PIT SLOPE MANUAL

supplement 10-1

RECLAMATION BY VEGETATION

VOL 1 - Mine Waste Description and Case Histories

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PIT SLOPE PROJECT

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THE PIT SLOPE MANUAL

The Pit Slope Manual consists of ten chapters, published separately. Most chapters have supplements, also published separately. The ten chapters are:

1. Summary
2. Structural Geology
3. Mechanical Properties
4. Groundwater
5. Design
6. Mechanical Support
7. Perimeter Blasting
8. Monitoring
9. Waste Embankments
10. Environmental Planning

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SUMMARY

Reclamation of waste material is of increasing concern to mine operators, not only over the life of a mine, but also after closure. Establishing vegetation is one means of reclaiming waste to some state of acceptability. This supplement discusses considerations and problems associated with assessing the suitability of a particular waste material for supporting vegetation. The text is not designed to explain how to vegetate Canadian mine wastes, but rather how to assess the feasibility of vegetating them, how to know what to look for, and where to get information.

<u>Factors Affecting Vegetation</u>

Volume 1 of the supplement explains how the climate, waste properties, and microbial activity affect the establishment and growth of vegetation. Climatic factors of most concern are the length of the frost-free period and the distribution and quantity of precipitation. Climate varies not only across Canada as macro-climate, but also within a mining area as micro-climate that assists or hinders vegetation growth. The micro-climate can be altered to some degree by pre-planning of the waste area and by special surface treatment which will assist plant growth.

The most important physical properties of mine wastes are particle-size distribution and moisture availability. These properties can occasionally be altered, but more often must be understood and handled as well as possible to assist plant growth.

Chemical properties are numerous and vary between and within wastes. Mineralogy and acidity have the greatest affect on the establishment of vegetation. Weathering will affect both the physical texture of the waste as well as the solubility of nutrients and the reactivity of the mineral components. The ones which present the greatest problems are the iron sulphide compounds.

Microbial activity may not be present in wastes when deposited, but is an essential component of healthy soil development and plant growth. Frequently, adequate airborne microbes are available, but in many cases it is necessary to artificially introduce by innoculating the soil to ensure adequate activity.

These factors affecting vegetation are not a complete list, but are those which most frequently influence the establishment of vegetation on Canadian mine wastes.

<u>Types of Mine Wastes</u>

Three types of mine waste occur in Canada

- overburden, rock, and tailings. These three types indicate three groups of growth problems that result from the nature of the material and their method of disposal.

Overburden may consist of a variety of different materials resulting from stripping in open pit and other surface operations. The common problem in Eastern Canada with this form of waste is acidity, whereas in the prairies it is salinity and moisture stress. Mountain regions present a topographic and climatic problem in obtaining a suitable vegetation cover. Good growth can be obtained where selective removal and placement of the topsoil and subsoil have been carried out. The present practice of disposing of overburden demonstrates the need to bury difficult materials and preserve a suitable soil cover.

Rock wastes are devoid of organic matter and very little soil size material exists. This leads to severe moisture stress, except in high rainfall areas. Rock dump surfaces that have some soil size fractions because of vehicle movement have been vegetated with reasonable success. Sloped embankments, however, have remained a problem. In some areas, redesigning the rock dump has reduced the impact of the steep slopes of coarse rock, but this is difficult in mountainous regions.

The size characteristics of tailings often closely resemble a sandy soil. With these, erosion, flooding, and dehydration are very common, but the most difficult problems are chemical and occur when sulphide minerals are present. Establishment of vegetation has been successful on many non-sulphide tailings and on some low-sulphide tailings. Three methods have been used - covering the tailings with topsoil or glacial till with little or no treatment; direct seeding of the tailings after making the necessary soil amendments all in one year; direct seeding of treated tailings with continued maintenance treatment for 5 to 10 years to ensure a strongly established cover. All three methods have worked well in specific situations, but they are not always entirely applicable to all tailings.

Procedure for Vegetating

A procedure is described for examining a mine waste and determining its suitability to support a vegetative cover by using the information in this supplement. This involves first collecting data pertinent to plant growth which will assist in discussions with agriculturalists and biologists experienced in reclamation. The second stage is a technical evaluation of the collected data by personnel experienced in reclamation or biological sciences. This involves understanding the subtle implications and interactions that could occur between the waste, the environment, and the plants. Field trials of vegetation on the waste would give additional indications of the potential for vegetation and available alternatives. The third stage involves assessing the economic advantages and suitability of vegetation as a means of reclamation.

Case Histories

The case histories included in this supplement illustrate what has been tried in reclamation and the problems that have been encountered. Using a common data sheet, the mine wastes are compared as to characteristics and the means of establishing vegetation. Industrial and consulting or academic contacts are presented to assist in obtaining more information about particular case histories.

Satellite Imagery and Cross-Referencing Index

A survey of Canadian mine wastes was conducted using LANDSAT satellite imagery. Over 700 mine sites were examined and the results are included in Volume 2 of this supplement. The wastes are classified as overburden, rock, and tailings. The degree of vegetation cover on each site is estimated. This allows a more general view of conditions for reclamation by vegetation. It assists in locating areas not covered in the case histories, where contacts might be beneficial.

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D. Murray was responsible for the supplement on Reclamation by Vegetation; address enquiries to him at P.O. Box 100, Elliot Lake, Ontario, P5A 2J6.

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The sixty mines that provided access to their wastes for characterization and background information related to vegetation establishment are included as case histories and their assistance has made this inventory possible.

Special thanks should go to Hudson Bay Mining and Smelting Co. Ltd., Flin Flon, for detailed comments on the arrangement of information for effective use within industry.

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INTRODUCTION

1. The objective of reclaiming wastes by vegetation is to improve their appearance and long-term stability. The main difficulty is that most wastes are essentially hostile to plant growth. The problem of vegetating is particularly complex because no two wastes are alike and, as a result, general rules are difficult to formulate. At present, the best procedure is to appraise the characteristics of a particular waste, find out what reclamation has been attempted on similar material in the past, and to proceed by trial and error.

2. This supplement outlines the general principles of reclamation by vegetation and summarizes existing experience in Canada. The information is not intended to be complete but rather represents the state of the art in 1975. It is meant to provide a starting point to assist a mine staff in what is still a largely empirical practice.

3. The supplement begins with a description of factors affecting vegetation of mine wastes and discusses basic biology which the experienced biologist may choose to omit. This is followed by a classification and description of the principal mine wastes, using data from an extensive survey of Canadian mines, both operating and closed.

4. The most significant section describes how the information contained in the inventory – particularly recent experience – can best be used to assess the potential to support vegetation of a given site. Guidance on vegetation procedures for specific sites is not given. The establishment procedures for a given site can best be evaluated by studying practice at sites having similar characteristics. An extensive list of Canadian reclamation case histories is given.

FACTORS AFFECTING VEGETATION

5. The major factors affecting vegetation are climate, physical properties, chemical parameters, and microbial activity. These factors interact in complex ways; their degree of influence depends on the stage of plant development, soil development, species involved, and time of year.

6. This section deals with ways in which these factors can adversely affect vegetation, ie, the ways in which growth is reduced and prevented. For each, the method of evaluating the influence is described, together with the range of possible results and the appropriate effect on vegetation. Usual treatment for agricultural soils is included where possible. The information given is not comprehensive, but at least will assist the non-expert to understand the factors that affect vegetation.

CLIMATE

7. Climate can be divided into macro- and micro-climate. Knowledge of both is required to assess reclamation possibilities.

8. Macro-climate refers to the general environment of the region or area; data can be obtained from established meteorological stations, the Atlas of Canada, or from the generalized maps contained in Appendix A. Extremes as well as average conditions should be determined.

Knowledge of temperature and moisture conditions is useful for identifying regions of similar plant environment, and hence for determining suitability of vegetation species and agricultural techniques.

9. The range of climate in Canada is large, but most of the land area has a temperate climate with cold winters and warm summers.

10. Micro-climate concerns the immediate plant environment. Such data is required where regional data is obtained from locations far removed from the operating area, or where there is extreme variation in relief and topography.

11. The micro-climate is a significant factor affecting vegetation. It can limit plant growth substantially but may be altered to enhance vegetation.

12. The following components of climate are of prime concern:

Temperature

Frost-Free Period

13. The frost-free period is defined as the period between the last occurrence of 0°C in the spring and the first occurrence of 0°C in the fall. Both length of period and starting dates are significant, eg, the probability of a late frost in the spring would affect the choice of spring versus fall planting. The map in Appendix A indicates that the frost-free period within Canada varies from less than 50 to over 170 days based on 25-to 30-year records.

Growing Season

14. The growing season is the period between the first occurrence of a mean daily temperature of 5.5°C in the spring and the last occurrence of a mean daily temperature of 5.5°C in the fall, ie, the period during which vegetation will grow. To obtain the growing season length add approximately 30 days to the frost-free period. Both frost-free period and growing season length will influence the choice of species and planting time.

Growing Degree Days

15. Growing degree days are the sum of the difference between mean daily temperature and 5.5°C for each day that the mean daily temperature is above 5.5°C. For example: two days at a mean temperature of 25°C would provide (25 - 5.5) x (2) = 39 growing degree days. Plant metabolism is insignificant at temperatures below 5.5°C and this parameter therefore represents an empirical indication of potential plant growth.

16. Although growing degree days are not normally recorded for specific grasses and legumes they can be used to compare areas and to determine the potential crop production. This factor may influence choice of vegetation and time of planting.

17. These parameters are recorded primarily as macro-climate data, ie, as average values over a large area; however, local values may be significantly higher or lower. Macro-climate factors cannot be changed by man but micro-climate can be altered to assist plant establishment.

18. Temperature and precipitation can be used to predict plant stress. For example, a light snow cover with rapid fluctuation in temperature may cause winter-kill of sensitive species. An adequate snow cover provides a buffer against rapid soil temperature fluctuation, thus protecting plant roots.

19. Surface temperatures are also affected during the growing season by colour of the surface, soil moisture content and ground cover. Black surfaces may bake young plants or roots and thus injure them.

Precipitation

20. Detailed seasonal precipitation data is required for predicting severe moisture stress. Total precipitation includes both rain and snow, which in due course will melt and either run off or pass through the soil to recharge the groundwater. Rain and snow contribute roughly equally to total precipitation.

21. The amount and distribution of water affects nutrient movement in the soil and its use by the plant. Many fertilizers must be dissolved in water to become available to plants. If there is excess water, components may be leached from the root zone.

22. Heavy winter snowfalls can extend the

period of spring runoff and delay access for planting.

23. The water runoff and evaporation characteristics will be different for north- and south-facing slopes due to the angle of incidence of the sun's rays. This applies even when the slopes are relatively flat.

24. Control of runoff, seepage and evaporation of water from an area is one of the most important aspects in establishing vegetation.

Wind

25. Strong or consistent prevailing winds can lead to surface erosion and dehydration, and to sandblasting and lodging of plants. Wind is not always a problem, but could be injurious to seedlings when they are being established if not adequately protected. Young seedlings are particularly susceptible to removal by wind. Uniformly textured soils are most susceptible to erosion. Moisture content of the wind and its speed over the ground surface influence drought conditions. Low moisture content and high wind speed will increase evaporation and transpiration.

26. The ground surface must be stabilized until the planted species can form sufficient cover and root growth to resist the effect of erosion. Surface stabilizers, mulches, wind breaks, snow fences or strip cultivation can provide suitable protection. Selecting plants which grow rapidly or have superior tolerance to drought is one means of overcoming some adverse conditions. Preventing plant damage from sandblasting and wind effects can be minimized by commencing planting close to banks or in protected areas, and gradually extending the vegetative cover into more exposed and open areas.

PHYSICAL PROPERTIES

Texture

Particle-size Distribution

27. Particle-size distribution in a waste material is the relative amount by weight of the various sizes of particles. This parameter, one of the most important physical properties, affects water retention and movement, nutrient availability, pore space, slope stability, aeration and erosion susceptibility. In general, the most satisfactory method of presenting particle-size distribution data is by means of an accumulation curve. The common classes of particle size and size limits of the classes are as follows:

Effective diameter	Particle term
Greater than 25 cm	boulders
25 cm to 7.5 cm	cobbles
7.5 cm to 2 mm	gravels
2 mm to 0.05 mm	sands
0.05 mm to 0.002 mm	silts
Less than 0.002 mm	clays

Textural class will influence quality of the soil.

28. A wide range of particle sizes is necessary: clay for cation exchange capacity and moisture properties, silt for moisture properties, sand for porosity, and gravel for aeration. An excess of a particular particle size may adversely affect the physical and chemical properties required for growth.

29. The gravel fraction is removed in conventional agricultural soil analysis. All physical and chemical properties are determined on the minus 2 mm material. A soil moisture content of 20% in a sample sized at 90% over 2 mm would only represent a moisture content of about 2% in the total unseparated sample. Normally, sandy soils can be expected to include 70% sand, 20% silt and 10% clay.

30. Improving the size distribution is difficult. In some cases, material in the required size range can be added. Excess of coarse material can be corrected by crushing the waste, although this is unlikely to be economic. The proportion of fines in tailings can be altered by modifying the milling process. Similarly, alternative extraction methods and post-extraction pelletizing can change size distribution.

31. If size changes cannot readily be made, growth can sometimes be improved by irrigating or adding mulches. The benefits of any particular

approach must be assessed for each case.

Density

32. A particle density is the unit weight of the solid material in the waste, and is usually expressed in grams per cubic centimetre (g/cm^3). In this form, particle density has the same numeric value as specific gravity, which is the ratio of the density of the solids to that of water. Bulk density is the total weight per unit volume of waste material, ie, including the volume of pores filled by air and water and including the weight of water.

33. Comparing bulk density and particle density reveals the degree of compaction or cementation in the soil. The closer the values, the greater the compaction. At high bulk densities approaching particle density, roots are unable to penetrate the ground. Such dense material normally occurs in layers and is called hardpan.

34. Normal soil has a particle density of about 2.65 g/cm^3 and a bulk density of about 1.5 g/cm^3. Bulk density can be reduced by adding mulch and in some cases by "working" the soil to reduce compaction.

Porosity

35. Soils contain a variable percentage of voids or pores which are occupied either by air or by water. Small pores are better able to retain water than large pores.

36. Soil aggregation depends on porosity and the presence of both large and small pores for air and water transfer within the soil.

37. Porosity is calculated from the bulk density and particle density measurements using the formula:

$$\text{porosity} = \frac{100(D_p - D_b)}{D_p}$$

where D_b = bulk density
D_p = particle density

38. Moisture content of unsaturated soils - ie, above the groundwater table - varies between two limits. The upper limit is the maximum amount of water that can be held in the pores by surface tension against the pull of gravity (field capacity). Water in excess of this limit draws away. The lower limit is the water trapped by individual soil particles; this water is normally not released by the soil and therefore cannot be used by plants (wilting point). The difference between the moisture contents at these two limits is known as the plant-available moisture.

39. The water content of soil is typically measured at a range of pressures from 0.1 to 15 bar, usually using pressure plate apparatus. Field capacity is defined for soils as the measurement at 0.3 bar and the wilting point is defined as that at 15 bar. For mine tailings the measurement at 0.1 bar is a better indication of field capacity.

40. Average sandy soil has an available moisture content of about 6%, while soils with high organic contents would normally be in the 17 to 20% range.

41. Water assists in transporting nutrients from soil to the plant. With excessive drainage, dissolved nutrients are washed from the soil root zone. With no drainage, anaerobic conditions may occur and restrict non-aquatic plant life.

42. Climatic conditions and vegetation type play a major role in establishing the necessary available moisture level. The level must be sufficient to meet evapotranspiration demands between rain periods.

43. Where available moistures are insufficient to meet this demand, mulches become necessary to reduce evaporation losses and the choice of vegetation becomes important to reduce transpirational demands.

Colour

44. Soil colour is important as it affects absorption and reflection of solar radiation, and indicates chemical changes in the waste material. The colour of a material governs the amount of light the material will absorb or reflect. Although standard colour comparison charts are available, colour data in this supplement has been indicated only in general categories. Dark

coloured materials may cause excessive absorption and elevated micro-climate temperatures. Light coloured surfaces may cause excessive radiation which would be detrimental to seedling growth.

45. Use of mulches is the usual way to correct adverse soil colours.

CHEMICAL PARAMETERS

Cation Exchange Capacity

46. Cation exchange capacity (CEC) is a measure of the negatively charged sites that can retain positively charged chemical elements in the soil, many of which are important for plant nutrition. The ammonium acetate method described by Black (1) is the most common for determining CEC. Cation exchange capacity is thus an indirect measure of the surface area available for water and nutrient retention. Not only capacity, but also composition of the chemical elements absorbed are important. This will influence ability of the soil to buffer or resist any changes in pH, consequently affecting lime requirements and the availability of nutrient elements absorbed on exchange sites.

47. A normal sandy soil has a CEC of about 6 meq/100 g. The CEC for clay-sized fraction and organic material may be as high as 300 meq/100 g. The addition of either of these materials to a soil can significantly alter the CEC of the soil.

Acidity and pH

48. Acidity of a material has three forms - active, reserve and potential. The active acidity is estimated by measuring the pH of a soil-water mixture and indicates the hydrogen ion activity in a suspension.

49. Reserve acidity is often referred to as the buffering capacity and sometimes as free or titratable acidity. Acids and bases are found on the surfaces of any material, and if some of the acids are released, then more from the surface become available. This also applies to bases. Buffering capacity is important in determining the amount of neutralizing agent required to correct an undesirable pH level and to assist nutrient availability.

50. Potential acidity, especially in mine wastes, may be referred to as oxidizable acidity. A mine waste may contain chemical elements such as sulphides in the reduced state. On exposure to oxidizing conditions in the environment, the reduced element oxidizes, and in the case of sulphide forms sulphuric acid. Although all three forms of acidity are important, it is the potential acidity which causes most problems and is most difficult to predict and control at present.

51. Average natural soils would be expected to possess a pH of between 5 and 7; pH outside this range affect plant growth. Soils below a pH of 3 and above 9 are likely to have serious plant growth problems.

52. Acid soils - those with a pH of less than 6 - are traditionally treated by applying limestone, lime or other basic material, or a combination of these. Alkaline pH can be corrected by leaching or by treating with acid or acid-generating material, eg, with sulphur, sulphide materials, or peat moss.

53. Extreme acidity or alkalinity can directly damage plant tissue. At less than extreme values, adverse conditions are attributed to the various chemical reactions that complex plant nutrients and make them unavailable to plants, or which dissolve toxic materials and make them available to plants in excessive amounts. Extremes of pH influence the level of soluble salts and otherwise contribute indirectly to unsatisfactory plant growth.

Available Nutrients

54. Measuring plant-available nutrients is important. This is done by using a chemical extractant that will approximate the ability of a plant to extract nutrients from a soil.

55. Even in the relatively uniform requirements of agriculture and forestry, there are regional differences in the use of extracting agents for available nutrients. Choosing a procedure and extracting agent for mine wastes is even more difficult. Many nutrients are necessary for satisfactory plant growth. Some however are of more significance than others because they are

needed in large amounts. Nutrients are therefore divided into two groups - macro-nutrients and micro-nutrients.

56. The presence of both macro- and micro-nutrients is essential for strong vegetative growth. Macro-nutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg).

57. Soil reactions, such as those of free iron and aluminum with available phosphorus, result in varying proportions of these elements being complexed and unavailable for plant utilization. Detailed determination and experimentation is required to indicate overall soil nutrient balances. However, some indication of probable nutrient deficiency is possible from a preliminary examination.

Toxicity

58. Although many elements are essential for plant growth, an excess is often poisonous. This is particularly true of micro-nutrients, but excess macro-nutrients can also be toxic. Different plants tolerate different levels of nutrient concentrations in the soil. If one particular element is likely to occur dissolved in high concentrations, then attention should be focussed on that element as being potentially toxic.

59. Literature describing the range of various elements found for different species of plants, indicating deficiency and toxicity is available (2,3,4,5). The values given however, are not necessarily relevant to other areas or crops; this subject is still under study in agricultural laboratories.

60. Commercial fertilizers or natural materials are traditionally used to correct soil nutrient deficiencies. The amount and type to add can be determined from a soil analysis. Alternatively, nutrients can be applied to the soil based only on a knowledge of plant requirements.

Electrical Conductivity and Soluble Salts

61. Electrical conductivity is a measure of the salt content of a soil suspension and is therefore an indirect measure of the osmotic pressure that plant roots must overcome for the plant to take up water and nutrients.

62. Soils with an electrical conductance greater than 4 mmhos/cm are considered saline and are usually unsatisfactory without such treatment as leaching or deep ploughing to lower the concentration of soluble constituents. Some plant species may assist in treating difficult areas by tolerating salt concentrations higher than 4 mmhos/cm. Soils can be made saline by adding too much fertilizer and care should be taken to guard against this.

63. Soluble salts are a measure of the chemical elements in the soil. Some elements are more toxic to plant growth than others, eg, sodium is more toxic than potassium at the same concentration. Thus the type of soluble element is important in assessing waste material as a plant growth medium.

Organic Matter

64. The content of organic matter (OM) is of vital importance as it affects not only the nutrient absorptive capacity (cation exchange capacity), water retention and release, but also bulk density, porosity, air and water movement, and soil structure. Organic matter is usually estimated by determining organic carbon. Care is required, however, with wastes containing sulphide because determining carbon content by combustion can give erroneous results.

65. Ideally, soils should contain greater than 5% by weight of organic matter. If none is present, it should be added or grown and permitted to contribute to the soil development process. When adding organic matter, the ratio of carbon to nitrogen (C:N ratio) should not be greater than 25:1. The nitrogen is needed for microbial decomposition of the OM. Additional nitrogen can be added as required.

Mineralogy

66. The mineralogical composition of any soil is exceedingly important because it dictates many characteristics of that soil as it develops and matures. The process of change of these minerals with time is called weathering. This weathering is both physical and chemical. The mineral make-

up of the parent material will affect the rate and degree of physical breakdown and the ultimate particle size distribution. This ultimately affects vegetation by influencing erodibility, moisture retention and compaction of the soil.

67. Chemical weathering is more complex and can influence soil and vegetation treatment directly or indirectly. As the ore weathers, individual mineral components such as Cu, Zn, Fe. etc, are released into the soil for contact with plants. The amounts released may be beneficial to plants but could be too highly concentrated and cause injury to plant tissue. Indirectly the ore may have the potential to oxidize sulphides such as pyrite and pyrrohotite to form sulphuric acid. If not buffered by other soil minerals this acid will change the pH. This change would then alter the concentration and availability of plant nutrients.

68. Potential problems such as this could be predicted from the minerals present in the young soil.

MICROBIAL ACTIVITY

69. The normal microbes in soil can be subdivided into four distinct groups. The first consists of heterotrophic bacteria which require organic carbon and most of which prefer to grow aerobically. However, the majority of organisms in this group are capable of anaerobic growth.

70. The second group comprises the fungi. These can range from unicellular organisms to the multi-cellular mushroom and most are capable of cellulose and lignin decomposition. Generally, fungi prefer a more acidic environment than the heterotrophic bacteria.

71. The third group is made up of the actinomycetes which possess characteristics of both the bacteria and the fungi, but are generally considered to be filamentous bacteria. Most actinomycetes are heterotrophs which utilize a wide variety of organic compounds and are noted for their ability to degrade humus.

72. The fourth group, the photoautotrophic algae, synthesize their cellular carbon from CO_2 and use light as an energy source. Algae are the least numerous group of micro-organisms in the soil. They are poorly adapted to heterotrophy, but do contribute a small proportion of the organic content of soil.

73. In general, the decomposition of organic matter involves a succession of reactions encompassing all groups of micro-organisms. Initially, any soluble plant products such as sugars, amino acids, and starch are used by the heterotrophic bacteria to synthesize new cellular material. In this process the bacteria multiply. During the metabolism of these products, the bacteria release organic acids into their micro-environments and, as the soluble nutrients are depleted, their numbers stabilize. The release of the organic acids lowers the pH, stimulating growth of the fungi which decompose the plant cellulose to soluble sugars which can be utilized by bacteria, fungi, actinomycetes and growing plants. The release of these sugars results in a stimulation of the bacteria which decompose the lipid portions of the plant producing short-chain fatty acids and CO_2 which are then available to other flora. The final step in the degradation of organic material is the decomposition of the humus by the actinomycetes.

74. Throughout the whole process, organically bound inorganic constituents are being released in a reduced form. On release, these are oxidized once again to become available for assimilation and incorporation into plant material.

75. Another important aspect of microbial activity during organic degradation is the accompanying leaching and weathering of inorganic metabolites from mineral particles by the organic acids released during metabolism of the sugars. These are then made available for subsequent microbial and plant growth. In addition, the polysaccharide and mucin capsular material of the bacteria and the mycelial growth of the fungi tend to bind soil particles together, increasing soil structure and making it more suitable for plant growth.

76. It is necessary to determine the presence and activity of cellulose-degrading and non-symbiotic nitrogen-fixing organisms. These are

essential links in the degradation process of plant material. It is as important to ensure the presence of these processes which will influence the self-sustaining ability of vegetation as it is to have correct procedures for the initial vegetation establishment.

77. From current literature it appears that once a suitable soil material or organic substrate is produced, soil organisms rapidly invade the site. The determination of whether a suitable soil exists is very critical with mine wastes, especially with tailings. The four groups of organisms can be expected to appear in the concentrations shown in the following table:

Organism	Organisms/gm dw of soil
Bacteria	$10^5 - 10^7$
Fungi	$10^2 - 10^4$
Actinomycetes	$10^1 - 10^2$
Algae	10^2

TYPES OF MINE WASTE

WASTE INVENTORY

78. Many types of mining waste are found in Canada and their inventory forms an important part of this supplement. Data collection involved two steps. First, an overview of all Canadian wastes was carried out through satellite imagery, forming the basis of an index of both mines and wastes which is contained in Volume 2 of this supplement. Second, a detailed study of sixty representative mine sites and their wastes was used to form detailed case histories, given in Appendix B of Volume 1.

79. The detailed investigation and characterization showed that wastes fall broadly into three categories: overburden, rock, and tailings.

80. Identifying a waste in one of these categories allows broad characteristics and vegetation procedures to be identified. However, it must be realized that all wastes are different and to some degree will require unique treatment.

81. In the inventory, each type of waste is described and distinctive characteristics are outlined. Common problems with the waste and the methods used for reclamation are described in the case histories.

Satellite Imagery and Cross-referencing Index

82. Results of satellite imagery studies are given in two parts in Volume 2. The first part is a cross-referenced index of wastes observed through satellite images. This provides an overview of the extent and location of mine wastes in Canada. The index permits rapid location of areas where at least some reclamation has been done. The waste type, commodity produced, and location are reported, as well as extent of vegetative cover on the waste.

83. The second part consists of topographic maps showing waste locations with more detail of the degree of vegetative cover and proximity to other wastes and communities.

Case Histories

84. Data from each mine waste studied are reported on a standard data sheet as in Appendix B. This enables a rapid comparison to be made of waste properties and gives the extent of any reclamation undertaken. The individual sheets are listed according to waste type, commodity produced and location. Individuals to contact for more information are identified.

85. Information is reproduced from reports submitted by contractors responsible for the work. They are listed as "source" on the data sheets. Reporting dates are noted.

86. An index of case histories is provided in addition to a map indicating areas surveyed.

87. Blank data sheets are provided for compilation of the user's own data.

OVERBURDEN

Description

88. Overburden is defined as the unconsolidated material that must be removed to expose the bedrock or orebody. Overburden consists of two components; pedogenic soil and surficial deposits. Pedogenic soil (topsoil) has undergone oxidation and weathering. Vegetation has grown on this material and a layered structure has developed. A surficial deposit (subsoil) is virgin material that is not presently undergoing weathering and oxidation. Little or no organic matter is present and the material has not supported plant growth. Both components of overburden occur at variable depths and thicknesses.

89. Overburden is excavated by dragline, scraper, or other earth moving equipment, transported, and dumped. Blasting is not normally required to loosen overburden although ripping is common.

90. Three disposal configurations are present: ridge, cone, and long slope, Fig 1. The method of disposal will affect the properties of the waste. For example, some methods preserve the overburden components as separate units while others mix the material. The bulk of overburden removal occurs in quarrying and open-pit coal mining.

91. Topsoil is normally about one metre thick, but may range from a few centimetres to several metres. The topsoil is in a steady state with the climate, vegetation and other environmental factors. It is generally more oxidized, more weathered, more acidic, richer in organic matter and has a more developed structure, than the underlying subsoil. Biological activity, plant root growth and organic matter decay normally take place in the topsoil.

92. Subsoil is less leached and oxidized and contains less organic matter. However, it has been affected by transporting agents, and is thus in partial equilibrium with its environment. The effect of climate and vegetation decreases with depth. The subsoil has received salts and dissolved minerals leached from the overlying topsoil. The depth of influence is governed by the soil drainage characteristics.

93. Mean characteristics of Canadian overburdens are shown in Table 1.

Common Problems

94. Plant-available nutrient levels are low and organic matter is frequently lacking. Acidic overburden is most common in the Maritimes. Two related characteristics are of equal concern - soil texture and salinity. Although not obvious from Table 1, salinity is a consistent problem in prairie regions. The interaction between texture and salinity is affected by climate. Climate is of most concern in some areas of the mountainous regions of Alberta and British Columbia because of unsuitablity of the environment for any plant growth.

Reclamation Practice

95. The natural characteristics of overburden can be preserved if suitably handled. Poor handling practice, however, has resulted in many overburden dumps which are extremely difficult to vegetate. Some of the disposal methods such as conical dumping which have resulted in poor conditions are rarely if ever used.

96. Overburden is the least complex waste to vegetate provided topsoil is kept at the surface. Fertilizer applied at the time of seeding is beneficial, but subsequent treatment depends on suitability of the soil. Grading and surface scarification to provide an adequate slope and loose surface is sometimes necessary with the extent depending on the desired vegetative cover.

97. Overburden wastes may resemble any soil. Surface characteristics of the waste material are related to that portion of the soil profile or overburden which is placed at the surface. The

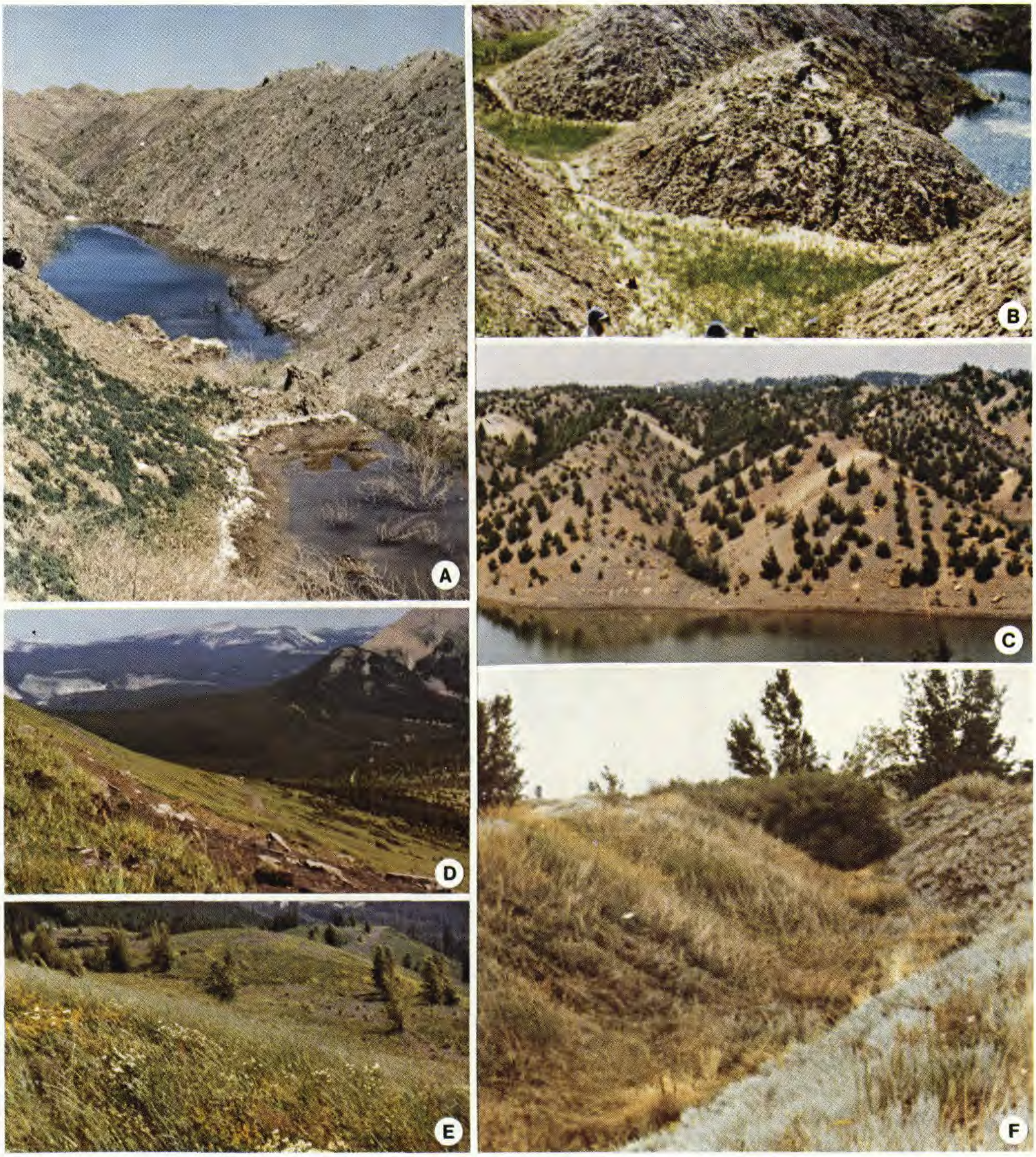

Fig 1 - Overburden Disposal: A - Ridged disposal and salinity problems; B - conical disposal with surface erosion and volunteer growth in valley bottom; C - reforestation of ungraded spoils, ridges at water line show large fluctuations in surface water levels; D - high altitude reclamation difficulties above the tree line; E - herbacious species seeded on regraded overburden; F - natural vegetation showing the influence of northern and southern aspects on species and ground cover.

Table 1: Characteristics of overburden

Property		Mean	Range	No.*
Particle size distribution	% <2 mm	38	8 - 95	91
	% sand	61	20 - 93	101
	% silt	32	6 - 76	102
	% clay	11	1 - 37	58
Moisture retention	0.1 bar %	25	7 - 12	102
	0.3 bar %	21	9 - 33	100
	15 bar %	9	2 - 19	100
Available water storage capacity	%	12	5 - 19	92
Bulk density	g/cm^3	1.42	1.10 - 1.99	86
Particle density	g/cm^3	2.27	1.40 - 2.90	89
pH	water	5.6	3.1 - 8.1	94
Cation exchange capacity	meq/100 g	16	1 - 118	92
Organic matter	%	4.4	0.3 - 6.6	27
Electrical conductivity	mmhos/cm	0.7	0.1 - 3.1	90
Available elements	P ppm	7.3	0.2 - 23	31
	K ppm	70	15 - 595	74
	Ca ppm	8950	60 - 66,000	70
	Mg ppm	175	10 - 566	74
Total analysis	N %	0.17	0.01 - 0.87	85
	S %	1.40	0.34 - 7.96	38
	Fe %	4.1	1.4 - 11.7	38
	Al %	8.0	1.3 - 11.0	40
	Ca %	1.99	0.09 - 16.62	38
	Mg %	1.0	0.20 - 2.63	38
	Na %	0.37	0.11 - 1.48	38
	K %	1.92	0.81 - 2.86	38
	Mn %	0.1	0.02 - 0.22	38
	Si %	25	7 - 30	40
	Ti ppm	6500	2900 - 9800	40

* Number of observations from 8 mine waste sites

amount of disturbance and erosion following placement will also have effects.

98. The stockpiling of topsoil and subsoil should be encouraged. The location of the stockpiles should be in areas where potential erosion is minimal. If the mine is expected to have a long life, the stockpile could be vegetated to prevent wind and water erosion. When mining ceases, the stockpiled soils could be placed over waste rock, tailings or poor subsoil.

99. Site-specific studies on soil profiles have been valuable in areas of potentially high saline and sodic soils. A knowledge of overburden stratification is essential if excavation and disposal of waste is to be planned to conserve the valuable strata.

100. Although overburden presents no major problems to vegetative growth, surface mulches, fertilizer or irrigation may still be required. Coarse-textured overburden may require mulches and

irrigation to overcome climatic stress or low water holding capacity of the soil materials. Irrigation must conform to the climate, eg, vegetation should not be allowed to become totally dependent on irrigation for moisture. Climatically suited vegetative species should be used for initial establishment. In general, this means grass-legume mixtures which tend to favour rapid soil development and therefore produce better growth conditions. In many instances, seed mixtures have consisted of 6 to 15 species at high application rates.

ROCK

Description

101. Waste rock is material other than overburden of no present economic value that must be removed to excavate the ore. It is occasionally stockpiled if recovery of contained minerals is expected to become economic in the future.

102. Waste rock is normally subjected to blasting, loading, hauling and dumping. The common practice in Canada is to end-dump rock to form piles with flat tops and steep slopes at the natural angle of repose. The regional topography affects the length of the slope. In mountainous regions, large slopes occur into valleys; on flat ground a shorter slope occurs as shown in Fig 2. Terracing with 6 to 15-m lifts is practised occasionally. The level portion of the dump may have soil-sized particles present as a fine textured surface with rock size increasing with distance down the slope. Rock wastes usually have only a small amount of soil-sized material at the surface. Open pit mining other than coal mines or rock quarries produces the bulk of the rock waste in Canada.

103. The properties of rock waste depend on mineralogy of the material and extent of handling or travel over the pile surface. Table 2 gives mean properties of waste rock.

Common Problems

104. Waste rock is more homogeneous than overburden with respect to physical properties such as particle-size distribution, water retention, bulk density and porosity. When dumped, waste rock tends to be coarse with abundant boulders and little soil-sized material (less than 2 mm). Weathering and truck travel on the surface of the rock dump may change this. The percentage of soil-sized particles ranges from 9 to 77% on the dump surface to 0% on slopes. The lack of soil-sized particles indicates low moisture retention. Because of this, drainage through the waste is rapid, there is little available water, and chemical properties of the wastes are affected by leaching Void size increases with depth below surface in the waste and with distance from the crest.

105. Rock wastes, therefore, present extreme problems in particle size distribution and moisture availability. They contain some soil-sized particles, but insufficient to provide adequate water storage. Vegetation is very dependent on rain throughout the growing season.

106. Waste rock is not entirely without plant nutrients. The oxidation process of weathering releases nutrients, but leaching removes them rapidly from the surface. Supply of available nutrients is therefore low.

107. Organic matter content is generally low and consequently very little microbial life exists.

108. Acidity is not usually a problem except in dumps containing sulphides. Chemical properties do not restrict the vegetating of the waste. The physical characteristics compounded by the large, coarse, steep slopes produced by current disposal methods present more difficult problems for plant growth than the chemical properties.

Reclamation Practice

109. Rock dump slopes are rarely graded to more gradual grades and terracing of long slopes is only occasionally practised. On these slopes virtually no soil-sized fraction exists and no vegetative growth is possible. To compensate for this, tall trees and bushes have been used to screen the area from public view. This is most effective on regularly terraced slopes.

110. On short slopes the voids between the coarse rocks have sometimes been filled with

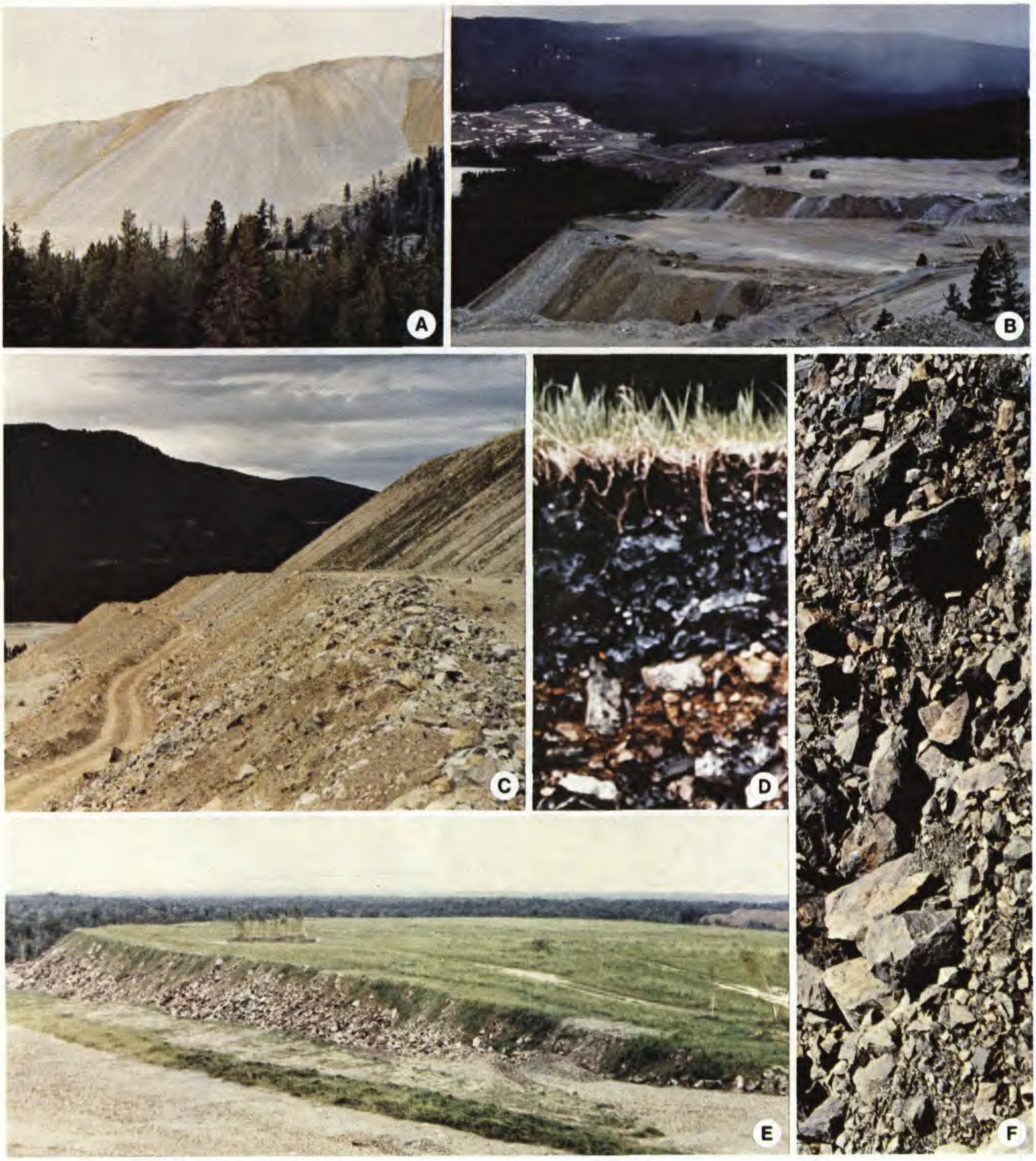

Fig 2 - Rock Disposal: A - long slopes at the angle of repose; B - dump surface is compacted and small in comparison to the slopes; C - terracing of rock wastes makes reclamation treatment easier; D - root penetration is slight because of lack of soil size material; E - surface is vegetated but coarse slopes are not; F - coarse texture lacking soil size material.

Table 2: Characteristics of waste rock

Property		Mean	Range	No.*
Particle size distribution	% <2 mm	24	10 - 78	67
	% sand	70	35 - 99	68
	% silt	24	9 - 39	57
	% clay	10	1 - 29	57
Moisture retention	0.1 bar %	15	4 - 28	42
	0.3 bar %	12	3 - 22	41
	15 bar %	5	0 - 11	41
Available water storage capacity	%	9	3 - 17	41
Bulk density	g/cm³	2.04	1.19 - 3.02	39
Particle density	g/cm³	2.73	2.05 - 3.06	25
pH	water	7.7	3.5 - 9.4	80
Cation exchange capacity	meq/100 g	11.4	0.3 - 32.4	80
Organic matter	%	2.5	0.1 - 19.5	69
Electrical conductivity	mmhos/cm	0.9	0.3 - 3.5	47
Available elements	P ppm	4.4	0 - 33.4	80
	K ppm	85	4 - 193	69
	Ca ppm	14,900	1540 - 45,500	69
	Mg ppm	260	15 - 1186	69
Total analysis	N %	0.01	0 - 0.12	76
	S %	0.04	0 - 0.15	3B
	Fe %	7	1 - 50	24
	Al %	6.2	0.1 - 13.2	26
	Mn %	0.12	0.01 - 0.32	26
	K %	1.09	0.01 - 2.97	19
	Na %	1.29	0.01 - 2.75	27
	Mg %	4.3	0.01 - 36	27
	Ca %	4.5	0.01 - 35	27
	Cd ppm	175	1 - 620	27
	Zn ppm	15	2 - 30	18
	Ti ppm	8500	500 - 50,000	18
	Ni ppm	85	20 - 250	13
	Mo ppm	136	10 - 450	10
	Co ppm	150	10 - 300	10

* Number of observations from 11 mine waste sites

soil-sized material. This has worked well, but on long slopes is impractical although there is no alternative method. There is scope for investigating other layouts of rock dumps which may better lend themselves to development of the needed soil-like layer at the dump surface.

111. Slope length should be minimized by terracing. If overburden is in limited supply it should only be used on outslopes since soil-sized particles will be most lacking in that region.

112. Surface compaction at the top of rock dumps is very common and some scarification will be needed to permit plant establishment. Shade provided by coarse rock on the dump surface sometimes is beneficial for seedling growth. The ridges or pockets capture seeds and wind-blown

fines. They provide shade from the sun and protection from wind while seedlings become established.

113. The poor moisture-retention in rock dumps means growth is dependent on rainfall. Vegetation should be chosen to suit the amount and seasonal distribution of rain. Irrigation, mulching or avoiding southern exposure will assist in reducing moisture loss. If irrigation is employed, care should be taken to avoid leaching of nutrients and washing away fines from the potential root zone.

114. Mineralogy and structure of the host rock will be useful in indicating how easily it will weather and break down into soil-sized particles. For example, some sedimentary rocks are easily weathered. If this is likely to occur within one or two years, reclamation may be delayed to take advantage of the additional soil-sized particles.

115. Sulphide waste rock, with a high potential for oxidation, has so far not been successfully vegetated. Burial is the only practice at present used to handle this material. Waste rock containing up to 1 - 2% total sulphide-sulphur may be neutralized by adding lime or limestone.

116. Nutrients are limited. Nitrogen, and to a lesser extent phosphorus, must be included in waste rock fertilization. Other nutrients are usually barely adequate to sustain growth.

117. Increasing the fines fraction of the waste rock sufficiently will offset problems of moisture retention. Waste rock dumps have been capped with material more amenable to growth although there are no documented instances. Over the long term, fine material in the capping may be eroded and work its way downwards to the rock dump and out of the vegetation root zone if a sufficiently stable plant cover is not established to hold the particles together at the surface of the dump.

118. In high precipitation areas, hydro-mulching and hydro-seeding has led to successful vegetation of rock-fill highway slopes. Although not widely tested on mining rock dumps, this method has potential applications. Agricultural planting techniques can only be used on slopes up to 15° - 20°. Slopes steeper than this should be avoided as they require more expensive aerial or hydro-spray methods of seeding.

119. Waste rock dumps have a high proportion of total exposed surface area occurring as slopes. An appropriate technique may be to terrace the slopes, and vegetate only the resulting horizontal surfaces using plants that will grow to a sufficient height to screen sloping surfaces from public view. Little work has been done on seeding of rock dumps or on the design and planning of dumps with respect to vegetation.

TAILINGS

Description

120. Tailings are waste products arising from grinding and treatment with chemicals to extract the desired minerals. Usually more than 90% of the original ore remains as tailings after the milling process.

121. Tailings are normally handled as a water slurry which is transported and deposited by natural settling. Asbestos tailings are an exception, being transported by conveyor belt in the dry state and placed in conical piles. The two basic disposal methods in Canada are into an artificial pond - usually created by damming - and into a natural waterbody (Fig 3).

122. Disposal into a pond results in the solids settling out and becoming segregated according to size. The coarse fractions settle near the deposition spigotting point, and the finer fractions are carried progressively further towards the discharge decant point of the tailings area. There is often a distinct boundary between coarse and fine fractions. The typical tailings pond is saucer-shaped in section with a single decant point.

123. Dams are constructed of waste rock, borrow material or tailings. They may be built across a valley, or completely around the pond perimeter depending on local topography.

124. Only a small portion, if any, of the tailings remains above water when dumped into a waterbody.

125. Tailings ponds can be classified as:

a. a pond with no significant variation of texture,

b. a pond with distinct areas of fine and coarse

Fig 3 - Tailings Disposal: A - dark surface typically subject to scorching; B - seepage causing stability problems, white colour reflects light and damages plants; C - debris resulting from flooding; D - vegetation may help surface stability but does not prevent deep-seated slides; E - fine material contributes to dewatering problems; F - organized seeding of entire section of tailings reduces wind erosion; G - chemically reactive waste.

tailings, or

c. a pond with horizontal layers of distinctly different fractions throughout the whole area.

126. Type a., the uniform texture, usually results from disposal into a water body; the texture can be coarse or fine. Coarse tailings are susceptible to wind erosion when dry. Drainage is very rapid causing surface leaching and water stress conditions. Ability to move equipment on the surface of tailings may depend on moisture content.

127. Properties of tailings are shown in Table 3. Asbestos tailings are distinctly different and are described separately.

Table 3: Characteristics of tailings

Property		Mean	Range	No.*
Particle size distribution	% <2 mm	95	20 - 100	148
	% sand	51	1 - 97	196
	% silt	43	0 - 96	195
	% clay	7	0 - 40	183
Moisture retention	0.1 bar %	22	0 - 55	138
	0.3 bar %	18	0 - 55	216
	15 bar %	4	0 - 20	215
Available water storage capacity	%	16	0 - 35	128
Bulk density	g/cm³	1.5	0.2 - 3.1	191
Particle density	g/cm³	2.91	0.01 - 4.29	310
pH	water	6.2	1.8 - 9.4	224
Cation exchange capacity	meq/100 g	2.63	0.19 - 46.5	206
Organic matter	%	2	0.02 - 25	224
Electrical conductivity	mmhos/cm	2	0.1 - 22.4	138
Available elements	P ppm	10	0.1 - 400	271
	K ppm	63	1 - 564	84
	Ca ppm	11,930	40 - 52,480	84
	Mg ppm	230	15 - 1328	84
Total analysis	N %	0.013	0.001 - 0.166	170
	S %	4.02	0.01 - 38.87	237
	Fe %	15.5	0.4 - 56.81	202
	Al %	2.8	0.1 - 8.1	61
	Ca %	1.7	0.01 - 10.95	162
	Mg %	1.2	0.04 - 5.0	164
	Na %	0.5	0.01 - 2.9	61
	K %	0.7	0.04 - 3.32	137
	Mn %	0.2	0.01 - 4.0	167
	Si %	22	4 - 37	134
	Cd ppm	38	2 - 280	115
	Cr ppm	1000	70 - 7000	31
	Co ppm	1140	100 - 9999	39
	Mo ppm	70	10 - 800	28
	Ni ppm	96	10 - 546	132
	Pb ppm	340	0.3 - 2810	139
	Ti ppm	2500	200 - 10,000	44
	Zn ppm	510	1 - 5000	149
	Cu ppm	130	1 - 750	164

*Number of observations from 43 mine waste sites

128. Asbestos tailings contain fibrous instead of granular material, and thus exhibit unique moisture retention and water movement characteristics. These wastes are unique in being disposed of dry in conical piles. They are described in a case history in Appendix B.

Common Problems

129. The range of tailings properties shown in Table 3 is large and as a result this category of waste is complex and difficult to describe. However some characteristics are virtually the same for all tailings, ie, per cent clay size material, water retention, bulk density, pH, organic matter content, and total nitrogen content. Analytical efforts usually need not be directed at these parameters.

130. Particle size of tailings is mainly less than 2 mm. The particles are angular or smooth depending on the milling process used and the rock type.

131. A useful particle size description is as follows:

- coarse tailings - at least 60% of the material in the sand-size range
- medium tailings - between 20% and 60% of the material in the sand-size range
- fine tailings or slimes - less than 20% of the material in the sand-size range.

132. Data in Table 3 applies to settled tailings, typical of material to be vegetated, rather than of fresh mill discharge.

133. Fine tailings can be expected to shrink and crack on drying, but do not have the elastic properties of clay. They must be considered as very fine silts.

134. Underground mines often use the coarse fraction of tailings as backfill, leaving only the fines for surface disposal. The clay-size particles are less susceptible to wind erosion than coarse tailings because of their high affinity for water. Fine tailings are therefore difficult to dewater. Travelling and working on their surface will require special care. Surface and sub-surface crusts may form and restrict root penetration. This crust formation is most common with high-sulphide wastes. Tailings with high moisture content need special attention since flooding and poor aeration are likely to occur giving a thixotropic condition.

135. Coarse fractions are susceptible to wind and water erosion because of the uniformity of particle size. Erosion of slopes is usually readily apparent. Erosion of flat surfaces, called sheet erosion, however, is not always as noticeable but can be equally as devastating to plant establishment.

136. The layering of different size fractions causes irregular water movement within the tailings with consequent problems, eg, perched water tables which may flood roots and hamper growth.

137. Bulk density and specific gravity do not appreciably vary beyond normal soil values, but occasionally where compacted layers occur, bulk density values have been over 3 g/cm^3.

138. The colour of most tailings when deposited is gray to brown. High-quartz tailings bleach when dry and form a white surface. Coal tailings or washings remain black in colour. Most other wastes, after drying and oxidation, take on shades of gray unless sulphide ore is present, in which case reds, browns and yellows form as oxidation proceeds. These colours tend to be related to particle size distribution.

139. Moisture content and movement are related to particle size. Coarse areas are susceptible to rapid leaching and retain little water, similar to sandy soils. Fine tailings or slimes present drainage or flooding problems; moisture levels remain at 30 to 40% by weight and dewatering proceeds extremely slowly, with a crust forming at the surface. These slimes lose strength when disturbed and consequently create a surface that is difficult to cultivate and traverse with equipment.

140. With tailings, pH, free acidity, and potential acidity must be considered. Iron tailings and non-sulphide tailings are neutral to slightly acidic. Sulphide wastes containing various forms of pyrite commonly have pH values of 2 to 4. Free and potential acidity become an increasing problem with sulphide-containing wastes. Wastes with more than 8% sulphide can be expected to have high potential acidity and to seriously

limit growth.

141. Cation exchange capacity (CEC) is so small it can be considered non-existent in most tailings with the exception of asbestos. Tailings other than asbestos have measured CEC much below conventional soils.

142. With the beginning of weathering, some exchange sites are produced. These may originate from the formation of iron and aluminum hydrous oxides and other compounds. Although exchange sites are few in number and are dependent on pH, they add to the buffering capacity of tailings materials and nutrient absorptive capacity. This characteristic may be critical in tailings containing sulphide minerals.

143. Sulphide-containing wastes pose particular problems. Although measured CEC is very low, there are indications that measuring techniques are unreliable; in some respects they may behave as though CEC is appreciably larger than measured.

144. The organic matter (OM) content of tailings is negligible. The milling process provides no source of organic matter prior to deposition. Other chemical reactions, however, can sometimes erroneously indicate the presence of OM in sulphide-containing wastes.

145. Mineralogical properties of the ore indirectly affect segregation in the tailings. For example, hardness affects fineness; softer material is usually finer and settles more slowly. Similarly, denser material settles faster. Mineralogical contents of tailings are shown in the case histories (Appendix B).

146. Tailings contain a large number of trace elements which are available in different degrees. The three major nutrients - phosphorus, potassium, and nitrogen - are too low to adequately sustain vegetation. Heavy metal toxicity is of minor concern. Calcium is a necessary additive when pH is below 6. Toxicity has not been a problem in Canada in vegetation programs once pH corrections have been made. The higher levels of available elements shown in Table 3 are not necessarily on vegetated wastes and therefore indicate the levels at an uncorrected pH level well below 6.

147. The accumulation of salts in the surface layers has been most common with deposits of fine tailings. Coarse fractions tend to be leached more readily. Salt accumulation is most likely to occur where upward movement of water occurs during dry periods. The formation of hardpan layers below the waste surface on some sulphide-containing wastes is related to salt leaching and precipitation.

148. Tailings alone offer little encouragement to vegetation. However, with time, the necessary components can be added to the basic structure to create a soil.

Reclamation Practice

149. Tailings have many potential growth-limiting factors. Variations in metallurgical or disposal practices may offset some problems. Amendments to the waste may correct other problems, while capping or alternative disposal methods which obviate the need to vegetate the tailings directly may be more practical in extreme cases.

150. Adverse chemical properties can be expected to be the greatest barrier to the reclamation of tailings, particularly where chemical weathering of sulphide minerals occurs.

151. Sulphur, as sulphides, may be capable of generating large amounts of acid in excess of the neutralizing capacity present in the tailings.

152. Acid neutralization for a typical cultivation depth of 30 cm could require more than 150 tonnes of limestone per hectare for each percentage point of sulphur as sulphide.

153. The acid generation mechanism is not instantaneous, but rather proceeds gradually until all sulphide sulphur has been converted. Consequently the neutralizing capability must be present during the extended period of this conversion.

154. Acidity within a material, although only directly damaging to growth properties in extreme cases, may result in other problems including excess soluble salts, presence of toxic elements and lack of nutrients.

155. Work to date indicates that although the potential for complete oxidation of sulphide exists, the depth of oxidation is limited by such factors as particle size distribution and water table level. Slimes areas tend to oxidize

rapidly, but depth of oxidation is shallow because of the high water table. Coarse material, because of increased drainage and therefore increased oxygen content, will oxidize to depths of 1 - 1.5 m.

156. Cultivation and the major portion of root activity occur to a depth of 15 - 25 cm. A vegetative cover has been established successfully on potentially oxidizable sulphides and non-sulphide tailings where this cultivation layer has been suitably modified. Vegetation has been successful on wastes with up to about 1% sulphide and studies have been encouraging for wastes containing up to 8%.

157. Chemical and physical properties are most significant in supporting plant life. However, particle size and moisture levels will affect the ability of equipment to make the necessary soil amendments, cultivation, and seeding. Slimes become thixotropic when handled and pose engineering problems with treatment. Coarse material is easier to handle with conventional equipment, but the higher moisture content of slimes produces superior growth once established.

158. There have been three approaches to vegetating tailings. First is burial under glacial till or topsoil with minimal or no treatment of the tailings, and seeding the capping. Availability of topsoil and costs of handling have limited this approach in many areas. Second is seeding directly on the waste or amended waste in one operation; results may depend on the type of amendment. Third is direct seeding and continued maintenance over a period of 5 to 10 years. This is usually successful provided maintenance is regular. In the second and third methods, a factor influencing results is the presence of organic matter at the surface. If the OM is deposited initially as sawdust, wood-chips, or sewage sludge, then method 2 is often successful. If only inorganic additions are made, however, the OM must be grown during a 5 to 10-year period.

159. Stabilizers provide wind and water erosion protection prior to plant establishment early in a vegetation program. They also improve the soil properties and are thus similar to mulches. Some that have been used include spray-on resins, water-expansible polymers, and bitumen, all with variable success.

160. Snow fences and coarse rock surface covers provide erosion control; the former, however, is not effective over long periods of time and the latter will hinder use of equipment.

161. The choice of mulches and stabilizers depends on the nature and degree of erosion availability of material, and cost. While spray-on chemicals and wood by-product materials can be applied by aerial or hydro-spray techniques, straw and hay should be disced into the soils, while jute and excelsior blankets have to be applied by hand. Chemical stabilizers will provide protection for only one to two years. Banks steeper than 20° are difficult to cultivate.

162. Soil stabilizers have adhesive properties or may react with the soil to provide a surface more resistant to erosion. Some stabilizers have the ability to aid in moisture infiltration, while limiting excess evaporation loss. These materials are useful during seeding or excessively windy periods. New types of stabilizers are being developed by various organizations and have good potential.

163. Irrigation is not always practical if required permanently but may have short-term value. Leaching of soluble salts from the root zone can be accomplished by irrigation if there are no continuing chemical reactions. If self-perpetuating vegetation will ultimately correct adverse moisture conditions, irrigation may be valuable in establishing such vegetation.

164. Tailings are the most diverse of mine wastes. Reclamation of tailings consequently presents the greatest challenge for establishing vegetation and provides opportunities for many innovations.

PROCEDURE FOR VEGETATING

SAMPLING AND ANALYSIS

165. An adequate sample of waste is essential to determine growth problems. It is also important to use appropriate analytical methods. This section describes how to examine a waste site, how to obtain suitable samples, and how to select analytical methods.

Site Examination

166. The range of conditions in the waste must be known. Much useful information can be obtained by walking over the entire area. Surface information of importance includes: textural changes, surface-water flows, exposure to wind and water erosion and bearing strength.

167. Pits should be also be dug to a depth of 1 m to observe the profile. Important profile information includes: degree of weathering, presence of compacted layers, textural changes, and moisture variations.

168. The ease of treatment and growth of vegetation depends on variations in the waste. The site examination will provide insight into the variations and indicate suitable sampling locations.

Sampling

169. The extent of sampling will be dictated by the extent of variation observed during the site examination. Samples weighing 200 to 300 g should be taken from each distinctly different material. For large areas, composite samples can be taken, but extremes should not be combined. Two or three profiles should be sampled to a depth of 1 m. Because the root zone and treatable zone are 15 to 20 cm deep, multiple samples should be made of this portion of the waste. Ten samples per hectare would be suitable for an area of uniform composition.

170. The importance of proper sampling cannot be overemphasized since any reclamation plans will be based on an analysis of these samples.

Analysis

171. Many tests can be performed in the field, eg, pH, bulk density, and moisture content. The procedures described by Black (1) were used in preparing the data sheets of Appendix B. The user should follow these methods so that he will be able to compare his results with the data provided, as well as adding to this data base.

ASSESSMENT PROCEDURE

172. From the inventory and case histories conducted it is apparent that some guidance in the use and applicability of the supplement is necessary. The following section describes a procedure for assessing reclamation by vegetation as a practical means of treating mining wastes when preparing for abandonment. An overview of this procedure is shown in Fig 4.

173. Wastes from mining operations are invariably unique. This individuality may result from location, climate, or chemical make-up. There are however many similarities of mine wastes that allow their grouping into broad categories with

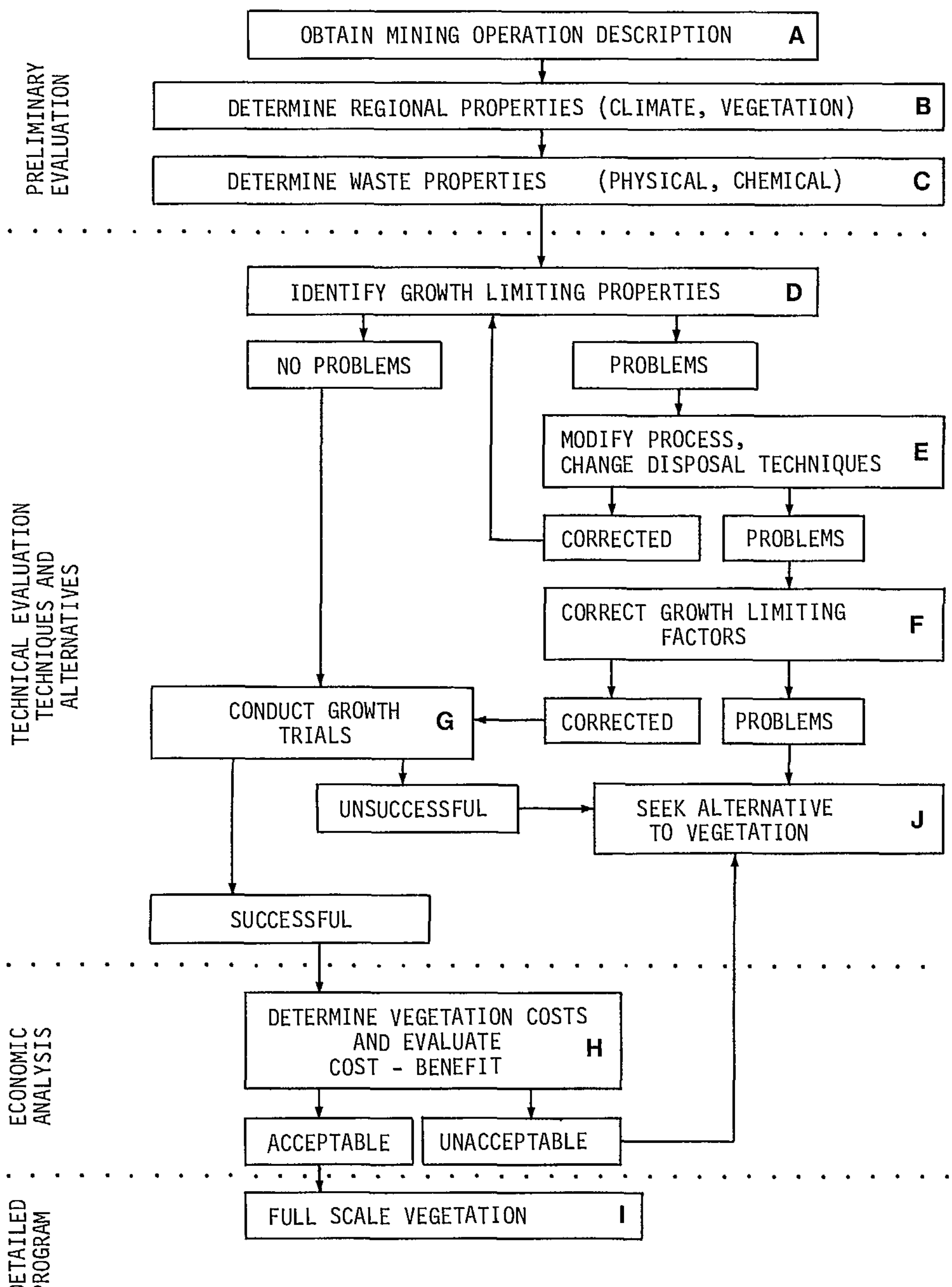

Fig 4 - Procedure for assessing reclamation by vegetation.

distinctive qualities. The categories are: tailings, overburden, and waste rock.

174. Establishing vegetation at present is essentially empirical and dependent both on planned land use and legislative requirements. A vegetative cover on mine wastes is not the only means of reclaiming them. The assessment procedure is therefore presented to assist the operator in using the information contained in this supplement to the best advantage. Guidance is given on identifying the unique characteristics or growth-inhibiting qualities, and on where to look for methods to deal with and correct the problems. From that, the economic and technical feasibility of establishing vegetation on a particular waste material can be assessed.

175. This approach is suitable for wastes associated with both existing and future operations. All of the steps of the flow diagram can be undertaken with existing operations using samples of waste. Where samples are not available for planned operations, a preliminary assessment, including order-of-magnitude costing, can be undertaken by comparing with operations described in the case histories, assuming some characteristics which cannot be determined empirically. Inherent in this approach is the need to by-pass certain steps of the flow diagram such as "Conduct Growth Trials". This requirement results in a preliminary assessment which should be applied with due caution.

176. Personnel familiar with agriculture, forestry, soil science or plant science are essential for constructive technical evaluation and detailed program preparation.

Preliminary Evaluation

(A) Mining Operation Description

177. This information includes mine location, mining method, and type of waste. For new operations, the choice of mining method should be considered at this stage since vegetation problems may be corrected by varying the mining method or waste disposal techniques.

(B) Regional Properties

178. Climatic maps of Canada are included in Appendix A to assist in estimating prevailing conditions. More detailed information can be obtained from the National Atlas of Canada or from local recording stations. Climatic parameters of interest include temperature and precipitation. Information on species choice and cultivation practices can be obtained from the nearest agricultural station or college.

(C) Waste Properties

179. Four characteristics of wastes are of greatest significance to a vegetative program - climate, texture, moisture availability, and mineralogy. Much preliminary planning can be based on a knowlege of these. Additional factors influencing growth, not discussed at length here, are slope, aspect, and time necessary to grow a plant cover.

180. More detailed site investigation is required to determine the application rate or method of treatment. Table 4 lists the properties which should be determined. Most can be determined with relative ease by suitably equipped laboratories.

Technical Evaluation

(D) Growth Limiting Factors

181. The data collected under (A), (B), and (C) should be reviewed by agriculturally-trained or experienced reclamation personnel. The section of this supplement on "Factors affecting Vegetation" (para 5) will provide assistance in making a preliminary assessment. The use of Appendices B and C and Volume 2 will help in initial economic assessment of specific problems.

(E) Modify Process

182. Consideration should be given to any modification of the mining process or disposal methods that will remove or alter a factor. Any proposed change in the process should be evaluated with the help of the case histories and the "Factors Affecting Vegetation".

Table 4: Critical parameters for mine wastes

Parameter	Overburden	Waste rock	Tailings
Particle size distribution curve	✓	✓	✓
Moisture retention curve	✓	✓	✓
Bulk density			✓
Colour			✓
Microbial activity	✓		
Organic matter	✓		
pH	✓	✓	✓
Acidity			✓
Cation exchange capacity			
Nutrients (N,P,K,...)	✓		
Electrical conductivity	✓		✓
Soluble salts	✓		✓
Total analysis (Fe,S,Mg,...)		✓	✓
Mineralogy	✓	✓	✓

(F) Correct the Growth Limiting Factors

183. Once problems are identified and the mining or milling process adjusted, possible alterations of the waste should be examined. This is necessary only if growth is still limited. The case histories and a knowledge of the factors affecting vegetation will be useful in completing this stage.

(G) Growth Trials

184. This should consist of laboratory and field trials. Laboratory or pot testing includes small-scale vegetation tests on the waste in either its natural or modified state. Once success is obtained in the laboratory, field trials should begin. Field test areas of less than one hectare are used for testing potential methods of establishing vegetation. Trained agricultural personnel will be required to assist in setting up these test plots.

Economic Analysis

(H) Cost-Benefit

185. Economic evaluation is made to determine the relative suitability of the successful vegetation alternatives as well as of alternative reclamation or waste handling methods. The result of this evaluation would show if vegetation is economically attractive (step I) or if some other form of reclamation without vegetation (step J) should be conducted. Contacts named in the case histories are probably the best source of information on current prices. Appendix C contains general guides to expenditures and relative costs in 1976 dollars of equipment and reclamation methods available.

Detailed Program

(I) Full-scale Vegetation

186. Wastes are specific to particular locations and consequently will require site-specific plans. The case histories will provide the best examples. With the bibliography, and all the data collected and field work completed, a detailed program for reclamation can be implemented at this stage by trained personnel.

187. A final step following successful vegetation is to compile a case history for future use.

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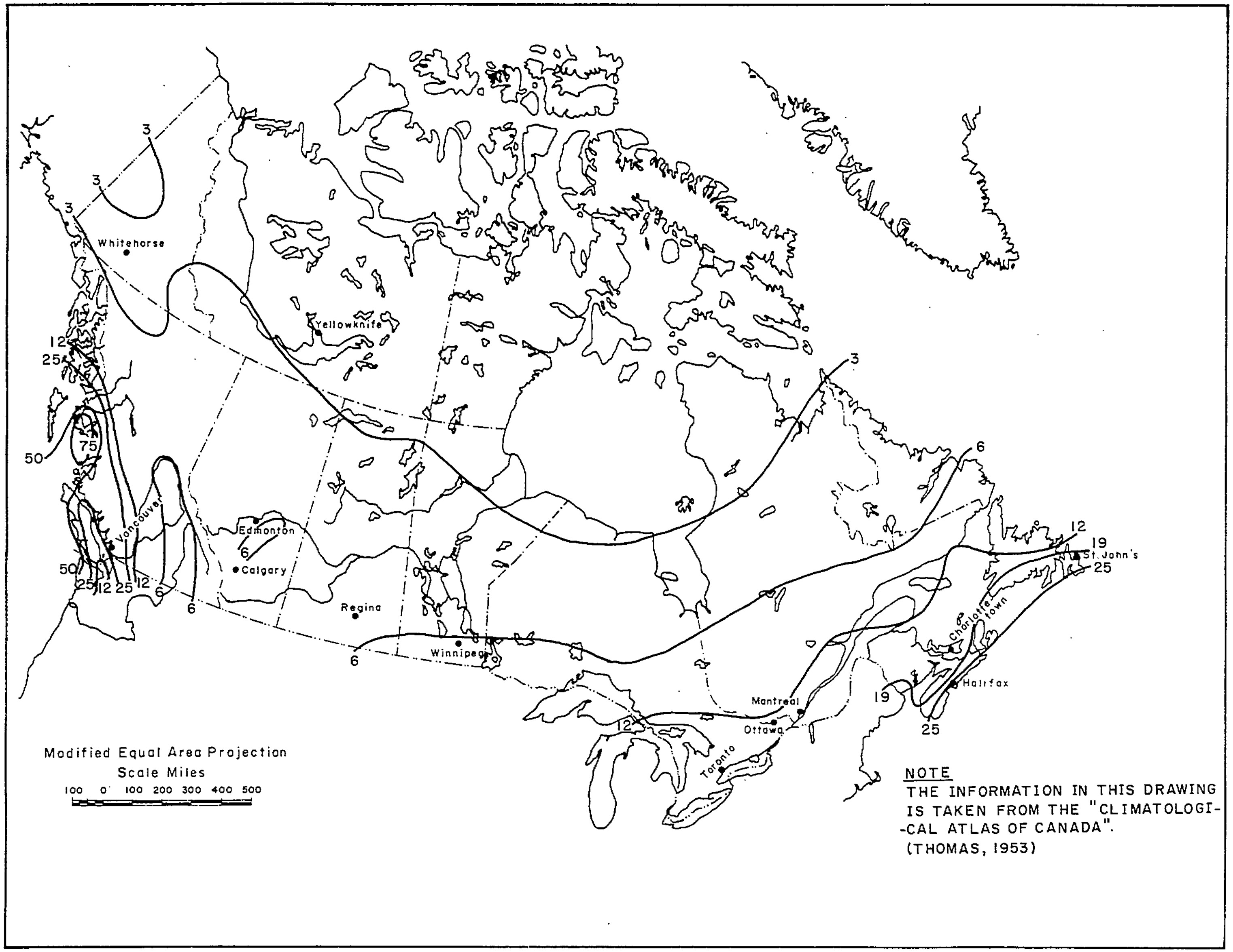
APPENDIX A

CLIMATIC MAPS

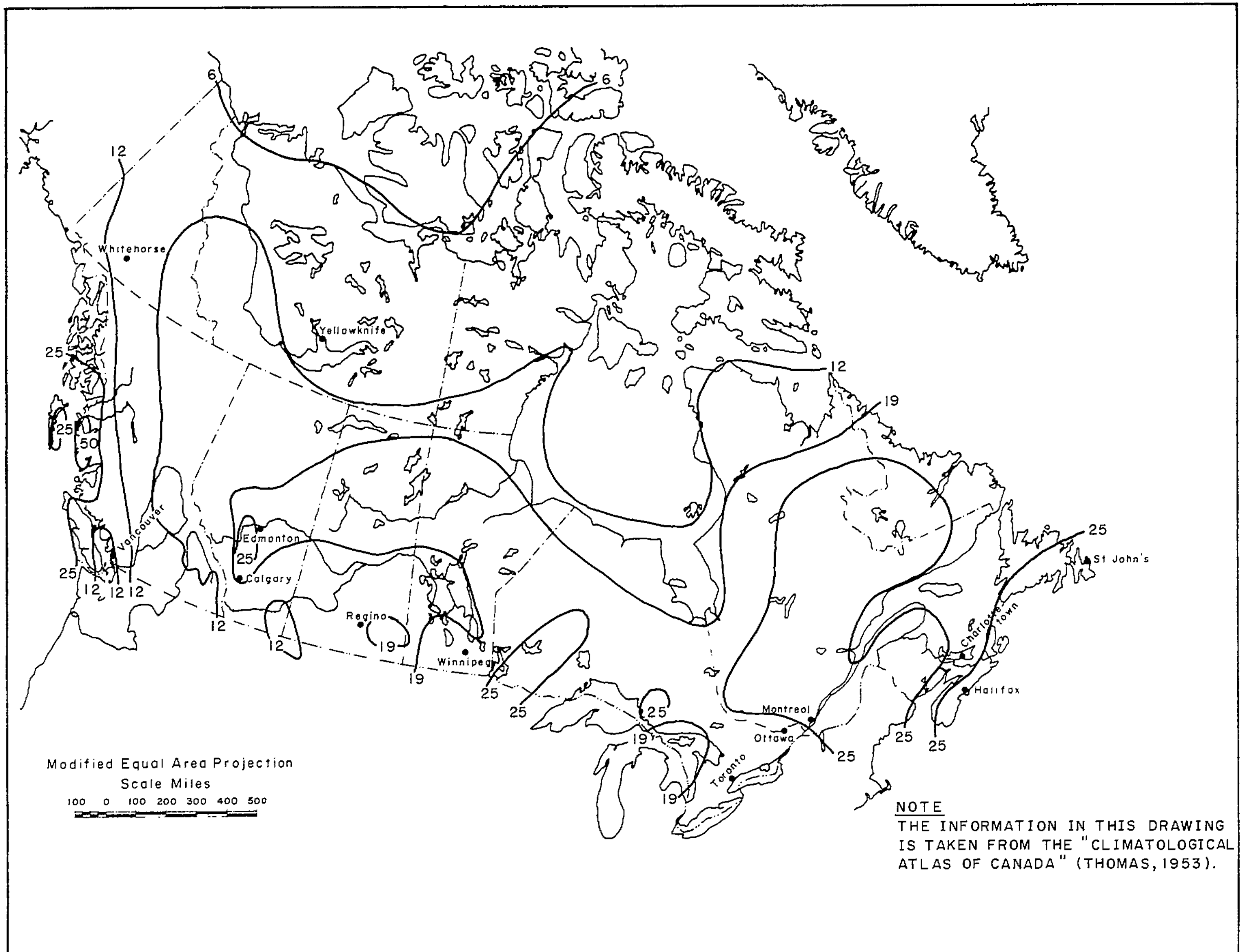
1. This appendix contains climatic maps of Canada compiled from various sources. The maps include growing degree days, frost free periods, temperature, and precipitation information. They provide a general guide to the macro-climate of various mining regions. More information can be obtained from sources listed on the maps and from the National Atlas of Canada(A-1).

REFERENCE

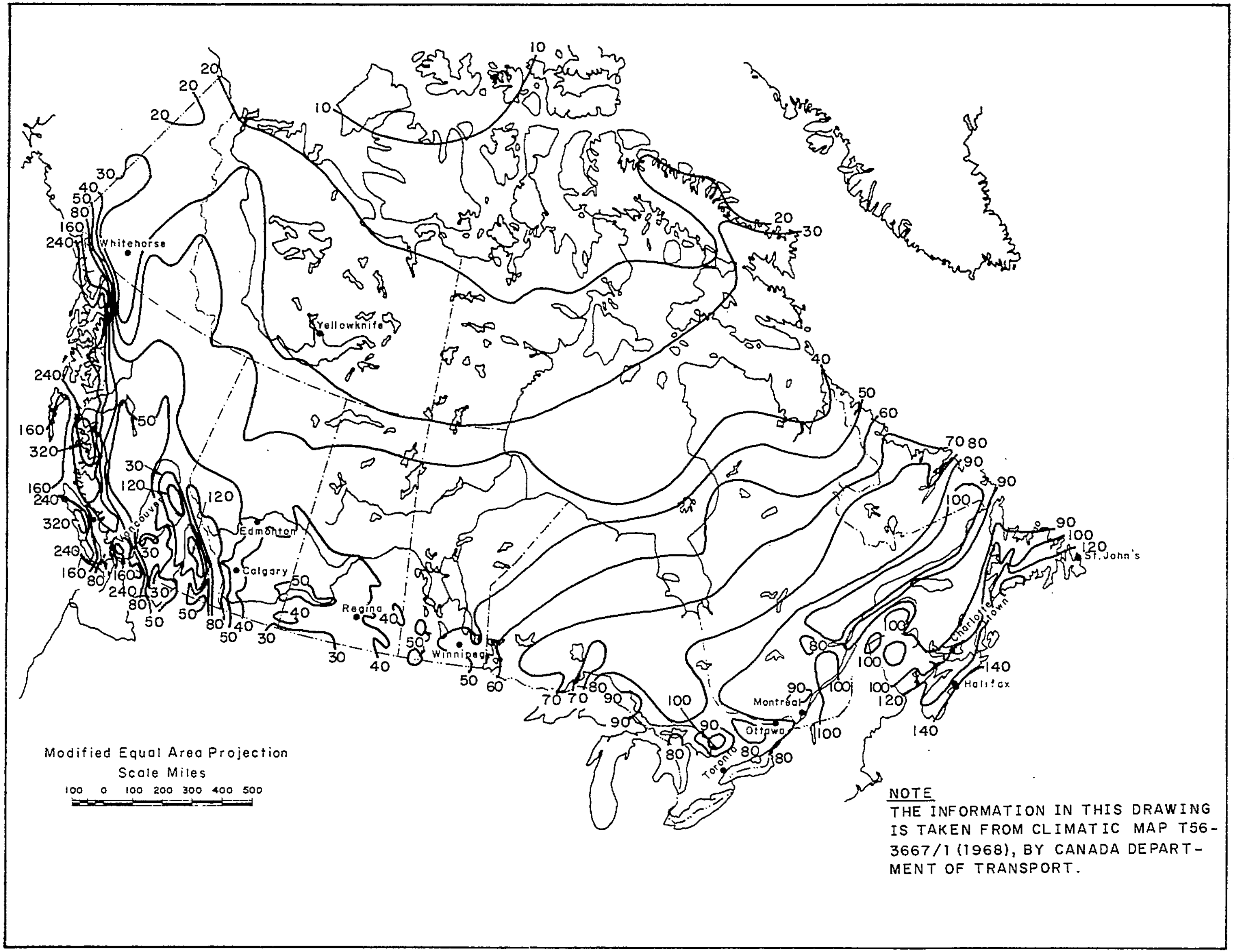
A-1. "The National Atlas of Canada" 4th edition compiled by The Department of Energy, Mines and Resources and Information Canada; The Macmillan Company of Canada Ltd., Toronto; 1974.



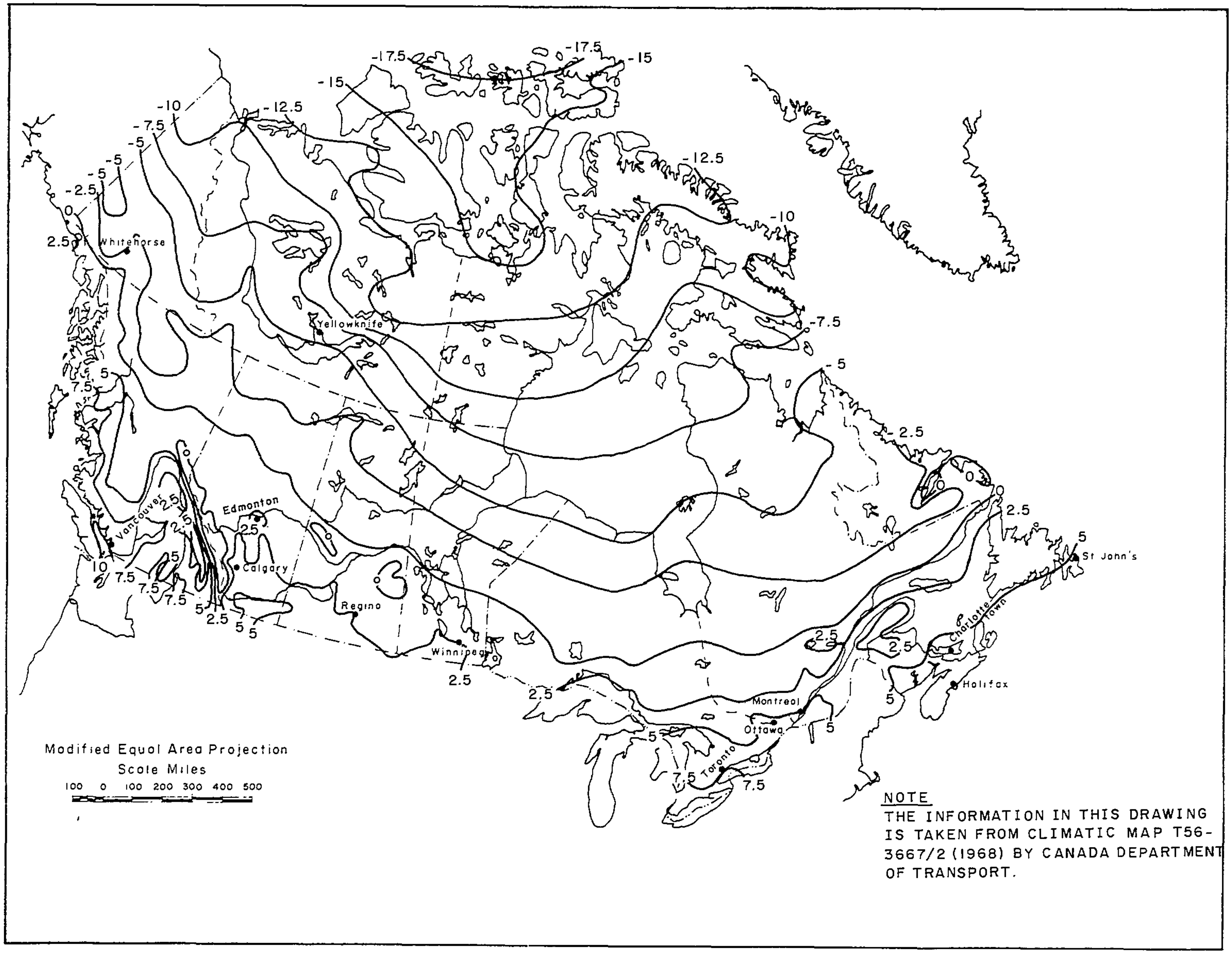
Mean spring season rainfall in centimetres for March, April and May



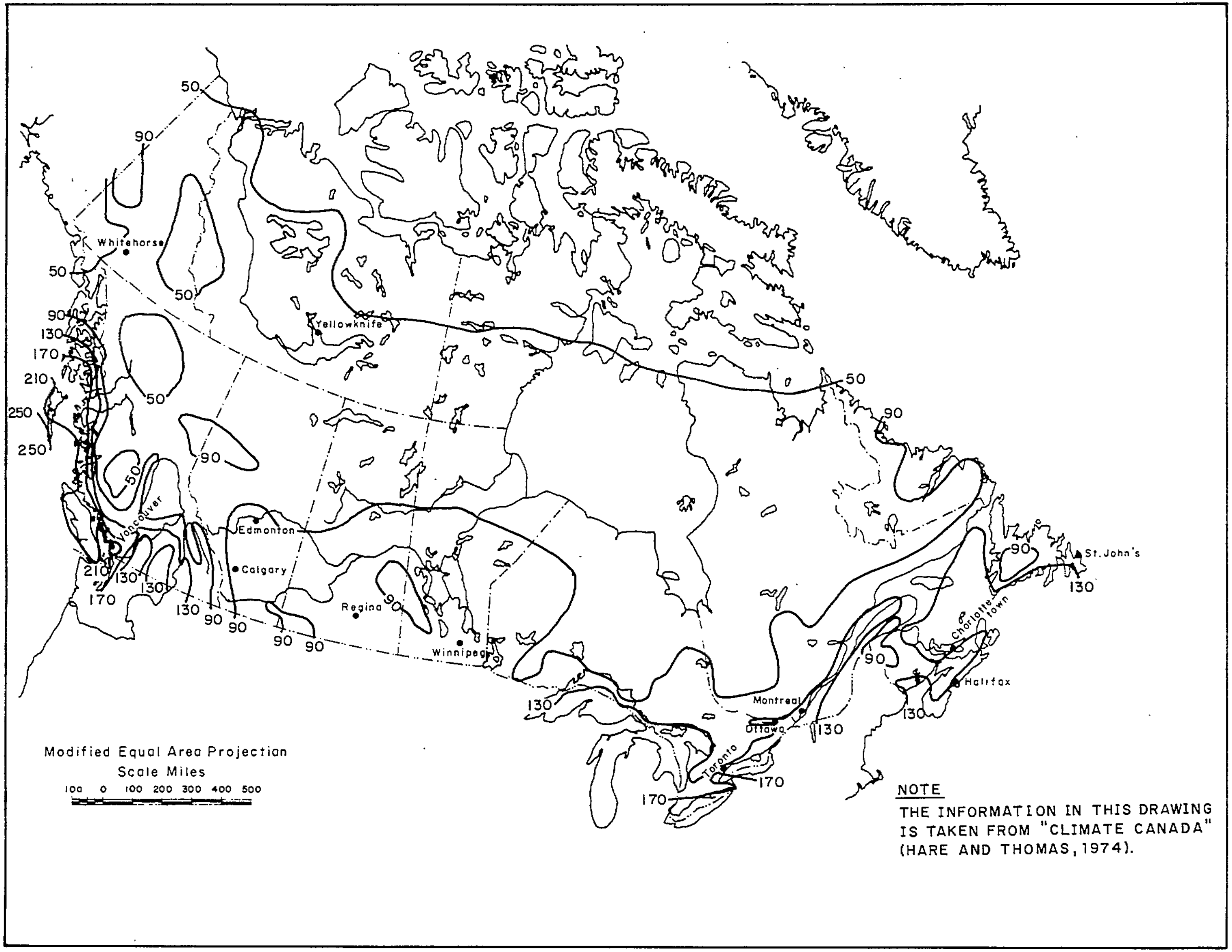
Mean summer season rainfall in centimetres for June, July and August



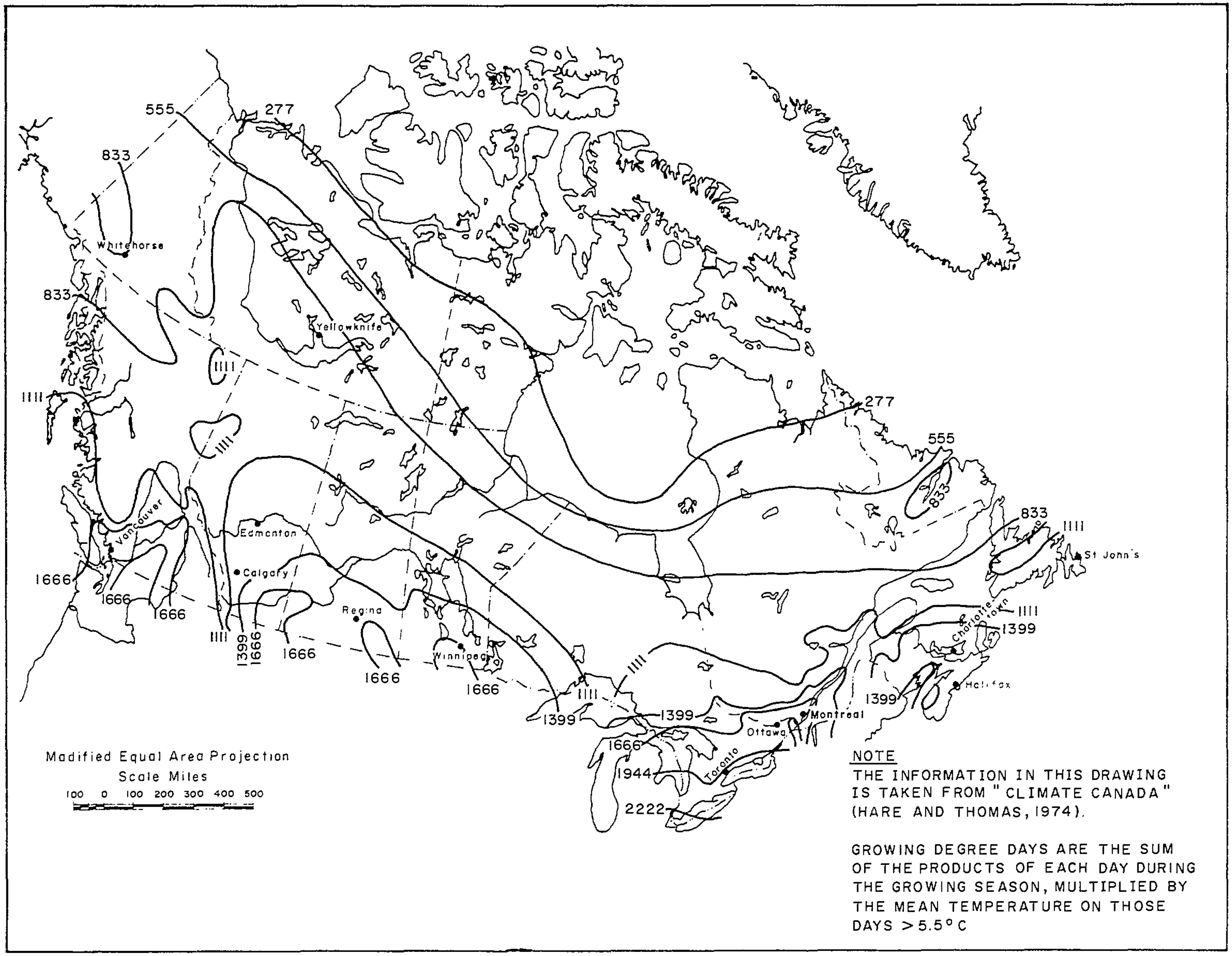
Mean annual precipitation in centimetres for period 1931 - 1960



Mean daily temperature in °C for period 1931 - 1960



Length of annual frost free period in days for period 1941 - 1970



Annual growing degree days

APPENDIX B

CASE HISTORIES

INTRODUCTION

1. The interpretations and results shown in the body of the supplement are based on case histories of over 60 mine sites. An effective use of the information results from arranging the source data in a uniform format. The data sheets are therefore printed to assist in comparing waste properties and growth conditions.

2. The data sheets are in order of waste type, commodity and location as listed in the index. Space has been allotted for additional information and for case histories which can be added as vegetation studies progress or can be used as a check list when investigating a new site.

3. Individual studies were done from 1973 to 1975 and the actual year of investigation is reported on the data sheet under "source". Mean values are arithmetic and may not be realistic for such units as pH. The range would be of more use in such cases. The presence of a "0" in the tables indicates that analysis gave a zero value. If no value appears, no analysis was available at the time.

4. A more extensive but less thorough coverage of wastes in Canada and reclamation through vegetation is presented in Volume 2 of this supplement entitled: - Mine Waste Inventory by Satellite Imagery.

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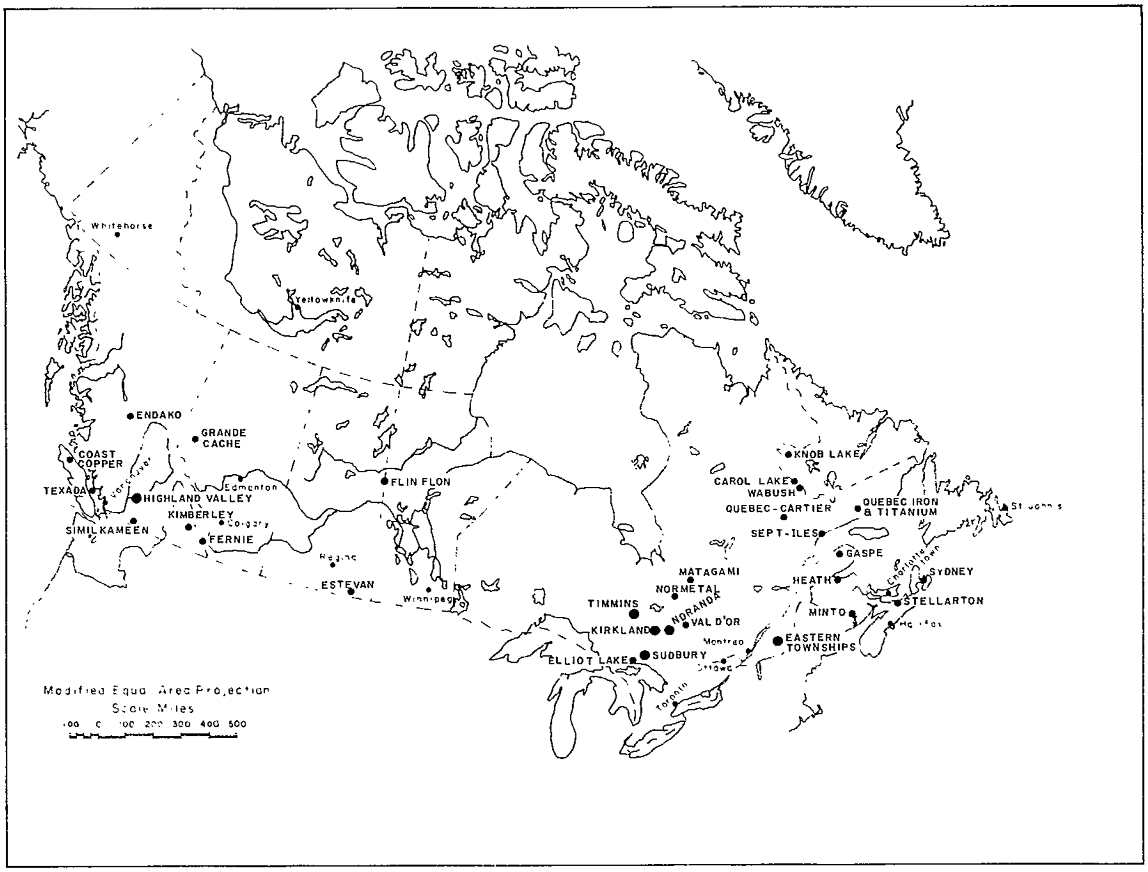

Mine location map

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COAL	OVERBURDEN	Thorburn Mining Ltd. P.O. Box 1000 Stellarton, N.S.	Stellarton, N.S.	STELLARTON AREA (N.S.) COAL RECLAMATION PROJ.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	
GROWING DEGREE DAYS		2939
FROST FREE PERIOD	start	Late May
	length in days	120
GROWING SEASON	start	Late April
	length in days	180 - 200
PRECIPITATION	annual cm	100
	growing season cm	81.6

OREBODY GEOLOGY

DISPOSAL METHOD & SIZE

Coal waste dumps (3) totalling 20 ha. Low mounds 2-10 m high.

WASTE MINERALOGY

Largely shale with some coal and sandstone.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	28	16 - 39
	% sand	80	69 - 87
	% silt	16	13 - 26
	% clay	5	4 - 6
MOISTURE RETENTION	0.1 bar %	23.6	20.5 - 27.3
	0.3 bar %	19.2	16.2 - 22.0
	15 bar %	7.7	6.9 - 8.9
AVAILABLE WATER STORAGE CAPACITY	%	11.5	8.3 - 13.8
BULK DENSITY	g/cm^3	1.2	1.1 - 1.4
PARTICLE DENSITY	g/cm^3	1.8	1.6 - 2.1

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.5	5.9 - 7.3
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	8.5	5.3 - 13.1
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.3	0.2 - 0.5
SOLUBLE SALTS	ppm	133	38 - 287
AVAILABLE ELEMENTS	P ppm	0.2	
	K ppm	76	50 - 95
	Ca ppm	4168	2810 - 6375
	Mg ppm	416	53 - 540
TOTAL ANALYSIS	N %	0.64	0.45 - 0.87
	S %		
	Fe %		
	Al %		

VEGETATION & COMMENTS

Regional: Mainly coniferous dominated by red spruce. Also eastern hemlock, eastern white pine, red pine, black spruce, white birch and red maple.

Volunteer: Dumps well grassed and treed with hardwoods. Dumps are indistinguishable from surrounding wooded areas; white birch, trembling aspen, cherries and red maple.

Introduced: None

Comments: Material being mined is old waste dumps that have naturally vegetated. Seeding is planned for the new wastes after coal separation.

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
SYDNEY AREA (N.S.)	Various locations on Cape Breton Island east coast, N.S.	Cape Breton Development Corporation P.O. Box 2500 Sydney, N.S. B1P 6K9	OVERBURDEN	COAL

ORE BODY GEOLOGY

Several coal seams, 1 - 2.5 m in thickness, located in shale and sandstone beds, dipping 10% - 12% under ocean. Overburden from 3 - 18 m thick.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	
GROWING DEGREE DAYS		2556
FROST FREE PERIOD	start	Late May
	length in days	120
GROWING SEASON	start	Early May
	length in days	180 - 200
PRECIPITATION	annual cm	127
	growing season cm	99.2

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

108 ha. Stripped overburden, in most cases, backfilled and covered with original topsoil.

VEGETATION & COMMENTS

Regional: Lowlands: white spruce and balsam fir; poorly drained areas have black spruce and tamarack. Hills: red maple, white and yellow birch, balsam fir, and white spruce.

Volunteer: Sparce and irregular grass and tree cover; white birch, alder, spruce, cherry, trembling aspen, and juniper.

Introduced: Direct seeding done 1975 in one area of respread topsoil. Grasses and legumes; good initial ground cover.

Comments: Experimental plots gave the basis for seeding 5 hectares Cultivation and limestone were used in preparation of the seed bed. Devco staff conducted test trials and reclamation work.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	35	17 - 57
	% sand	60	35 - 79
	% silt	33	16 - 53
	% clay	16	8 - 24
MOISTURE RETENTION	0.1 bar %	27	20 - 43
	0.3 bar %	20.9	8.6 - 30.8
	15 bar %	8.6	1.3 - 11.9
AVAILABLE WATER STORAGE CAPACITY	%	12.2	6.2 - 18.9
BULK DENSITY	g/cm^3	1.3	1.1 - 1.7
PARTICLE DENSITY	g/cm^3	2.1	1.4 - 2.9

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	3.8	2.3 - 7.1
	CaCl		
CATION EXCHANGE CAPACITY	meq /100g	5.1	1.2 - 6.8
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.8	0.1 - 3.1
SOLUBLE SALTS	ppm	804	25 - 4280
AVAILABLE ELEMENTS	P ppm	2.3	1.0 - 3.0
	K ppm	87	15 - 595
	Ca ppm	1527	60 - 10,000
	Mg ppm	199	36 - 566
TOTAL ANALYSIS	N %	0.28	0.07 - 0.84
	S %	1.2	0.35 - 2.4
	Fe %	5.8	3.34 - 11.7
	Al %	7.8	1.3 - 11
	Ca %	0.24	0.09 - 0.54
	Mg %	0.5	0.2 - 0.89
	Na %	0.28	0.13 - 0.44
	K %	2.10	0.81 - 2.86
	Mn %	0.10	0.02 - 0.19
	Si %	20	7 - 29
	Ti ppm	5800	3900 - 7800

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COAL	OVERBURDEN	N.B. Coal Ltd. P.O. Box 520 Minto, New Brunswick EOE 1J0	Minto - Chipman areas of New Brunswick	MINTO AREA (N.B.)

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	
GROWING DEGREE DAYS		3156
FROST FREE PERIOD	start	Late May
	length in days	120
GROWING SEASON	start	Late April
	length in days	180 - 200
PRECIPITATION	annual cm	100
	growing season cm	69.4

OREBODY GEOLOGY

Coal seam 40 to 45 cm thick, 10 to 40 m deep, located in red-grey shales with some sandstone. Overburden of 30 cm soil over approximately 1 m glacial drift (clayey silt with boulders and stones).

DISPOSAL METHOD & SIZE

Stripped land - 4600 ha. Flat-lying, low relief. Parallel ridges 10 - 15 m high and 10 - 35 m apart. 40° slopes. About 10% of area forms ponds.

WASTE MINERALOGY

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	36	19 - 57
	% sand	71	34 - 93
	% silt	25	7 - 38
	% clay	8	3 - 10
MOISTURE RETENTION	0.1 bar %	21.5	10.9 - 57
	0.3 bar %	18.7	10.3 - 24.5
	15 bar %	7.0	3.8 - 8.8
AVAILABLE WATER STORAGE CAPACITY	%	11.7	5.6 - 16.1
BULK DENSITY	g/cm^3	1.5	1.2 - 1.8
PARTICLE DENSITY	g/cm^3	2.5	2.2 - 2.9

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	4.9	3.1 - 7.7
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	9.5	6.0 - 12.2
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.3	0.1 - 1.2
SOLUBLE SALTS	ppm	308	33 - 3220
AVAILABLE ELEMENTS	P ppm		
	K ppm	72	30 - 180
	Ca ppm	2278	60 - 4960
	Mg ppm	190	29 - 462
TOTAL ANALYSIS	N %	0.07	0.03 - 0.19
	S %	1.03	0.34 - 2.4
	Fe %	5.4	4.8 - 5.8
	Al %	9.2	7.4 - 10.5
	Ca %	0.44	0.14 - 0.81
	Mg %	0.95	0.52 - 1.13
	Na %	0.24	0.11 - 0.39
	K %	2.07	1.49 - 2.71
	Mn %	0.12	0.08 - 0.22
	Si %	28	26 - 30
	Ti ppm	7940	6700 - 9800

VEGETATION & COMMENTS

Regional: Acadian forest region - primarily coniferous; black and red spruce, balsam fir, eastern white pine, red maple, sugar maple, yellow and white birch

Volunteer: White birch, trembling aspen, alder; scattered grasses and herbs

Introduced: Planned reclamation, jack pine, red pine, black locust

Comments: The material was left 3 or 4 years to weather. Prior to 1969 the banks were flattened; since then, left. Tree planting of 1840 ha done in the spring with mixed varieties. Fertilizing and liming were tried but were, not conclusively responsive. Original planting practices since abandoned included fall planting, using peat pots, tubelings, wildstock and cuttings.

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
BIENFAIT - ESTEVAN AREA (SASKATCHEWAN)	Estevan, Bienfait area of Saskatchewan	Manitoba and Sask. Coal Co. Ltd. Manalta Coal Ltd.	OVERBURDEN	COAL

ORE BODY GEOLOGY

Lignite coal located in sandstone, siltstone and claystone units of Ravenscrap Formation of Paleocene age. Overburden of glacial till plains (Souris Plain).

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.2
GROWING DEGREE DAYS		1528
FROST FREE PERIOD	start	Late May
	length in days	100
GROWING SEASON	start	Late April
	length in days	180
PRECIPITATION	annual cm	42
	growing season cm	36

WASTE MINERALOGY

Loam to clay overburden. Silty to clay bedrock.

DISPOSAL METHOD & SIZE

9,980 hectares. Various mining methods left overburden as ridges, cones and graded areas. No regular pattern. Irregular water filled pockets.

VEGETATION & COMMENTS

Regional: Stoney granic grassland to cultivated grain crops.

Volunteer: Alkali grass, wild barley, sage, sweet clover, slender wheat grass. Typical plant cover is 20-50% cover with areas containing 80% cover.

Introduced: Limited but successful.

Comments: Experimental plots on 1% of area involving some grading, fertilizer, and seed. Natural encroachment is being observed.
Soils are moderately saline, deficient in N and P, contained areas which are highly sodic. Crusts in some areas promoted runoff into lower areas. Many portions of the soils contained erodible material. Mine personnel are involved in treating old wastes as well as altering mining to reduce problems of future wastes.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	96.4	91.6 - 100
	% sand	26.6	0.1 - 51.1
	% silt	45.4	32.1 - 68.7
	% clay	28.1	10.1 - 47.3
MOISTURE RETENTION	0.1 bar %	34.3	26.2 - 69.5
	0.3 bar %	22.7	17.4 - 29.3
	15 bar %	12.8	6.7 - 18.6
AVAILABLE WATER STORAGE CAPACITY	%	9.9	7.7 - 12.7
BULK DENSITY	g/cm^3	1.4	1.33 - 1.54
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.8	7.3 - 8.4
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	6.1	5.9 - 18.1
ORGANIC MATTER	%	2.03	0.29 - 5.32
ELECTRICAL CONDUCTIVITY	mmhos/cm	3.52	0.49 - 9.78
SOLUBLE SALTS	ppm	523	1 - 2678
AVAILABLE ELEMENTS	P ppm	1	0 - 5
	K ppm	164	90 - 290
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.08	0.02 - 0.18
	S %		
	Fe %		
	Al %		

SOURCE

University of Saskatchewan
Soil Science Dept.
Saskatoon, Sask.

Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COAL	OVERBURDEN	McIntyre Mines Ltd. P.O. Box 2000 Grande Cache, Alberta TOE OYO	13 Km N of Grande Cache Alberta, 64 Km E of Alberta-B.C. border	McINTYRE PORCUPINE SMOKY RIVER

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	0
GROWING DEGREE DAYS		1800 - 2100
FROST FREE PERIOD	start	Mid May - June
	length in days	51 - 108
GROWING SEASON	start	April - Mid May
	length in days	90 - 140
PRECIPITATION	annual cm	40 - 64
	growing season cm	20 - 40

OREBODY GEOLOGY

Sub-bituminous coal located in siltstones and sandstones, folded and thrust faulted into mountains and high hills.

DISPOSAL METHOD & SIZE

Total of 32.4 ha of various sizes and ages. From flat to rolling top 3°-6° to steep slopes up to 40° mainly 15°-21° at elevation of 1400-1600 m asl

WASTE MINERALOGY

Weathering products of heterogeneous mixture of fragmented siltstones, sandstones and coal.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	37	8 - 67
	% sand	53	34 - 75
	% silt	36	25 - 50
	% clay	13.5	9 - 17
MOISTURE RETENTION	0.1 bar %	26.7	21.4 - 32.2
	0.3 bar %	23.1	18.7 - 28.9
	15 bar %	11.0	8.8 - 13.4
AVAILABLE WATER STORAGE CAPACITY	%	12.1	B.7 - 17.1
BULK DENSITY	g/cm^3		
PARTICLE DENSITY	g/cm^3	2.4	2.2 - 2.65

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.9	7.8 - 8.1
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	16.3	10.3 - 23.5
ORGANIC MATTER	%	5.0	2.6 - 6.4
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.4	0.1 - 1.2
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	3.9	0.5 - 11.5
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %		

VEGETATION & COMMENTS

Regional: Transitional zone between sub-alpine and boreal forest. Sub-alpine at higher elevations; boreal at lower. Alpine tundra on hill summits. Lodgepole pine in both forests. White spruce dominant on lower, Englemann spruce at higher elevations. Deciduous trees in valley bottoms and low-lying areas.

Volunteer: Not sufficient time to assess prior to reclamation seeding.

Introduced: Planned reclamation by staff at the mine.

Comments: Surface compacted areas ripped by caterpillar; surface harrowed with light; flexible set of self-cleaning harrows constructed from underground mining tracks. Penetration 8-10 cm; seeding by cyclone seeders, by hand or from truck; spring seeding. Seed mix: crested wheat grass 2D%; timothy 20%; creeping red fescue 20%; brome grass 20%; alfalfa 20%. Rate: 67.2 Kg/ha. Surface harrowed after seeding. Heavy N-P-K fertilizer based on soil analysis (330-560 Kg/ha); tree and shrub planting program. Areas recontoured to 26° or less and seeded in 1974. Covered with "topsoil"; unconsolidated surface material that had been removed, stockpiled and replaced. "Topsoil" is a mixture of weathered siltstone, sandstone and some glacial till. Coverage: 26.3% - 22.4% crested wheat, rest timothy. Native species are expected to encroach on seeded area within 5-10 years and consequently remove annual maintenance fertilizer requirements.

SOURCE R.M. Hardy and Associates Ltd.
Calgary, Alberta Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
KAISER ERICKSON	Michel Creek Valley, 32 Km NNE of Fernie, B.C., 16 Km W of Continental Divide	Kaiser Resources Ltd. P.O. Box 2000 Sparwood, B.C. VOB 2GO	OVERBURDEN	COAL

ORE BODY GEOLOGY

Bituminous coal located in sandstones and siltstones thrust faulted into mountains.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4
GROWING DEGREE DAYS		2400-2700
FROST FREE PERIOD	start	Mid June
	length in days	<98
GROWING SEASON	start	Late May
	length in days	90-110
PRECIPITATION	annual cm	63-102
	growing season cm	15-25

WASTE MINERALOGY

Weathering products of fine silt to sand fillings voids between angular blocks of siltstones, sandstone, conglomerate and coal.

DISPOSAL METHOD & SIZE

13.4 ha - Flat terraces connected by long steep slopes which are stable at 10°-22°. Pit has very steep sides and end walls.

VEGETATION & COMMENTS

Regional: Interior sub-alpine forest.
Lodgepole pine predominates and some douglas fir, alpine larch, white spruce, Engelmann spruce, balsam poplar. Areas of grasslands.

Volunteer: Spotty weeds insufficient for acceptability of reclamation.

Introduced: Planned reclamation by mine staff.

Comments: Recontoured to 26° or less; long slopes broken by terraces into lengths of 6-15 m vertical distance. Very heavy, ridged harrow used which disturbs surface and penetrate to 15 cm. Compacted areas loosened with caterpillar-ripper. Seeding by agricultural techniques, hand "cyclone seeders", helicopter seeding and hydroseeding (on slopes).
Spring seeding. Variable seed mix of grasses and legumes;
Seed rate of 50 kg/ha.
Seed mix includes native species
Surface harrowed after seeding
Heavy N-P-K fertilization first year based on soil analysis (200-400 Kg/ha) follow-up second year (200-250 Kg/ha)
Active shrub and tree planting program.
Areas seeded 1973 and maintained since then on a regular basis.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	29	24 - 37
	% sand	68	67 - 70
	% silt	23	19 - 25
	% clay	9	8 - 11
MOISTURE RETENTION	0.1 bar %	22.5	19.4 - 26.7
	0.3 bar %	17.6	15.1 - 21.0
	15 bar %	8.1	6.6 - 9.6
AVAILABLE WATER STORAGE CAPACITY	%	9.6	7.1 - 11.4
BULK DENSITY	g/cm^3	1.8	1.73 - 1.99
PARTICLE DENSITY	g/cm^3	2.4	2.34 - 2.52

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.0	5.9 - 6.3
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	8.7	6.5 - 12
ORGANIC MATTER	%	6.4	6.02 - 6.62
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.8	1 - 2.4
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	21	19.5 - 23
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %		

SOURCE

R.M. Hardy and Associates Ltd.
Calgary, Alberta   Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COAL	OVERBURDEN	Kaiser Resources Ltd. P.O. Box 2000 Sparwood, B.C.	Michel Creek Valley, 32 Km NNE of Fernie, B.C., 16 Km W of Continental Divide.	KAISER LOWER C

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4
GROWING DEGREE DAYS		2400 - 2700
FROST FREE PERIOD	start	Mid June
	length in days	<98
GROWING SEASON	start	Late May
	length in days	90 - 100
PRECIPITATION	annual cm	63 - 102
	growing season cm	15 - 25

OREBODY GEOLOGY

Bituminous coal located in sandstones and siltstones thrust faulted into mountains.

DISPOSAL METHOD & SIZE

5.7 ha - rolling slopes 8°-26°.

WASTE MINERALOGY

Weathering products of fine silt to sand filling void between angular blocks of siltstone, sandstone, conglomerate and coal.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	26	17 - 43
	% sand	78	63 - 88
	% silt	16	6 - 29
	% clay	6	6 - 7
MOISTURE RETENTION	0.1 bar %	17.3	15.3 - 20.6
	0.3 bar %	13.3	10.8 - 16.8
	15 bar %	7.0	5.9 - 8.5
AVAILABLE WATER STORAGE CAPACITY	%	6.3	4.8 - 8.3
BULK DENSITY	g/cm³	1.82	
PARTICLE DENSITY	g/cm³	2.05	1.96 - 2.11

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.6	7.5 - 7.6
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	10.3	6.9 - 12.3
ORGANIC MATTER	%	5.9	5.6 - 6.0
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.4	0.2 - 0.5
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	19	12 - 23
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %		

VEGETATION & COMMENTS

Regional: Interior sub-alpine forest. Lodgepole pine predominates and some douglas fir, alpine larch, white spruce, Engelmann spruce, balsam poplar. Areas of grasslands.

Volunteer: Spotty weeds insufficient to be acceptable in reclamation. Such areas retreated.

Introduced: Planned reclamation by staff at the mine.

Comments: Recontoured to 26° or less; long slopes broken by terraces into lengths of 6-15 m vertical distance. Very heavy, ridged harrow used which disturbs surface and penetrate to 15 cm. Compacted areas loosened with caterpillar-ripper. Seeding by agricultural techniques, hand "cyclone seeders", helicopter seeding and hydro-seeding (on slopes). Spring seeding. Variable seed mix of grasses and legumes; Seed rate of 50 kg/ha. Seed mix includes native species. Surface harrowed after seeding. Heavy N-P-K fertilization first year based on soil analysis (200-400 Kg/ha) follow-up second year (200-250 Kg/ha) Active shrub and tree planting program. Area seeded 1973 and maintained on a regular basis.

SOURCE

R.M. Hardy and Associates Ltd.
Calgary, Alberta
Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
KAISER McGILLIVRAY	Michel Creek Valley, 32 Km NNE of Fernie, B.C., 16 Km W of Continental Divide.	Kaiser Resources Ltd. P.O. Box 2000 Sparwood, B.C. VOB 2GO	OVERBURDEN	COAL

ORE BODY GEOLOGY

Bituminous coal located in sandstones and siltstones thrust faulted into mountains.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4
GROWING DEGREE DAYS		2400 - 2700
FROST FREE PERIOD	start	Mid June
	length in days	<9B
GROWING SEASON	start	Late May
	length in days	90 - 110
PRECIPITATION	annual cm	63 - 102
	growing season cm	15 - 25

WASTE MINERALOGY

Weathering products of fine silt to sand fillings voids between angular blocks of siltstone, sandstone, conglomerate and coal.

DISPOSAL METHOD & SIZE

14.6 ha - hummocky and rolling stable slopes of 8°-21°. Pit has high wall face of 38° and unstable.

VEGETATION & COMMENTS

Regional: Interior sub-alpine forest.
Lodgepole pine predominates and some douglas fir, alpine larch, white spruce, Engelmann spruce, balsam poplar. Areas of grasslands.

Volunteer: Spotty weeds insufficient for acceptability of reclamation.

Introduced: Planned reclamation by mine staff.

Comments: Recontoured to 26° or less; long slopes broken by terraces into lengths of 6-15 m vertical distance. Very heavy, ridged harrow used which disturbs surface and penetrate to 15 cm. Compacted areas loosened with caterpillar-ripper. Seeding by agricultural techniques, hand "cyclone seeders", helicopter seeding and hydro-seeding (on slopes).
Spring seeding. Variable seed mix of grasses and legumes;
Seed rate of 50 kg/ha.
Seed mix includes native species.
Surface harrowed after seeding.
Heavy N-P-K fertilization first year based on soil analysis (200-400 Kg/ha) follow-up second year (200-250 Kg/ha).
Active shrub and tree planting program.
Area seeded 1973 and maintained on a regular basis.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	47	28 - 65
	% sand	67	65 - 69
	% silt	22	20.5 - 24
	% clay	10	9 - 11
MOISTURE RETENTION	0.1 bar %	22.4	19.2 - 24.1
	0.3 bar %	18.4	16.8 - 19.9
	15 bar %	6.5	6.2 - 6.8
AVAILABLE WATER STORAGE CAPACITY	%	12	10.4 - 13.8
BULK DENSITY	g/cm^3	1.33	1.25 - 1.38
PARTICLE DENSITY	g/cm^3	2.08	2.06 - 2.09

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.5	7.4 - 7.5
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	7.68	5.65 - 9.78
ORGANIC MATTER	%	6.35	6.02 - 6.62
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.2	0.1 - 0.3
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	8.5	2.0 - 17.5
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %		

SOURCE

R.M. Hardy and Associates Ltd.
Calgary, Alberta
Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER	ROCK	Anaconda Canada Ltd. Caribou Mine P.O. Box A Bathurst, N.B.	48 km West of Bathurst, N.B.	ANACONDA CARIBOU MINE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.3
GROWING DEGREE DAYS		1400
FROST FREE PERIOD	start	Late May
	length in days	168
GROWING SEASON	start	Early May
	length in days	197
PRECIPITATION	annual cm	111
	growing season cm	57

OREBODY GEOLOGY

Supergene enrichment capping above primary ore in Middle Ordovician phyllite.
Ore - fine grained massive pyrite lenses. Chalcocite and covellite plentiful (copper 3.9%).

DISPOSAL METHOD & SIZE

Over mountain edge. Non terraced dump. 5.3 ha including 1.6 ha as slopes.

WASTE MINERALOGY

Chloritic and sericitic agrillite and schist with graphitic schists

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	35	
	% sand	98	
	% silt	1	
	% clay		
MOISTURE RETENTION	0.1 bar %	10	
	0.3 bar %	14	
	15 bar %	2	
AVAILABLE WATER STORAGE CAPACITY	%	12	
BULK DENSITY	g/cm^3	2.2	
PARTICLE DENSITY	g/cm^3	2.65	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	3.5	
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	3.7	
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.2	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %	3	
	Al %	13.2	
	Ca %	0.03	
	Mg %	12	
	Na %	0.37	
	Mn %	0.1	
	Cr ppm	200	
	Co ppm	100	
	Ni ppm	20	
	Pb ppm	1000	
	Ti ppm	50000	
	Zn ppm	10	

VEGETATION & COMMENTS

Regional: Mixed woodland with Balsam fir and birch dominating.

Volunteer: None

Introduced: None

SOURCE

Research and Productivity Council
Frederiction, New Brunswick
Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
GASPE COPPER COPPER MOUNTAIN & NEEDLE MOUNTAIN	Murdockville, Gaspe Peninsula, Que.	Gaspe Copper Ltd. Murdockville, Que.	ROCK	COPPER MOLYBDENUM

ORE BODY GEOLOGY

Limey quartzite, porcellanite, and skarn rocks of Devonian age. Mineralization within a pyrometasomatic alteration aureole.
Needle Mountain: bedded replacements in metamorphosed calcareous siltstones and argillaceous limestones.
Copper Mountain: molybdenum stock work in metamorphosed calcareous siltstone. (.4% Cu, .019% Mo). Extensive oxide cap. (0.45% Cu).
Ore - iron sulphides, copper sulphides, and molybdenum sulphides.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.5
GROWING DEGREE DAYS		1072
FROST FREE PERIOD	start	Early June
	length in days	163
GROWING SEASON	start	Mid May
	length in days	174
PRECIPITATION	annual cm	148
	growing season cm	47

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

Dumps are flat topped built out from hillsides.
Copper Mountain waste 64.8 ha
Needle Mountain waste 10.5 ha

VEGETATION & COMMENTS

Regional: Woodland dominated by spruce.

Volunteer: None

Introduced: None

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	21.4	20.5 - 22.3
	% sand	93.2	92.7 - 93.7
	% silt		-
	% clay		
MOISTURE RETENTION	0.1 bar %	13.5	9 - 18
	0.3 bar %	11	8 - 14
	15 bar %	0.3	0.2 - 0.4
AVAILABLE WATER STORAGE CAPACITY	%	10	6 - 14
BULK DENSITY	g/cm^3	2.2	
PARTICLE DENSITY	g/cm^3	2.65	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.1	7 - 7.1
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	4.14	3.75 - 4.53
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm		
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %	1.5	1.0 - 2.0
	Al %	4.8	4.2 - 5.3
	Mn %	D.1	0.05 - 0.2
	Ca %	2	
	Mg %	3.6	
	Na %	D.37	
	Cr ppm	200	
	Co ppm	100	
	Mo ppm	30	10 - 5D
	Ni ppm	20	
	Pb ppm	300	
	Ti ppm	10,000	
	Zn ppm	20	10 - 30
	Cu ppm	400	300 - 500

SOURCE Research and Productivity Council
Fredericton, New Brunswick
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER IRON	ROCK	Cominco Ltd. Trail, B.C.	Near Bensen River and Port McNeill on Vancouver Island.	COAST COPPER BENSON LAKE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	7.9
GROWING DEGREE DAYS		2300
FROST FREE PERIOD	start	Mid May
	length in days	175
GROWING SEASON	start	Mid March
	length in days	220
PRECIPITATION	annual cm	163.8
	growing season cm	24.5

OREBODY GEOLOGY

Skarn mineralization resulting from contact of Karmutsen volcanics with Quatsino limestones.
Ore - Magnetite, chalcopyrite, pyrrhotite, with pyrite, and calcite.

DISPOSAL METHOD & SIZE

4 ha - single level dumps totalling
4 ha - in a sheltered valley.

WASTE MINERALOGY

Chlorite, some illite, quartz, amphibole and calcite.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	17.9	12.5 - 30.5
	% sand	81.1	72.4 - 87.6
	% silt	13.4	9.3 - 19.5
	% clay	5.6	2.8 - 8.3
MOISTURE RETENTION	0.1 bar %	13.7	8.2 - 25.4
	0.3 bar %	8.2	6.7 - 8.9
	15 bar %	2.9	2.2 - 3.8
AVAILABLE WATER STORAGE CAPACITY	%	6.9	6.0 - 8.6
BULK DENSITY	g/cm^3	2.39	1.93 - 2.63
PARTICLE DENSITY	g/cm^3	2.96	2.93 - 3.00

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	8.4	7.7 - 9.4
	CaCl	7.3	7.0 - 7.6
CATION EXCHANGE CAPACITY	meq/100g	1.8	1.0 - 2.7
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.2	0.7 - 1.9
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm		
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.01	0.002 - 0.05
	S %	0.06	0.005 - 0.12
	Fe %	12.7	8.10 - 20.5
	Al %	6.05	4.50 - 7.40
	Ca %	6.85	5.05 - 8.95
	Mg %	3.9	2.35 - 4.95
	Na %	1.25	0.73 - 1.90
	K %	0.22	0.16 - 0.30
	Mn %	0.16	0.12 - 0.19
	Si %	18	17 - 19
	Co ppm	167	100 - 200
	Ni ppm	217	200 - 250
	Ti ppm	11,400	7500 - 15,500
	Cu ppm	82	40 - 125

VEGETATION & COMMENTS

Regional: Western hemlock, some sitka spruce and western red cedar with an understory of shrubs and herbs (mainly ferns).

Volunteer: Limited growth by trees, shrubs and herbs at the perimeter of the dump.

Introduced: Test work and reclamation after completion of mining.

Comments: Seeding of the dump surface was done in 1973 without any scarification or slope alterations. Grass cover has been good on level surfaces with some legumes but the slopes have been subject to movement and patchy growth.
Test areas are being observed and evaluated periodically.

SOURCE

University of British Columbia
Soil Science Dept.
Vancouver, B.C.

Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
BETHLEHEM COPPER	Highland Valley, B. C. (Merritt-Kamloops) Elevation: 1400 meters	Bethlehem Copper Corp. Box 520 Ashcroft, B. C. VOK 1AO	ROCK	COPPER MOLYBDENUM

ORE BODY GEOLOGY

Disseminated sulphides along the contacts of granodiorite and quartzdiorite intrussions.
Ore - Chalcopyrite, bornite and molybdenite with sericite, chlorite, clay minerals and epidote.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.9
GROWING DEGREE DAYS		1350
FROST FREE PERIOD	start	Early July
	length in days	20
GROWING SEASON	start	May
	length in days	166
PRECIPITATION	annual cm	37.5
	growing season cm	6.2

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

Total disturbed area of 910 hectares. Many terraced and non terraced dumps. Long slopes into the Highland Valley

VEGETATION & COMMENTS

Regional: Lodgepole pine forest to mixed lodgepole pine - Engelmann spruce stand.

Volunteer: Lodgepole pine, buffalo berry, juniper, rose, herbs and grasses.

Introduced: Only limited test plots established by non mine personnel.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	20.7	12.6 - 41.4
	% sand	60.2	54.9 - 65.1
	% silt	27.9	22.8 - 30.9
	% clay	11.9	9.4 - 14.6
MOISTURE RETENTION	0.1 bar %	17.6	17.0 - 18.9
	0.3 bar %	16	14.6 - 16.7
	15 bar %	6.4	5.4 - 7.8
AVAILABLE WATER STORAGE CAPACITY	%	11.2	10.7 - 12.0
BULK DENSITY	g/cm^3	1.57	1.19 - 2.05
PARTICLE DENSITY	g/cm^3	2.74	2.63 - 2.88

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.9	7.1 - 8.3
	CaCl	6.9	6.6 - 7.1
CATION EXCHANGE CAPACITY	meq/100g	15.1	11.5 - 19.1
ORGANIC MATTER	%	0.4	0.2 - 0.8
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.8	0.4 - 1.4
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	6.8	0.1 - 29.7
	K ppm	101	90 - 134
	Ca ppm	7240	3960 - 14,140
	Mg ppm	158	112 - 336
TOTAL ANALYSIS	N %	.01	.005 - 0.015
	S %	0.03	0.022 - 0.044
	Fe %	3.4	2.82 - 3.98
	Al %	9.5	8.7 - 10.2
	Ca %	0.6	0.4 - 0.8
	Mg %	0.53	0.48 - 0.57
	Na %	2.1	1.87 - 2.40
	K %	1.35	1.07 - 1.63
	Mn %	0.04	
	Si %	27	26 - 27
	Zn ppm	16	14 - 17
	Cu ppm	505	390 - 620

SOURCE University of British Columbia
Soil Science Dept.
Vancouver, B.C. Date: 1964

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER MOLYBDENUM	ROCK	Lornex Mining Corp. Ltd P.O. Box 1500 Logan Lake, B.C. VOK 1W0	Highland Valley, B.C. (Merritt-Kamloops) Elevation: 1400 m	LORNEX

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.9
GROWING DEGREE DAYS		1350
FROST FREE PERIOD	start	Early July
	length in days	20
GROWING SEASON	start	May
	length in days	166
PRECIPITATION	annual cm	34.5
	growing season cm	10.0

OREBODY GEOLOGY

Disseminated sulphides along the contacts of granodionite and quartzdiorite intrussions.
Ore - chalcopyrite, bornite and molybdenite with sericite, chlorite, clay minerals and epidote

DISPOSAL METHOD & SIZE

No completed dumps at present. Ultimately 4550 ha of terraced rock dump.

WASTE MINERALOGY

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	24.B	16.4 - 34.6
	% sand	61	54.0 - 73.1
	% silt	27.5	19.9 - 32.4
	% clay	11.5	7.0 - 16.4
MOISTURE RETENTION	0.1 bar %	16.9	15.2 - 1B.B
	0.3 bar %	15.5	14.4 - 16.4
	15 bar %	5.9	5.7 - 6.4
AVAILABLE WATER STORAGE CAPACITY	%	10.9	9.5 - 12.4
BULK DENSITY	g/cm^3	1.76	1.54 - 1.98
PARTICLE DENSITY	g/cm^3	2.49	2.05 - 2.73

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.8	7.2 - 8.2
	CaCl	6.7	6.6 - 6.7
CATION EXCHANGE CAPACITY	meq /100g	7.68	5.94 - 9.18
ORGANIC MATTER	%	0.3	0.11 - 0.4
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.3	0.8 - 1.6
SOLUBLE SALTS	ppm	149	26 - 2B1
AVAILABLE ELEMENTS	P ppm	5.6	0.9 - 17.9
	K ppm	84	49 - 153
	Ca ppm	57B0	1540 - 9570
	Mg ppm	130	80 - 169
TOTAL ANALYSIS	N %	0.007	0.005 - 0.012
	S %	0.05	0.03 - 0.06
	Fe %	2.13	1.61 - 2.45
	Al %		
	Ca %	0.29	0.15 - 0.41
	Mg %	0.19	0.17 - 0.21
	Na %	2.46	2.19 - 2.75
	K %	1.3	1.2 - 1.4
	Mn %	0.12	0.09 - 0.15
	Al %	B.7	8.6 - 8.9
	Si %	26	
	Zn ppm	20	15 - 23
	Cu ppm	450	330 - 570

VEGETATION & COMMENTS

Regional: Lodgepole pine forest to mixed Lodgepole pine - Engelmann spruce stands.

Volunteer: None

Introduced: Limited test works on a very small area.

SOURCE University of British Columbia
Soil Science Dept.
Vancouver, B.C. Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
SIMILKAMEEN	Princeton, B.C. Elevation 760 meters	Similkameen Mining Co. P.O. Box 520 Princeton, B.C.	ROCK	COPPER GOLD

ORE BODY GEOLOGY

Volcanogenic ore mineralization occuring in volcanic rocks adjacent to syenite plug.
Ore - pyrites

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	5.5
GROWING DEGREE DAYS		2580
FROST FREE PERIOD	start	Early July
	length in days	107
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATION	annual cm	35.9
	growing season cm	14.1

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

Total disturbed mine area (to 1974) 250 ha.
Terraced dump ultimately.

VEGETATION & COMMENTS

Regional: Douglas fir, lodgepole pine and Engelmann spruce.

Volunteer: Trees - trembling aspen
Low plants - dwarf fireweed, whiteleaved phacelia
Total ground cover - 20%

Introduced: None

Comments: - growth on waste favours areas composed of fine material, either overburden soil mixed with the waste or waste crushed by movement of machinery.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	16.3	9.5 - 30.7
	% sand	61.8	42.0 - 76.6
	% silt	26.6	15.9 - 39.3
	% clay	11.6	5.1 - 28.8
MOISTURE RETENTION	0.1 bar %	18.9	14.7 - 28.1
	0.3 bar %	15.1	13 - 21.6
	15 bar %	7.9	6.8 - 11.2
AVAILABLE WATER STORAGE CAPACITY	%	11	7.9 - 16.9
BULK DENSITY	g/cm^3	1.69	1.19 - 1.98
PARTICLE DENSITY	g/cm^3	2.67	2.55 - 2.77

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.9	7.3 - 8.1
	CaCl	7.2	6.7 - 7.5
CATION EXCHANGE CAPACITY	meq/100g	20.5	10.5 - 30.8
ORGANIC MATTER	%	0.59	0.22 - 1.51
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.2	0.5 - 1.8
SOLUBLE SALTS	ppm	278	6 - 635
AVAILABLE ELEMENTS	P ppm	8.2	0 - 33.4
	K ppm	131	75 - 193
	Ca ppm	13,790	6730 - 20,040
	Mg ppm	451	178 - 1186
TOTAL ANALYSIS	N %	D.011	0.001 - 0.039
	S %	0.06	0.05 - 0.06
	Fe %	7.18	6.74 - 7.51
	Al %	7.8	7.7 - 8.D
	Ca %	1.83	1.33 - 2.28
	Mg %	2.3	2.1 - 2.4
	Na %	2.28	2.03 - 2.58
	K %	1.06	0.94 - 1.23
	Mn %	0.12	0.11 - 0.12
	Si %	21	19 - 24
	Zn ppm	21	16 - 27
	Cu ppm	168	140 - 21D

SOURCE University of British Columbia
Soil Science Dept.
Vancouver, B.C. Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
IRON	ROCK	Iron Ore Co. of Canada 1245 Sherbrooke St. W. Montreal, Que.	Labrador City and Wabrith, Newfoundland	CAROL LAKE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	-3.5
GROWING DEGREE DAYS		660
FROST FREE PERIOD	start	Early July
	length in days	128
GROWING SEASON	start	Early June
	length in days	145
PRECIPITATION	annual cm	87.5
	growing season cm	40.5

OREBODY GEOLOGY

Upper Wabush Iron Formation
Ore - Specularite, magnetite, and hematite with quartz schist

DISPOSAL METHOD & SIZE

Rock dumps built out from hills 60 ha.
Tops of dumps are well compacted with little degradation.

WASTE MINERALOGY

Mainly sideritic quartzite (quartz carbonate) with minor amounts of amphibole schist.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	53.2	50.3 - 55.0
	% sand	96.5	95.6 - 97.4
	% silt		
	% clay		
MOISTURE RETENTION	0.1 bar %	9	8 - 9
	0.3 bar %	7	5 - 8
	15 bar %	2	
AVAILABLE WATER STORAGE CAPACITY	%	5	3 - 6
BULK DENSITY	g/cm^3	2.3	2.2 - 2.4
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.6	6.2 - 7.3
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.87	1.25 - 2.18
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.4	0.3 - 0.5
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.004	0.001 - 0.010
	S %		
	Fe %		
	Al %		

VEGETATION & COMMENTS

Regional: Upland ericaceous heath

Volunteer: None

Introduced: None

SOURCE

Research and Productivity Council
Fredericton, New Brunswick Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
WABUSH	Wabush, Newfoundland North of Sept-Iles	Wabush Mines, P.O. Box B7B, Sept-Iles, Que.	ROCK	IRON

ORE BODY GEOLOGY

Wabush Iron Formation, faulted and schistose quartz, specularite and magnetite.
Ore - Hematite, magnetite and specular hematite (banded quartz hematite).

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	-3.5
GROWING DEGREE DAYS		660
FROST FREE PERIOD	start	Early July
	length in days	128
GROWING SEASON	start	Early June
	length in days	145
PRECIPITATION	annual cm	87.5
	growing season cm	40.5

WASTE MINERALOGY

Mainly quartzite and lean iron rock plus some chloritized amphibolite.

DISPOSAL METHOD & SIZE

Rocks are dumped out from the hillside in vicinity of open pits. Dumps have flat tops and sloping sides. Not terraced. 40 ha

VEGETATION & COMMENTS

Regional: Upland ericaceous heath

Volunteer: None

Introduced: No information available.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	59.5	29.0 - 77.7
	% sand	97	95.1 - 99.6
	% silt		
	% clay		
MOISTURE RETENTION	0.1 bar %	11	6 - 20
	0.3 bar %	7	4 - 13
	15 bar %	3	1 - 7
AVAILABLE WATER STORAGE CAPACITY	%	4	3 - 6
BULK DENSITY	g/cm^3	2.4	2.3 - 2.5
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	5.96	4.5 - 7.3
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	3.44	0.63 - 8.44
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.9	0.2 - 1.9
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.004	0.001 - 0.010
	S %		
	Fe %	50	
	Al %	0.3	0.1 - 0.5
	Ca %	0.14	0.01 - 0.36
	Mg %	0.04	0.01 - 0.06
	Na %	0.02	0.01 - 0.02
	Mn %	0.03	
	Cr ppm	400	
	Co ppm	233	200 - 300
	Mo ppm	10	
	Ni ppm	20	
	Pb ppm	20	
	Ti ppm	833	500 - 1000
	Cu ppm	1	

SOURCE Research and Productivity Council
Frederiction, New Brunswick Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
IRON	ROCK	Quebec Cartier Mining Company, Gagnon, Quebec.	8 km. from Gagnon, Que.	QUEBEC CARTIERS LAC JEANNINE

CLIMATE

ANNUAL MEAN TEMPERATURE		°C	-2.7 - +1.1
GROWING DEGREE DAYS			724 - 784
FROST FREE PERIDD	start		Mid June
	length in days		128 - 136
GROWING SEASON	start		Mid May
	length in days		151 - 179
PRECIPITATION	annual cm		93.4 - 116.7
	growing season cm		44.5 - 53.9

OREBODY GEOLOGY

Quartz specular hematite with border of quartzite, quartz mica schist and marble in a plunging antriclinal structure. North, granitic gneiss. South, thick quartzite.
Ore - Hematite, magnetite and quartz specular hematite

DISPOSAL METHOD & SIZE

Flat top rock dump build out from hillside. Not terraced 225 ha.

WASTE MINERALOGY

Lean ore, quartzite and quartz mica schist. Some marble and granitic gneiss.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	46.1	45.7 - 46.5
	% sand	96.9	96.8 - 97.0
	% silt		
	% clay		
MOISTURE RETENTION	0.1 bar %	7	4 - 11
	0.3 bar %	5	3 - 8
	15 bar %	3	2 - 5
AVAILABLE WATER STORAGE CAPACITY	%	5	3 - 7
BULK DENSITY	g/cm³	2.2	2.1 - 2.2
PARTICLE DENSITY	g/cm³		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.7	7.6 - 7.7
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.6	0.3 - 0.9
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.4	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.001	
	S %		
	Fe %	5	
	Al %	5.3	
	Ca %	0.43	0.14 - 0.71
	Mg %	0.33	0.18 - 0.48
	Na %	0.19	0.01 - 0.37
	Mn %	0.1	
	Cr ppm	350	300 - 400
	Co ppm	10	
	Mo ppm	10	
	Ni ppm	20	
	Pb ppm	20	
	Ti ppm	7500	5000 - 10,000
	Cu ppm	1	

VEGETATION & COMMENTS

Regional: Upland ericaceous heath

Volunteer: None

Introduced: Fireweed, mountain rice, grey birch, willow

Comment: A small amount of induced vegetation cover exists but it has no effective control over erosion. No additional information available on reclamation attempts.

SOURCE

Research and Productivity Council
Fredericton, New Brunswick Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
TEXADA	W. coast of Texada Island, 110 km N.W. of Vancouver.	Texada Mines Ltd. P.O. Box 10, Gillies Bay, B.C.	ROCK	IRON COPPER GOLD SILVER

ORE BODY GEOLOGY

Iron-copper ore bodies enclosed in intermittent skarn zone formed along contact between limestone and intrusive granodiorite.
Ore - Magnetite, pyrrhotite, specularite, chalcopyrite, sphalerite with pyrite, calcite and quartz.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	10.7
GROWING DEGREE DAYS		3300
FROST FREE PERIOD	start	Mid April
	length in days	251
GROWING SEASON	start	Mid March
	length in days	258
PRECIPITATION	annual cm	94.6
	growing season cm	18.2

WASTE MINERALOGY

Chlorite, some illite, quartz, amphibole and calcite.

DISPOSAL METHOD & SIZE

Total including mine site, 42 ha. Currently disposed into the Strait of Georgia.

VEGETATION & COMMENTS

Regional: Mixed stands of Douglas fir and western hemlock. Few tall shrubs but abundant low shrubs, herbs and moss.

Volunteer: Sparse tree seedlings, some grass, herbs and shrubs. Good growth in area where overburden soil is present.

Introduced: None

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	24.2	14.5 - 29.9
	% sand	77.7	69.9 - 83.8
	% silt	18.2	10.4 - 29.1
	% clay	4.2	1.0 - 8.9
MOISTURE RETENTION	0.1 bar %	12.3	10.5 - 15.2
	0.3 bar %	8.6	7.3 - 10.9
	15 bar %	4.5	3.6 - 6.0
AVAILABLE WATER STORAGE CAPACITY	%	7.8	6.9 - 9.2
BULK DENSITY	g/cm^3	2.69	2.23 - 3.02
PARTICLE DENSITY	g/cm^3	2.9	2.7 - 3.06

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.7	6.4 - 8.2
	CaCl	7.3	6.2 - 7.6
CATION EXCHANGE CAPACITY	meq /100g	8.34	1.22 - 32.36
ORGANIC MATTER	%	9	0.7 - 19.5
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	20.8	0.5 - 146.4
AVAILABLE ELEMENTS	P ppm	1.9	0.10 - 10.9
	K ppm	24	3.7 - 84.5
	Ca ppm	29,995	7125 - 54,475
	Mg ppm	213	250 - 950
TOTAL ANALYSIS	N %	0.02	0.002 - 0.12
	S %	0.03	0.001 - 0.14
	Fe %	4.1	0.9 - 10.1
	Al %	2.6	0.8 - 6.2
	Ca %	26.2	9.6 - 34.9
	Mg %	0.93	0.49 - 1.72
	Na %	0.21	0.04 - 0.56
	K %	0.17	0.01 - 0.42
	Si %	7	2 - 15
	Mn %	0.14	0.04 - 0.32
	Ti ppm	2670	1000 - 6000
	Zn ppm	5	1.5 - 11
	Cu ppm	79	13 - 207

SOURCE University of British Columbia
Soil Science Dept.
Vancouver, B.C. Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
MOLYBDENUM	ROCK	Placer Development Ltd Endako, B.C.	Central British Columbia near Fraser Lake	ENDAKO

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	2.9
GROWING DEGREE DAYS		1900
FROST FREE PERIOD	start	Mid June
	length in days	79
GROWING SEASON	start	Late April
	length in days	163
PRECIPITATION	annual cm	55.4
	growing season cm	20.9

OREBODY GEOLOGY

Ore located in quartz veins within Endako quartz monzonite, altered and intruded.
Ore - molybdenum with pyrite, calcite, magnetite, and specularite.

DISPOSAL METHOD & SIZE

Active rock dump - 1.3 ha

WASTE MINERALOGY

Kaolinite, illite, montmorillonite, feldspar, quartz, and calcite.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	20.8	13.9 - 33.5
	% sand	76.9	73.8 - 81.6
	% silt	14.3	11.9 - 16.4
	% clay	8.8	5.1 - 14.2
MOISTURE RETENTION	0.1 bar %	11.5	11.0 - 12.5
	0.3 bar %	9.5	8.3 - 11.1
	15 bar %	5.4	5.1 - 6.0
AVAILABLE WATER STORAGE CAPACITY	%	6.1	5.9 - 6.5
BULK DENSITY	g/cm^3		
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	8.2	7.7 - 8.3
	CaCl	7.4	7.1 - 7.5
CATION EXCHANGE CAPACITY	meq /100g	9.95	7.26 - 15.34
ORGANIC MATTER	%	0.72	0.30 - 1.05
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.6	0.4 - 0.8
SOLUBLE SALTS	ppm	12.0	4.3 - 22.6
AVAILABLE ELEMENTS	P ppm	0.3	0.10 - 0.7
	K ppm	72	56.5 - 99.5
	Ca ppm	5534	1680 - 9825
	Mg ppm	233	100 - 345
TOTAL ANALYSIS	N %	0.02	0.002 - 0.040
	S %	0.003	0.001 - 0.008
	Fe %	2.6	2.6 - 2.7
	Al %	8.2	8.1 - 8.2
	Ca %	0.29	0.23 - 0.37
	Mg %	0.54	0.5 - 0.57
	Na %	2.3	2.15 - 2.5
	K %	2.85	2.77 - 2.97
	Mn %	0.07	0.01 - 0.1
	Si %	26	24 - 28
	Mo ppm	417	400 - 450
	Ni ppm	150	100 - 200
	Ti ppm	4000	
	Zn ppm	12.7	5 - 24
	Cu ppm	45	10 - 80

VEGETATION & COMMENTS

Regional: Mixed stands of lodgepole pine and Douglas fir or stands mainly of Engleman spruce.

Volunteer: None

Introduced: Grasses and legumes in small patches but little continuous program at this time.

SOURCE

University of British Columbia
Soil Science Dept.
Vancouver, B.C.
Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
CANADIAN CAREY	Eastern Townships, S.E. Que. 100 km N.E. of Sherbrooke, Que.	Carey Canadian Mines Ltd., P.D. Box 190, East Broughton, Que.	TAILINGS	ASBESTOS

ORE BODY GEOLOGY

Sedimentary and volcanic rocks of Palaeozoic and Precambrian age. Mainly schists, quartzites, slates and metabasalts folded and metamorphosed during Orodivician period.
Ore - Chrysotile Asbestos

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4 - 5.2
GROWING DEGREE DAYS		1667
FROST FREE PERIOD	start	Early June
	length in days	90
GROWING SEASON	start	Late April
	length in days	170 - 180
PRECIPITATION	annual cm	107
	growing season cm	57.2

WASTE MINERALOGY

85-90% asbestos minerals, mainly crysotile and antigorite. Occasional coating by silica, prucite and talc carbonate. 10-15% quartz, mafics

DISPOSAL METHOD & SIZE

Flat top mounds with perimeter dam slopes of 30-40°.

VEGETATION & COMMENTS

Regional: Mixed broadleaf deciduous and evergreen forest.

Volunteer: None on untouched tailings (even on tailings up to 60 years old) Some vegetation on areas where small portions of topsoil have been trapped on the surface; eg perennial rye grass, foxtail barley, Kentucky blue grass, white sweet clover, vetch, trembling aspen, pin-cherry, paper birch, balsam, poplar, willow, golden rod and New England aster.

Introduced: Perennial rye grass, Kentucky blue grass, alfalfa, alsike clover, balsam fir, red spruce, and cottonwood. Test work being conducted under contract.

Comments: No successful vegetation of entire waste area has been accomplished but much has gone into study. Numerous small plots have been set up by industry, government, and McGill University.
Solutions have been obtained at high rates of mulch and fertilizer but is not necessarily economic or considered permanent. Studies are still underway.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	86	80 - 99
	% sand	91	87 - 94
	% silt	5	3 - 7
	% clay	4	3 - 6
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	12.3	
	15 bar %	4.9	
AVAILABLE WATER STORAGE CAPACITY	%	7.4	
BULK DENSITY	g/cm³	1.3	0.9 - 1.6
PARTICLE DENSITY	g/cm³	2.22	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	9.3	9.1 - 9.4
	CaCl	9.1	8.9 - 9.3
CATION EXCHANGE CAPACITY	meq/100g	59.9	34.5 - 109.2
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.9	0.55 - 1.6
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.7	0.4 - 1.2
	K ppm	2	0 - 7
	Ca ppm	8	5 - 12
	Mg ppm	194	185 - 265
TOTAL ANALYSIS	N %	0.003	
	S %		
	Fe %	5.3	2.7 - 7.3
	Al %	0.4	0.25 - 0.57
	Ca %	0.3	0 - 0.68
	Mg %	23	22.5 - 24.0
	Na %	0.04	0 - 0.11
	K %	0.03	0 - 0.05
	Si ppm	1800	1720 - 1910
	Cr ppm	0.17	0 - 0.35
	Ni ppm	0.12	0 - 0.24

SOURCE Quebec Asbestos Mining Association
Black Lake, Quebec
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
ASBESTOS	TAILINGS	Canadian Johns-Manville Co. Ltd. Asbestos, Que. J1T 3N2	Eastern Townships, S.E. Que. 40 km N of Sherbrooke, Que.	ASBESTOS

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4 - 5.2
GROWING DEGREE DAYS		1667
FROST FREE PERIOD	start	Early June
	length in days	90
GROWING SEASON	start	Late April
	length in days	170 - 180
PRECIPITATION	annual cm	107 - 112
	growing season cm	57.2 - 62.7

OREBODY GEOLOGY

Sedimentary and volcanic rocks of Palaeozoic and Precambrian age. Mainly schists, quartzites, slates and metabasalts folded and metamorphosed during Orodivician period.
Ore - Chrysotile Asbestos

DISPOSAL METHOD & SIZE

flat top mounds with perimeter dam slopes of 30-40°

WASTE MINERALOGY

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	45	20 - 70
	% sand	87	78 - 90
	% silt	5	3 - 9
	% clay	8	6 - 13
MOISTURE RETENTION	0.1 bar %	0.007	0.004 - 0.016
	0.3 bar %	12.3	
	15 bar %	4.9	
AVAILABLE WATER STORAGE CAPACITY	%	7.4	
BULK DENSITY	g/cm^3	1.3	0.9 - 1.6
PARTICLE DENSITY	g/cm^3	2.22	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	9.1	9.0 - 9.3
	CaCl	8.9	8.8 - 9.0
CATION EXCHANGE CAPACITY	meq /100g	37.6	28.0 - 52.7
ORGANIC MATTER	%	0.25	0.05 - 0.52
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.75	0 - 1.0
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.6	0.4 - 1.0
	K ppm	3	0 - 11
	Ca ppm	9	6 - 12
	Mg ppm	110	75 - 135
TOTAL ANALYSIS	N %	0.009	0.004 - 0.017
	S %		
	Fe %	5.3	2.7 - 7.3
	Al %	0.4	0.25 - 0.57
	Ca %	0.3	0 - 0.68
	Mg %	23	22.5 - 24.0
	Na %	0.04	0 - 0.11
	K %	0.03	0 - 0.05
	Si ppm	1800	1720 - 1910
	Cr ppm	0.17	0 - 0.35
	Ni ppm	0.12	0 - 0.24

VEGETATION & COMMENTS

Regional: Mixed broadleaf deciduous and evergreen forest.

Volunteer: None on untouched tailings (even on tailings up to 60 years old) Some vegetation on areas where small portion of topsoil has been trapped on surface; eg perennial rye grass, foxtail barley, Kentucky blue grass, white sweet clover, vetch, trembling aspen, pincherry, paper birch, balsam, poplar, willow, golden rod and New England aster.

Introduced: Perennial rye grass, Kentucky blue grass, alfalfa, alsike clover, balsam fir, red spruce, and cottonwood. Test work being conducted under contract.

Comment: No successful vegetation of entire waste area has been accomplished but much has gone into study. Numerous small plots have been set up by industry, government, and McGill University.
Solutions have been obtained at high rates of mulch and fertilizer but is not necessarily economic or considered permanent. Studies are still underway.

SOURCE Quebec Asbestos Mining Association
Black Lake, Quebec Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
LAKE ASBESTOS	Eastern Townships, S.E. Que. 80 km N.E. of Sherbrooke, Que.	Lake Asbestos of Que. Ltd. Black Lake, Quebec.	TAILINGS	ASBESTOS

ORE BODY GEOLOGY

Sedimentary and volcanic rocks of Palaeozoic and Pre-cambrian age. Mainly schists, quartzites, slates and metabasalts folded and metamorphosed during Orodivician period.
Ore - Chrysotile Asbestos

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4 - 5.2
GROWING DEGREE DAYS		1667
FROST FREE PERIOD	start	Early June
	length in days	90
GROWING SEASON	start	Late April
	length in days	170 - 180
PRECIPITATION	annual cm	107
	growing season cm	57.2

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

Conical mounds; up to 122 m high with slopes of 30-40°.

VEGETATION & COMMENTS

Regional: Mixed broadleaf deciduous and evergreen forest.

Volunteer: None on untouched tailings (even on tailings up to 60 years old). Some vegetation on areas where small portion of topsoil has been trapped on surface; eg perennial rye grass, foxtail barley, Kentucky blue grass, white sweet clover, vetch, trembling aspen, pin-cherry, paper birch, balsam, poplar, willow, golden rod and New England aster.

Introduced: Perennial rye grass, Kentucky blue grass, alfalfa, alsike clover, balsam fir, red spruce, and cottonwood. Test work being conducted under contract.

Comments: No successful vegetation of entire waste area has been accomplished but much has gone into study. Numerous small plots have been set up by industry, government,and McGill University.
Solutions have been obtained at high rates of mulch and fertilizer but is not necessarily economic or considered permanent. Studies are still underway.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	40	35 - 45
	% sand	88	83 - 92
	% silt	6	4 - 8
	% clay	7	4 - 9
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	12.3	
	15 bar %	4.9	
AVAILABLE WATER STORAGE CAPACITY	%	7.4	
BULK DENSITY	g/cm^3	1.1	0.95 - 1.14
PARTICLE DENSITY	g/cm^3	2.22	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	9.2	9.1 - 9.3
	CaCl	8.9	8.7 - 9.2
CATION EXCHANGE CAPACITY	meq /100g	66.5	26.7 - 101.2
ORGANIC MATTER	%	0.17	0.12 - 0.26
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.6	0.53 - 0.8
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	1.2	0.4 - 5.6
	K ppm	4	0 - 9
	Ca ppm	7	4 - 11
	Mg ppm	145	98 - 195
TOTAL ANALYSIS	N %	0.006	
	S %		
	Fe %	5.3	2.7 - 7.3
	Al %	0.4	0.25 - 0.57
	Ca %	0.3	0 - 0.68
	Mg %	23	22.5 - 24.0
	Na %	0.04	0 - 0.11
	K %	0.03	0 - 0.05
	Si ppm	1800	1720 - 1910
	Cr ppm	0.17	0 - 0.35
	Ni ppm	0.12	0 - 0.24

SOURCE Quebec Asbestos Mining Association
Black Lake, Quebec
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
ASBESTOS	TAILINGS	Asbestos Corp. Ltd. Thetford Mines, Que.	Eastern Townships, S.E. Quebec, 80 km N.E. Sherbrooke, Que.	THETFORD MINES

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4 - 5.2
GROWING DEGREE DAYS		1667
FROST FREE PERIOD	start	Early June
	length in days	90
GROWING SEASON	start	Late April
	length in days	170 - 180
PRECIPITATION	annual cm	112
	growing season cm	57.2 - 62.7

OREBODY GEOLOGY

Sedimentary and volcanic rocks of Palaeozoic and Pre-cambrian age. Mainly schists, quartzites, slates and metabasalts folded and metamorphosed during Orodivician period.
Ore - Chrysotile Asbestos

DISPOSAL METHOD & SIZE

Conical mounds; up to 122 m high with slopes of 30-40°.

WASTE MINERALOGY

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	55	50 - 65
	% sand	90	89 - 92
	% silt	5	4 - 6
	% clay	5	4 - 6
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	12.3	
	15 bar %	4.9	
AVAILABLE WATER STORAGE CAPACITY	%	7.4	
BULK DENSITY	g/cm^3	1.1	0.95 - 1.14
PARTICLE DENSITY	g/cm^3	2.22	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	9.1	9.0 - 9.2
	CaCl	B.8	8.7 - 8.9
CATION EXCHANGE CAPACITY	meq/100g	54.6	31.7 - 71.9
ORGANIC MATTER	%	0.38	
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.67	0.52 - 0.83
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.6	0 - 1.6
	K ppm	2	0 - 4
	Ca ppm	10	8 - 12
	Mg ppm	155	116 - 193
TOTAL ANALYSIS	N %	0.004	
	S %		
	Fe %	5.3	2.7 - 7.3
	Al %	0.4	0.25 - 0.57
	K %	0.03	0 - 0.05
	Na %	0.04	0 - 0.11
	Mg %	23	22.5 - 24.0
	Ca %	0.3	0 - 0.68
	Si ppm	1B00	1720 - 1910
	Cr ppm	0.17	0 - 0.35
	Ni ppm	0.12	0 - 0.24

VEGETATION & COMMENTS

Regional: Mixed broadleaf deciduous and evergreen forest.

Volunteer: None on untouched tailings (even on tailings up to 60 years old). Some vegetation on areas where small portion of topsoil has been trapped on surface; eg perennial rye grass, foxtail barley, Kentucky blue grass, white sweet clover, vetch, trembling aspen, pin-cherry, paper birch, balsam, poplar, willow, golden rod and New England aster.

Introduced: Perennial rye grass, Kentucky blue grass, alfalfa, alsike clover, balsam fir, red spruce, and cottonwood. Test work being conducted under contract.

Comments: No successful vegetation of entire waste area has been accomplished but much has gone into study.
Numerous small plots have been set up by industry, government, and McGill University.
Solutions have been obtained at high rates of mulch and fertilizer but is not necessarily economic or considered permanent. Studies are still underway.

SOURCE Quebec Asbestos Mining Association
Black Lake, Quebec Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
ANACONDA CARIBOU MINE	Bathurst, N.B.	Anaconda Canada Ltd., P.O. Box A, Bathurst, N.B.	TAILINGS	COPPER

ORE BODY GEOLOGY

Supergene enrichment capping above primary ore in Middle Ordovician phyllite.
Ore - Fine-grained massive pyrite lenses. Chalcocite and covellite plentiful. (copper 3.9%)

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.3
GROWING DEGREE DAYS		1400
FROST FREE PERIOD	start	Early June
	length in days	168
GROWING SEASON	start	Early May
	length in days	197
PRECIPITATION	annual cm	111
	growing season cm	57

WASTE MINERALOGY

Approximate 70% pyrite, 5% pyrrhotite and 20% silicates.

DISPOSAL METHOD & SIZE

3 ponds, total 6.5 ha
Filling natural depressions behind a retaining dam.

VEGETATION & COMMENTS

Regional: Mixed woodland; Balsam fir and birch dominant.

Volunteer: None

Introduced: None

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	46	27 - 67.7
	% silt	48.4	25.4 - 63.3
	% clay	5.7	0.7 - 9.6
MOISTURE RETENTION	0.1 bar %	15.6	14.8 - 16.3
	0.3 bar %	11.2	9.2 - 14.8
	15 bar %	1	
AVAILABLE WATER STORAGE CAPACITY	%	3.8	0.9 - 9
BULK DENSITY	g/cm^3	2.5	
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	5.5	5.3 - 5.6
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.4	0.3 - 0.63
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.6	
SOLUBLE SALTS	ppm	9900	
AVAILABLE ELEMENTS	P ppm	0.43	0.2 - 0.6
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	38	
	Fe %		
	Al %	2.6	2.1 - 3.1
	Ca %	0.04	0.01 - 0.1
	Mg %	0.36	
	Na %	0.02	0.01 - 0.02
	Mn %	0.05	0.04 - 0.05
	Cd ppm	50	
	Cr ppm	100	
	Co ppm	200	
	Mo ppm	10	
	Ni ppm	20	
	Ti ppm	5330	4000 - 6000

SOURCE Research and Productivity Council
Frederiction, New Brunswick
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER LEAD ZINC	TAILINGS	Heath Steele Mines Ltd. Box 400 Newcastle, N.B.	50 km NW of Newcastle, New Brunswick	HEATH STEELE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.1
GROWING DEGREE DAYS		1362
FROST FREE PERIOD	start	Early June
	length in days	166
GROWING SEASON	start	Early May
	length in days	197
PRECIPITATION	annual cm	122.8
	growing season cm	55.5

OREBODY GEOLOGY

Steeply dipping lenses of massive sulphides in (volcanic and sedimentary) Ordovician belt (tetagouche group). Quartz feldspar porphyry (hanging wall) and chloritic tuff (footwall).
Ore - Massive sulphides lenses (chalcopyrite, galena, sphalerite, pyrite and pyrrhotite)

DISPOSAL METHOD & SIZE

Two areas; old - 10 ha new - 66 ha small pond near concentrator.

WASTE MINERALOGY

approx. 70% pyrite, 5% pyrrhotite, 20% silicates

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	43	12.3 - 76.9
	% silt	61.6	19.3 - 91.1
	% clay	4.3	1.2 - 8.2
MOISTURE RETENTION	0.1 bar %	15.7	11.0 - 21.3
	0.3 bar %	10.4	6.3 - 14.0
	15 bar %	2.0	0.7 - 4.0
AVAILABLE WATER STORAGE CAPACITY	%	9	5 - 13
BULK DENSITY	g/cm³	2.1	0.2 - 3.1
PARTICLE DENSITY	g/cm³		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	4.4	2.2 - 5.8
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.58	0.3 - 0.63
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.93	0.6 - 1.4
SOLUBLE SALTS	ppm	3375	2300 - 4500
AVAILABLE ELEMENTS	P ppm	0.4	0.2 - 0.8
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %	1.15	0.1 - 5.2
	Ca %	0.09	0.01 - 0.15
	Mg %	0.22	0.04 - 0.60
	Na %	0.08	0.02 - 0.2
	Mn %	0.02	0.01 - 0.03
	Cd ppm	100	
	Cr ppm	250	100 - 500
	Co ppm	5249	500 - 9999
	Mo ppm	30	
	Ni ppm	20	
	Pb ppm	25	20 - 50
	Ti ppm	1000	
	Zn ppm	1345	70 - 2500

VEGETATION & COMMENTS

Regional: Old spruce forest; not regenerating.

Volunteer: Very limited and uncertain as to growth on waste or other material.

Introduced: None

Comments: Weathered tailings supported only 2% germination in tests
In old tailings,5-8 cm hardpan layer formed at 15-60 cm depth
The old tailings have low pH while the fresher material has high pH. Vegetation plots have occured where tailings are thin or organic matter has fallen on the surface and on decaying trees.

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
GASPE COPPER COPPER MOUNTAIN NEEDLE MOUNTAIN	Murdockville, Que. on the Gaspe peninsula. Mines are approx. 2 km apart.	Gaspe Copper Ltd. Murdockville, Que.	TAILINGS	COPPER MOLYBDENUM

ORE BODY GEOLOGY

Limey quartzite, porcellanite and skarn rocks of Devonian age. Mineralization within a pyrometasomatic alteration aureole.
Needle Mountain: bedded replacements in metamorphosed calcareous siltstones and argillaceous limestones.
Copper Mountain: Copper - molybdenum stock work in metamorphosed calcaerous siltstone. (.4% Cu, .019% Mo). Extensive oxide cap. (0.45% Cu).
Ore - iron sulphides, copper sulphides and molybdenum sulphides.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.5
GROWING DEGREE DAYS		1072
FROST FREE PERIOD	start	Early June
	length in days	163
GROWING SEASON	start	Mid May
	length in days	174
PRECIPITATION	annual cm	147.8
	growing season cm	47

WASTE MINERALOGY

Quartz-sulphide

DISPOSAL METHOD & SIZE

Three tailings areas totalling 777 ha started between 1955 and 1974 consisting of approx 3% slopes of encircling dams. Separation of pyrite into one of the 3 ponds.

VEGETATION & COMMENTS

Regional: Woodland dominated by spruce

Volunteer: On banks only. Pond is active. Black and slender bent grass; aster; pearly everlasting, fireweed; horsetails; reed bentgrass, timothy.

Introduced: Bank of #1 pond. Yarrow; couch grass; brome, daisy, cocksfoot; red fescue; strawberry, barley; timothy; red clover; vetch; (timothy prevalent).

Comments: Outer wall of #1 tailings dam successfully revegetated by introduced and voluntary, even in areas not re-vegetated. More abundant growth in treated areas. Revegetation inhibited on E & W slopes by prevailing winds.
Only apparent problem to establishing vegetation cover is instability of the slopes. Vegetation established only on the banks by one of two methods. 1) Topping with soil and seeding on that by hydroseeder and 2) direct seeding on the cultivated surface. In both cases vegetation is maintained by continued fertilization. The vegetation program is on the pyrite free portion of the mill tailings. Areas of 2-4 ha are seeded each year. The floated pyrite rich portion is placed in a second settling area and is not included in the vegetation program.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	52.2	15.1 - 53.5
	% silt	42.1	39.8 - 44.3
	% clay	5.1	4.5 - 5.5
MOISTURE RETENTION	0.1 bar %	20	17 - 22
	0.3 bar %	7.8	6.0 - 10.6
	15 bar %	1.1	0.8 - 1.5
AVAILABLE WATER STORAGE CAPACITY	%	7	5 - 9
BULK DENSITY	g/cm^3	1.9	1.8 - 1.9
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.2	
	CaCl		
CATION EXCHANGE CAPACITY	meq /100g	1.04	0.94 - 1.09
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.2	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %		
	Na %	0.66	0.51 - 0.74
	Mn %	0.12	0.07 - 0.2
	Cr ppm	300	
	Co ppm	100	
	Mo ppm	20	
	Ni ppm	40	
	Pb ppm	27	
	Ti ppm	10,000	
	Cu ppm	100	

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER ZINC GOLD	TAILINGS	Falconbridge Copper Ltd Lake Dufault Div P.O. Box 40, Commerce Court W. Toronto	NW of Rouyn-Noranda, Quebec	FALCONBRIDGE COPPER LAKE DUFAULT

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1179
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	14D - 150
PRECIPITATION	annual cm	90.2
	growing season cm	45.2

OREBODY GEOLOGY

Ore located in acidic volcanic (rhyolite) overlying a more widespread basic volcanic
Ore - Pyrite, chalcopyrite, sphalerite and small amounts of pyrrhotite

DISPOSAL METHOD & SIZE

6.5 ha

WASTE MINERALOGY

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	54.8	
	% silt	37.0	
	% clay	8.2	
MOISTURE RETENTION	0.1 bar %	21	
	0.3 bar %	10	
	15 bar %	2	
AVAILABLE WATER STORAGE CAPACITY	%	8	
BULK DENSITY	g/cm^3	1.6	1.4 - 1.8
PARTICLE DENSITY	g/cm^3	3.03	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	5.9	
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.2	
ORGANIC MATTER	%	3.1	
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.2	
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm		
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	10.3	
	Fe %		
	Al %		
	K %	15.3	

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: 18% moss cover, mainly in moist, depressed areas; some grass and seedings.
Variety of plants on clay layer over a spill area (herbs, shrubs and grasses; 1.7% coverage).

Introduced: None on tailings surface, but a clay cap was seeded. Small area for evaluation as a once over treatment.

Comments: Rehabilitation attempted on 2 ha; 11.2 mt/ha lime spread and capped with clay fill.
Seeded with alsike clover, timothy, rye
Single treatment.

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec
Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
NORANDA HORNE MINE	Rouyn-Noranda, Que.	Noranda Mines Ltd., Horne Division, Noranda, Quebec.	TAILINGS	COPPER GOLD SILVER

ORE BODY GEOLOGY

Ore located in acidic volcanics, mainly rhyolite, overlying a more widespread basic volcanic sequence.
Ore - Pyrrhotite-chalcopyrite, magnetite, pyrite and sphalerite.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1179
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	90.2
	growing season cm	45.2

WASTE MINERALOGY

Approximately 50% pyrrhotite.

DISPOSAL METHOD & SIZE

Total 144 ha
Deposited in a natural depression behind retaining dams.

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jacks pine, balsam poplar.

Volunteer: None

Introduced: Rye, birdsfoot trefoil, Canada blue grass, red top, red fescue, timothy (test plots directly on surface of No. 3 pond).

Comments: - a 30 cm clay cap, seeded with alsike clover and grasses has been successful;
- experimental growth directly on tailings, with some lime (up to 110 mt/ha) and fertilizer (up to 1340 kg/ha 5-20-20) being conducted.
- Nurse crop used in some areas (rye).
Research and growth trials are being handled by mine staff and contracts.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	34	26 - 52
	% silt	61	45 - 70
	% clay	5	0 - 12
MOISTURE RETENTION	0.1 bar %	41	32 - 47
	0.3 bar %	33	4 - 44
	15 bar %	12	8 - 14
AVAILABLE WATER STORAGE CAPACITY	%	25	18 - 30
BULK DENSITY	g/cm^3	1.2	1 - 1.6
PARTICLE DENSITY	g/cm^3	3.18	2.91 - 3.97

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	4.5	2.2 - 7.4
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.07	0.19 - 1.98
ORGANIC MATTER	%	3.9	1.3 - 10.3
ELECTRICAL CONDUCTIVITY	mmhos/cm	2.8	0.6 - 5.7
SOLUBLE SALTS	ppm	9200	580 - 23,780
AVAILABLE ELEMENTS	P ppm	17	5 - 50
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	6.64	0.52 - 19.69
	Fe %	28.8	23.07 - 34.5
	Al %		

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec

Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER	TAILINGS	Noranda Mines Ltd. Noranda, Quebec.	NW of Rouyn-Noranda, Quebec. approx. 20 km.	WHAITE AMULET

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1179
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	90.2
	growing season cm	45.2

OREBODY GEOLOGY

Ore located in acidic volcanics mainly rhyolite, overlying a more widespread basic volcanic sequence
Ore - Pyrrhotite-chalcopyrite-magnetite and pyrite-sphalerite

DISPOSAL METHOD & SIZE

32 ha
encircling dam

WASTE MINERALOGY

Mainly pyrrhotite and pyrite

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	34.1	12.2 - 64
	% silt	59.1	31.0 - 82
	% clay	6.8	3.2 - 13.2
MOISTURE RETENTION	0.1 bar %	38.6	26 - 55
	0.3 bar %	29.6	12 - 50
	15 bar %	9.8	3 - 20
AVAILABLE WATER STORAGE CAPACITY	%	19.8	8 - 31
BULK DENSITY	g/cm³	1.2	1 - 1.4
PARTICLE DENSITY	g/cm³	2.9	2.73 - 3.1

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	3.3	2.6 - 6.1
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.4	0.3 - 2.7
ORGANIC MATTER	%	0.8	0.2 - 3.1
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.1	0.2 - 2.0
SOLUBLE SALTS	ppm	11,601	5779 - 24,752
AVAILABLE ELEMENTS	P ppm	30	10 - 70
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.002	0.001 - 0.002
	S %	2.81	0.52 - 5.84
	Fe %	15.1	12.5 - 17.9
	Al %		

VEGETATION & COMMENTS

Regional: Dense forest - black spruce - white birch, trembling aspen, jack pine, balsa poplar.

Volunteer: None

Introduced: Rye, creeping red fescue, alsike clover, timothy, Canada blue grass, red top.
Organized reclamation program through mine staff and contract work.

Comments: Attempted revegetation in 1969

Plants died off after 1st growing season.
Program continued 1970-71; no significant success.
Plot tests undertaken 1972; various levels of limestone and 335 kg/ha (5-20-20) fertilizer.
Approximately 0.5 ha retained vegetation through 1974.
Species employed include rye, creeping red fescue, timothy, Canada blue grass, red top.
Studies are continuing.

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec
Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
MINES DE POIRIER	95 km N of Amos, Quebec	Rio Algom Ltd., Joutel, Quebec.	TAILINGS	COPPER ZINC

ORE BODY GEOLOGY

Massive sulphides in a layer of volcanic dacite and tuff.
Chlorite alteration associated with soft host rock.
Ore - de Poirier: 33% sulphide, mainly pyrrhotite
- Joutel: 70% sulphides

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	0.4
GROWING DEGREE DAYS		1110
FROST FREE PERIOD	start	Early June
	length in days	90
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATION	annual cm	92.2
	growing season cm	47.4

WASTE MINERALOGY

Serpentine, quartz, pyrite, epidote and feldspars

DISPOSAL METHOD & SIZE

40 ha contained in circular area enclosed by clay and tailings embankments.

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: None

Introduced: None

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	79	71 - 85
	% silt	16	11 - 23
	% clay	5	4 - 6
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	18	7 - 23
	15 bar %	1.1	0.2 - 2.0
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm^3	1.95	1.62 - 2.21
PARTICLE DENSITY	g/cm^3	3.62	3.54 - 3.69

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.7	5.7 - 7.6
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.5	1.4 - 1.6
ORGANIC MATTER	%	0.1	
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	16,070	8600 - 43,750
AVAILABLE ELEMENTS	P ppm	3	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.002	0.001 - 0.002
	S %	3.4	1.0 - 7.8
	Fe %	35.08	29.79 - 43.02
	Al %		
	Ca %	0.47	0.41 - 0.65
	Mg %	1.72	1.18 - 2.19
	K %	0.06	0.04 - 0.09
	Mn %	0.03	0.03 - 0.04
	Si ppm	13.3	10.3 - 15.7
	Cd ppm	34	28 - 46
	Ni ppm	146	89 - 230
	Pb ppm	201	110 - 320
	Zn ppm	622	460 - 910
	Cu ppm	222	90 - 327

SOURCE University of Sherbrooke
Centre for Rechnology of the Environment
Sherbrooke, Quebec Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER ZINC LEAD	TAILINGS	Texas Gulf Inc. Ecstall Mining Ltd. Timmins, Ont.	25 km N of Timmins, Ont.	TEXASGULF

CLIMATE

ANNUAL MEAN TEMPERATURE		°C	1.4
GROWING DEGREE DAYS			1120
FROST FREE PERIOD	start		Early June
	length in days		80 - 100
GROWING SEASON	start		Early May
	length in days		140 - 150
PRECIPITATION	annual cm		85.6
	growing season cm		43

OREBODY GEOLOGY

Massive sulphide in rhyolite breccia and andesite occur at interface between basic diorite and gabbro, and acidic Archaen volcanic rocks.
Ore - pyrite sulphides

DISPOSAL METHOD & SIZE

Total of 324 ha. Central discharge to a low-lying perimiter dam.

WASTE MINERALOGY

20% pyrite, 20% chlorite, 50% quartz

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	19	16 - 22
	% silt	78	75 - 81
	% clay	3	
MOISTURE RETENTION	0.1 bar %	26.5	25 - 28
	0.3 bar %	2.6	2.5 - 2.6
	15 bar %	4	3 - 5
AVAILABLE WATER STORAGE CAPACITY	%	22	21 - 22
BULK DENSITY	g/cm^3	1.5	1.4 - 1.6
PARTICLE DENSITY	g/cm^3	3.05	2.97 - 3.13

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	5.9	5.4 - 6.4
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g		
ORGANIC MATTER	%	5.8	5.5 - 6.1
ELECTRICAL CONDUCTIVITY	mmhos/cm	2.05	1.90 - 2.20
SOLUBLE SALTS	ppm	6750	6360 - 7140
AVAILABLE ELEMENTS	P ppm	26	10 - 41
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	9.6	9.6 - 9.7
	Fe %	15.5	15.3 - 15.7
	Al %		

VEGETATION & COMMENTS

Regional: Dense forest dominated by spruce, fir and pine with occasional bog or swamp area.

Volunteer: None (active pond).

Introduced: On clay overburden of tailings berm; crown vetch, timothy, rye but no regular vegetation program.

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec

Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
PAMOUR PORCUPINE	Pamour Porcupine Ltd., Schumacher Division, Pamour, Ontario.	N.E. of Timmins, Ont.	TAILINGS	COPPER

ORE BODY GEOLOGY

(Bonded chert and carboniferous slate interbedded with pyroclastrics). Located mainly along interface between volcanics and the sediments of Temiskeming group.
Ore - 85% chalcopyrite, 10% bornite and 5% tetrahedrite-tennantite, with small amounts of pyrite and pyrrhotite.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1120
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	85.6
	growing season cm	43.2

WASTE MINERALOGY

Sericite, quartz, gypsum/anhydrite with high quantities of pyrite and pyrrhotite.

DISPOSAL METHOD & SIZE

Dammed valleys of 24 ha

VEGETATION & COMMENTS

Regional: Dense forest dominated by spruce, fir and pine.

Volunteer: None.

Introduced: Some along perimeter where organic material had blown onto tailings. Quack grass, timothy, red top, white clover, alsike clover, wild barley, birdsfoot trefoil.

Comments: Acid sulphide tailings; abandoned since 1930's. Methods studied: asbestos wastes to neutralize acids - too little spread to have produced a significant buffering effect: - various other techniques of lime and fertilizer have not produced success to date.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	17.8	
	% silt	73	
	% clay	9.2	
MOISTURE RETENTION	0.1 bar %	24	
	0.3 bar %	22	
	15 bar %	6	
AVAILABLE WATER STORAGE CAPACITY	%	16	
BULK DENSITY	g/cm³	2.0	1.9 - 2.0
PARTICLE DENSITY	g/cm³	3.63	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	2.5	
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.3	
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.1	
SOLUBLE SALTS	ppm	17,965	12,275 - 23,654
AVAILABLE ELEMENTS	P ppm	35	
	K ppm	25	
	Ca ppm	1800	
	Mg ppm	4200	
TOTAL ANALYSIS	N %		
	S %	37	35 - 39
	Fe %	41	40 - 42
	Al %		

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER ZINC	TAILINGS	Hudson Bay Mining & Smelting Co., Flin Flon, Manitoba. R8A 1N9	Flin Flon, on Manitoba - Saskatchewan border.	HUDSDN BAY MINING & SMELTING

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	-2.2- +.6
GROWING DEGREE DAYS		1128 - 1425
FROST FREE PERIOD	start	
	length in days	120
GROWING SEASON	start	Mid May
	length in days	146
PRECIPITATION	annual cm	47.6
	growing season cm	23.1

OREBODY GEOLOGY

Metamorphic volcanic and sedimentary rocks. Ore located in quartz prophyry.
Ore - Massive sulphides containing chalcopyrite, pyrite and sphalerite with some disseminated chloride schist.

DISPOSAL METHOD & SIZE

253 ha; area retained by natural and man-made dams. Decant drains over a concrete control structure.

WASTE MINERALOGY

Pyrite, pyrrhotite and quartz.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm		
	% sand	70	49 - 94
	% silt	47	23 - 82
	% clay	5	1 - 12
MOISTURE RETENTION	0.1 bar %	26	25 - 28
	0.3 bar %	17	16 - 18
	15 bar %	7	6 - 9
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³	1.7	1.4 - 1.84
PARTICLE DENSITY	g/cm³	3.35	3.15 - 3.48

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.5	4.9 - 7.4
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	24.1	14.1 - 46.5
ORGANIC MATTER	%	0.4	0.3 - 0.5
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	B184	3984 - 16,368
AVAILABLE ELEMENTS	P ppm	0.5	0.5 - 0.8
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	20	16.5 - 26.5
	Fe %	24	23.1 - 24.8
	Al %	3.3	2.1 - 4.2
	Ca %	2	1.2 - 2.4
	Mg %	1.9	1.07 - 2.8
	Na %	0.37	0.24 - 0.43
	K %	0.6	0.38 - 0.8
	Mn %	0.08	0.07 - 0.09
	Si ppm	4.7	
	Co ppm	5000	

VEGETATION & COMMENTS

Regional: Coniferous forest.

Volunteer: None.

Introduced: Oats, barley, brome grass, quack grass, perennial rye grass, Kentucky blue grass, red fescue.

Comments: Reclamation attempts commenced in 1971.
2 ha experimental plot.
Mine staff studied the wastes and conducted test work without adequate success at maintaining a cover. They are looking at alternative methods of reclamation.

SOURCE

Hudson Bay Mining & Smelting Co
Flin Flon, Manitoba

Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
LORNEX	Highland Valley, B.C. (Merritt-Kamloops) elevation 1400 meters	Lornex Mining Corp. Ltd P.O. Box 1500, Logan Lake, B.C. VOK 1WO	TAILINGS	COPPER MOLYBDENUM

ORE BODY GEOLOGY

Disseminated sulphides along contacts of granodiorite and quartz diorite intrusions.
Ore - Chalcopyrite, bornite and molybdenite with sericite, chlorite, clay minerals and epidote.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.9
GROWING DEGREE DAYS		1350
FROST FREE PERIOD	start	Early July
	length in days	20
GROWING SEASON	start	Early May
	length in days	166
PRECIPITATION	annual cm	34.5
	growing season cm	10.0

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

Highland valley bottom behind a retaining dam.

VEGETATION & COMMENTS

Regional: Lodgepole pine forest to mixed lodgepole pine - Engelman spruce stands.

Volunteer: None.

Introduced: None (active pond).

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	43.6	25.2 - 62.0
	% silt	45.9	31.3 - 60.4
	% clay	10.6	6.7 - 14.4
MOISTURE RETENTION	0.1 bar %	28.8	22.3 - 35.2
	0.3 bar %	25.2	17.8 - 32.6
	15 bar %	7.5	5.2 - 9.8
AVAILABLE WATER STORAGE CAPACITY	%	19.5	17.1 - 21.8
BULK DENSITY	g/cm^3		
PARTICLE DENSITY	g/cm^3	2.61	2.59 - 2.62

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.7	7.4 - 8.0
	CaCl	7.1	7.0 - 7.2
CATION EXCHANGE CAPACITY	meq/100g	4.7	2.6 - 6.8
ORGANIC MATTER	%	0.3	0.05 - 0.54
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.0	
SOLUBLE SALTS	ppm	126	
AVAILABLE ELEMENTS	P ppm	0.85	0.80 - 0.90
	K ppm	141	102 - 180
	Ca ppm	7135	6470 - 7800
	Mg ppm	148	114 - 182
TOTAL ANALYSIS	N %	0.02	0.014 - 0.027
	S %	0.1	0.04 - 0.16
	Fe %	1.19	0.95 - 1.44
	Al %	7.5	6.8 - 8.1
	Ca %	0.21	0.19 - 0.23
	Mg %	0.15	0.11 - 0.19
	Na %	2.2	2.18 - 2.23
	K %	1.49	1.32 - 1.65
	Mn %	4	3 - 4
	Si ppm	28	27 - 28
	Zn ppm	15	12 - 18
	Cu ppm	130	50 - 210

SOURCE University of British Columbia
Soil Science Dept.
Vancouver, B.C. Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
COPPER MDLYBDENUM	TAILINGS	Bethlehem Copper Corp. Box 520, Ashcroft, B.C. VOK 1A0	Highland Valley, B.C. (Merritt-Kamloops) Elevation: 1400 m	BETHLEHEM COPPER

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3.9
GROWING DEGREE DAYS		1350
FROST FREE PERIOD	start	Early July
	length in days	20
GROWING SEASON	start	Early May
	length in days	166
PRECIPITATION	annual cm	38.4
	growing season cm	7.1

OREBODY GEOLOGY

Disseminated sulphides along contacts of granodiorite and quartz diorite intrusions
Ore - Chalcopyrite, bornite and molybdenite with sericite, chlorite, clay minerals and epidote

DISPOSAL METHOD & SIZE

Tailings placed behind a large dam across a valley constructed of tailings. Area of disturbed land 910 ha.

WASTE MINERALOGY

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	89.7	
	% silt	6.7	
	% clay	3.6	
MOISTURE RETENTION	0.1 bar %	7.4	
	0.3 bar %	7.4	
	15 bar %	1.9	
AVAILABLE WATER STORAGE CAPACITY	%	5.5	
BULK DENSITY	g/cm^3		
PARTICLE DENSITY	g/cm^3	2.67	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.4	
	CaCl	6.6	
CATION EXCHANGE CAPACITY	meq/100g	5.6	
ORGANIC MATTER	%	0.18	
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.3	
	K ppm	55	
	Ca ppm	5150	
	Mg ppm	22	
TOTAL ANALYSIS	N %	0.007	
	S %	0.003	
	Fe %	1.71	
	Al %	7.5	
	Mn %	2.0	
	K %	0.72	
	Na %	2.9	
	Mg %	0.39	
	Ca %	0.49	

VEGETATION & COMMENTS

Regional: Lodgepole pine forest to mixed lodgepole pine - Engelmann spruce stands.

Volunteer: None (operating pond)

Introduced: None

Comment: No vegetation program on the tailings except on the dam portion which includes overburden topping.

SOURCE

University of British Columbia
Soil Science Dept.
Vancouver, B.C.

Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
COAST COPPER BENSON LAKE	Near Bensen River (and Port McNeill) on Vancouver Island	Cominco Ltd. Trail, B.C.	TAILINGS	COPPER GOLD IRON SILVER

ORE BODY GEOLOGY

Skarn mineralization resulting from contact of Karmutsen volcanics with Quatsino limestones. Ore - Magnetite, chalcopyrite, pyrrhotite with pyrite and calcite

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	7.9
GROWING DEGREE DAYS		2300
FROST FREE PERIOD	start	
	length in days	175
GROWING SEASON	start	Mid March
	length in days	220
PRECIPITATION	annual cm	163.8
	growing season cm	24.5

WASTE MINERALOGY

Chlorite, quartz feldspar, amphibole, gypsum and pyrite

DISPOSAL METHOD & SIZE

Tailings - Most was deposited into Bensen Lake but 1 ha is exposed in an emergency pond.

VEGETATION & COMMENTS

Regional: Mostly western hemlock; some sitka spruce and western red cedar. Understory of shrubs and herbs (mainly ferns).

Volunteer: Abundant growth in areas of stumps, and other organic material.

Introduced: Test work and reclamation done after completion of mining. Establishment of grasses and legumes.

Comments: Extensive seeding and fertilizing program begun in 1973. Mixture of grasses and legumes. Growth ranges from complete coverage (fine tailings) to bare (coarse, brown coloured tailings).
Lab tests indicate optimum limestone addition of 45 mt/ha plus N + P fertilizers.
Test areas are being observed periodically by mine personnel.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	25.2	19.7 - 30.1
	% silt	72.9	68.5 - 77.6
	% clay	1.9	1.4 - 2.7
MOISTURE RETENTION	0.1 bar %	27.6	25.4 - 31.3
	0.3 bar %	18.8	17.5 - 30.2
	15 bar %	5.2	4.6 - 6.0
AVAILABLE WATER STORAGE CAPACITY	%	25.7	20.8 - 35.3
BULK DENSITY	g/cm^3	1.7	1.57 - 1.81
PARTICLE DENSITY	g/cm^3	1.4	0.01 - 3.64

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	5.9	2.7 - 7.9
	CaCl	5.5	2.5 - 7.4
CATION EXCHANGE CAPACITY	meq/100g	5.11	0.45 - 60.74
ORGANIC MATTER	%	1.56	0.18 - 2.75
ELECTRICAL CONDUCTIVITY	mmhos/cm	3.64	2.3 - 10.1
SOLUBLE SALTS	ppm	249	67 - 2328
AVAILABLE ELEMENTS	P ppm	0.2	0.1 - 1.0
	K ppm	75	0.5 - 287
	Ca ppm	8773	50 - 23,625
	Mg ppm	74	15 - 125
TOTAL ANALYSIS	N %	0.007	0.001 - 0.07
	S %	0.66	0.06 - 2.34
	Fe %	28.2	17.5 - 36.0
	Al %	2.5	2.0 - 3.0
	Ca %	6.74	6.25 - 7.6
	Mg %	2.02	1.55 - 3.16
	Na %	0.57	0.49 - 0.61
	K %	0.17	0.11 - 0.23
	Mn %	0.14	0.12 - 0.2
	Si ppm	16	15 - 19
	Co ppm	200	
	Ni ppm	100	
	Ti ppm	4800	2000 - 8000
	Zn ppm	7	1 - 13
	Cu ppm	106	80 - 140

SOURCE

University of British Columbia
Soil Science Dept.
Vancouver, B.C.

Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
ZINC LEAD COPPER	TAILINGS	Brunswick Mining & Smelting, P.O. Box 3000, Bathurst, N.B.	Northern New Brunswick near Bathurst	BRUNSWICK #6

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4
GROWING DEGREE DAYS		1425
FROST FREE PERIOD	start	Early June
	length in days	170
GROWING SEASON	start	Early May
	length in days	197
PRECIPITATION	annual cm	99
	growing season cm	49

OREBODY GEOLOGY

Massive sulphides on contact between Ordovician augen schist, chloritic tuffs and argillite on stratigraphic footwall, and iron formation and rhyolitic tuff on hanging wall. Local structural reversal of sequence.
Ore - chalcopyrite, sphalerite, galena, pyrite and pyrrhotite

DISPOSAL METHOD & SIZE

0.0B ha pilot plant tailings

WASTE MINERALOGY

70% Pyrite, 5% pyrrhotite

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	31	23.7 - 36.6
	% silt	53.1	39.4 - 69.8
	% clay	9.2	6.5 - 13.1
MOISTURE RETENTION	0.1 bar %	19.3	16.9 - 21.9
	0.3 bar %	21.4	13.8 - 29.5
	15 bar %	6.4	4.5 - 7.5
AVAILABLE WATER STORAGE CAPACITY	%	15	9 - 22
BULK DENSITY	g/cm³		
PARTICLE DENSITY	g/cm³		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	3.8	2.2 - 4.9
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.04	0.78 - 1.25
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	3.1	2.2 - 3.6
SOLUBLE SALTS	ppm	3000	2300 - 3600
AVAILABLE ELEMENTS	P ppm	0.5	0.2 - 0.6
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %	0.5	
	Ca %	5.7	5.0 - 7.1
	Mg %	0.6	
	Na %	0.01	
	Mn %	0.1	0.03 - D.1
	Cd ppm	67	50 - 100
	Cr ppm	100	
	Co ppm	267	200 - 300
	Mo ppm	10	
	Ni ppm	20	
	Ti ppm	2000	
	Zn ppm	69D	70 - 1500
	Cu ppm	90	70 - 100

VEGETATION & COMMENTS

Regional: Mixed woodland and variety of evergreen and deciduous. Poplar and balsam fir dominate.

Volunteer: None

Introduced: No program at present.

Comments: Cemented surface of tailings makes handling and growth difficult.

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
BRUNSWICK #12	Northern New Brunswick near Bathurst	Brunswick Mining and Smelting, P.O. Box 3000, Bathurst, N.B.	TAILINGS	ZINC LEAD COPPER

ORE BODY GEOLOGY

Massive sulphide lenses stratigraphically above Ordovician sequence of argillite, greywacke, graphic schists, augen schist, and chloritic tuffaceous metasediments, and below iron formation, metasiltstone, argillite and rhyolitic tuff. Locally reversed.
Ore - Chalcopyrite, sphalerite and galena.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4
GROWING DEGREE DAYS		1425
FROST FREE PERIOD	start	Early June
	length in days	170
GROWING SEASON	start	Early May
	length in days	197
PRECIPITATION	annual cm	94
	growing season cm	49

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

141 ha in 2 separate ponds at Brunswick 12 encircling tailings dams and building of small settling units within the entire settling area.

VEGETATION & COMMENTS

Regional: Mixed woodland and variety of evergreen and deciduous. Poplar and balsam fir dominate.

Volunteer: None.

Introduced: None.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	31.5	20.3 - 38.8
	% silt	60	41.4 - 81
	% clay	9.4	0.4 - 23.3
MOISTURE RETENTION	0.1 bar %	21	19 - 23.4
	0.3 bar %	23.5	21.5 - 25.0
	15 bar %	5.2	3.6 - 6.5
AVAILABLE WATER STORAGE CAPACITY	%	18	17 - 20
BULK DENSITY	g/cm^3		
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	4.1	2.2 - 6
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.8	0.94 - 2.5
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm	2.1	1.4 - 2.4
SOLUBLE SALTS	ppm	16,170	9500 - 20,000
AVAILABLE ELEMENTS	P ppm	0.3	0.2 - 0.3
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	36.7	
	Fe %		
	Al %	0.23	0.10 - 0.5
	Ca %	1.9	0.7 - 2.9
	Mg %	0.34	0.12 - 0.48
	Na %	0.02	
	Mn %	0.04	0.02 - 0.07
	Cd ppm	50	
	Cr ppm	100	
	Co ppm	433	400 - 500
	Mo ppm	10	
	Ni ppm	20	
	Pb ppm	10	
	Ti ppm	200	
	Zn ppm	2670	1500 - 5000

SOURCE Research and Productivity Council
Fredericton, New Brunswick
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
ZINC COPPER	TAILINGS	Manitou-Barvue Mines Ltd. Box 1500, Val d'or, Que.	Val d'or, P.Q. (N.W. Quebec)	MANITOU-BARVUE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1110
FRDST FREE PERIOD	start	Early June
	length in days	98
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATION	annual cm	90.2
	growing season cm	45

OREBODY GEOLOGY

Ore - Massive sulphides 15%, including pyrite, sphalirite, chalcopyrite and galena. (Barvue) sericite, quartz, carbonates, and chlorite in gangue

DISPOSAL METHOD & SIZE

Originally uncontrolled discharge 111 ha now 6 m spigotted dam encloses 49 ha of the 111 ha.

WASTE MINERALOGY

Serpentine, quartz, pyrite (40%) epidote and feldspars

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	54	18 - 83
	% silt	42.6	17 - 75
	% clay	10	7 - 13
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	14	1 - 40
	15 bar %	0.8	0.1 - 1.5
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm^3	1.49	1.12 - 1.81
PARTICLE DENSITY	g/cm^3	2.9	2.8 - 3.01

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: Active pond - none.
Inactive area - very little (less than 1%)
Inactive area flooded by spill of fresh tailings in 1972.

Introduced: None

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.7	2.5 - 7.6
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	D.6	0.3 - 0.8
ORGANIC MATTER	%	0.1	
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	7910	2000 - 28,600
AVAILABLE ELEMENTS	P ppm		
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.018	0.002 - 0.094
	S %	1.3	0.3 - 2.5
	Fe %	9.6	4.74 - 19.5
	Al %		
	Ca %	0.59	0.22 - 1.05
	Mg %	1.D9	0.34 - 1.83
	K %	0.74	D.12 - 1.32
	Mn %	D.05	0.01 - 0.08
	Si ppm	31	25 - 37
	Cd ppm	28	2 - 76
	Ni ppm	16	10 - 43
	Pb ppm	825	130 - 2810
	Zn ppm	264	100 - 650
	Cu ppm	96	39 - 150

SOURCE University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
MATTAGAMI LAKE	Matagami, Que. (N.W. Quebec)	Mattagami Lake Mines Ltd. Matagami, Quebec.	TAILINGS	ZINC COPPER GOLD SILVER

ORE BODY GEOLOGY

Ore - Massive sulphides 20-40% pyrite, 15% sphalerite, 5% pyrrhotite, 2% chalcopyrite, 10% magnetite, 40% talc and 40% chlorite.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	0.4
GROWING DEGREE DAYS		1110
FROST FREE PERIOD	start	Early June
	length in days	90
GRDWING SEASON	start	Early May
	length in days	160
PRECIPITATIDN	annual cm	92.2
	growing season cm	47.4

WASTE MINERALOGY

Predominantly quartz; minor pyrite, serpentine, epidotes, calcite, feldspar and tourmaline.

DISPOSAL METHOD & SIZE

222 ha in lake enclosed by embankments;
101 ha exposed above lake level.
Same area used by Orchan Mine.

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: birch.

Introduced: Experimental project since 1970. Surface coverage of over 25% in seeded areas.

Comments: Grasses seeded using lime and fertilizer on cultivated tailings. Maintenance fertilizer is applied each year and additional lime is added annually. Trees have been transplanted into grassed areas. This is on relatively fresh unoxidized tailings. Areas of oxidized tailings are still under study by mine staff for a suitable vegetation method.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	62	39 - 85
	% silt	33	15 - 51
	% clay	10	10 - 10
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	18	7 - 40
	15 bar %	1.4	0.5 - 4.0
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³	1.8	1.67 - 2.1
PARTICLE DENSITY	g/cm³	3.31	3.30 - 3.31

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.5	5.9 - 7.2
	CaCl		
CATION EXCHANGE CAPACITY	meq /100g	2.7	2.2 - 3.3
ORGANIC MATTER	%	0.1	
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	9783	5000 - 25,200
AVAILABLE ELEMENTS	P ppm	3	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.03	0.005 - 0.053
	S %	12.9	0.3 - 32.2
	Fe %	27.4	21.44 - 35.83
	Al %		
	Ca %	1.91	1.63 - 2.17
	Mg %	1.24	0.77 - 1.77
	K %	0.06	0.04 - 0.10
	Mn %	0.29	0.04 - 0.49
	Si ppm	14.7	12.8 - 17.1
	Cd ppm	37	20 - 48
	Ni ppm	200	134 - 299
	Pb ppm	588	360 - 790
	Zn ppm	1123	450 - 1820
	Cu ppm	271	164 - 373

SOURCE University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
ZINC COPPER	TAILINGS	Normetal Mines Ltd. Kerr Addison Mines Ltd. Normetal, Quebec	Normetal, P.Q. (N.W. Quebec)	NORMETAL MINE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	0.4
GROWING DEGREE DAYS		1110
FROST FREE PERIOD	start	Early June
	length in days	90
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATION	annual cm	92.2
	growing season cm	47.4

OREBODY GEOLOGY

Ore located in sericitized volcanic tuffs
Ore - massive sulphides; pyrite 35-40%, pyrrhotite 7%, chalcopyrite 5%

DISPOSAL METHOD & SIZE

2 ponds, 71 ha encircling dams with steep slopes.

WASTE MINERALOGY

Serpentine, quartz, pyrite, epidote, tourmaline, minor feldspar, muscovite and calcite

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	48	8 - 80
	% silt	39	10 - 86
	% clay	16	3 - 40
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	16	3 - 30
	15 bar %	2	0.2 - 3
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³	1.6	1.3 - 2.55
PARTICLE DENSITY	g/cm³	3.26	2.68 - 4.29

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	5.8	2.2 - 7.6
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.4	0.3 - 0.6
ORGANIC MATTER	%	0.2	D.1 - 0.5
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	14,7000	44 - 56,800
AVAILABLE ELEMENTS	P ppm	4	3 - 17
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.02	0.002 - 0.11
	S %	8.7	0.3 - 30.3
	Fe %	28.61	8.09 - 56.83
	Al %		
	Ca %	1.2	0.04 - 2.1
	Mg %	0.94	0.22 - 1.65
	K %	0.31	0.04 - 0.97
	Mn %	0.09	0.03 - 0.24
	Si ppm	18.2	3.9 - 35.8
	Cd ppm	50	14 - 120
	Ni ppm	132	52 - 261
	Pb ppm	1179	10 - 2710
	Zn ppm	1076	100 - 2400
	Cu ppm	228	21 - 375

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: Some in seeded areas but none on bare tailings.

Introduced: Older pond - seeded since 1969
new pond - soil cap and sand cover added to dry parts of the tailings and seeded.

Comments:
Trials on Tailings
- lime needed - at least 67mt/ha
- asbestos tailings tried for neutralization - unsuccessfully
- sawdust and wood chips used as mulch

Capped Areas
- soil capped areas - 90% vegetation coverage in seeding year
- heavy fertilization used
- mixture of grasses and legumes seeded
- 50-75% vegetation coverage in sand-capped areas
- organized as a once over treatment at completion of mining.

SOURCE University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
ORCHAN	Matagami, Que. (N.W. Quebec)	Orchan Mines Ltd. Matagami, Quebec.	TAILINGS	ZINC COPPER

OREBODY GEOLOGY

Ore located in biotite
Ore - massive sulphides; 60%

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	0.4
GROWING DEGREE DAYS		1110
FROST FREE PERIOD	start	Early June
	length in days	90
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATION	annual cm	92.2
	growing season cm	47.4

WASTE MINERALOGY

Predominantly quartz; minor pyrite, serpentine, epidotes, calcite, feldspar and tourmaline.

DISPOSAL METHOD & SIZE

222 ha in lake enclosed by embankment. 110 ha above water level. Same area used by Mattagami Lake Mine.

VEGETATION & COMMENTS

Comment: Are depositing wastes into same pond as Mattagami Lake Mine and contribute proportionately to the stabilization of that area.
See Mattagami Lake Mine.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	72	55 - 85
	% silt	25	13 - 36
	% clay	6	2 - 9
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	13	8 - 26
	15 bar %	1	0.5 - 2.0
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm^3	1.85	1.76 - 1.97
PARTICLE DENSITY	g/cm^3	3.2	2.73 - 3.5

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.7	6.2 - 7.2
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	3.6	3.4 - 3.9
ORGANIC MATTER	%	0.4	0.3 - 0.5
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	5332	3300 - 8500
AVAILABLE ELEMENTS	P ppm	3.9	3.0 - 7.4
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.02	0.002 - 0.09
	S %	12	8 - 15
	Fe %	32.5	21.8 - 40.94
	Al %		
	Ca %	1.39	1.14 - 1.69
	Mg %	1.5	1.25 - 2.0
	K %	0.04	0.04 - 0.06
	Mn %	0.4	0.13 - 0.6
	Si ppm	15.1	13.2 - 18.9
	Cd ppm	46	32 - 67
	Ni ppm	173	98 - 278
	Pb ppm	588	310 - 830
	Zn ppm	1454	860 - 2140
	Cu ppm	326	254 - 399

SOURCE University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
NICKEL COPPER	TAILINGS	The International Nickel Co. of Canada Ltd. Sudbury, Ontario	Copper Cliff on west edge of Sudbury, Ont.	COPPER CLIFF

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4.8
GROWING DEGREE DAYS		1510 - 1842
FROST FREE PERIOD	start	Late June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	75.8
	growing season cm	37.2

OREBODY GEOLOGY

Interfacial zone between nickel irruptive (consisting principally of acidic gabbro, norite, and diorite or quartz diorite and quartz diorite breccia) and Archaen mafic and intermediate metavolcanics, granites and acidic rocks. Ore - Massive and breccia sulphides, and disseminated or stringer sulphides in silicates. Sulphide minerals include pyrrhotite, pentlandite chalcopyrite and cubanite.

DISPOSAL METHOD & SIZE

Tailings pond M1 (144 ha), M2 (156 ha) and CD (240 ha). Encircling dam and natural topography.

WASTE MINERALOGY

50% feldspar, 20% amphibole, 10% quartz, 1% pyroxene, 6% biotite, 5.6% pyrrhotite, 0.6% magnetite, 0.5% pentlandite, 0.3% chalcopyrite. Pond M1 is pyrrhotite stockpile.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	60.9	21.8 - 81.3
	% silt	36.9	16.1 - 93.2
	% clay	4.2	1.3 - 9.2
MOISTURE RETENTION	0.1 bar %	27	18 - 44
	0.3 bar %	17	8 - 40
	15 bar %	4	1 - 10
AVAILABLE WATER STORAGE CAPACITY	%	13	3 - 32
BULK DENSITY	g/cm³	1.44	1.1 - 1.7
PARTICLE DENSITY	g/cm³	2.94	2.8 - 3.14

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	5	3 - 7
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.98	0.23 - 6.33
ORGANIC MATTER	%	2.0	0.1 - 25.3
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.0	0.1 - 5.1
SOLUBLE SALTS	ppm	3035	300 - 9771
AVAILABLE ELEMENTS	P ppm	69	10 - 400
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.001	0.001 -0.002
	S %	2.2	0.26 - 8.3
	Fe %	9.8	7.4 - 14.6
	Al %		

VEGETATION & COMMENTS

Regional: None to sparce birch.

Volunteer: Alaskan birch. Only after establishment of a grass cover on oldest area (4 m high).

Introduced: 25-50% Canada blue - 0-5% crested wheat, timothy, smooth brome, red top and legumes.

Comments: Over a 15 year period they have developed a method of vegetating their tailing directly using lime and fertilizer with annual maintenance and a companion crop with fall seeding. Crops grown on the tailings are used as a mulch on dryer areas and investigations are now into chemical stabilizers. Reclamation staff responsible for test work and treatment.

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
EAST FALCONBRIDGE	Falconbridge, Ont. N.W. of Sudbury	Falconbridge Nickel Mines Ltd., Falconbridge, Ontario.	TAILINGS	COPPER NICKEL

ORE BODY GEOLOGY

Interfacial zone between nickel irruptive (consisting principally of acidic gabbro, norite, and diorite or quartz diorite and quartz diorite breccia) and Archaen mafic and intermediate metavolcanics, granites and acidic rocks. Ore - Massive and breccia sulphides, and disseminated or stringer sulphides in silicates. Sulphide minerals include pyrrhotite, pentlandite chalcopyrite and cubanite.

CLIMATE

ANNUAL MEAN TEMPERATURE		°C	4.8
GROWING DEGREE DAYS			151D - 1842
FROST FREE PERIOD	start		Early June
	length in days		80 - 100
GROWING SEASON	start		Early May
	length in days		140 - 150
PRECIPITATION	annual cm		75.8
	growing season cm		37.2

WASTE MINERALOGY

Pyrrhotite

DISPOSAL METHOD & SIZE

26 ha encircling dam on 3 sides. Steep bank slopes. slopes.

VEGETATION & COMMENTS

Regional: None.

Volunteer: wild barley.

Introduced: Timothy, red top, red fescue, red clover, birdfoot trefoil, poplar.

Comments: Research has been underway since 1964 seeding directly on the tailing with lime additives and on gravel caping of the tailings. Some degree of success has been had but patches of acidic ground occur through both methods.
Work is continuing by mine staff.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	31	1 - 43
	% silt	55	25 - 80
	% clay	14	2 - 30
MOISTURE RETENTION	0.1 bar %	34	19 - 43
	0.3 bar %	27	12 - 40
	15 bar %	5	2 - 10
AVAILABLE WATER STORAGE CAPACITY	%	22	9 - 30
BULK DENSITY	g/cm³	1.3	1.2 - 1.5
PARTICLE DENSITY	g/cm³	2.9	2.7 - 3.15

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.8	4.3 - 8.0
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.6	0.3 - 2.7
ORGANIC MATTER	%	0.7	0.2 - 1.7
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.7	0.5 - 3.5
SOLUBLE SALTS	ppm	4168	410 - 8345
AVAILABLE ELEMENTS	P ppm	29	10 - 115
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.002	
	S %	0.6	0.17 - 1.73
	Fe %	12	4.1 - 22.5
	Al %		

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
NICKEL COPPER	TAILINGS	Falconbridge Nickel Mines Ltd. Falconbridge, Ont. POM 1S0	10 km N of Falconbridge Ont.	FAULT LAKE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4.8
GROWING DEGREE DAYS		1510
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	75.8
	growing season cm	37.2

OREBODY GEOLOGY

Interfacial zone between nickel irruptive (consisting principally of acidic gabbro, norite, and diorite or quartz diorite and quartz diorite breccia) and Archaen (mafic and intermediate metavolcanics, granites and acidic rocks).
Ore - Massive and breccia sulphides, and disseminated or stringer sulphides in silicates. Sulphide minerals include pyrrhotite, pentlandite chalcopyrite and cubanite.

DISPOSAL METHOD & SIZE

21 ha, active tailings, in operation since 1963. Older exposed surfaces oxidizing and forming indurate iron pans. Surface liquid in many areas.

WASTE MINERALOGY

40% pyrrhotite, 30% feldspar 20% quartz

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE	% <2mm	100	
DISTRIBUTION	% sand	25	10 - 40
	% silt	72	58 - 86
	% clay	3	2 - 4
MOISTURE	0.1 bar %	36	32 - 40
RETENTION	0.3 bar %	28	27 - 28
	15 bar %	5	
AVAILABLE WATER STORAGE CAPACITY	%	23	22 - 23
BULK DENSITY	g/cm^3	1.3	1.2 - 1.4
PARTICLE DENSITY	g/cm^3	3.3	3.15 - 3.45

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6	5.8 - 6.2
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.4	
ORGANIC MATTER	%	5.8	4.5 - 7.1
ELECTRICAL CONDUCTIVITY	mmhos/cm	3.5	2.3 - 4.6
SOLUBLE SALTS	ppm	8437	400 - 12,875
AVAILABLE ELEMENTS	P ppm	5	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	14.93	4.38 - 25.48
	Fe %	32.96	16.08 - 49.83
	Al %		

VEGETATION & COMMENTS

Regional: None to sparce birch and oak.

Volunteer: None

Introduced: None

Comments: Staff is investigating vegetation establishment and conducting test work on capping and direct seeding with lime and fertilizer additions.

SOURCE

Montreal Engineering Co. Ltd.
Montreal, Quebec

Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
NICKEL RIM	Approx. 40 km North of Falconbridge, Ont.	Falconbridge Nickel Mines Ltd., Falconbridge, Ont. POM 1SO	TAILINGS	NICKEL

ORE BODY GEOLOGY

Interfacial zone between nickel irruptive (consisting principally of acidic gabbro, norite, and diorite or quartz diorite and quartz diorite breccia) and Archaen (mafic and intermediate metavolcanics, granites and acidic rocks).
Ore - Massive and breccia sulphides, and disseminated or stringer sulphides in silicates. Sulphide minerals include pyrrhotite, pentlandite chalcopyrite and cubanite.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	4.8
GROWING DEGREE DAYS		1510 - 1842
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	75.8
	growing season cm	37.2

WASTE MINERALOGY

70% silicate gouge and 30% pyrrhotite

DISPOSAL METHOD & SIZE

14 ha, 3 main sites adjacent to and part of a water body. Some dammed valleys and spills.

VEGETATION & COMMENTS

Regional: Sparce birch and oak growth.

Volunteer: Cat-tails around margin of flooded site.

Introduced: On till cap - timothy, Canada blue grass, red fescue, red clover, and a cover crop of rye.

Comments: - gravel cap average of 15 cm thick
- ratios of sulphate/sulphur and ferric to total iron indicate gravel cap becoming contaminated by capillary rise of salts
- cap seeded in 1973
Studies are continuing by staff and contract work.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	74	70 - 80
	% silt	20	14 - 26
	% clay	5	4 - 7
MOISTURE RETENTION	0.1 bar %	19	15 - 24
	0.3 bar %	12.2	10 - 16
	15 bar %	4	2 - 5
AVAILABLE WATER STORAGE CAPACITY	%	9	6 - 11
BULK DENSITY	g/cm³	1.4	1.3 - 1.7
PARTICLE DENSITY	g/cm³	2.92	2.87 - 3.03

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	3.7	2.7 - 6.4
	CaCl		
CATION EXCHANGE CAPACITY	meq /100g	0.9	0.3 - 1.9
ORGANIC MATTER	%	2.6	0.3 - 11.0
ELECTRICAL CONDUCTIVITY	mmhos/cm	2.9	0.8 - 6.2
SOLUBLE SALTS	ppm	2240	530 - 4960
AVAILABLE ELEMENTS	P ppm	41	5 - 102
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.002	
	S %	1.91	0.01 - 4.52
	Fe %	16.1	2.5 - 21.6
	Al %		

SOURCE

Montreal Engineering Co. Ltd.
Montreal, Quebec Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
LEAD ZINC SILVER	TAILINGS	Cominco Ltd. Sullivan Mine, Kimberley, B.C.	Less than 3 km N of Kimberley, B.C. Elevation: 1220 meters	SULLIVAN

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	5.0
GROWING DEGREE DAYS		2650
FROST FREE PERIOD	start	
	length in days	95
GROWING SEASON	start	
	length in days	181
PRECIPITATION	annual cm	3B
	growing season cm	14

OREBODY GEOLOGY

Layered sulphide deposit of hydrothermal origin in sedimentary rock.
Ore - Sulphides

DISPOSAL METHOD & SIZE

Total of 250 hectares one of iron tailings; one of silica tailings. Perimeter dam of tailings with steep slopes.

WASTE MINERALOGY

Massive sulphide including pyrite

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	31.2	5.3 - 61.B
	% silt	55	31.0 - 84.1
	% clay	13.8	4.8 - 29.6
MOISTURE RETENTION	0.1 bar %	36.9	30.1 - 45.6
	0.3 bar %	29.7	15.2 - 39.7
	15 bar %	11.3	3.1 - 19.6
AVAILABLE WATER STORAGE CAPACITY	%	18	10.2 - 28
BULK DENSITY	g/cm^3	1.25	1.15 - 1.36
PARTICLE DENSITY	g/cm^3	2.78	2.55 - 3.17

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	3.2	2.3 - 7.0
	CaCl	3.1	2.3 - 7.0
CATION EXCHANGE CAPACITY	meq/100g	8.6	1.5 - 21.0
ORGANIC MATTER	%	5.87	0.84 - 20.63
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	2.5	1.5 - 3.5
	K ppm	24.4	0.5 - 131
	Ca ppm	2528	40 - 12,740
	Mg ppm	431	48 - 1328
TOTAL ANALYSIS	N %	0.027	0.001 - 0.135
	S %	6.57	2.74 - 11.46
	Fe %	17.3	8.5 - 32.0
	Al %	5	3.1 - 6.4
	Ca %	0.25	0.01 - 1.16
	Mg %	0.8	0.31 - 2.1
	Na %	0.64	0.21 - 1.01
	K %	1.1	0.41 - 1.9
	Mn %	0.46	0.16 - 0.74
	Si ppm	15	11 - 21
	Cd ppm	80	70 - 90
	Cr ppm	70	
	Pb ppm	1.5	0.3 - 4.7
	Zn ppm	542	113 - 1890

VEGETATION & COMMENTS

Regional: Western birch and lodgepole pine stand with some Douglas fir and ponderosa pine.

Volunteer: bullrushes in wet areas only.

Introduced: None

Comments: Rapidly oxidized and has been examined by Cominco staff but has not responded to studies to date.

SOURCE University of British Columbia
Soil Science Dept.
Vancouver, B.C.
Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
CAMFLO	Malartic, Quebec (N.W. Quebec)	Camflo Mines Ltd., Box 640, Malartic, Quebec.	TAILINGS	GOLD

ORE BODY GEOLOGY

Ore - quartz-feldspar, porphyry ore (90% of production).
diorite ore (10% of production).

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1110
FROST FREE PERIOD	start	Early June
	length in days	98
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATION	annual cm	90.2
	growing season cm	45

WASTE MINERALOGY

Principally quartz and feldspar. Minor amounts of calcite and serpentine.

DISPOSAL METHOD & SIZE

81 ha perimeter. Embankments up to 7.6 m.

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: None (active pond)

Introduced: None.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	50	18 - 60
	% silt	43	33 - 70
	% clay	7	5 - 12
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	18	11 - 32
	15 bar %	2	1 - 3
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³	1.39	1.37 - 1.43
PARTICLE DENSITY	g/cm³	2.72	2.67 - 2.78

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.4	6.4 - 8.2
	CaCl		
CATION EXCHANGE CAPACITY	meq /100g	0.7	
ORGANIC MATTER	%	0.1	0.1 - 0.3
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	2620	495 - 4790
AVAILABLE ELEMENTS	P ppm	3	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	.008	0.002 - 0.016
	S %	0.7	0.3 - 1.8
	Fe %	3.41	2.51 - 4.73
	Al %		
	Ca %	1.72	1.54 - 2.13
	Mg %	0.5	0.3 - 1.07
	K %	1.88	1.71 - 2.04
	Mn %	0.05	0.04 - 0.0B
	Si ppm	30.9	30.4 - 31.4
	Cd ppm	11	2 - 17
	Ni ppm	36	18 - 56
	Pb ppm	32	20 - 50
	Zn ppm	100	
	Cu ppm	27	25 - 30

SOURCE

University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
GOLD	TAILINGS	Teck Corporation Ltd. Lamaque Mine, Val d'Or, Quebec	Val d'Or, Que. (N.W. Quebec) Adjacent Sigma Mine.	LAMAQUE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1110
FROST FREE PERIOD	start	Early June
	length in days	98
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATION	annual cm	90.2
	growing season cm	45

OREBODY GEOLOGY

Ore located in veins of quartz, tourmaline, and calcite, associated with pyrite
Ore - gold

DISPOSAL METHOD & SIZE

Rock and gravel embankment 5-8 m high 262 ha

WASTE MINERALOGY

Predominantly quartz and epidote with minor pyrite tourmaline, feldspar, calcite and muscovite.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	37	30 - 47
	% silt	55	50 - 60
	% clay	11	10 - 14
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	22	19 - 24
	15 bar %	1	
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm^3	1.46	1.33 - 1.61
PARTICLE DENSITY	g/cm^3	2.76	2.76 - 2.77

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.4	6.8 - 8.1
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.6	0.5 - 0.8
ORGANIC MATTER	%	0.1	
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	3020	2200 - 5000
AVAILABLE ELEMENTS	P ppm	3	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.007	0.001 - 0.014
	S %	0.8	0.7 - 1.0
	Fe %	4.5	4.24 - 4.72
	Al %		
	Ca %	2.1	1.97 - 2.22
	Mg %	1.19	0.92 - 1.33
	K %	0.6	0.5 - 0.65
	Mn %	0.10	0.09 - 0.14
	Si ppm	27.6	25.6 - 28.5
	Cd ppm	B3	18 - 280
	Ni ppm	67	59 - 84
	Pb ppm	25	10 - 50
	Zn ppm	100	
	Cu ppm	32	28 - 35

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: None (active pond).

Introduced: 0.5 ha experimental plot - limited success.

SOURCE

University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec
Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
SIGMA	Val d'Or, (N.W. Que.) adjacent Lamaque Mine	Sigma Mines (Quebec) Ltd., Val d'Or, Quebec.	TAILINGS	GOLD

ORE BODY GEOLOGY

Ore located in veins of quartz, toumaline and pyrite.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1110
FROST FREE PERIOD	start	Early June
	length in days	98
GROWING SEASON	start	Early May
	length in days	160
PRECIPITATIDN	annual cm	90.2
	growing season cm	45

WASTE MINERALOGY

Quartz predominate, minor tourmaline, muscovite, feldspar, and calcite.

DISPOSAL METHOD & SIZE

2 ponds 14 m embankment of tailings and waste rock. Steep sided; one pond 40 ha other pond 73 ha.

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam and poplar.

Volunteer: Numerous species in seeded areas but none on untreated wastes.

Introduced: Seeding done of abandoned ponds.
16 ha - 1973
24 ha - 1974

Comments: Uniform coverage but growth is poor with a good portion of exposed surface. Nutrient deficiencies common except in older areas with thicker legume growth. Treatment has been fertilizer and seed with no follow-up maintenance. Work was contracted.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	54	4 - 82
	% silt	42	18 - 88
	% clay	5	2 - 8
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	17	7 - 40
	15 bar %	0.9	0.5 - 1.0
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm^3	1.5	1.35 - 1.67
PARTICLE DENSITY	g/cm^3	2.75	2.72 - 2.82

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.1	6.D - 7.7
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.3	
ORGANIC MATTER	%	0.2	0.1 - 0.3
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	1180	530 - 2100
AVAILABLE ELEMENTS	P ppm	3.3	3.0 - 8.8
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.006	0.001 - 0.015
	S %	1.0	0.5 - 2.1
	Fe %	4.46	3.98 - 6.07
	Al %		
	Ca %	1.58	1.26 - 1.91
	Mg %	1.36	0.85 - 1.61
	K %	0.48	0.05 - 0.90
	Mn %	0.09	0.07 - 0.10
	Si ppm	29	26 - 30
	Cd ppm	16	9 - 35
	Ni ppm	94	47 - 194
	Pb ppm	72	10 - 480
	Zn ppm	100	
	Cu ppm	47	26 - 92

SOURCE University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
GOLD	TAILINGS	Chesterville Mines Ltd. Chesterville, Ontario.	Chesterville, Ontario (N.E. end of Larder Lake)	CHESTERVILLE

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1120
FROST FREE PERIDD	start	Early June
	length in days	8D - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	85.6
	growing season cm	43

OREBODY GEOLOGY

Ore located in carbonate rocks, talc and chlorite schists cut by quartz stockworks.

DISPOSAL METHOD & SIZE

Discharged on the shore of a lake

WASTE MINERALOGY

Principally quartz, minor tourmaline and feldspars.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	82	75 - 88
	% silt	16	10 - 22
	% clay	3	2 - 3
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	9	5 - 15
	15 bar %	1	1 - 2
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³	1.63	1.58 - 1.67
PARTICLE DENSITY	g/cm³	2.83	

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.4	6.5 - 8.0
	CaCl		
CATION EXCHANGE CAPACITY	meq./100g	0.9	D.5 - 1.3
ORGANIC MATTER	%	0.1	
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	6700	3000 - 8600
AVAILABLE ELEMENTS	P ppm	3	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.039	0.003 - 0.111
	S %	1.7	0.3 - 3.4
	Fe %	7.5	7.1 - 7.79
	Al %		
	Ca %	2.1	2.0 - 2.3
	Mg %	1.5	1.3 - 1.6
	K %	D.13	0.09 - 0.18
	Mn %	0.17	0.14 - 0.20
	Si ppm	26.5	25.8 - 26.9
	Cd ppm	19	18 - 19
	Ni ppm	439	426 - 456
	Pb ppm	30	10 - 5D
	Zn ppm	100	
	Cu ppm	41	31 - 53

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: 90% coverage. Wet-terrain plants.

Introduced: None

SOURCE

University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec. Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
DOME	Timmins-Porcupine, Ontario.	Dome Mines Ltd., South Porcupine, Ontario. PON 1HO	TAILINGS	GOLD

ORE BODY GEOLOGY

Ore located in quartz and ankerite veins and lenses formed in sediments and volcanics, minor sulphides.
Ore - gold.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1120
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	85.6
	growing season cm	43

WASTE MINERALOGY

Quartz, feldspar, pyrite and pyrrhotite.

DISPOSAL METHOD & SIZE

Total 142 ha in several ponds retained by perimeter dams. Some dams have been graded to improve the slope while others have steep slopes.

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam and poplar.

Volunteer: Some natural encroachment but unclear as to areas volunteer and treated.

Introduced: 6-year growth - predominantly birdsfoot trefoil and timothy.
2-year growth - predominantly timothy and some birdsfoot trefoil.

Comments: Vegetation was started in 1969.
38 ha have been vegetated by natural colonization or by seeding.
45° slopes flattened to 10°.
North-end steep slopes were hydro-seeded
Problem: berm erosion and slumping.
Vegetation has been done mainly by agricultural methods using a once-over treatment using Birdsfoot trefoil and timothy as species and fertilizer at seeding time.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	31	2 - 70
	% silt	59	26 - 81
	% clay	9	4 - 18
MOISTURE RETENTION	0.1 bar %	31	22 - 42
	0.3 bar %	3	1.4 - 3.9
	15 bar %	3	2 - 4
AVAILABLE WATER STORAGE CAPACITY	%	25	12 - 35
BULK DENSITY	g/cm^3	1.3	1.0 - 1.6
PARTICLE DENSITY	g/cm^3	2.86	2.83 - 2.90

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.8	7.0 - 8.3
	CaCl		
CATION EXCHANGE CAPACITY	meq/1DDg		
ORGANIC MATTER	%	1.1	0.7 - 1.4
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.6	0.3 - 1.0
SOLUBLE SALTS	ppm	1605	41 - 3160
AVAILABLE ELEMENTS	P ppm		
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %	1.3	0.1 - 3.4
	Fe %	7.3	6.2 - 8.5
	Al %		

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
GOLD	TAILINGS	Omega Mines Ltd. 1250, 505 Burrard St. Vancouver, B.C.	Less than 3 km N of the town of Larder Lake in NE Ontario	OMEGA

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1120
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	85.6
	growing season cm	43

OREBODY GEOLOGY

Ore located in basalt, amdesite, dacite, ana talc chlorite schist cut by quartz veins
Ore - gold

DISPOSAL METHOD & SIZE

Initially tailings dumped into lake. Then into 2 ponds, contained by perimeter dams.

WASTE MINERALOGY

Principally quartz; minor feldspar, epidote, traces of serpentine and muscovite.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	14	7 - 20
	% silt	87	80 - 93
	% clay		
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	11	3 - 21
	15 bar %	1.25	0.5 - 2.0
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³	1.5	1.1 - 2.12
PARTICLE DENSITY	g/cm³	3.69	3.57 - 3.82

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.0	1.8 - 7.7
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.4	0.7 - 3.6
ORGANIC MATTER	%	0.1	0.1 - 0.3
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	15,013	1100 - 72,400
AVAILABLE ELEMENTS	P ppm	3.3	3.0 - 4.B
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.022	0.004 - 0.091
	S %	3.3	0.30 - 9.1
	Fe %	11.0	4.08 - 39.6
	Al %		
	Ca %	1.86	1.66 - 2.32
	Mg %	1.0	0.06 - 1.73
	K %	0.79	0.25 - 2.09
	Mn %	0.1	0.01 - 0.15
	Si ppm	24.8	11.5 - 32.0
	Cd ppm	38	12 - 140
	Ni ppm	161	62 - 546
	Pb ppm	76	10 - 240
	Zn ppm	100	
	Cu ppm	65	20 - 153

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: coverage on gold tailings areas 75-90%, predominantely trees.
High graphite pond about 50% cover.

Introduced: None

SOURCE University of Sherbrooke
Centre for Technology of the Environment
Sherbrooke, Quebec
Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
PAMOUR PORCUPINE	N.E. of Timmins, Ont.	Pamour Porcupine Mines Ltd., Pamour, Ontario.	TAILINGS	GOLD

ORE BODY GEOLOGY

Ore pyrite and pyrrhotite located in quartz, calcite and ankerite.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1120
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	85.6
	growing season cm	43.2

WASTE MINERALOGY

Pyrite and pyrrhotite less than 2%, also quartz. calcite and ankerite.

DISPOSAL METHOD & SIZE

Perimeter dams containing 209 ha as a series of 3 ponds.

VEGETATION & COMMENTS

Regional: Dense forest dominated by spruce, fir and pine.

Volunteer: None

Introduced: Test work being done by various groups with no coordination of testing efforts.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	34	13 - 56
	% silt	57	37 - 76
	% clay	9	7 - 11
MOISTURE RETENTION	0.1 bar %	31	23 - 38
	0.3 bar %	25	14 - 35
	15 bar %	3	2 - 3
AVAILABLE WATER STORAGE CAPACITY	%	22	12 - 32
BULK DENSITY	g/cm^3	1.4	1.3 - 1.6
PARTICLE DENSITY	g/cm^3	2.82	2.76 - 2.87

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.3	7.0 - 7.5
	CaCl		
CATION EXCHANGE CAPACITY	meq /100g	3.0	0.9 - 5.0
ORGANIC MATTER	%	0.4	0.2 - 0.6
ELECTRICAL CONDUCTIVITY	mmhos/cm	0.8	0.2 - 1.5
SOLUBLE SALTS	ppm	6500	6398 - 6600
AVAILABLE ELEMENTS	P ppm	23	20 - 25
	K ppm	44	28 - 60
	Ca ppm	4250	4200 - 4300
	Mg ppm	110	100 - 120
TOTAL ANALYSIS	N %		
	S %	0.9	0.44 - 1.36
	Fe %	3.2	3.0 - 3.3
	Al %		

SOURCE Montreal Engineering Co. Ltd.
Montreal, Quebec

Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
GOLD COPPER	TAILINGS	Upper Canada Resources Ltd. 908, 40 University Ave. Toronto, Ont. M5J 1T1	Between Kirkland Lake and Larder Lake N.E. Ontario	UPPER CANADA

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.4
GROWING DEGREE DAYS		1120
FROST FREE PERIOD	start	Early June
	length in days	80 - 100
GROWING SEASON	start	Early May
	length in days	140 - 150
PRECIPITATION	annual cm	85.6
	growing season cm	43

OREBODY GEOLOGY

Upper Canada - ore located in sodium - syenite cut by quartz veins (>85% Si)
Upper Beaver - ore located in syenite
Ore - Upper Canada - gold
Upper Beaver - gold, copper sulphides

DISPOSAL METHOD & SIZE

Tailings fill small lake 67 ha

WASTE MINERALOGY

Feldspar, quartz, epidote, with small amounts of calcite, serpentine and traces of pyrite.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	40	3 - 68
	% silt	50	30 - 77
	% clay	10	2 - 20
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %	20	11 - 31
	15 bar %	2	1 - 2
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³	1.4	1.3 - 1.52
PARTICLE DENSITY	g/cm³	2.78	2.77 - 2.81

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.1	6.8 - 7.2
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.0	0.4 - 1.5
ORGANIC MATTER	%	0.1	
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm	2425	1740 - 3440
AVAILABLE ELEMENTS	P ppm	3	
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %	0.005	0.002 - 0.009
	S %	3.7	1.5 - 7.0
	Fe %	5.81	4.65 - 6.85
	Al %		
	Ca %	1.68	1.54 - 1.94
	Mg %	1.54	1.38 - 1.63
	K %	2.7	2.21 - 3.3
	Mn %	0.15	0.13 - 0.22
	Si ppm	25.2	21.8 - 30.8
	Cd ppm	17	14 - 25
	Ni ppm	99	43 - 152
	Pb ppm	294	100 - 650
	Zn ppm	110	100 - 150
	Cu ppm	66	29 - 153

VEGETATION & COMMENTS

Regional: Dense forest - black spruce, white birch, trembling aspen, jack pine, balsam, poplar.

Volunteer: aspens predominate

Introduced: None

SOURCE

University of Sherbrooke,
Centre for Technology of the Environment
Sherbrooke, Quebec Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
CAROL LAKE	Labrador City and Wabush, Newfoundland	Iron Ore Co. of Canada 1245 Sherbrooke St. W. Montreal, Quebec.	TAILINGS	IRON

ORE BODY GEOLOGY

Upper Wabush Iron Formation.
Ore - Specularite, magnetite, and hematite with quartz schist.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	-3.9
GROWING DEGREE DAYS		660
FROST FREE PERIOD	start	Early July
	length in days	128
GROWING SEASON	start	Early June
	length in days	145
PRECIPITATION	annual cm	87.5
	growing season cm	40.5

WASTE MINERALOGY

Quartz-iron

DISPOSAL METHOD & SIZE

102 ha - Tailings are dewatered, dislimed and discharged into a lake, tailings rise 21 m above lake surface in places. Dikes have been constructed where necessary for containment.

VEGETATION & COMMENTS

Regional: Upland ericaceous heath.

Volunteer: None.

Introduced: Hair grass, fireweed, grey birch, timothy and willow

Comments: Reclamation experiments have been attempted but very little detail available. Plants did not flourish and experimental shrubs had high mortality rate.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	94.6	93.7 - 95.5
	% silt	1.1	0.1 - 1.7
	% clay	5.2	4.6 - 5.6
MOISTURE RETENTION	0.1 bar %	6.9	3.9 - 10.2
	0.3 bar %	3.8	3.2 - 4.6
	15 bar %	0.5	0.4 - 0.5
AVAILABLE WATER STORAGE CAPACITY	%	3	3 - 4
BULK DENSITY	g/cm^3	2.0	1.9 - 2.0
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.7	7.4 - 7.9
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.73	0.63 - 0.93
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.23	0.20 - 0.30
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %	0.1	0.1 - 0.2
	Ca %	0.7	
	Mg %	4.3	4 - 5
	Na %	0.02	
	Mn %	0.4	0.4 - 0.5
	Cr ppm	833	500 - 1000
	Co ppm	100	
	Mo ppm	10	
	Ni ppm	20	
	Pb ppm	50	
	Ti ppm	200	
	Cu ppm	3	1 - 5

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
IRON	TAILINGS	Wabush Mines P.O. Box 878 Sept-Iles, Quebec	Wabush, Labrador North of Sept-Iles	WABUSH

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	-3.9
GROWING DEGREE DAYS		660
FROST FREE PERIOD	start	Early July
	length in days	128
GROWING SEASON	start	Early June
	length in days	145
PRECIPITATION	annual cm	87.5
	growing season cm	40.5

OREBODY GEOLOGY

Wabush Iron formation, faulted and schistose quartz specularite and magnetite.
Ore - Hematite, magnetite (banded quartz hematite)

DISPOSAL METHOD & SIZE

253 ha - Tailings dewatered to approximately 40% solids and piped to lake for disposal. Tailings rise approximately 30 m above lake level and slope into the lake.

WASTE MINERALOGY

quartz-iron

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	86.1	83.1 - 88.7
	% silt	6.2	1.7 - 12.2
	% clay	7.2	3.4 - 9.6
MOISTURE RETENTION	0.1 bar %	11.6	10.6 - 13.3
	0.3 bar %	6.7	3.6 - 9.5
	15 bar %	1	
AVAILABLE WATER STORAGE CAPACITY	%	6	3 - 9
BULK DENSITY	g/cm³	2.1	2.0 - 2.2
PARTICLE DENSITY	g/cm³		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.0	6.9 - 7.1
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.94	0.63 - 1.25
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.4	0.2 - 0.7
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %	0.2	D.1 - 0.3
	Ca %	0.03	0.02 - 0.05
	Mg %	0.5	0.3 - 0.6
	Na %	0.02	
	Mn %	1	
	Cr ppm	833	500 - 1000
	Co ppm	103	100 - 11D
	Mo ppm	10	
	Ni ppm	20	
	Pb ppm	50	
	Ti ppm	200	
	Cu ppm	5	2 - 10

VEGETATION & COMMENTS

Regional: Upland ericaceous heath

Volunteer: Wild sedge, horsetail, birch, couch grass and fire weed.

Introduced: Common rye grass, yellow clover, crownvetch, fall rye timothy and alfalfa.

Comments: Vegetation attempts made initially, somewhat unsuccessful. Natural reseeding has occurred in fertilized plots. Many introduced species have spread to some of the untouched low-lying wet areas. Little effective erosion control has been brought about by vegetation cover, as vegetation occurs only in wet areas where erosion is not a problem.
Mine personnel are establishing test areas in an ongoing program. Vegetation establishment has been tried along with other alternatives. Success has been limited so far to the moist areas of the tailings with emphasis on the use of 1 or 2 legumes with or without a grass companion. Vegetation is one of several stabilization methods that has been studied. In addition to agricultural seeding, they are: irrigation, chemical stabilizers, hydro mulching, mulch blankets, wood cellulose mulch and asphalt stabilizer with the mulches.

SOURCE Research and Productivity Council
Fredericton, New Brunswick Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
QUEBEC CARTIER LAC JEANNINE	8 km from Gagnon, Que.	Quebec Cartier Mining Company, Gagnon, Quebec.	TAILINGS	IRON

ORE BODY GEOLOGY

Quartz specular hematite with bands of quartzite, quartz, mica, schist and marble in a plunging anticlinal structure. North, granitic gneiss. South, thick quartzite.
Ore - Hematite, magnetite and quartz specular hematite.

CLIMATE

ANNUAL MEAN TEMPERATURE		°C	-2.7 - +1.1
GROWING DEGREE DAYS			724 - 784
FROST FREE PERIOD	start		Mid June
	length in days		128 - 136
GROWING SEASON	start		Mid May
	length in days		151 - 179
PRECIPITATION	annual cm		93.4 - 116.7
	growing season cm		44.5 - 53.9

WASTE MINERALOGY

Quartz-iron.

DISPOSAL METHOD & SIZE

285 ha - Tailings pumped into large area and retained by dikes.

VEGETATION & COMMENTS

Regional: Upland ericaceous heath.

Volunteer: None

Introduced: None

Comment: Tailings have lower silt and clay fractions than most other iron tailings.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	96.6	96.2 - 97.2
	% silt	2.5	1.6 - 3.4
	% clay	3	2 - 3
MOISTURE RETENTION	0.1 bar %	2.6	1.8 - 3.0
	0.3 bar %	1.2	0.8 - 1.6
	15 bar %	0.4	0.3 - 0.5
AVAILABLE WATER STORAGE CAPACITY	%	1.0	
BULK DENSITY	g/cm^3	2.5	2.0 - 2.9
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.8	7.6 - 8.0
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	1.25	0.63 - 1.88
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.4	0.2 - 0.5
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %	2.8	0.4 - 4.0
	Al %	0.4	0.3 - 0.5
	Ca %	0.24	0.15 - 0.29
	Mg %	2.3	0.36 - 3.6
	Na %	0.01	
	Mn %	0.04	0.03 - 0.04
	Cr ppm	7000	
	Ni ppm	30	20 - 50
	Ti ppm	1000	
	Cu ppm	1	

SOURCE Research and Productivity Council
Fredericton, New Brunswick
Date: 1974

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
IRON	TAILINGS	Iron Ore Co. of Canada 1245 Sherbrooke St. W. Montreal, Que.	Sept Isles, Que.	SEPT ISLES

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	1.2
GROWING DEGREE DAYS		952
FROST FREE PERIOD	start	Mid June
	length in days	156
GROWING SEASON	start	Mid May
	length in days	180
PRECIPITATION	annual cm	110
	growing season cm	46.7

OREBODY GEOLOGY

DISPOSAL METHOD & SIZE

159 ha - Tailings contained after deposit by sand and earth dams.

WASTE MINERALOGY

clay-iron

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	74.7	58.5 - 86.2
	% silt	20.2	7.2 - 37.9
	% clay	4.6	3.5 - 6.5
MOISTURE RETENTION	0.1 bar %	14.4	9.8 - 18.5
	0.3 bar %	8.8	7.1 - 11.1
	15 bar %	1	1 - 2
AVAILABLE WATER STORAGE CAPACITY	%	7	6 - 10
BULK DENSITY	g/cm^3	2.5	2.3 - 2.6
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.1	5.5 - 6.6
	CaCl		
CATION EXCHANGE CAPACITY	meq./100g	0.94	0.63 - 1.25
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm	0.3	0.2 - 0.3
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %	0.2	0.1 - 0.5
	Mg %	0.1	
	Na %	0.02	
	Mn %	0.18	0.15 - 0.2
	Cr ppm	500	
	Co ppm	200	
	Mo ppm	10	
	Ni ppm	20	
	Pb ppm	20	
	Ti ppm	667	500 - 1000
	Cu ppm	1	

VEGETATION & COMMENTS

Regional: Open wood heathland.

Volunteer: None

Introduced None

SOURCE

Research and Productivity Council
Fredericton, New Brunswick Date: 1974

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
TEXADA	W. coast of Texada Island, N.W. of Vancouver.	Texada Mines Ltd., Box 10, Gillies Bay, B.C.	TAILINGS	IRON COPPER GOLD SILVER

ORE BODY GEOLOGY

Iron-copper ore bodies enclosed in intermittent skarn zone formed along contact between limestone and intrusive granodiorite.
Ore - Magnetite, pyrrhotite specularite, chalcopyrite, sphalerite with pyrite, calcite and quartz.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	10.7
GROWING DEGREE DAYS		3300
FROST FREE PERIOD	start	Mid April
	length in days	251
GROWING SEASON	start	Mid March
	length in days	258
PRECIPITATION	annual cm	94.6
	growing season cm	18.2

WASTE MINERALOGY

Chlorite, quartz, feldspar, amphibole, gypsum and pyrite.

DISPOSAL METHOD & SIZE

Total including mine site, 42 ha. Tailings are currently being disposed into the Strait of Georgia.

VEGETATION & COMMENTS

Regional: Mixed stands of Douglas fir and western hemlock. Few tall shrubs but abundant low shrubs, herbs and moss.

Volunteer: Seedling trees and herbs. Survival is poor as distance from organic substrate is increased.

Introduced: None

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	6.6	1.8 - 10.9
	% silt	91.4	86.1 - 96.3
	% clay	2.0	1.1 - 3.0
MOISTURE RETENTION	0.1 bar %	29.9	28.2 - 31.9
	0.3 bar %	25.4	22.5 - 28.5
	15 bar %	8.5	7.6 - 9.1
AVAILABLE WATER STORAGE CAPACITY	%	21.3	20.6 - 22.8
BULK DENSITY	g/cm³		
PARTICLE DENSITY	g/cm³		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	6.6	2.4 - 7.9
	CaCl	6.5	2.3 - 7.7
CATION EXCHANGE CAPACITY	meq/100g	4.1	1.86 - 10.2
ORGANIC MATTER	%	5.94	1.11 - 8.14
ELECTRICAL CONDUCTIVITY	mmhos/cm	5.1	2.4 - 22.4
SOLUBLE SALTS	ppm	339	124 - 1443
AVAILABLE ELEMENTS	P ppm	0.3	0.1 - 1.4
	K ppm	21.2	0.5 - 50.5
	Ca ppm	31,114	7275 - 52,473
	Mg ppm	328	115 - 905
TOTAL ANALYSIS	N %	0.004	0.001 - 0.011
	S %	2.6	0.11 - 8.3
	Fe %	30.3	21.0 - 37.3
	Al %	1.7	1.1 - 2.5
	Ca %	9.5	7.6 - 10.9
	Mg %	2.7	1.8 - 4.1
	Na %	0.17	0.11 - 0.28
	K %	0.14	0.07 - 0.26
	Mn %	0.39	0.29 - 0.54
	Si ppm	8	7 - 10
	Co ppm	433	300 - 600
	Ti ppm	1500	1000 - 2000
	Zn ppm	27	25 - 32
	Cu ppm	443	306 - 540

SOURCE

University of British Columbia
Soil Science Dept.
Vancouver, B.C. Date: 1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE
MOLYBDENUM	TAILINGS	Placer Development Ltd Endako, B.C.	Central British Columbia near Fraser Lake	ENDAKO

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	2.9
GROWING DEGREE DAYS		1900
FROST FREE PERIOD	start	Mid June
	length in days	79
GROWING SEASON	start	Late April
	length in days	163
PRECIPITATION	annual cm	55.4
	growing season cm	16.4

OREBODY GEOLOGY

Ore located in quartz veins within Endako quartz monzonite, altered and intruded.
Ore - Molybdenum with pyrite, calcite, magnetite and specularite.

DISPOSAL METHOD & SIZE

2 ponds totaling 2.1 ha retained by several large dams of tailings. Active pond.

WASTE MINERALOGY

Kaolinite, illite, feldspar and quartz.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm	100	
	% sand	68.1	65.2 - 70.9
	% silt	25.5	23.4 - 27.5
	% clay	6.5	5.7 - 7.3
MOISTURE RETENTION	0.1 bar %	16.6	
	0.3 bar %	9.0	
	15 bar %	3.9	
AVAILABLE WATER STORAGE CAPACITY	%	12.6	
BULK DENSITY	g/cm³	1.31	1.24 - 1.38
PARTICLE DENSITY	g/cm³	2.64	2.62 - 2.66

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	7.5	6.8 - 8.2
	CaCl	7.0	6.3 - 7.5
CATION EXCHANGE CAPACITY	meq /100g	5.22	1.58 - 12.19
ORGANIC MATTER	%	1.26	0.02 - 6.62
ELECTRICAL CONDUCTIVITY	mmhos/cm	1.0	0.5 - 2.0
SOLUBLE SALTS	ppm	35.1	5.8 - 128.6
AVAILABLE ELEMENTS	P ppm	3.2	0.1 - 19.0
	K ppm	140	41 - 564
	Ca ppm	2440	695 - 3940
	Mg ppm	89	20 - 140
TOTAL ANALYSIS	N %	0.03	0.001 - 0.17
	S %	0.07	0.03 - 0.18
	Fe %	2.55	2.20 - 2.90
	Al %	6.95	6.80 - 7.10
	Ca %	0.09	0.04 - 0.14
	Mg %	0.27	0.23 - 0.31
	Na %	2.01	1.86 - 2.17
	K %	3.21	2.10 - 3.32
	Mn %	0.04	0.03 - 0.05
	Si ppm	27	26 - 28
	Mo ppm	750	700 - 800
	Ni ppm	150	100 - 200
	Ti ppm	3500	3000 - 4000
	Zn ppm	14	5 - 22
	Cu ppm	65	20 - 110

VEGETATION & COMMENTS

Regional: Mixed stands of lodgepole pine and Douglas fir or stands mainly of Engelmann spruce.

Volunteer: None except a small number of shrubs and herbs in seeded and fertilized areas.

Introduced: Grasses and legumes on a dam slope. Some reclamation test work by mine staff.

Comments: Seeding and fertilizing since 1969 around edge of dams, and on sloping and terraced sides. Grasses and legumes seeded.
0 - 50° slopes. Growth ranges from none (in slumping areas) to good.

SOURCE

University of British Columbia
Soil Science Dept.
Vancouver, B.C.
Date: 1975

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY
RIO ALGOM LTD NORDIC	Elliot Lake, Ont. 16D km W of Sudbury, Ontario.	Rio Algom Ltd. Box 1500 Elliot Lake, Ont.	TAILINGS	URANIUM

ORE BODY GEOLOGY

Uranium deposits in sheet-like, pyrite, quartz-pebble conglomerate beds in the lower most part of the Huronian System. Ore conglomerate contains pebbles of quartz, with some chert and jasper pebbles. Matrix of abundant pyrite, quartz, and feldspar, some muscovite, sericite, chlorite and epidote.

CLIMATE

ANNUAL MEAN TEMPERATURE	°C	3-4
GROWING DEGREE DAYS		1444
FROST FREE PERIOD	start	Early June
	length in days	100 - 110
GROWING SEASON	start	Late April
	length in days	170 - 180
PRECIPITATION	annual cm	80-90
	growing season cm	38

WASTE MINERALOGY

Mainly quartz with traces of pyrite, sericite and rutile.

DISPOSAL METHOD & SIZE

Inactive areas cover 330 ha. Retained behind dams in topographic depressions from 4 ha to 81 ha. Operating areas potentially 405 ha.

VEGETATION & COMMENTS

Regional: Great Lakes - St. Lawrence Forest region of mixed woods. Dominated with white pine, red pine, hemlock, birch, maple, oak and basswood.

Volunteer: None without treatment except common cat-tails in flooded areas.

Introduced: Mainly agricultural species used on a variety of test plots involving direct seeding on the tailings, sawdust capping, glacial till caps. Requires neutralization prior to any surface treatment.
Co-operative reclamation programs between the mines and CANMET.
Treatments require maintenance and are being assessed.
Success since 1971.

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE	% <2mm	100	
DISTRIBUTION	% sand	74	19 - 99
	% silt	25.8	0.9 - 81.0
	% clay		
MOISTURE	0.1 bar %		
RETENTION	0.3 bar %	14.7	1.18 - 37.4
	15 bar %	4.4	0.27 - 13.4
AVAILABLE WATER STORAGE CAPACITY	%	10.5	0.91 - 24.0
BULK DENSITY	g/cm^3	1.4	1.33 - 1.49
PARTICLE DENSITY	g/cm^3	2.75	2.71 - 2.78

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water	2.2	1.9 - 2.5
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g	0.76	0.09 - 1.75
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE	P ppm	2.0	0 - 3.9
ELEMENTS	K ppm	0.26	0.11 - 0.41
	Ca ppm	227	761 - 378
	Mg ppm	0.04	0.03 - 0.05
TOTAL ANALYSIS	N %		
	S %	2.68	1.18 - 4.25
	Fe %	2.56	1.15 - 3.65
	Al %	1.98	1.77 - 2.18
	Ca %	0.4	0.038 - 0.87
	Mg %	0.04	0.028 - 0.043
	K %	1.09	1.01 - 1.14
	Mn %	<0.01	
	Mo ppm	<500	
	Ni ppm	<100	
	Pb ppm	<500	
	Zn ppm	<100	
	Cu ppm	<100	

SOURCE CANMET
Elliot Lake Laboratory
Date: 1971-1975

COMMODITY	WASTE TYPE	CONTACT	LOCATION	MINE

CLIMATE

ANNUAL MEAN TEMPERATURE °C

GROWING DEGREE DAYS

FROST FREE PERIOD start
length in days

GROWING SEASON start
length in days

PRECIPITATION annual cm
growing season cm

OREBODY GEOLOGY

DISPOSAL METHOD & SIZE

WASTE MINERALOGY

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm		
	% sand		
	% silt		
	% clay		
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %		
	15 bar %		
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm³		
PARTICLE DENSITY	g/cm³		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water		
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g		
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm		
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %		

VEGETATION & COMMENTS

SOURCE

MINE	LOCATION	CONTACT	WASTE TYPE	COMMODITY

ORE BODY GEOLOGY

CLIMATE

ANNUAL MEAN TEMPERATURE °C

GROWING DEGREE DAYS

FROST FREE PERIOD start
length in days

GROWING SEASON start
length in days

PRECIPITATION annual cm
growing season cm

WASTE MINERALOGY

DISPOSAL METHOD & SIZE

VEGETATION & COMMENTS

PHYSICAL PROPERTIES

		MEAN	RANGE
PARTICLE SIZE DISTRIBUTION	% <2mm		
	% sand		
	% silt		
	% clay		
MOISTURE RETENTION	0.1 bar %		
	0.3 bar %		
	15 bar %		
AVAILABLE WATER STORAGE CAPACITY	%		
BULK DENSITY	g/cm^3		
PARTICLE DENSITY	g/cm^3		

CHEMICAL PROPERTIES

		MEAN	RANGE
pH	water		
	CaCl		
CATION EXCHANGE CAPACITY	meq/100g		
ORGANIC MATTER	%		
ELECTRICAL CONDUCTIVITY	mmhos/cm		
SOLUBLE SALTS	ppm		
AVAILABLE ELEMENTS	P ppm		
	K ppm		
	Ca ppm		
	Mg ppm		
TOTAL ANALYSIS	N %		
	S %		
	Fe %		
	Al %		

SOURCE

APPENDIX C

COST

COST ANALYSIS AND EQUIPMENT CHOICE

1. Relatively early in the planning of a mining operation, there is already sufficient information to develop a tentative vegetative program, and to determine the order of magnitude of costs and its technical and economic feasibility. For the most part, this is based on standard agricultural techniques and practices, and on experience at other mines.

2. Following preliminary evaluation of potential vegetation problems and suitable techniques order-of-magnitude estimates of costs can be developed. This section provides a breakdown of the various unit costs.

3. Economic as well as technical parameters can be evaluated at each of the decision points in the flow chart (Fig 4 in main text).

4. Waste dumps can be buried as an alternative to modifying its properties. Using shallow banks of desirable material may be cheaper than using steep banks of the same or less desirable material. Surface agricultural techniques requiring a one-time application may be better than aerial techniques requiring follow-up maintenance procedures. Increasing the proportion of flat area in waste dumps may offset the higher costs of vegetating sloping faces.

5. The cost of vegetation should not normally exceed the value of the reclaimed land. However, public relations considerations or legislated requirements may provide intangible non-economic incentives to vegetate.

6. At some economic point, however, the cost of vegetation exceeds the benefits, or justifies some alternative reclamation or disposal method. Underwater or underground disposal or some combination of these are possible alternatives.

UNIT VEGETATION COSTS

7. The following tables should allow first-order estimates of vegetation costs to be derived for an area for which standard soil properties are known or which can be estimated from known data for similar properties.

8. Use of the tables requires a knowledge of most probable range of soil properties from which chemical treatment costs can be determined. Size of the area will dictate the size of equipment required, while knowledge of surface stability will determine methods of applying chemicals and soil treatment. Unless otherwise noted, costs are in 1976 dollars.

Equipment

9. Standard agricultural techniques may be applied where slopes are not steep, wet or unstable. Costs are given for both new and used equipment with the choice made on the basis of probable usage; life expectancy of used equipment is rated at about one-half of that for new equipment. Life expectancy for new equipment can be 15 years for a tractor and 20 years for implements. Costs shown in the tables are those most probable at a retail dealer in an agricultural community, but do not include transportation to the site.

10. Capital expenditure in Table C-1 is based on retail prices of the most suitable equipment for the area treated. Conditions that may affect

Table C-1: Equipment costs

Implement	Rating	New	Used
0-16 Ha			
Tractor	30 P.T.O. hp	$ 5,000	$ 3,000
Cultivator	1.5 m	700	350
Discer	3 m	3,000	1,500
Spreader	5 m	1,000	500
Press drill	3.7 m	5,000	3,000
TOTAL		14,700	8,350
16-130 Ha			
Tractor	60 P.T.O. hp	11,500	6,000
Cultivator	3 m	1,500	750
Discer	5 m	6,000	3,000
Spreader	6 m	1,500	750
Press drill	3.7 m	5,000	3,000
TOTAL		25,500	13,500
130-260 Ha			
Tractor	70 P.T.O. hp	14,000	7,500
Cultivator	3.7 m	2,000	1,000
Discer	5.5 m	7,000	3,500
Spreader	6 m	1,500	750
Press drill	7.3 m	10,000	6,000
TOTAL		34,500	18,750

costs are brand name, sales area, substitution of larger or smaller equipment, or use of equipment other than that listed.

11. The maintenance costs shown in Table C-2 group together operating, repair and service costs. They are calculated as a percentage of original costs depending on size of area treated. Examples of the percentages used are:

134 to 260 ha, 7.5% of cost
20 to 130 ha, 6.0% of cost
0 to 16 ha, 4.5% of cost.

The costs in Table C-2 are subject to change because of operating time and abrasive or corrosive nature of the waste.

Table C-2: Equipment depreciation and maintenance costs (cost/ha/year)

Plot Size	Depreciation		Maintenance	Total
	Tractor	Implements		
4 ha	$ 33.50	$ 48.50	$ 66.25	$148.25
16 ha	8.50	12.25	27.50	48.25
20 ha	15.50	14.00	22.00	52.50
65 ha	4.75	4.50	9.50	18.75
130 ha	2.50	2.00	6.00	10.50
134 ha	3.00	3.00	4.75	10.75
194 ha	2.00	2.25	4.25	8.50
260 ha	150	1.50	4.00	7.00

Mulching

12. Mulch costs can vary from $50 to $2000 per ha, depending on availability of mulch material, transportation costs to the site, and application methods. Straw or hay would be the probable choice where available, while wood shavings, moss, or synthetic fiber mulches, etc, could be used. Differences in cost between these alternatives should be minimal. Stabilizer blankets, including jute mesh or excelsior blanket (Curlex) are expensive, probably approaching $3700 per ha installed. These have an application on steep, unstable slopes where mulching is required and discing or other techniques can not be used.

Custom Work

13. Custom contracting costs in Table C-3 are based on standard agricultural techniques. The

Table C-3: Custom contractor costs (cost/ha/year)

Area in hectares	Smallest area	Largest area
0-4	$100.00	$80.00
4-16	80.00	50.00
16-20	50.00	45.00
20-65	45.00	25.00
65-130	25.00	20.00
130-194	20.00	20.00
194-260	20.00	20.00

costs for this service would be subject to wide variations and those indicated should be used only as a guide. Availability of a custom contractor must be considered; timing of reclamation projects could conflict with normal agricultural schedules, resulting in a potential contractor with the necessary equipment being unavailable.

14. The costs in Table C-3 assume that machinery, maintenance and labour are supplied by the contractor. They exclude transportation to the site but include spreading, tillage, and seeding except where lime rates are high and mulching is required. Normal agricultural equipment is not suitable for reclamation in special areas, and specialized contractors will be required for such operations as mulching, hydro-seeding, and aerial seeding.

Limestone, Fertilizer and Seed

15. Seed costs vary considerably between species but $80 - $200 per hectare is reasonable for good quality seed. Seeding rates depend on the number of species used, on the waste properties, and on the method of seeding.

16. Limestone and fertilizer costs are based on source of supply, quantity purchased, method of supply - bagged, bulk, or liquid - and on whether applied or delivered off site. The relative concentrations of nitrogen, phosphorus and potassium reported as N-P-K will alter fertilizer costs without necessarily altering bulk quantity purchased. Table C-4 shows some alternative fertilizer selections and costs. Application rates can range from 500 to 1000 kg/ha/year.

17. Limestone application rates are dependent on the cause of acidity. With material containing less than 1% sulphur, normal agricultural lime

Table C-4: Fertilizer prices

	F.O.B.	Bagged load (60 tons)	Bulk load (70 tons)
Nitrogen			
34-0-0	Brandon*	$115/ton	$105/ton
46-0-0	Alta**	167/ton	155/ton
25-25-0	Brandon	167/ton	157/ton
11-48-0	Brandon	176/ton	166/ton
11-55-0	Brandon	202/ton	192/ton
Phosphorous			
0-46-0	Idaho		$165/ton
11-48-0	Brandon	$176/ton	166/ton
11-55-0	Brandon	202/ton	192/ton
Potassium			
0-0-62	Rocanville***	$ 45/ton truck load (170 kg drums)	$ 45/ton 20/ton truck or car load

* Simplot
** Cominco
*** Sylvite

requirements can be assumed. Lime requirements can range up to 10 tonnes per hectare. With sulphide-sulphur contents higher than 1%, additional testing and experience is needed to determine the lime requirement. Estimates for these conditions are 10 to 200 tonnes of limestone per hectare. In such cases, texture of the limestone may also be significant in maintaining suitable soil reaction stability.

Special Techniques

18. Alternative seeding or treatment techniques may be desirable or may be required in some cases. Aerial seeding, useful on wet or unstable surfaces, is applicable when soil treatment material, eg, limestone, is not required. Where such modification is required, modified all-terrain vehicles have been used; costs of these are not available. Hydroseeding is useful on steep banks where seed, fertilizer, and mulch can be applied in one operation, but this has the same limitations as aerial seeding if limestone incorporation is required. Hydroseeding however, can be used as an alternative to drill seeding once an area has been cultivated. This may be beneficial to stabilize the surface if a binder must be sprayed following seeding. Actual costs would be proportionately more than indicated for small jobs to cover charges for moving equipment to and from the site. Surface sealants, useful on banks or surfaces for stabilization while vegetation is being established, demonstrate highly variable costs depending on local wind and water erosion conditions and on the length of time the surface stability has to be retained. Slag or waste rock capping can be used where bank treatment for vegetation would require incorporation of treatment materials. The depth of an applied cap would depend on factors relating to the upward mobility of toxic salts from a waste material, ie, permeability of cover, precipitation regime, erosion, etc. The following list gives a range of costs for alternative treatment techniques which could be used in place of agricultural techniques on which the other costs are based, assuming uniform tillable material.

19. The costs reported for these special techniques may alter greatly if the equipment is not readily available. For example, aircraft transportation is likely to be required in remote areas.

1. Aerial seeding
   Approximate cost - $625/ha
2. Hydro seeding
   Approximate cost - $625/ha
3. Surface sealants (Coherex, Curasol, etc.)
   Approximate cost - $250 to $1250/ha (applied)
4. Slag or waste rock coverage - 20 cm depth
   Approximate cost - $2500 to $3750/ha
5. Capping-soil, gravel, sand, clay or combination
   10 cm depth - $4000/ha
   30 cm depth - $12,500/ha
6. Ripping, grading - $125 to $250/ha
7. Major re-contouring, shaping
   $625 to $12,500/ha
8. Planting shrubs and trees
   $125 to $500/ha

20. The total costs indicated by adding the derived component costs are those for the initial year of reclamation. Costs in subsequent years will depend on the degree of stability of the

waste material and on the speed at which acceptable soil material and vegetation are established. For waste requiring little modification, only minimal costs would be incurred after the first year, probably no more than 10 to 20% of the initial costs for the first one or two years. In extremely harsh waste material, however, a continuing program of soil conditioning may be required for five or more years at an annual cost similar to that of the initial year.

GLOSSARY

ACIDITY, ACTIVE

The activity of hydrogen ion in the aqueous phase of a soil, measured and expressed as a pH value.

ACIDITY, FREE (titratable acidity)

The titratable acidity in the aqueous phase of a soil, expressed in milliequivalents per unit mass of soil or in other suitable units.

ACIDITY, POTENTIAL (oxidizable acidity)

The amount of exchangeable hydrogen ion in a soil that can be rendered free or active in the soil solution by cation exchange, usuallly expressed in milliequivalents per unit mass of soil.

AGGREGATION, SOIL

The cementing or binding together of several soil particles into a secondary unit which will not disintegrate easily. These aggregate structures are of special importance to soil structure.

AVAILABLE NUTRIENT

That portion of any element or compound in the soil that can readily be absorbed and assimilated by growing plants. Not to be confused with "exchangeable."

AVAILABLE WATER

The portion of water in a soil that can be absorbed by plant roots, usually considered to be that water held in the soil against a tension of up to approximately 15 bars. See field capacity.

AVAILABLE WATER-HOLDING CAPACITY (soils)

The capacity to store water available for use by plants, usually expressed in linear depths of water per unit depth of soil. Commonly defined as the difference between the percentage of soil water at field capacity and the percentage at wilting point. This difference multiplied by the bulk density and divided by 100 gives a value in surface inches of water per inch depth of soil. See field capacity, and wilting point.

BIOMASS

The amount of plant and animal matter in a given area. May be distinguished as plant and animal biomass or below and above ground biomass. Usually expressed in g/m^2.

BUFFER, BUFFERING CAPACITY

Waters which tend to resist changes in pH are said to be buffered. In nature, water bodies that have a high buffering capacity usually rely on chemical equilibria involving calcium or sodium carbonate, bicarbonate, carbonic acid and water. The relatively soluble calcium or sodium salts are derived from natural sources like limestone through the action of water enriched with carbon dioxide from organic sources while draining through the upper soil horizons.

CATION-EXCHANGE CAPACITY

The sum total of exchangeable cations that a soil can adsorb (sometimes called total-exchange capacity, base-exchange capacity, or cation-adsorption capacity), expressed in milliequivalents per 100 g of soil or of other adsorbing material, such as clay.

CHELATED (complexed)

Bound. In plant nutrition, the term refers to the binding of one ion to another, usually an organic compound. Chelation can increase or decrease the solubility of ions.

COMPANION CROP (nurse crop)

A crop usually sown with another to improve soil and microclimatic conditions to encourage the growth of the desired crop.

CULTIVATION

Tillage to prepare land for seeding or transplanting, and later to control weeds and loosen the soil.

DECANT

Structure developed to drain water from the surface of tailings behind an embankment.

EVAPO-TRANSPIRATION

A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

FIELD CAPACITY (field moisture capacity)

The amount of soil water remaining in a soil after the free water has been allowed to drain away for a day or two if the root zone has been previously saturated. It is the greatest amount of water that the soil will hold under conditions of free drainage, usually expressed as a percentage of the oven-dry weight of soil.

FROST FREE PERIOD

Used in the supplement as the period between the last occurrence of 0°C in the spring and the first occurrence of 0°C in the fall.

GRASS

A member of the botanical family Gramineae, characterized by bladelike leaves arranged on the culm or stem in two ranks.

GRADE OF FERTILIZER

The amount of each element present in a fertilizer - the higher the grade the greater the quantity of the elements available.

GROWING DEGREE DAYS

A concept used as a rough estimate for the amount of warmth or heat available for plant growth. If the mean temperature for a day is t°C, then the number of growing degree days, above a base temperature of 5.5°C is:

$$G.D.D. = \sum n(t-5.5°C)$$

where n = number of days

GROWING SEASON

Used in this supplement as the period between the first occurrence of a mean daily temperature of 5.5°C in the spring and the last occurrence of a daily temperature of 5.5°C in the fall. Generally the period of active vegetative growth.

HARDEN OFF

A term used to describe the processes a plant undergoes in preparation for winter or cooler conditions - complex physiological changes, the storage of nutrients and the reduction of water content in the plant.

HARDPAN

A hardened soil layer in the lower A or the B horizon caused by cementation of soil particles with organic matter or with materials such as silica, sesquioxides, or calcium carbonate. The hardness does not change appreciably with changes in moisture content, and pieces of the hard layer do not slake in water.

HYDROSEEDING

Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

LEACHING

The removal of materials in solution by the passage of water through soil.

LEGUME

A name given to members of the pea or bean family. Legume roots have nodules containing nitrogen-fixing bacteria.

LODGING

A plant that has been knocked down from its natural erect position and cannot recover is known as lodged. Lodging is caused by weak plants, heavy rains or winds.

MACRO-NUTRIENT

Elements or compounds required in large amounts by living organisms; they include H, O, N, P, K, Ca, Mg. "Macro" refers to quantity.

MICRO-CLIMATE

Describes small local variations (spacially or temporally) in climate related to buildings, vegetation or ground surface.

MICRO-NUTRIENT

Elements required in very small amounts for the growth of living organisms. "Micro" refers to the amount rather than to the element being essential. Examples include Cu, Zn, Mo, Fe, B, and Cl.

NPK

Nitrogen, phosphorus, potassium - usually as contained in various fertilizers.

MULCH

A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, prevent blowing, retain soil moisture, curtail erosion, and modify soil temperature.

NITROGEN FIXATION

The conversion of elemental nitrogen (N_2) to organic combinations or to forms readily useable in biological processes.

OVERBURDEN

Used in this supplement as the unconsolidated material that must be removed to expose the bedrock or orebody. It consists of topsoil and subsoil.

RECLAMATION

The process of returning a disturbed area to its natural state, or to a state suitable for equivalent or superior use or benefit. Most frequently used in conjunction with areas whose properties have been drastically changed.

REHABILITATION

Restoration to the original or equally satisfactory condition. Normally used to describe restoration of land disturbed by construction.

RHIZOME

An underground stem.

ROCK WASTE

Used in this supplement as material of no present economic value other than overburden that must be removed to excavate the ore. It includes stockpiles of ore containing potentially economic concentrations.

SOIL

The upper portion of the earth's layer that has been weathered by environmental factors. Agricultural soil is stratified and has an organic humus fraction containing living forms.

SOIL CONDITIONER

Any material added to a soil for the purpose of improving its physical condition.

SOIL ORGANIC MATTER

The organic fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil sample passed through a 2 mm sieve.

SOIL PROFILE

The stratified organization of agricultural soil into litter, humus and weathered parent mineral layers.

SPIGOTTING

A procedure generally used in the upstream method of construction for dams or tailings embankments for which spigots are employed and the tailing slurry meanders in a series of loose streams that result in discontinuous horizontal stratification.

SUBSOIL

The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

SWARD

A stand of uniform vegetation, usually given to grass cover.

TAILINGS

Used in this supplement as waste products arising from the grinding and treatment with chemicals to extract desired minerals.

THIXOTROPY

When some materials are kneaded, without altering the water content, cohesion decreases considerably. This effect is known as thixotropy.

TOPSOIL

Presumed fertile soil material; used as a top dressing. Distinction has been made among synthetic, weathered, and geologic topsoils. Synthetic topsoil can include sand and stone chips as well as fly ash, sawdust, or manure not usually a part of geological soil and rock. Weathered topsoil is the natural top-dressing material that has been subjected to weathering throughout geologic time.

TOXIC, TOXICITY

Poisonous. Applied to both inorganic and organic chemicals which, even in extremely low concentrations, may kill organisms or reduce their growth vigour.

VEGETATION

General term including grasses, legumes, shrubs, trees naturally occurring and planted intentionally.

WILTING POINT (or permanent wilting point)

The water content of soil on an oven-dry basis at which plants, specifically sunflower plants, wilt and fail to recover their turgidity when placed in a dark humid atmosphere. The percentage of water at the wilting point approximates the minimum water content in soils under plants in the field at depths below the effects of surface evaporation. It is approximated by the moisture content at 15-bar tension.