the rock pile. The few seepage zones observed to date occur at the toe of the pile, and monitoring to date indicates they flow only sporadically.

Figure 3.3 Profile in test pit TP-2, northwest sector of pile. Lower orange flagging is 1.0 m depth.

Test pits dug both by hand and by excavator indicated that the majority of the waste rock pile platforms are not highly compacted. While the majority of waste rock pile platform areas received only moderate compaction during mine operation, some areas such as ramps and haul roads experienced prolonged heavy equipment traffic and are highly compacted.

3.2.2 Chemistry

Waste rock geochemistry is discussed in detail in Altura Environmental Consulting (2009). Results of this study indicate that the waste rock is in large part of neutral to slightly alkaline paste pH, with sporadic pockets of net acidic material.

As discussed in section 2.7, soil nutrient analysis was carried out at the two reference sites, SP-1 and SP-2. Similar sampling was also conducted at two waste rock sites, VT-WR-01 on the Brown McDade East Pile, and VT-WR-02 on the Heustis Pile near the mill site. Complete results are given in Appendix A. Available nutrient levels at the Brown McDade East Pile site are similar to those of reference site SP-2, with a potential excess indicated only for Ca, and low levels of available N, P, and B. Soil granulometry performed on site SP-2 and the East Pile sample also show the two to be a similar sandy loam.

The results from the Heustis Pile site indicate potentially excessive levels of S, Ca, Cu and Zn, and similarly low levels of N, P and B.

3.2.3 Erosional Processes

No macro-scale surface erosion features such as rilling and gullying are observed on the Brown McDade waste rock pile platforms or slopes (Figure 3.4). Nonetheless, it is noted that the fine-grained size particles tend to form a thin and weak indurated crust in many areas of the rock pile. This armouring may be a result of a combination of: i) raindrop erosion (where the impact of raindrop entrains clay and fine silt particles leaving a cement-like crust of coarser sand-size material), ii) freeze-thaw processes (USDA, 1996) and iii) dissolution and evaporation of readily soluble salts. This crusting provides a poor substrate for seed germination, and thus negatively affects plant colonization.

Figure 3.4 Angle of repose slopes. Right: lower west area, showing abundant coarse rock; Left: lower southwest area with relatively higher proportion of fine material (typical of most of waste rock pile).

3.3 Vegetation

No records of revegetation activities over the Brown McDade waste rock pile have been found to date; therefore, any existing vegetation is considered to voluntarily colonizing the site.

As shown in Figure 3.5 and in the aerial photograph in Figure 3.2, vegetation cover is very sparse over most of the Brown McDade waste rock pile. Nonetheless, several species have been successful in establishing over much of the site, albeit in very low density.

3.3.1 Voluntary Colonization

The following species, in order of approximate abundance of individuals, have been observed to be voluntarily colonizing the Brown McDade waste rock pile. Figure 3.5 shows photos of some of these species. Section 3.3.3 discusses potential factors that are contributing to voluntary establishment on the rock pile.

Table 3.1 Voluntary colonizing species on the Brown McDade waste rock pile

Common Name	**Scientific Name**	**Comment**
Grass species (undifferentiated)	*various*	Throughout waste rock pile area, but most prolific in east pile
Foxtail Barley	*Hordeum hubatum*	Throughout waste rock pile area
Willow (undifferentiated)	*Salix spp.*	Throughout waste rock pile area
Fireweed	*Epilobium agustifolium*	Throughout waste rock pile area
River Beauty /Dwarf Fireweed	*Epilobium latifolium*	Throughout waste rock pile area, although more prolific 1 km to west at the Heustis rock pile area
White Spruce	*Picea glauca*	Throughout waste rock pile area
Trembling Aspen	*Populus tremuloides*	Only noted in southern sector of waste rock pile
Balsam Poplar	*Populus balsamifera*	Only noted in west part of waste rock pile at old ammonium nitrate storage area
Dockleaf Smartweed?	*Polygonum lagathifolium*	Throughout waste rock pile area, but most prolific in mid level west pile (see Figure 3.5)
Small Leaved Pussytoes	*Antennaria pulcherimma*	Seems to occur in same zones as foxtail barley
Kinnikinnick	*Arctostaphylus uva-ursi*	Only one individual observed (crest of east pile)

Figure 3.5 Examples of voluntary colonization in Brown McDade waste rock pile. Clockwise from top left: white spruce and showy pussytoes; dockleaf smartweed?; willow.

3.3.2 Potentially Invasive or Undesirable Species

Of the species listed in Table 3.1, foxtail barley and dockleaf smartweed are widely considered to be potentially undesirable. While foxtail barley is a common early colonizer in disturbed and nutrient-poor soils, its sharp-pointed awns are potentially harmful to wildlife. Nonetheless, the absence of the species in climax and late sucessional communities indicate that abundance of this species should naturally diminish as succession advances. Confirmation of the dockleaf smartweed is required, as there are similar non-invasive species that may be native to the area.

3.3.3 Potential Factors Affecting Revegetation

The following factors have been observed based on field reconnaissance to date:

- virtually all zones of the waste rock pile support some vegetation. There is no evidence indicating unsuitability of the waste rock media from a plant toxicity point of view. Results of geochemical analyses are expected in December and should provide further information in this respect.

- The two areas supporting the least vegetation on the waste rock pile tend to be:

    - Flat areas with little topographic relief, particularly those with some degree of compaction (see Figure 3.6); and

    - Angle of repose slopes.

  Possibly, both compaction and exposure to elements are negatively affecting vegetation density on the flat areas. The angle of repose slopes show little or no macro-scale signs of erosion, however as mentioned in section 3.2.3 an indurated crust is observed in many slope areas where fines accumulate on the slope faces.

- Highest vegetation density is found on the mid-level west pile area, where material contains a higher amount of fines, and where the pile surface is extremely hummocked (see Figure 3.6). Possibly, the favorable material texture and the creation of micro-sites are positively affecting vegetation density.

- The physical expanse of the waste pile (eg. distance from areas of natural vegetation) may be limiting the establishment of many local species with smaller seed and fragment dispersal radii such as evergreen, kinnikinnick, and crowberry.

Figure 3.6 Top: platform of lower southwest pile, minimal voluntary colonization. Bottom: platform of mid west pile showing greater voluntary colonization. Potential influencing factors may be: i) soil texture and degree of compaction (lower southwest pile is coarser and shows evidence of compaction by bulldozer), and ii) hummocks on mid west pile have created micro sites to better trap moisture and seed, and provide protection from the elements.

4.0 Restoration Framework

4.1 Conceptual Successional Sequence

A preliminary model of the local successional sequence has been derived based on: i) site information including observations of the Brown McDade waste rock pile, and the older, naturally recovered chronosequence areas discussed in section 2.6.2; and ii) a well-documented and long term chronosequences of a comparable ecosystem in Alaska.

Areas of glacial retreat can provide excellent examples of succession chronosequences in sub-alpine ecosystems such as the one in which the Brown McDade waste rock pile is situated (Ellenburg and Strutt, 1988). An excellent study by Viereck (1966) identified successional chronosequences in a single study area located in the ecotone between boreal forest and alpine tundra in the McKinley River area of the Alaska range. The ecosystems were located on four progressively younger outwash terraces of the McKinley River approximately 1 km west of the recent terminal moraine of the Muldrow Glacier at elevation 730 to 760 masl. The four successional ecosystems, and were then age-dated using both superpositional relationships and tree and shrub ring counts, and were found to be up to 300 years old. The vegetation and soil development characteristics were then compared to a climax alpine tundra stand on a late Wisconsin-age outwash terrace located located nearby, estimated to be 5000 to 9000 years of age.

Viereck identified the four successional stages as follows: i) pioneer (25 to 30 years), ii) meadow (100 years), iii) early shrub (150 to 200 years), and iv) late shrub (200 to 300 years). Several of the key plant species in Viereck's study are identical to those found in the Mount Nansen area (eg. scrub birch, crowberry, willow, labrador tea, white spruce, kinnikinnick). Nonetheless, it should be noted that Viereck's study area is wetter than the Mount Nansen area (515 mm annual precipitation versus 270 mm) and thus the overall trajectory and climax ecosystem of Viereck's Alaska site is more comparable to the 'moist' reference area presented in section 2.7.1.

A summary of Viereck's findings of frequency and coverage of successional plant communities is given in Table 4.1. Note that only key species potentially relevant to the Mount Nansen area are included. It should be clarified that while no quantitative data for white spruce is included in the paper, Viereck mentions its occurrence in the succession series starting at the meadow stage (but with sparse cover and low frequency through to the climax phase). Initial mosses and lichens occur in the pioneer stage and include *Stereocaulon paschale* (a known nitrogen-fixing lichen) and *Ditrichum flexicaule*.

Table 4.1 Successional species at outwash terraces, McKinley River area, Alaska (after Viereck, 1966)

Common Name	**Scientific Name**	**I Pioneer** 25-30 years	**II Meadow** 100 years	**III Early Shrub** 150-200 yrs	**IV Late Shrub** 200-300 yrs	**V Climax Tundra** 5,000-9,000 yrs
Scrub Birch	*Betula glandulosa*		***1***	***4***	***4***	***3***
Bilberry	*Vaccinium uliginosum*		+	**+**	***2***	***2***
Kinnikinnick	*Arctostaphylos uva-ursi*	+	***2***	*1*		
Labrador tea	*Ledum groenlandicum and/or L. decumbens*			*r*	*r*	***2***
Crowberry	*Empetrum nigrum*		+	**+**	***1***	+
Lowbush cranberry	*Vaccinium vitis-idaea*			+	+	***2***
Prickly Rose	*Rosa acicularis*				*r*	
Blue-green willow	*Salix glauca*	*r*	*1*	**+**	***1***	*r*
Barrenground willow	*Salix brachycarpa*	**+**	***1***	***1***	*r*	
Barratt willow	*Salix barrattiana*		***1***	***2***	**+**	
Fireweed	*Epilobium agustifolium*	*r*	**+**	**+**	*r*	
River Beauty /Dwarf Fireweed	*Epilobium latifolium*	+	*r*	*r*		
Balsam Poplar	*Populus balsamifera*	**+**	**+**	*r*		
Altai Fescue	*Festuca altaica*		*1*	*1*	**+**	

bold and green shading indicate a frequent species (occurring in ≥70% of the 100 m^2 quadrats)

r erratic occurrence, usually only one or two plants in the 100 m^2 quadrat

\+ occasional, but less than 5% of total plot area

1 abundant or common but insignificant in cover, less that 5% cover of total plot area

2 very abundant or common, but low in cover,5 to 25% cover of total plot area

3 25 to 50% of the total plot irrespective of number of specimens

4 50 to 75% cover, irrespective of numbers

5 75 to 100% cover, irrespective of numbers

Incorporating Viereck's data and that from the local chronosequences (section 2.6.2), reference areas (section 2.7), and initial colonizers of the Brown McDade waste rock pile, a conceptual successional sequence has been derived and is given in Figure 4.1.

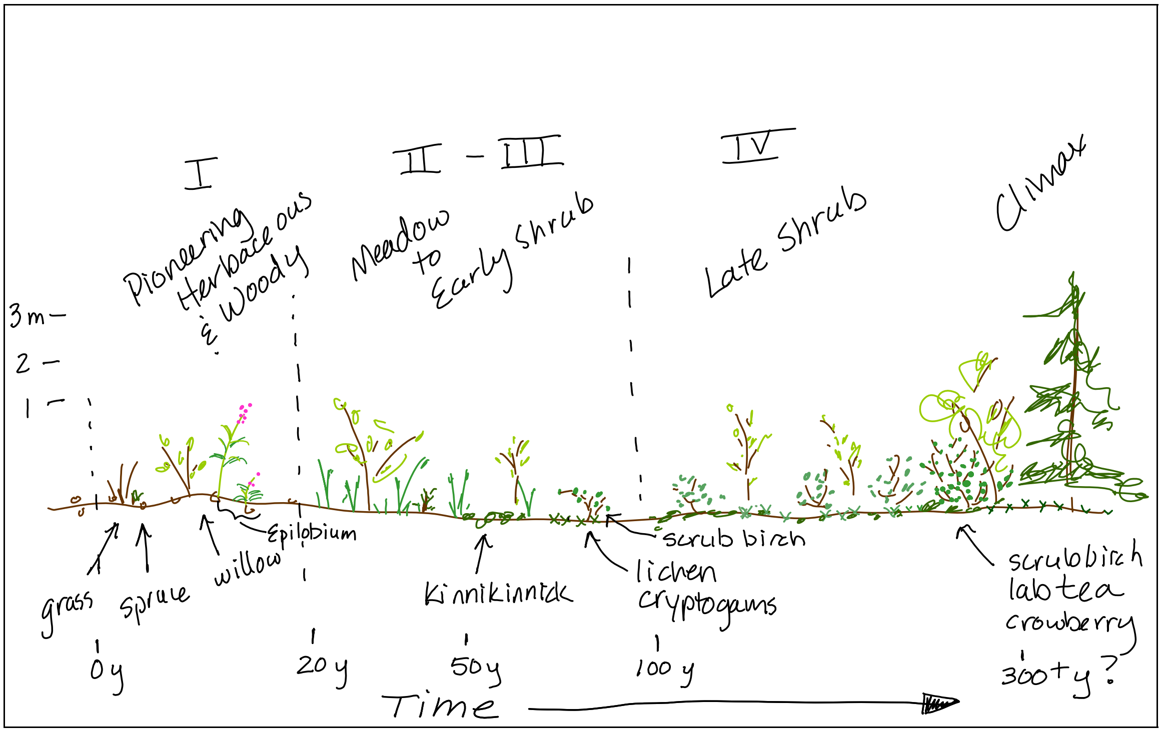


Figure 4.1 Preliminary model of local successional sequence.

As noted in section 2.6.2, willow are a key species in initial colonization. Spruce, albeit in very low density, are also frequently observed in the rock pile area in disturbances less than 10 years old. *Epilobium spp.* (fireweed, dwarf fireweed) are also common early colonizers. While both spruce and willow persist through to the climax vegetation community, *Epilobium spp.* appear to be substantially diminished in density by the pioneering woody stage. Grasses colonize early, however are observed to be much more dominant in the older disturbances such as the 1970's vintage exploration trenches (see Figure 2.4), and on the East Pile (developed in the late 1980's). Grasses appear to be major colonizers of some disturbed sites, while other sites have very few individuals. Grass species appear to persist into the later shrub stages, but by the climax stage are notably absent (as shown in the two reference site climax communities in section 2.7).

Kinnikinnick appears to be a late pioneering stage species and in the local study area, persists through to the climax vegetation community. Only a single kinnikinnick individual was observed colonizing the Brown McDade east waste rock pile, and occurred less than five metres from a climax vegetation area. In the older disturbances reviewed, kinnikinnick shows a strong propensity for opportunistic spreading along disturbance margins into the non-vegetated areas.

In the local area, a 'biological' or cryptogamic soil crust development is visually discernible in the order of 30 years following disturbance. This observation is in order-of magnitude agreement with recovery rates documented in the Northern Great Basin (1000 m elevation and 350 mm precipitation). In this location, gelatinous lichen formation is noted to occur in 20 years and early colonizing lichens and mosses in 25 years (Belnap et al., 2001). It is also noted that factors such as soil stability and available moisture greatly affect time to the regeneration of the biological soil crust, with drier ecosystems showing much slower regeneration times. Belnap et al. also indicate that the gelatinous lichens (eg. *Collema spp.*) are nitrogen-fixing, and thus very important to soil development.

Although prolific in the climax vegetation community, only one local example of scrub birch colonization was observed in the disturbed areas (see Figure 2.4). Nonetheless, taking the work of Viereck, one can see that scrub birch colonization would begin at the second (meadow) successional stage. Sharman and Smyth (2002) note that once planted, scrub birch is their best growing shrub on high elevation waste rock piles in northern British Columbia. Viereck's work also indicates crowberry and potentially bilberry to be potential second stage successional species, however bilberry's affinity for more moist habitats may limit its potential as a revegetation species in the well drained waste rock environment.

Labrador tea is shown to be a late stage successional species, and along with its moist or poorly drained preferred habitat regime, is not considered a primary target species for revegetation.

4.2 Restoration Filters

Section 3.3.3 mentions several barriers or 'filters' that have a negative influence on vegetation establishment. The main filters at the Brown McDade waste rock pile are considered to be:

1. Compaction
2. Surface Induration or Crusting
3. Exposure to Elements (lack of micro-sites suitable for plant establishment – low moisture and few seed trap sites)
4. Expanse of the Disturbed area (beyond the seed dispersal/suckering/spreading radii of many species)

These filters must be removed or reduced in order to achieve a successful restoration. Filters 1 through 3 may largely be mitigated during the physical preparation phase and these measures are discussed in section 4.4.1. Proposed mitigation of filter 4 is through the use of 'island' or 'pocket' planting and is discussed in section 4.4.2. Placement of woody debris (section 4.4.2) helps enhance micro-sites and encourage propagation of cryptogamic species, thus contributing to reducing filters 3 and 4.

4.3 Target Trajectory

The studies conducted to date indicate that there are no insurmountable barriers in ultimately achieving a climax vegetation community at the Brown McDade waste rock pile. Although several 'filters' are at present blocking much of the colonization, with certain techniques and time, these issues can be overcome and a functioning successional ecosystem established that is similar to that of the surrounding area. Therefore, the end ecosystem target for the site would be that of the two reference site communities presented in section 2.7, and the target trajectory would be the successional sequence presented in section 4.1.

Due to the somewhat coarse and well drained nature of the waste rock along with the predominant south to west aspect of the site, ultimately a community resembling the 'well-drained' rather than 'poorly drained' reference area is most apt to be dominant over much of the waste rock pile.

Nonetheless, a few precautionary notes are in order. As demonstrated by the timelines in Viereck (1966) and discussed in previous section, it is important to keep in mind that in this high elevation, cool and semi-arid environment, vegetative growth and soil development is extremely slow. Evolution to a fully functioning climax ecosystem comparable to the two reference ecosystems is expected to take several centuries, and in some cases may not develop as anticipated (Clewell and Aronson, 2007). Although it is unlikely that the trajectory path or the end ecosystem target will be achieved exactly as originally projected, it is through studying these local processes that we can best identify key local plant species and techniques that help to create an environment amenable to the initiation of ecological processes.

4.4 Conceptual Restoration Plan

4.4.1 Physical Preparation

As noted previously, filters potentially inhibiting plant germination and growth include: i) surface crusting due to either compaction from heavy equipment or induration from micro-scale erosional processes; and ii) large exposed areas with minimal relief and undulation providing minimal shelter for seeds, plants and areas for moisture accumulation. Adequate preparation of the site prior to revegetation activities is essential to mitigate the effects of these filters by incorporating the waste rock pile into the local landscape, minimizing potential for long term erosion, and providing suitable micro sites for plant propagation. Pending a forthcoming decision on the backfill plan for the adjacent Brown McDade Pit, the following are anticipated to be the major components of the physical preparation phase:

- Removal and appropriate disposal of the small amount of debris (crushed drums, fragments of metal pipe) that remain in some areas on the waste rock pile surface

- Recontouring and resloping of remaining angle of repose rock pile slopes: reduce of angle of any remaining angle of repose slopes to gradients in the order of 20-25° (for landscape integration, long term stability, and to improve access for revegetation work). Given the relatively short slopes, this may be done effectively with a medium-size bulldozer (Caterpillar D7-D9).

- De-compacting and preparation of micro-sites: ripping to at least 0.8m depth of platform and compacted areas using a long shank ripper and bulldozer (grader rippers are not of sufficient depth). To provide vegetation micro-sites, the surface of both slopes and flatter areas should be left as undulating and hummocky (0.5m to 1m relief, with irregular spacing of 1 to 5m between hummocks). This may be best accomplished using a small or medium-size excavator (eg. Caterpillar 200 to 300 series)

4.4.2 Revegetation Approach

Use of the "island" or "pocket planting" colonization model is proposed for the Brown McDade waste rock pile to mitigate the filter identified in section 4.2, whereby the expanse of the disturbance was recognized an important barrier to colonization by those species with relatively small seed dispersal, suckering, or spreading radii. This method focuses on the establishment of islands or patches of native plants that will provide seed and/or physically spread into adjacent areas. Native island practice has been used at high elevation waste rock pile disturbances at the Quintette Mine in northern B.C. since 1991 with a certain degree of success (Sharman and Smyth, 2002). Techniques and methods have been adaptively refined over the years based on the various successes and failures. In general, the native species islands are preferentially located in moisture-collecting areas that are not subject to drying winds. As of 2002, approximately 30 different species were being utilized in the Quintette program, reduced from the initial 80 species. Planting a given species in 'clusters' has been found to increase pollination efficiency, rather than evenly spacing individuals across an island. While the islands are established mainly by transplants direct seeding of some species complements the program. Ideal spacing of the islands is difficult to determine. Up to 2002, the average expansion distance of species from the islands was 25 m, however this average value is a calculated result of several islands with little or no expansion offset by a few islands with as much as 500 m expansion. For the Brown McDade waste rock pile, it is considered that a spacing of up to 15 m between island edges may be an acceptable starting point, nonetheless, it is important to vary the spacing, island size and plant establishment techniques early in the restoration process to determine optimal methods.

The incorporation of dead (rotted or sound) woody debris from climax vegetation areas is considered to be of critical importance to the restoration program. Woody debris is of great benefit in ecological restoration of disturbed areas through: i) providing a form of slow-release nitrogen and organic matter, ii) creating habitat for small animals such as rodents and birds, iii) providing a source of moss and lichen spores and plant fragments, and iv) creating micro-sites and protection for emerging seedlings (NP 501, 2008). Both coarse (≥10 cm diameter) trunks and roots and fine (sticks, branches, brush) of a full variety of species are recommended, and may be harvested from the local area for disbursement over the site once the physical preparation work is complete.

4.4.3 Key Revegetation Species

To identify key revegetation species, those earmarked in the conceptual successional model from section 4.1 were reviewed with respect to abundance, frequency, moisture and habitat preferences, successional stage emergence, persistence over consecutive successional stages, degree of voluntary colonization, and contribution to soil development.

Species targeted for revegetation measures must be suitable for growth in a low moisture and low organic content soil environment. For this reason, labrador tea was not selected due to both its late stage successional emergence and its known preference for high organic soil environments. The viability of bilberry (*Vaccinium uliginosum*) is also in doubt – this species frequents high-organic content soils so may or may not be adaptable to establishment on waste rock. However, this species is noted as a frequent and relatively early-stage succession species, and thus for the interim is included in the proposed revegetation species list.

Fireweed and dwarf fireweed were not selected because of relatively high voluntary colonization and non-persistence into later successional stages. These two species are expected to naturally and adequately colonize the waste rock pile without any special measures.

Species ranked as ‘Primary’ importance in the revegetation efforts are those that tend to have higher abundance in climax and sub-climax stages, and/or significantly contribute to soil development. It is suggested that the majority of revegetation effort should be focused on establishment of these species. ‘Secondary’ species have persistent, yet lower abundance in the successional community, and still play a vital role in community diversity and ecology. Efforts should be made to include these species in the program, but not to the detriment of the Primary species.

Table 4.2 lists the selected key revegetation species along with suggested propagation methodologies. Due to the well-drained condition of the waste rock, it may be difficult to establish even easily rooted cuttings such as willow and balsam poplar by direct planting into the pile. Willow cutting trials by EDI Environmental Dynamics are underway on the Heustis Rock Pile to help determine the feasibility of direct cutting establishment. For the planning purposes, where applicable Table 4.2 indicates transplant of nursery-rooted cuttings for the selected species.

Table 4.2 Key species proposed for revegetation

Common Name	Scientific Name	Actively Colonizing Waste Rock Pile?	Propagation	Colonization Mechanism into Disturbed Areas	Proposed Establishment Method	Importance in Revegetation Program	Comments
Scrub Birch	*Betula glandulosa*	No	Seed	Unknown Animals?	Direct seeding (trials underway), or transplant of nursery-grown plant	Primary	Important species through to climax vegetation
Spruce (White, Black)	*Picea glauca/mariana*	Yes	Seed	Windblown cones?	Direct seed; salvage existing seedlings where possible	Secondary	
Bilberry	*Vaccinium uliginosum*	No	Cutting or seed	Unknown Animals?	Transplant of rooted cuttings	Primary	May or may not be apt for growth on low-organic sites
Kinnikinnick	*Arctostaphylos uva-ursi*	No[1]	Cutting or seed	Edge encroachment	Transplant of rooted cuttings	Primary	
Crowberry	*Empetrum nigrum*	No	Seed	Edge encroachment?	Transplant of rooted cuttings	Secondary	
Lowbush cranberry	*Vaccinium vitis-idaea*	No	Cutting or seed	Edge encroachment?	Transplant of rooted cuttings	Minor	Identified as later stage successional species (Early Shrub, 150-200 years) in Viereck, 1966
Willow	*Salix spp.*	Yes	Seed or cutting	Windblown seed dispersion	Direct seed; transplant of rooted cuttings	Primary	
Balsam Poplar	*Populus balsamifera*	Yes	Seed or cutting	Windblown seed dispersion	Direct seed;transplant of rooted cuttings	Secondary	Does not persist to later successional phases, but is likely important contributor of organic matter
Grasses, eg. Altai Fescue	*Festuca altaica*	Yes	Seed	Windblown seed dispersion	Direct seed and nursery plant transplant	Secondary	
Lichens and Mosses	-	No	Fragmentati on, possibly spores	Animals? Wind?	Old woody debris and dead brush	Primary	Very important role in soil development (nitrogen fixing and microbial activity)

[1] only one individual observed (crest of east pile)

4.5 2008 Revegetation Research

Related revegetation research initiated in 2008 included:

- Scrub Birch Germination Site Trials: as shown in photos in Figure 4.2, a small amount of scrub birch (Betula glandulosa) seed was collected in early September 2008. Later that month, two separate scale direct seeding trials, one on the East Pile, the other on the Heustis Rock Pile were established. The plots each measure 1 m by 1 m and are intended to test the germination of scrub birch by direct seeding on three different media: i) waste rock, scarified using hand tools, ii) scarified and screened waste rock (+3/8" fraction removed); and iii) scarified and screened waste rock inoculated with a small amount of organic soil from a nearby undisturbed site. Germination will also be tested under nursery conditions in spring 2009 using the small remaining amount of seed collected.

- Other Cuttings and Seeds: approximately twenty-five dormant stem and root cuttings of kinnikinnick (*Arctostaphylus uva ursi*), and five stems of laborador tea and mossberry (*Ledum groenlandicum* and *Empetrum nigrum*), were taken from site in late September 2008, and were 'heeled in' for the winter, for spring rooting trials (see Figure 4.3). In addition, a small amount of labrador tea seed was collected.

Figure 4.2 Scrub birch trials. Clockwise from upper right: i) seed-containing catkins at collection site SP-2; ii) VT-WR-02 plots on Heustis Rock pile; iii) screening organics from adjacent undisturbed site for inoculation into waste rock fines; and iv) VT-WR-01 plots on Easte Rock pile.

Figure 4.3 Kinnikinnick 'roll' for overwintering stems.

5.0 Restoration Plan Implementation

5.1 Program Description and Project Timeline

Restoration works for the Brown McDade waste rock pile are proposed to be carried out over a four-year period in order to allow for two full seasons of seed and cutting collection, plant propagation, and outplanting.

Year one will see completion of physical site preparation, woody debris placement, plant salvage and transplant, and the first phase of direct seeding, leaving only ongoing revegetation and monitoring activities for years two through four.

The project schedule assumes that any nursery-propagated plants will be outplanted in spring or early summer to maximize seedling survival (Sharman and Smyth, 2002). For many species, this will require that plants be started the year before and overwintered.

Seed collection from local areas will take place during late summer to early fall. Cutting collection in year one will be done in late fall in order to provide starter stock for late winter nursery propagation; thereafter it is proposed that cutting collection be done from April through May at sites pre-selected during the prior year (digging down through snow cover as required). This practice should produce better quality cuttings and reduce cutting die-off due to fall harvesting and cold storage for several months prior to nursery rooting.

Operational trials are proposed to start early in the program as seed and seedling availability allows. It is noted that some trials including willow pole cuttings and direct seeding of scrub birch are already underway at the site. Future programs should continue to test these and other key species with respect to with propagation method, micro-site preference, and site preparation methods.

Finally, it is proposed that effectiveness monitoring be initiated in late summer of year two, and conducted annually through to year four. Thereafter, the monitoring schedule should be adjusted in accordance with the results obtained to date. It is strongly recommended that a detailed monitoring program be designed prior to beginning any of the restoration works. The primary objective of the effectiveness monitoring program is to measure the success the restoration efforts in achieving the restoration goals for the waste rock pile. Parameters to measure during monitoring include plant abundance, functional status, seedling recruitment, and spreading or expansion to new areas. Additional chronosequence or ‘sequential reference’ sites in the surrounding local area should be identified to help (albeit in a broad sense) evaluate the progress of the site along its target trajectory. Soil chemistry and development should also be monitored, but at a lower frequency than vegetation monitoring.

The proposed project timeline is given in Table 5.1.

Table 5.1 Proposed project timeline of Brown McDade waste rock pile restoration

	Year 1				Year 2				Year 3				Year 4			
	Late Winter	Spring/ Early Summer	Late Summer/ Fall	Early Winter	Late Winter	Spring/ Early Summer	Late Summer/ Fall	Early Winter	Late Winter	Spring/ Early Summer	Late Summer/ Fall	Early Winter	Late Winter	Spring/ Early Summer	Late Summer/ Fall	Early Winter
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Plant Salvage from Waste Rock Pile (spruce, willow)		X														
Physical Preparation of Site		X														
Woody Debris Collection and Placement		X														
Transplanting of salvaged plants		X														
Operational Scale Trials		X	X			X										
Seed Collection (typically late summer or fall)			X				X									
Seed Cleaning and Pre-Treatment			X	X			X	X		X	X					
Direct Seeding			X				X			X				X		
Cutting Collection			X			X				X				X		
Nursery Plant Propagation (seeds and cuttings)					X	X						X	X			
Outplanting of Nursery-Grown Plants						X				X				X		
Nursery Plant Overwintering								X	X			X	X			
Monitoring							X				X				X	

5.2 Harvesting Ethics

As noted in the underlying assumptions for the ecological restoration approach for this site (section 1.3.2), all plants used in the revegetation program will be of provenance of less than 5 kilometres from the Brown McDade waste rock pile, and are to be propagated by seed or vegetative means (eg. no transplants of wild-growing plants).

These restoration measures described in the preceding sections require harvesting of the following plant material from undisturbed sites: i) woody debris, ii) seed, and iii) live cuttings. In order to minimize ecosystem effects during native plant material harvesting, several organizations have established guidelines for ethical collection, including criteria for the amount of material to be collected from a given area, the frequency and timing of collection, pre-identification of rare and infrequent species, and measures to maximize the use of the collected material.

It is recommended that site-specific harvesting guidelines be established for this project, possibly using existing guidelines as templates and incorporating local criteria as appropriate. Examples of guidelines may be found at the Washington Native Plant Society (http://www.wnps.org/policies/collection_policy.htm) and the Garry Oak Ecosystem Recovery Team websites (http://www.goert.ca/at_home_guidelines_native.php).

5.3 Enhancing Social Capital

Ecological restoration of the Brown McDade waste rock pile presents numerous opportunities to incorporate social and cultural values and community buy-in both during and after the main restoration activities, or as is often coined today, "enhancing social capital". To this end, it is recommended to closely involve the local community in every facet of this project, for example:

- consulting with the local community to identify activities that they may wish to carry out in the area (eg. sustenance hunting, berry picking, medicinal plant gathering), and incorporate these goals into the restoration strategy as possible;
- training and hiring local community members to harvest seed, cuttings, and woody debris from undisturbed areas, and to assist with planting;
- encouraging development of local contractors for roles in plant propagation and physical site preparation work; and
- collaborating with local groups to disseminate information on the project, to participate in joint monitoring, and to help protect the site during the restoration process.

6.0 Conclusions and Recommendations

6.1 Conclusions

It is proposed that the ecological restoration program for the Brown McDade waste rock pile be conducted over a four year period. Site preparation will involve recontouring, de-compacting, woody debris placement and creating hummocked surfaces that favour moisture accumulation and provide plant shelter and seed trap locations. Key native species of local provenance will be established in functional 'islands' or 'pockets' of plant communities over the waste rock pile surface that over time will mature and expand to adjacent areas of the pile.

Although several factors or 'filters' were identified that are currently inhibiting vegetation growth on the waste rock, it is believed that mitigation may be achieved through adequate site preparation and incorporation of the native island concept.

Attainment of a landscape identical to that of the surrounding environment might not occur in the end, and at any rate, is a very long term, centuries-away goal. Nonetheless, with implementation of this plan, including monitoring and incorporating adaptive management, establishment of a successional and functional ecosystem in harmony with the local environment is considered feasible and can be carried out largely using established techniques and with local resources.

6.2 Recommendations

This is a conceptual-level plan, and as such other information is required prior to development of a working plan. Activities to provide this additional data are as follows:

- conduct a systematic reconnaissance-level local vegetation inventory (this will help to finalize list of potential species, in particular nitrogen-fixing species [eg. *Astralagus spp, Hedysarum spp. Dryas spp., Oxytropis spp.*], and local grass species suitable for revegetation);
- identify additional chronosequence sites and conduct more thorough plant inventory of these sites in order to better understand succession of later species, identify other potential revegetation species, and designate trajectory reference areas;
- determine final reclamation area (in order to design physical preparation works, estimate plant quantities, and estimate island spacing, geometry and location);
- continue with workshops with community and other stakeholders to identify natural and social capital opportunities;
- develop site-specific harvesting ethics guidelines; and
- conduct additional propagation research (operational scale) – scrub birch, willow, and other key species.

7.0 Acknowledgements

The author wishes to thank Hugh Copland, previously of Assessment and Abandoned Mines Division of the Yukon Government for giving permission to utilize revegetation aspects of the Brown McDade waste rock study for a final course project assignment for the Native Species and Natural Processes program at the University of Victoria.

David Polster, M.Sc. R.P.Bio., provided invaluable feedback of this final project assignment, and where possible, his comments have been incorporated into this report.

8.0 References

Altura Environmental Consulting (2009). *Brown McDade Waste Rock Pile, Mount Nansen Mine Site, Yukon, Geochemical Characterization.* Prepared for the Assessment and Abandoned Mines Branch, Energy, Mines and Resources, Government of Yukon, 237 pp.

Author and Date Unspecified. *Mount Nansen Closure Objectives*, 1 page circular.

Belnap, J., Kaltenecker, J.H., Rosentreter, R., Williams, J., Leonard, S., and Eldridge, D., 2001. Biological Soil Crusts: Ecology and Management. Technical Reference 1730-2, U.S. Department of the Interior, 118 pp.

Clewell, A.F., and Aronson, J. *Ecological Restoration: Principles, Values and Structure of an Emerging Profession.* Publication of the Society for Ecological Restoration International. Island Press, 217 pp.

Conor Pacific, 2000. *Mount Nansen Minesite – Historical Review, Site Assessment, and Field Sampling Program.* Final Report Version 2. Prepared for Indian and Northern Affairs Canada, 223 pp.

EDI Environmental Dynamics Inc., 2007. *Mt. Nansen Terrestrial and Aquatic Effects Study 2006-06. Volume 1 of 3 -- Report.* Compiled for the Government of Yukon, Abandoned Mines Branch (Type II), Energy, Mines and Resources, 143 pp.

Ellenburg, H., and Strutt, G.K. 1988. *Vegetation Ecology of Central Europe.* CUP Archive, 731 pp.

Garry Oak Ecosystem Recovery Team. *Guidelines for the Collection and Use of Native Plants.* http://www.goert.ca/at_home_guidelines_native.php , accessed Nov. 28/08.

Government of Yukon, 2008) Yukon Plateau, Boreal Cordilera Ecozone 175. In Ecoregions of the Yukon Territory, Part 2, http://www.emr.gov.yk.ca/oilandgas/pdf/bmp_yukon_plateau_ecoregion.pdf , accessed Oct. 15, 2008.

NP 501, 2008. NP 501: Design Principles for Natural Processes. Course Lecture Notes, October 17-21, 2008, University of Victoria, D. Polster, professor.

Sharman and Smyth, 2002. The Progression of Native Species Island Establishment and Monitoring Practices on High-Elevation Waste Rock Dumps at Quintette Operating Corporation. In Proceedings of the 26th Annual British Columbia Mine Reclamation Symposium, 2002, pp. 34-48.

USDA, 1996. Soil Quality Information Sheet, Soil Quality Indicators: Soil Crusts. Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA. http://soils.usda.gov/sqi/publications/files/sq_sev_1.pdf, accessed Nov. 20, 2008, 2 pp.

Viereck, L.A., 1966. *Plant Succession and Soil Development on Gravel Outwash of the Muldrow Glacier, Alaska.* Ecological Monographs, Vol. 36, No.8, pp. 181-199.

Washington Native Plant Society. *Policy on Collection and Sale of Native Plants.* http://www.wnps.org/policies/collection_policy.htm, accessed Nov. 28/08.

Appendix A Soil Sample Test Results

Bodycote TESTING GROUP

Report Transmission Cover Page

Bill To:	Altura Environmental Consulting	Project:	Lot ID:	**648610**
Report To:	Altura Environmental Consulting	ID:	Approval Status:	Approved
	PO Box 2004	Name:	Invoice Frequency:	by Lot
	Marsh Lake, YT, Canada	Location:	COD Status:	Cash Client
	Y0B 1Y2	LSD:	Control Number:	
Attn:	Diane Lister	P.O.:	Date Received:	Oct 14, 2008
Sampled By:		Acct code:	Date Reported:	Nov 21, 2008
Company:			Report Number:	1177410

Contact	Company	Address
Diane Lister	Altura Environmental Consulting	PO Box 2004 Marsh Lake, YT Y0B 1Y2 Phone: (867) 335-2006 Fax: Email: dianelister@gmail.com

Copies	Delivery	Format
1	Email - Multiple Reports	PDF

_______ PAGES IN THIS TRANSMISSION

Notes To Clients:

- This report was issued to include addition of particle size analysis on samples 2570 and 2571requested by Diane of Altura on November 20, 2008. The report format is also changed. Report 1177410 is an addendum to reports 1160814 to 1160817.

Reports associated with this Lot

Id/Format/Report Date		Id/Format/Report Date		Id/Format/Report Date	
1160814 Farm Soil 1	17-Oct-08	1160815 Farm Soil 1	17-Oct-08	1160816 Farm Soil 1	17-Oct-08
1160817 Farm Soil 1	20-Oct-08				

Bodycote TESTING GROUP

Sample Custody

Bill To:	Altura Environmental Consulting	Project:	
Report To:	Altura Environmental Consulting	ID:	
	PO Box 2004	Name:	
	Marsh Lake, YT, Canada	Location:	
	Y0B 1Y2	LSD:	
Attn:	Diane Lister	P.O.:	
Sampled By:		Acct code:	
Company:			

Lot ID:	**648610**
Control Number:	
Date Received:	Oct 14, 2008
Date Reported:	Nov 21, 2008
Report Number:	1177410

Sample Disposal Date: November 19, 2008

All samples will be stored until this date unless other instructions are received. Please indicate other requirements below and return this form to the address or fax number on the bottom of this page.

☐ Extend Sample Storage Until ______________________ (MM/DD/YY)

The following charges apply to extended sample storage:

Storage for 1 to 5 samples per month	$ 10.00
Storage for 6 to 20 samples per month	$ 15.00
Storage for 21 to 50 samples per month	$ 30.00
Storage for 51 to 200 samples per month	$ 60.00
Storage for more than 200 samples per month	$ 110.00

☐ Return Sample, collect, to the address below via:

- ☐ Greyhound
- ☐ Loomis
- ☐ Purolator
- ☐ Other (specify) ______________________

Name ______________________

Company ______________________

Address ______________________

____

Phone ______________________

Fax ______________________

Signature ______________________

Bodycote TESTING GROUP

Analytical Report

Bill To:	Altura Environmental Consulting	Project:		Lot ID:	**648610**
Report To:	Altura Environmental Consulting	ID:		Control Number:	
	PO Box 2004	Name:		Date Received:	Oct 14, 2008
	Marsh Lake, YT, Canada	Location:		Date Reported:	Nov 21, 2008
	Y0B 1Y2	LSD:		Report Number:	1177410
Attn:	Diane Lister	P.O.:			
Sampled By:		Acct code:			
Company:					

		Reference Number	648610-2567	648610-2568	648610-2569	
		Sample Date				
		Sample Time				
		Sample Location				
		Sample Description	SP-1 / 0 / 8 / E / 1	SP-1 / 0 / 8 / E / 1	SP-2 / 0 / 8 / E / 1	
		Matrix	Farm Soil	Farm Soil	Farm Soil	
Analyte		**Units**	**Results**	**Results**	**Results**	Nominal Detection Limit
Aggregate Organic Constituents						
Organic Matter		% by weight	47.8	10.0	52.2	0.1
Available Nutrients						
Ammonium - N	Available-dry basis	mg/kg	<1	<0.5	6.4	0.3
Nitrate - N	Farmsoil	ppm	<1	<1	<1	1
Phosphorus	Farmsoil	ppm	<5	<5	13	5
Potassium	Farmsoil	ppm	26	50	94	10
Sulfate-S	Farmsoil	ppm	11	54	3	1
Copper	FS Micro-nutrients	ppm	0.56	1.62	0.50	0.02
Iron	FS Micro-nutrients	ppm	32.0	171	167	0.04
Manganese	FS Micro-nutrients	ppm	3.10	0.581	17.7	0.006
Zinc	FS Micro-nutrients	ppm	1.20	2.45	4.86	0.01
Base saturation	FS Base Saturation	%	100	100	10	
Calcium	FS Base Saturation	%	86.6	84.1	7.3	
Magnesium	FS Base Saturation	%	12.9	14.7	1.5	
Sodium	FS Base Saturation	%	<0.6	0.5	<0.4	
Potassium	FS Base Saturation	%	0.5	0.7	1.2	
TEC	FS Base Saturation	meq/100g	14.1	18.3	19.5	
Calcium	FS Macro-nutrients	ppm	2450	3080	290	10
Magnesium	FS Macro-nutrients	ppm	222	327	36	5
Sodium	FS Macro-nutrients	ppm	<20	20	<20	20
Boron	FS Micro-nutrients	ppm	<0.2	<0.2	<0.2	0.1
Hot Water Soluble						
Boron	FS Micro-nutrients	ppm	<0.2	<0.2	<0.2	0.1
Soil Acidity						
pH	1:2 Soil:Water	pH	7.2	7.2	4.3	
Electrical Conductivity	Sat. Paste equiv based on 1:2	dS/m at 25 C	0.26	0.28	0.15	0.02
Water Soluble Parameters						
Chloride	Available	mg/kg	5	4	8.0	0.5
Lime Requirement						
pH	SMP	pH	Not Required	Not Required	5.2	
Lime		T/ac	0	0	3.8	0.4

Bodycote TESTING GROUP

Analytical Report

Bill To:	Altura Environmental Consulting	Project:		Lot ID:	**648610**
Report To:	Altura Environmental Consulting	ID:		Control Number:	
	PO Box 2004	Name:		Date Received:	Oct 14, 2008
	Marsh Lake, YT, Canada	Location:		Date Reported:	Nov 21, 2008
	Y0B 1Y2	LSD:		Report Number:	1177410
Attn:	Diane Lister	P.O.:			
Sampled By:		Acct code:			
Company:					

		Reference Number	648610-2570	648610-2571		
		Sample Date				
		Sample Time				
		Sample Location				
		Sample Description	SP-2 / 0 / 8 / E / 1	VT-WR-01 SN / 0 / 8 / E / 1		
		Matrix	Farm Soil	Farm Soil		
Analyte		**Units**	**Results**	**Results**	**Results**	Nominal Detection Limit
Physical and Aggregate Properties						
Sand	Soil Texture	%	70.0	63.2		0.1
Silt	Soil Texture	%	22.2	22.9		0.1
Clay	Soil Texture	%	7.8	13.9		0.1
Texture			Sandy Loam	Sandy Loam		

Bodycote TESTING GROUP

Analytical Report

Bill To:	Altura Environmental Consulting	Project:	Lot ID:	**648610**
Report To:	Altura Environmental Consulting	ID:	Control Number:	
	PO Box 2004	Name:	Date Received:	Oct 14, 2008
	Marsh Lake, YT, Canada	Location:	Date Reported:	Nov 21, 2008
	Y0B 1Y2	LSD:	Report Number:	1177410
Attn:	Diane Lister	P.O.:		
Sampled By:		Acct code:		
Company:				

		Reference Number	648610-2570	648610-2571	648610-2572	
		Sample Date				
		Sample Time				
		Sample Location				
		Sample Description	SP-2 / 0 / 8 / E / 1	VT-WR-01 SN / 0 / 8 / E / 1	VT-WR-02 SN / 0 / 8 / E / 1	
		Matrix	Farm Soil	Farm Soil	Farm Soil	
Analyte		**Units**	**Results**	**Results**	**Results**	Nominal Detection Limit
Aggregate Organic Constituents						
Organic Matter		% by weight	1.8	2.1	0.4	0.1
Available Nutrients						
Ammonium - N	Available-dry basis	mg/kg	<0.4	<0.3	<0.3	0.3
Nitrate - N	Farmsoil	ppm	<1	<1	<1	1
Phosphorus	Farmsoil	ppm	8	6	12	5
Potassium	Farmsoil	ppm	53	102	94	10
Sulfate-S	Farmsoil	ppm	1	2	158	1
Copper	FS Micro-nutrients	ppm	0.47	1.50	29.3	0.02
Iron	FS Micro-nutrients	ppm	114	15.6	103	0.04
Manganese	FS Micro-nutrients	ppm	7.39	5.11	20.6	0.006
Zinc	FS Micro-nutrients	ppm	0.94	11.0	260	0.01
Base saturation	FS Base Saturation	%	100	100	100	
Calcium	FS Base Saturation	%	80	85.6	81.1	
Magnesium	FS Base Saturation	%	14	12.1	16.6	
Sodium	FS Base Saturation	%	<4	<0.8	<0.8	
Potassium	FS Base Saturation	%	5.8	2.3	2.3	
TEC	FS Base Saturation	meq/100g	2.4	11.4	10.4	
Calcium	FS Macro-nutrients	ppm	380	1960	1690	10
Magnesium	FS Macro-nutrients	ppm	41	168	210	5
Sodium	FS Macro-nutrients	ppm	<20	<20	<20	20
Boron	FS Micro-nutrients	ppm	<0.2	<0.2	<0.2	0.1
Hot Water Soluble						
Boron	FS Micro-nutrients	ppm	<0.2	<0.2	<0.2	0.1
Soil Acidity						
pH	1:2 Soil:Water	pH	5.1	7.6	7.0	
Electrical Conductivity	Sat. Paste equiv based on 1:2	dS/m at 25 C	0.06	0.24	0.69	0.02
Water Soluble Parameters						
Chloride	Available	mg/kg	5	4	5.7	0.5
Lime Requirement						
pH	SMP	pH	7.4	Not Required	Not Required	
Lime		T/ac	<0.4	0	0	0.4

Approved by: Anthony Neumann

Anthony Neumann, MSc
Laboratory Operations Manager

Bodycote TESTING GROUP

Methodology and Notes

Bill To:	Altura Environmental Consulting	Project:		Lot ID:	**648610**
Report To:	Altura Environmental Consulting	ID:		Control Number:	
	PO Box 2004	Name:		Date Received:	Oct 14, 2008
	Marsh Lake, YT, Canada	Location:		Date Reported:	Nov 21, 2008
	Y0B 1Y2	LSD:		Report Number:	1177410
Attn:	Diane Lister	P.O.:			
Sampled By:		Acct code:			
Company:					

Method of Analysis

Method Name	Reference		Method	Date Analysis Started	Location
Ammonium-N (Extractable) in Soil	Carter	*	Extraction of NO3-N and NH4-N with 2.0 M KCl, 6.2	15-Oct-08	BTG Edmonton
Boron in farm soil	McKeague	*	Hot Water Soluble Boron - Azomethine -H Method, 4.61	15-Oct-08	BTG Edmonton
Chloride in farmsoil	SSSA Book Series, no. 3	*	Testing Soils for Sulfur, Boron, Molybdenum, and Chlorine, Chapter 10	15-Oct-08	BTG Edmonton
Macronutrients in Farm Soils	McKeague		Ammonium Acetate Extractable Cations, 4.51	15-Oct-08	BTG Edmonton
Micronutrients in Farm Soil	McKeague	*	DTPA-TEA Extractable Elements, 4.65	15-Oct-08	BTG Edmonton
Nutrients in Farm Soil	Comm. Soil Sci. Pl. Anal.	*	Modified Kelowna Soil Test, Vol 26, 1995	15-Oct-08	BTG Edmonton
Organic Matter by Ignition	McKeague	*	Loss on Ignition (LOI), 3.8	14-Oct-08	BTG Edmonton
Particle Size Analysis - FS	Carter	*	Hydrometer Method, 55.3	20-Nov-08	BTG Edmonton
pH and Conductivity in farm soil	McKeague	*	1:2 Soil:Water Ratio, 4.12	15-Oct-08	BTG Edmonton
SMP Lime Requirements	Carter	*	Shoemaker-Mclean-Pratt Single-Buffer Method, 12.2	15-Oct-08	BTG Edmonton
Sulfate in Farm Soil	McKeague	*	Sulfate Extractable by 0.1M CaCl2, 4.47	15-Oct-08	BTG Edmonton

** Bodycote method(s) based on reference method*

References

Carter	Soil Sampling and Methods of Analysis
Comm. Soil Sci.	Communications in Soil Science and Plant Analysis
Guideline	Bodycote Testing Group,
McKeague	Manual on Soil Sampling and Methods of Analysis
SSSA Book	Soil Testing and Plant Analysis

Comments:

- This report was issued to include addition of particle size analysis on samples 2570 and 2571requested by Diane of Altura on November 20, 2008. The report format is also changed. Report 1177410 is an addendum to reports 1160814 to 1160817.

Please direct any inquiries regarding this report to our Client Services group.
Results relate only to samples as submitted.
The test report shall not be reproduced except in full, without the written approval of the laboratory.

Bodycote TESTING GROUP

Farm Soil Analysis

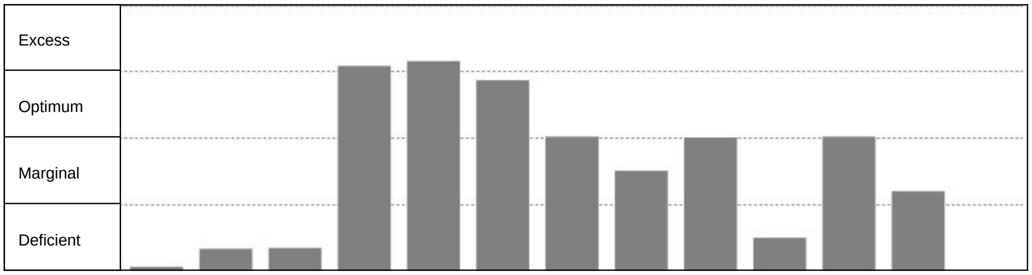
Bill To:	Altura Environmental Consulting	Grower Name:		Lot Number:	648610
Report To:	Altura Environmental Consulting	Client's Sample Id:		Report Number:	1160814
	PO Box 2004	Field Id:	SP-1	Date Received:	Oct 14, 2008
		Acres:		Disposal Date:	Nov 13, 2008
	Marsh Lake, YT., Canada	Legal Location:		Report Date:	Oct 17, 2008
	Y0B 1Y2	Last Crop:	Crop not provided	Arrival Condition:	
Agreement:	87827				

Nutrient analysis (ppm)

Depth	N*	P	K	S**	Ca	Mg	Fe	Cu	Zn	B	Mn	Cl	BiCarbP
0" - 6"	<1	<5	26	11	2450	222	32.0	0.56	1.20	<0.2	3.10	5	
6" - 12"	<1	<5	50	54	3080	327	171	1.62	2.45	<0.2	0.581	4	

Soil Quality

pH	EC(dS/m)	OM(%)	Sample#
7.2	0.26	47.8	2869161
7.2	0.28	10.0	2869180



pH	EC	OM
Alkaline	*Very Toxic*	*High*
Neutral	*Toxic*	*Normal*
Acidic	*Caution*	*Low*
Very Acidic	*Good*	*Very Low*

	N*	P	K	S**
Total lbs/acre	4	10	52	130
Estimated lbs/acre	5	10	52	160

Texture *n/a* Hand Texture *n/a*

Sand n/a % Silt n/a % Clay n/a %

Ammonium <1 mg/kg

BS 100 %

Ca 86.6 % Mg 12.9 % Na <0.6 % K 0.5 %

TEC 14.1 meq/100g Na <20 ppm

Lime 0 T/ac Buffer pH Not Required Est. N Release n/a

*Nitrate-N **Sulfate-S n/a = not analysed

RECOMMENDATIONS FOR BALANCED CROP NUTRITION

	Timber - Poplar					Native grass				
Macro-nutrients	Yield	N	P2O5	K2O	S	Yield	N	P2O5	K2O	S
Growing Condition		To be added (lbs/acre)				T/ac	To be added (lbs/acre)			
Excellent		89	59	111	0	4.7	78	46	112	0
Average		49	29	79	0	3.1	57	38	100	0
Your Goal						0.0				
Removal Rate (Seed/Total)						4.7	0 / 177	0 / 52	0 / 224	0 / 22
Micro-nutrients	Iron	Copper	Zinc	Boron	Manganese	Iron	Copper	Zinc	Boron	Manganese
To be added (lbs/ac)	n/a	n/a	n/a	n/a	n/a	0.0	0.0	0.0	2.0	0.0

Copper may be low for cereals in rotation.
Add Boron or try a test strip.

Comments:

-

Recommendations are based on general research consensus. They should not replace responsible judgement.

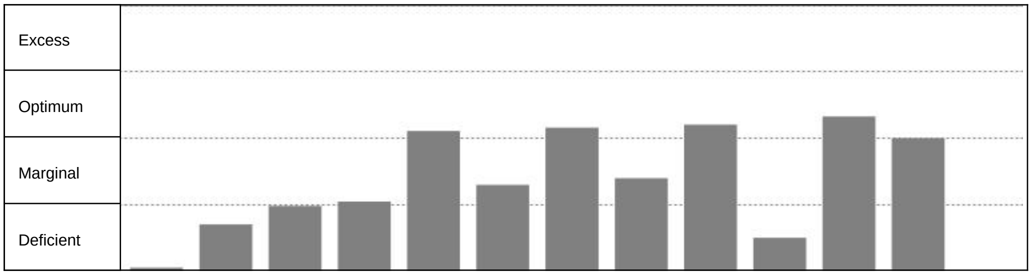
Bodycote TESTING GROUP

Farm Soil Analysis

Bill To:	Altura Environmental Consulting	Grower Name:		Lot Number:	648610
Report To:	Altura Environmental Consulting	Client's Sample Id:		Report Number:	1160815
	PO Box 2004	Field Id:	SP-2	Date Received:	Oct 14, 2008
		Acres:		Disposal Date:	Nov 13, 2008
	Marsh Lake, YT., Canada	Legal Location:		Report Date:	Oct 17, 2008
	Y0B 1Y2	Last Crop:	Crop not provided	Arrival Condition:	
Agreement:	87827				

Nutrient analysis (ppm) / Soil Quality

Depth	N*	P	K	S**	Ca	Mg	Fe	Cu	Zn	B	Mn	Cl	BiCarbP	pH	EC(dS/m)	OM(%)	Sample#
0" - 3"	<1	13	94	3	290	36	167	0.50	4.86	<0.2	17.7	8.0		4.3	0.15	52.2	2869181
3" - 6"	<1	8	53	1	380	41	114	0.47	0.94	<0.2	7.39	5		5.1	0.06	1.8	2869182



pH	EC	OM
Alkaline	Very Toxic	High
Neutral	Toxic	Normal
Acidic	Caution	Low
Very Acidic	Good	Very Low

	N*	P	K	S**
Total lbs/acre	2	21	147	5
Estimated lbs/acre	4	21	147	9

Texture *n/a* Hand Texture *n/a*

Sand n/a % Silt n/a % Clay n/a %

Ammonium 6.4 mg/kg

BS 10 %

Ca 7.3 % Mg 1.5 % Na <0.4 % K 1.2 %

TEC 19.5 meq/100g Na <20 ppm

Lime 3.8 T/ac Buffer pH 5.2 Est. N Release n/a

*Nitrate-N **Sulfate-S n/a = not analysed

RECOMMENDATIONS FOR BALANCED CROP NUTRITION

	Timber - Poplar					Native grass				
Macro-nutrients	Yield	N	P2O5	K2O	S	Yield	N	P2O5	K2O	S
Growing Condition		To be added (lbs/acre)				T/ac	To be added (lbs/acre)			
Excellent		90	52	75	18	4.7	79	40	77	19
Average		50	21	41	6	3.1	57	32	63	14
Your Goal						0.0				
Removal Rate (Seed/Total)						4.7	0 / 177	0 / 52	0 / 224	0 / 22
Micro-nutrients	Iron	Copper	Zinc	Boron	Manganese	Iron	Copper	Zinc	Boron	Manganese
To be added (lbs/ac)	n/a	n/a	n/a	n/a	n/a	0.0	0.0	0.0	2.0	0.0

Copper may be low for cereals in rotation.
Add Boron or try a test strip.
Magnesium %BS is low.

Comments:

-

Recommendations are based on general research consensus. They should not replace responsible judgement.

Bodycote Testing Group www.bodycote.com www.bodycotetesting.com
7217 Roper Road NW · Edmonton · AB · T6B 3J4 · Canada · Tel: +1 (780) 438-5522 · Fax: +1 (780) 438-0396

Bodycote TESTING GROUP

Farm Soil Analysis

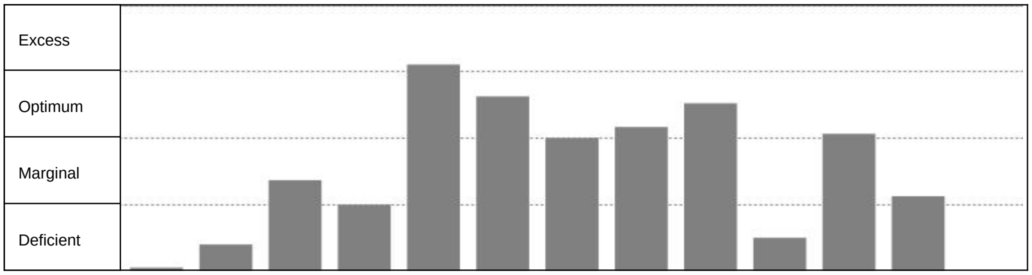
Bill To:	Altura Environmental Consulting	Grower Name:		Lot Number:	648610
Report To:	Altura Environmental Consulting	Client's Sample Id:		Report Number:	1160816
	PO Box 2004	Field Id:	VT-WR-01 SN	Date Received:	Oct 14, 2008
		Acres:		Disposal Date:	Nov 13, 2008
	Marsh Lake, YT., Canada	Legal Location:		Report Date:	Oct 17, 2008
	Y0B 1Y2	Last Crop:	Crop not provided	Arrival Condition:	
Agreement:	87827				

Nutrient analysis (ppm)

Depth	N*	P	K	S**	Ca	Mg	Fe	Cu	Zn	B	Mn	Cl	BiCarbP
0" - 3"	<1	6	102	2	1960	168	15.6	1.50	11.0	<0.2	5.11	4	

Soil Quality

pH	EC(dS/m)	OM(%)	Sample#
7.6	0.24	2.1	2869183



pH	EC	OM
Alkaline	*Very Toxic*	*High*
Neutral	*Toxic*	*Normal*
Acidic	*Caution*	*Low*
Very Acidic	*Good*	*Very Low*

	N*	P	K	S**
Total lbs/acre	1	6	103	2
Estimated lbs/acre	4	12	205	8

Texture *n/a* Hand Texture *n/a*

Sand n/a % Silt n/a % Clay n/a %

Ammonium <0.3 mg/kg

BS 100 %

Ca 85.6 % Mg 12.1 % Na <0.8 % K 2.3 %

TEC 11.4 meq/100g Na <20 ppm

Lime 0 T/ac Buffer pH Not Required Est. N Release n/a

*Nitrate-N **Sulfate-S n/a = not analysed

RECOMMENDATIONS FOR BALANCED CROP NUTRITION

	Timber - Poplar					Native grass				
Macro-nutrients	Yield	N	P2O5	K2O	S	Yield	N	P2O5	K2O	S
Growing Condition		To be added (lbs/acre)				T/ac	To be added (lbs/acre)			
Excellent		90	58	54	19	4.7	79	45	56	20
Average		50	27	18	7	3.1	58	37	41	14
Your Goal						0.0				
Removal Rate (Seed/Total)						4.7	0 / 178	0 / 52	0 / 225	0 / 22
Micro-nutrients	Iron	Copper	Zinc	Boron	Manganese	Iron	Copper	Zinc	Boron	Manganese
To be added (lbs/ac)	n/a	n/a	n/a	n/a	n/a	0.0	0.0	0.0	2.0	0.0

Parts of the field may be Iron deficient.
Add Boron or try a test strip.

Comments:

-

Recommendations are based on general research consensus. They should not replace responsible judgement.

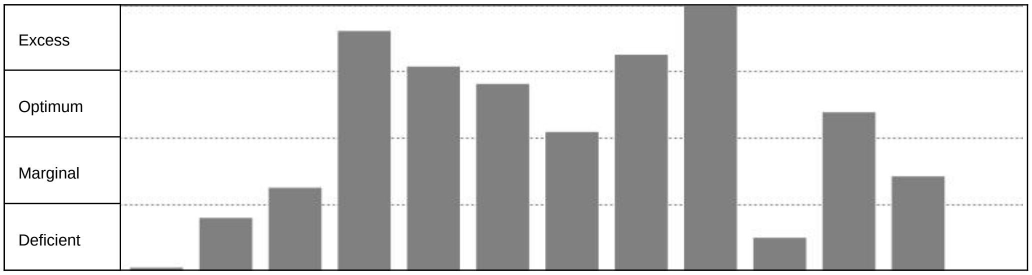
Bodycote TESTING GROUP

Farm Soil Analysis

Bill To:	Altura Environmental Consulting	Grower Name:		Lot Number:	648610
Report To:	Altura Environmental Consulting	Client's Sample Id:		Report Number:	1160817
	PO Box 2004	Field Id:	VT-WR-02 SN	Date Received:	Oct 14, 2008
		Acres:		Disposal Date:	Nov 13, 2008
	Marsh Lake, YT., Canada	Legal Location:		Report Date:	Oct 20, 2008
	Y0B 1Y2	Last Crop:	Crop not provided	Arrival Condition:	
Agreement:	87827				

Nutrient analysis (ppm)

Depth	N*	P	K	S**	Ca	Mg	Fe	Cu	Zn	B	Mn	Cl	BiCarbP
0" - 3"	<1	12	94	158	1690	210	103	29.3	260	<0.2	20.6	5.7	



Soil Quality

pH	EC(dS/m)	OM(%)	Sample#
7.0	0.69	0.4	2869184

pH	EC	OM
Alkaline	Very Toxic	High
➔ Neutral	Toxic	Normal
Acidic	Caution	Low
Very Acidic	➔ Good	➔ Very Low

	N*	P	K	S**
Total lbs/acre	1	12	94	158
Estimated lbs/acre	4	24	188	643

*Nitrate-N **Sulfate-S n/a = not analysed

Texture *n/a* Hand Texture *n/a*

Sand n/a % Silt n/a % Clay n/a %

Ammonium <0.3 mg/kg

BS 100 %

Ca 81.1 % Mg 16.6 % Na <0.8 % K 2.3 %

TEC 10.4 meq/100g Na <20 ppm

Lime 0 T/ac Buffer pH Not Required Est. N Release n/a

RECOMMENDATIONS FOR BALANCED CROP NUTRITION

	Timber - Poplar					Native grass				
Macro-nutrients	Yield	N	P2O5	K2O	S	Yield	N	P2O5	K2O	S
Growing Condition		To be added (lbs/acre)				T/ac	To be added (lbs/acre)			
Excellent		90	51	60	0	4.8	84	39	63	0
Average		50	20	25	0	3.1	63	31	49	0
Your Goal						0.0				
Removal Rate (Seed/Total)						4.8	0 / 179	0 / 52	0 / 227	0 / 22
Micro-nutrients	Iron	Copper	Zinc	Boron	Manganese	Iron	Copper	Zinc	Boron	Manganese
To be added (lbs/ac)	n/a	n/a	n/a	n/a	n/a	0.0	0.0	0.0	2.0	0.0

Zinc level may be toxic
Add Boron or try a test strip.

Comments:

-

Recommendations are based on general research consensus. They should not replace responsible judgement.