THE PHYSICAL LIMITATIONS TO VEGETATION ESTABLISHMENT OF SOME SOUTHERN BRITISH COLUMBIA MINE WASTE MATERIALS

by

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ABSTRACT

Vegetation establishment on mine wastes is ultimately limited by the edaphic properties of the wastes. This thesis examines, characterizes and interprets the physical properties of some southern British Columbia mine wastes:- to elucidate the feasibility of various reclamation procedures. Waste areas, including both mill tailings, rock dumps and adjacent natural soils are characterized.

The project primarily addresses three areas in British Columbia affected by sulfide mining activities; the Princeton area, the Highland Valley area and the Kimberley area. Waste materials examined were derived from the Similkameen, Copper Mountain, Lornex, Bethlehem and Sullivan mines. Minor examination of the now revegetated Jersey Mine tailings located near Salmo, B.C. was also included.

Field work involved mapping waste materials and natural soils and then systematically sampling the various units delineated. Laboratory methods were employed to define and compare the properties of samples collected.

Limited water storage capacity was found to be a major problem in waste rock dump material. Mill tailings were found to have acceptable available water storage capacities. Some mill tailings may have aeration porosity deficiencies when wet. Cation exchange capacities, while usually adequate in waste rock dump materials, are sometimes very low in

mill tailings; a factor that will present serious fertility problems in revegetation.

Some adjacent coarse coniferous forest soils were found to have similar properties to waste rock dump material while some adjacent grass dominated soils were found to have similar properties to the mine tailings. Waste rock dump material appears best suited to eventual revegetation by aborescent species, while mill tailings appear best suited to eventual revegetation by grass or forb species.

Soil processes were found to be both active and rapid in both types of waste material.

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INTRODUCTION

The ultimate objective of this thesis is to outline and interpret the physical properties of mine wastes so as to make the designing of reclamation treatments more effective and realistic.

The establishment of vegetation on metal mine tailings has been attempted for many years. The object of initial attempts was primarily to stabilize tailings areas to reduce wind erosion and to ensure that water erosion did not threaten the soundness of the tailings dams. Other methods of stabilization, such as the use of chemical polymers or covering materials such as gravel were tried with limited success, (Dean and Havens, 1972). Stand establishment was realized on only a few areas with most attempts unsuccessful. In general tailings areas proved to be highly "unpalatable" to plant life. By the mid-sixties the mining industry had experienced many changes. High grade low waste underground mines began to be replaced by large, low grade high waste surface mines. Tailings ponds increased in size and large acreages of waste rock material began to accumulate.

In British Columbia the need to revegetate mine wastes probably became, and still is, more obvious than elsewhere. Traditionally mines were developed in the back country, but from the mid-sixties to the present time, mines have been largely developed in settled areas and are of the surface mine type rather than the smaller underground operations.

Surface metal mining leaves three features on the landscape; the tailings, the waste rock dumps and the pit. The pit is to all extent beyond the scope of revegetation. Its almost vertical walls and complete absence of fine material preclude establishment of significant plant life. The waste rock dumps and the dried tailings areas, however, by the nature of their material, offer the biotic community a potential foot hold.

WASTE ROCK DUMPS

Waste rock dumps consist of rock which is too low in grade to be sent to the mill, and overburden, often glacial till, removed from the mining operation. Chemical problems are usually minor unless pyrite or other reduced sulfide content is very high. The main problem is the large size of the fragments that do not go through the crusher. These fragments may be up to several decimeters or more in diameter. The current method for disposing of this material is to dump it in depressions off the sides of hills creating waste rock dumps. Resulting dumps may exceed 700 hectares (1500 acres) for an individual mine (Thirgood and Gilmore, 1971). Some attempt at selective dumping is usually made with coarse material being dumped first followed by fine material or overburden. Traffic from the huge trucks, which may exceed 150 tons gross weight, compact and crush the surface layer on the dump increasing the amount of fine sized material.

MILL TAILINGS

Tailings are the fine textured by-products of the primary extraction of metaliferious minerals. Ore grade rock goes to the mill where it is ground and subjected to the milling processes. Generally the lower grade the deposit, the finer the ore must be ground. Some present mines are grinding rock finer than - 400 mesh with the finer products of the grinding having particle sizes as low as 0.15 to 0.010 microns (Duncan, 1972). This ground rock is subjected to froth floatation processes and the desired metallic material removed. The undesired silicate gangue minerals and undesired metallic minerals are then pumped as a slurry into the tailings pond.

A number of methods are used to create the tailings pond (Klohn, 1972). In British Columbia, because of the topography, tailings ponds are often created by damming a valley and creating an artificial lake. These ponds may take on considerable size. The Lornex pond in the Highland Valley approaches 700 hectares (1500 acres) in size, (Thirgood, Gilmore, 1971). At the end of the mining operation the water supply is cut off and the tailings pond is allowed to dry up.

The end result is an artificial lacustrine-like deposit. The physical properties are usually more favourable to plant life than in the waste rock dumps.

Previous Research and Revegetation Attempts

Although it has been suggested that water stress may be the most growth limiting factor (McLennan, 1956) most works in revegetation research have been chemically or vegetatively biased. Good discussions of the chemical properties of mine waste materials are given by Nielson and Paterson (1972) and by Lavkulich et al (1975). Nielson and Paterson acknowledge the importance of physical properties to successful vegetation growth as does Gardiner (1974) of Mined-Land Reclamation-Cominco Ltd..

Most plot type experiments have involved massive fertiliser applications, heavy liming and heavy seeding. These have had limited success but appear to be the most popular contemporary approach. (Gordon, 1969; Weston 1973; Young 1969).

Some realization of the importance of retained water is evident by mulching experiments described by Young (1969) and Gordon (1969) at the Copper Cliff and Hollinger Mine tailings areasin Ontario. The need for irrigation both for stand establishment and to control acidity through leaching techniques has initiated some research into physical properties by South African researchers James and Mrost (1965).

Van Lear (1971) of the United States Forest Service has shown that the texture of coal wastes are critical for the growth of K-31 Tall Fescue. He has shown that a relationship exists between toxicity for plants and textural class in potentially toxic material and that this determines the success or failure of stand establishment. Some usage of sewage sludge to provide erosion protection and improve moisture infiltration into the soil has been described by Capp and Gilmore (1973) and indicates an appreciation for the importance of physical parameters to successful revegetation. Water conservation in the form of snow retaining fences, jet netting and straw mulches have been used by Jacoby (1968) to help retain snow for subsequent water reserves.

A good view point of the problem of moisture availability in mining revegetation attempts is given by May (1975). He points out that at least half of western North America receives less than 38cm. (15 inches) of precipitation a year and that in many regions at least 80% of this comes as snow. Losses from runoff and evaporation further reduce this amount. He feels the greatest problem in revegetating these areas is the limited moisture availability for plant growth. This limited moisture availability also restricts seed germination and seedling establishment.

Plate 1

MILL TAILINGS
(SULLIVAN MINE)

WASTE ROCK DUMP
(LORNEX MINE)

Outline of Study

As indicated earlier, the physical properties of mine wastes in relation to reclamation in areas of limited available precipitation are probably the most limiting to successful revegetation. This study attempts to characterize the various mine wastes encountered and to relate the mine wastes to the surrounding soils in the study area.

Waste materials and adjacent natural soils were mapped in the field after preliminary orientation with existing air photographs and soil survey information.

Sampling density of waste materials varied but attempted to ensure statistical significance of the results by including at least one heavily duplicated sample of each waste type. Mine waste rock dump material from the Similkameen Mine and iron tailings material of the Sullivan Mine were heavily sampled for greater statistical significance than other areas with the same waste types and were used as a basis of comparison with waste materials from other areas. One complete sample from each natural soil association mapped within the bounds the study area was collected.

Laboratory studies were conducted to define the physical properties of each sample. Interpretations were made on the basis of previous agronomic research and correlations with the properties of adjacent natural soils.

LOCATION OF STUDY SITES

INDEX TO NUMBERED SITES

1. PRINCETON - Similkameen Mine Copper Mountain Mine
2. HIGHLAND VALLEY - Lornex Mine Bethlehem Mine
3. KIMBERLEY - Sullivan Mine
4. SALMO - Jersey Mine(Canex Mine)

Matërials from the Similkameen Mine, Copper Mountain Mine, Lornex Mine and the Bethlehem Mine are somewhat similar, being derived from low grade sulfide containing igneous and volcanic rocks. Wastes from these areas are usually mildly alkaline-alkaline in reaction. Materials from the Sullivan Mine are distinct, being derived from massive sulfide containing sedimentary rocks. Wastes from this mine are usually extremely acid in reaction.

MATERIALS AND METHODS

Sampling rationale and preparation

Both waste areas and adjacent undisturbed soil sites were sampled for laboratory determinations. Natural soils were sampled according to horizonation to a depth of 100 cm or occurance of rock. Tailings materials that exhibited apparent horizonation were sampled similarly. Waste rock dumps were sampled to a depth of 50 cm with samples representing the 0 to 15 cm and 15 cm to 50 cm material being taken. Deeper samples were not taken due to the difficulties in digging deeper pits. Large samples of all material less than 100 cm were kept with visual estimates made of greater than 100 cm material.

Natural sites were characterized vegetatively with the hope that their physical properties would enable comparative predictions about the suitability of various plant communities for the environment of the waste materials.

Some sites were sampled in much greater density than others with the hope that statistical significance might outline subtle pedogenic processes such as illuviation. Where possible undisturbed core samples were taken.

Samples were air dried and then carefully rolled with a wooden roller, avoiding the crushing of integral particles. These samples were then sieved through a 2mm sieve with the fine material and coarse fragments both weighed to determine percent fine material. Corrections were made, based on proportions of greater than 100 mm material estimated visually.

PARTICLE SIZE ANALYSIS

The fine fraction of soil constitutes the most active fraction, both in terms of water and gaseous phenomena and nutritional balance. Particle size distributions were determined by the hydrometer method as outlined by Day(1956) with 30% H_2O_2 being used to destroy organic matter. A few Sullivan Mine iron tailings samples were treated with citrate dithionite as outlined by Harris and Lavkulich (1972), to remove amorphous iron oxides. Textural classification was made according to the 1950 U.S.D.A. textural classification system.

WATER RETENTION

The ability of soil to store water for subsequent plant use has long been of considerable interest to agronomists. If water becomes deficient to the metabolism of the plant, dehydration of the protoplasm occurs and with it retardation of enzymatic, photosynthetic and other life processes of the plant. (Devlin, 1966)

It is customary to designate the available water storage capacity (A.W.S.C.) as the amount of water the soil is able to provide between Field Capacity Tension and Permanent Wilting Point Tension. Field Capacity Tension is the tension at which the drainage rate from the rooting zone has dropped to a low value and Field Capacity then is the water content of a soil at this tension. Permanent Wilting Point Tension is the tension at the lower limit of the available water content range. At this tension, the plant is unable to extract sufficient water for its life processes and suffers irreversible wilting as a result. Permanent Wilting Point then is the water content of a soil at this tension. In practice the 0.1 and 0.3 bar water contents are the laboratory estimates of the Field Capacity of coarse and medium to fine textured soils and the 15.0 bar water content is the laboratory estimate of the Permanent Wilting Point.

Available Water Storage Capacities were determined for the less than 2 mm material and then corrected for the percent coarse fragments in the soil.

In practice, the 0.1 and 0.3 bar water contents are the laboratory estimates of the field capacity of coarse and medium to fine textured soils, and the 15 bar water content is the laboratory estimate of the Permanent Wilting Point.

Water contents of waste materials were determined at tensions of 0.1, 0.3, 0.9, .3 and .15 bars using porous plate extractors as described in Baver et al (1972). Water contents of adjacent natural soils were determined at tensions of 0.1, 0.3, and 15 bars.

Available Water Storage Capacity was then calculated from differences between the laboratory estimate of the Field Capacity and the Permanent Wilting Point, corrected for coarse fragments.

BULK DENSITY

Bulk density as defined by Buckman and Brady (1960), is the weight of a unit volume of oven dry soil. This volume contains both solids and pores and is a function of soil structure and particle density.

Bulk densities of surface soils within the clay, clay loam and silt loam textural classes normally range from 1.00 to as high as 1.60 gm per cm^3 depending on their condition. Very compact subsoils may run as high as 2.00 gm per cm^3. Bulk density in combination with particle density enables calculations of total porosity.

Bulk densities were determined for surface layers of waste rock dumps by an in situ method. The method employed involved carefully digging a pit and removing and weighing all material. The pit was then lined with a plastic bag and filled with water. The plastic bag and water were likewise removed and weighed. The ratio of the two weights constituted the bulk density. Bulk densities of the tailings and undisturbed control sites were obtained through conventional core sampling techniques.

PARTICLE DENSITY

Particle density as defined by Buchman and Brady (1960) is the weight of a unit volume of soil solids. In most soils particle densities range between 2.60 and 2.75 gm per cm^3. Soils that contain unusual accumulations of heavier minerals may have particles densities in excess of 2.75 grams per $cm.^3$

Because waste materials are not true soils and unusual mineralogical associations occur, particle densities were determined. The pycnometer method as outlined by Black *et al* (1965) was used to determine these densities.

TOTAL AND AERATION POROSITY

Porosity consitutes the proportion of voids in a soil volume. These voids enable liquid and gaseous exchange phenomena to occur. Total porosity consists of water retention porosity and aeration porosity. Aeration porosity is the proportion of the soil volume filled with air at field capacity. Baver *et al* (1972) state the total porosity of an average soil is about 50%. Sandy soils would be somewhat lower and clay or organic rich soils higher. Smaller pores are able to retain water against gravity, while larger pores are unable to retain this water and are drained and contribute to the aeration porosity. Aeration porosity must be sufficient to allow adequate diffusion of oxygen. This oxygen is necessary for the growth of plants, particularly roots, for nutrient and water absorption, the prevention of the accumulation of toxic inorganic compounds, and microbial soil life (Devlin, 1966). Hanks and Thorp (1956) have shown aeration porosity to be particularly critical to seedlings. They have shown that emergence of wheat declines as oxygen is restricted past certain limits and that the necessary aeration porosity for adequate oxygen diffusion corresponds with 16% aeration porosity for a silty loam and 25% for a fine sandy loam.

Total porosity was calculated, as a volume fraction, from particle densities and bulk densities according to the equation

$$\text{Total Porosity} = 1 - \frac{\text{Bulk Density}}{\text{Particle Density}}$$

Aeration porosity was calculated by subtracting water porosity at field capacity from total porosity.

HYDRAULIC CONDUCTIVITY

Hydraulic conductivity describes the relative ease by which a soil allows water to pass through a layer or profile and is defined in terms of the velocity of flow of water over the gross cross section per unit hydraulic gradient. Undisturbed core samples were used to determine hydraulic conductivities as described in Baver et al (1972).

CATION EXCHANGE CAPACITY

Cation exchange capacity is a parameter used to quantify the exchangeable cations of a soil and is usually expressed in milliequivalents per 100 gm of soil. Although normally thought of as a chemical parameter, its basic physical nature and effect on physical properties make it of considerable interest in interpretations with other physical properties. Baver et al (1972) cite it as having tremendous impacts on viscosity, swelling and plasticity of a soil. Gill and Reaves (1956) showed that soil-clod shrinkage more closely corresponds to cation exchange capacity than to specific area or plastic index.

Cation exchange capacity was determined by the ammonium acetate method as outlined by Black in Black et al (1965).

Sample Letter Code

P	Similkameen Mine Waste Rock Dump
L	Lornex Mine Waste Rock Dump
B	Bethlehem Mine Waste Rock Dump
SF	Sullivan Mine Iron Tailings
SS	Sullivan Mine Siliceous Tailings

Plate 2

M I L K W E E D I N V A D I N G W A S T E R O C K D U M P
(S I M I L K A M E E N M I N E)

S A N D Y L O A M T E X T U R E D M I L L T A I L I N G S
(C O P P E R M O U N T A I N M I N E)

SIMILKAMEEN AND COPPER MOUNTAIN MINES - PRINCETON, B.C.

WASTE ROCK DUMPS AND TAILINGS

The Similkameen Mine and adjacent Copper Mountain Mine are located 10 miles south of Princeton, B.C.. The Copper Mountain Mine is no longer active but was extensively worked by underground and surface methods until 1957. The medium sized Similkameen open pit mine started in the early 1970's. Daily mill production of the Similkameen Mine was about 15,000 tons at the time of field work. Waste dumps are located adjacent to the pit and tailings are deposited in the Smelter Lake Tailings Area on the opposite side of the Similkameen River. Tailings of the old Copper Mountain Mine are stored in a now dry tailings area adjacent to Princeton townsite.

GEOLOGY AND GEOMORPHOLOGY

Both mines are examples of volcanogenic type ore deposits with mineralization occurring in volcanic breccias and associated syenite plugs. Much of the mineralization occurs in pyritic zones with the main metal recovered being copper. The bedrock geology of the area has been reported by Dolmage (1934) and Preto (1972).

Glaciation has left an unconsolidated mantle on the land with glacial till, glacial-fluvial and colluvial deposits being the most widespread. Smaller areas of lake sediment and bedrock are distributed through the area. Surficial geology of the area is described by Nasmith (1962).

SOILS

Soils of the area are reported in a preliminary reconnaisance soil survey by the Soils Division Canada Agriculture. (Provisional draft, 1974.) Soils of the area range from Dark Brown or Black Chernozems in the valley bottom to Brunizolic and Luvisolic soils at higher elevations.

Soil descriptions and natural vegetation lists of adjacent soils are described in tables A-2 to A-8 of the appendix. A summary of physical properties of the various soils is given in table IV.

CLIMATE

Climatic data for the area is summarized in table A-12 of the appendix. Mean annual precipitation for the area, as reported by Princeton airport (1965 and 1970) is 36 cm. Precipitation in the growing season, May to August, amounts to 10.5 cm. Winter snow amounts to 150cm. Average maximum temperature at Princeton for this period is 33°C. It is evident from this data that summer drought is of major importance.

DESCRIPTION OF SITES

The sample sites of the Similkameen Mine waste rock dumps are shown in Plate 2. Sample sites of the adjacent soil and vegetation sites are shown in Figure A-1 of the appendix. Descriptions of the Similkameen Mine waste rock dumps and Copper Mountain tailings are given in tables I. Descriptions of the adjacent soil sites and species lists are given in tables A-2 to A-8 of the appendix.

RESULTS AND DISCUSSION

It was initially felt that insufficient water holding capacity would probably be the most important growth limiting physical property. To elucidate this fact available water storage capacities were determined as outlined in the materials and methods section of this report. Water retention data for the waste materials and natural soils are listed in tables A-9 and A-11 of the appendix. Mean water retention curves for the less than 2mm fraction of the waste materials are shown in figures 2 and 3.

Table I

DESCRIPTION OF SIMILKAMEEN MINE WASTE ROCK DUMPS

74-P-1, 2, 3, 4, 5, 6, 7, 8, 9, 10,11,12,13,14

LAYER	CM	
A	0 - 15	Grayish brown (10YR 5/2 - 5/3) and light brownish gray (10 YR 6/2), very stoney, (less than 25% soil sized material)* sandy loam, compacted, fragments angular
B	15 - 45	Grayish brown (10 YR 5/2 - 5/3) and light brownish gray (10 YR 6/2), very stoney (less than 25% soil sized material) sandy loam, compacted, fragments angular
D	45+	Same as B above but more rocky

DESCRIPTION OF COPPER MOUNTAIN TAILINGS

(Granby A, B, C)

LAYER	CM	
A	0 - 25	Dark grey (7.5 YR 4/1) and very uniform loamy sand
B	25 - 50	Dark grey (7.5 YR 4/1) and very uniform sand
C	50 - 100+	Dark grey (7.5 YR 4/1) and very uniform loamy sand - sandy loam

Note: Surface completely unstable and prone to blowing.

* soil sized refers to fine earth fraction or less than 2 mm fraction of the material.

Table II

PARTICLE SIZE ANALYSIS - SIMILKAMEEN MINE WASTE ROCK DUMPS
(by weight)

Sample #	< 2mm	Sand	Silt	Clay	
	%				
Similkameen Waste rock dumps					
0 - 15 cm					
P-1A	31	48	36	16	Loam
P-1A	21	63	24	13	Sandy Loam
P-3A	22	60	28	12	Sandy Loam
P-4A	15	53	33	14	Sandy Loam
P-5A	22	68	27	5	Sandy Loam
P-6A	19	66	23	11	Sandy Loam
P-8A	26	60	28	12	Sandy Loam
P-11A	12	72	22	6	Sandy Loam
P-12A	13	77	16	7	Sandy Loam
P-13A	14	72	18	10	Sandy Loam
P-14A	10	58	28	14	Sandy Loam
Mean waste rock - 0-15cm	19	63	26	11	Sandy Loam
Similkameen waste rock dumps					
15 - 45 cm					
P-1B	17	54	39	7	Sandy Loam - Loam
P-2B	18	61	26	13	Sandy Loam
P-3B	18	71	19	10	Sandy Loam
P-4B	14	66	24	10	Sandy Loam
P-5B	11	66	23	11	Sandy Loam
P-6B	15	42	29	29	Clay Loam - Loam
P-7B	13	64	30	6	Sandy Loam
P-8B	17	60	24	16	Sandy Loam
P-11B	13	55	35	10	Sandy Loam
P-12B	12	58	28	14	Sandy Loam
P-13B	10	60	29	11	Sandy Loam
P-14B	10	65	24	11	Sandy Loam
Mean waste rock - 15-40 cm	14	60	28	12	Sandy Loam
Roadside Berm Sand					
P-10A	77	84	8	8	Loamy Sand
P10B	73	80	12	8	Loamy sand-Sandy loam
Copper Mountain Tailings					
Layer A	100	81	14	5	Loamy sand
Layer B	100	81	15	4	Loamy sand
Layer C	100	78	17	5	Loamy sand - sandy loam

SAMPLE SITES - SIMILKAMEEN MINE

WASTE ROCK DUMPS

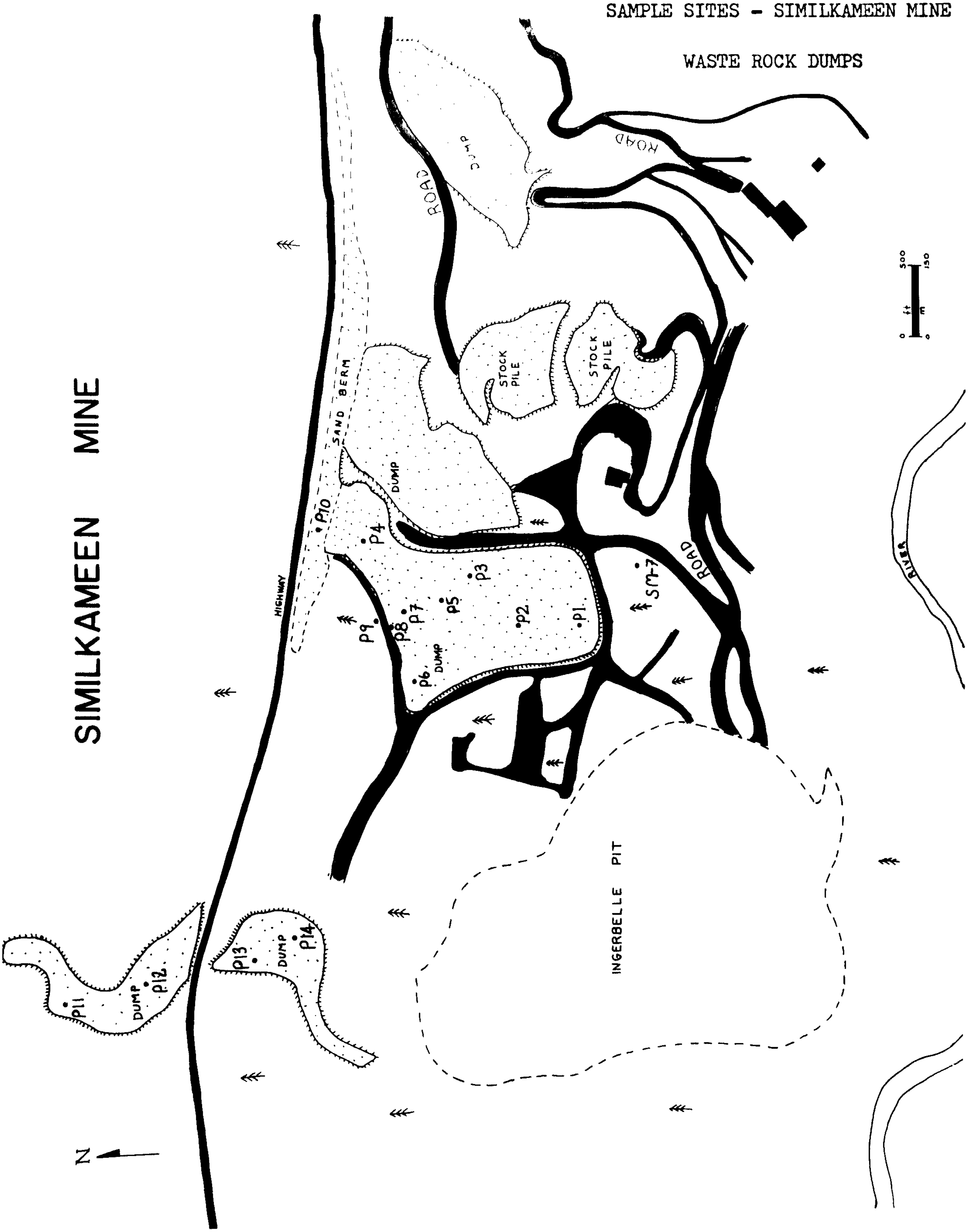
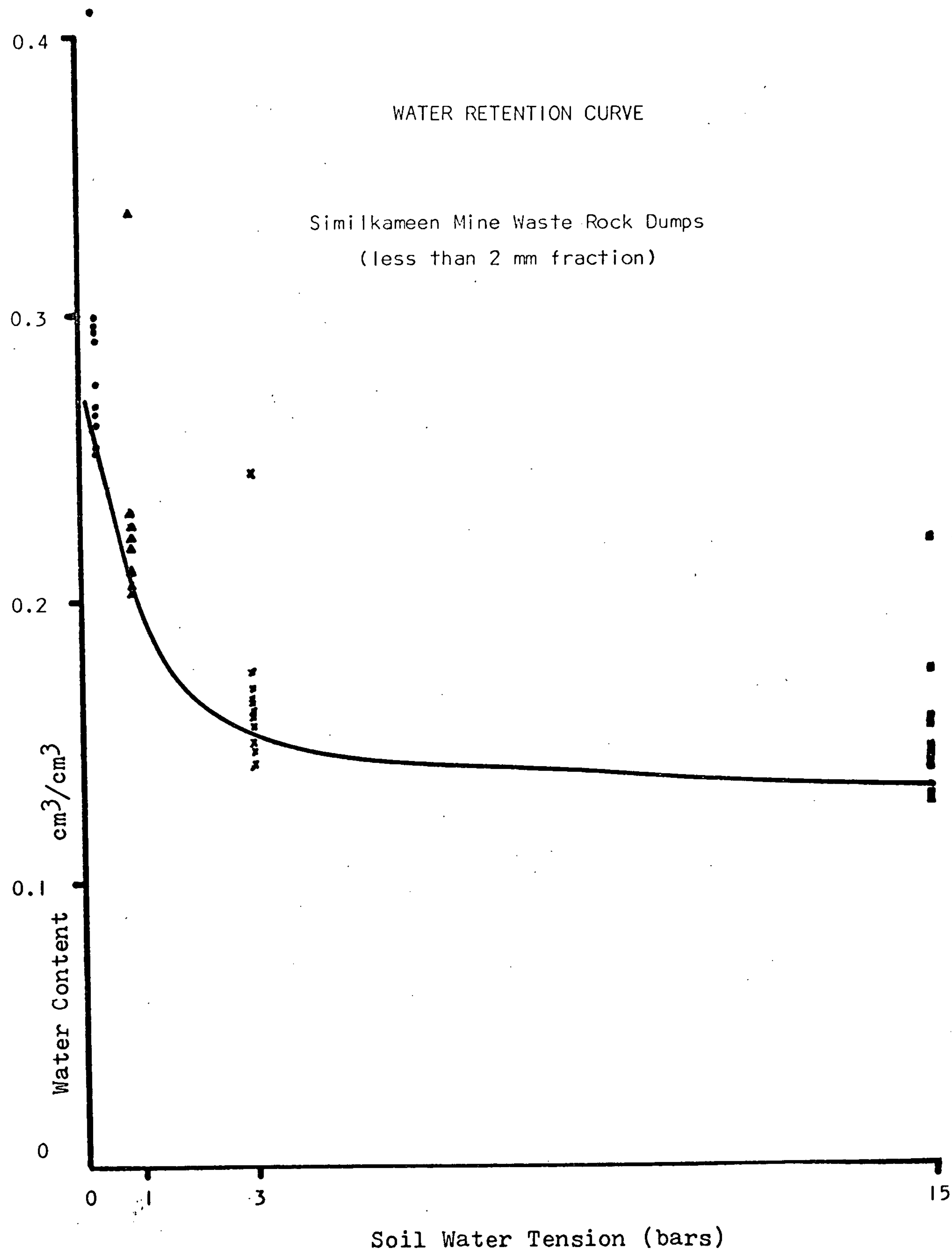
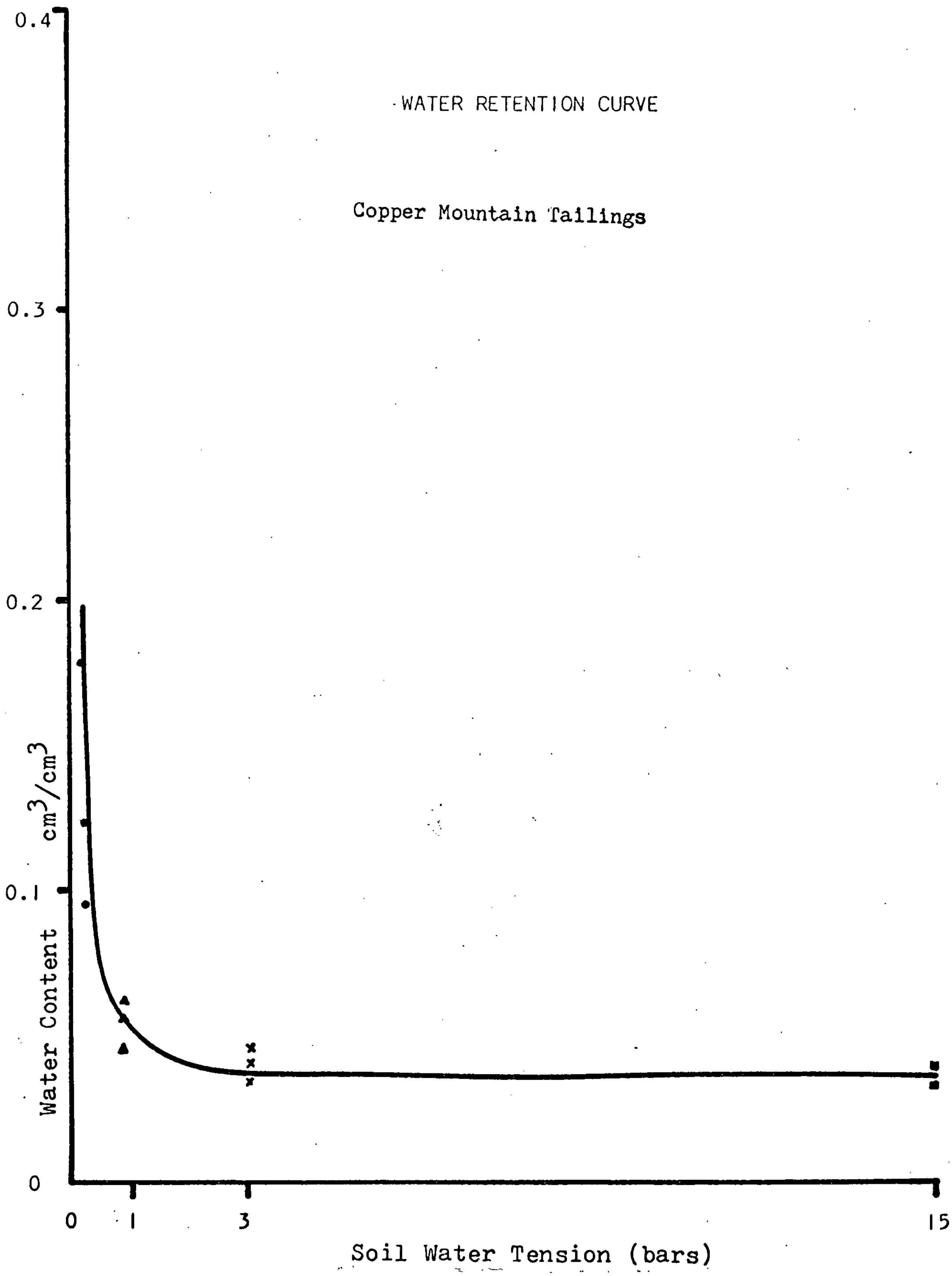


Figure 2


WATER RETENTION CURVE
Similkameen Mine Waste Rock Dumps
(less than 2 mm fraction)
0.4
0.3
0.2
0.1
0
Water Content cm3/cm3
0
1
3
15
Soil Water Tension (bars)


WATER RETENTION CURVE
Copper Mountain Tailings
0.4
0.3
0.2
0.1
0
Water Content cm3/cm3
0
1
3
15
Soil Water Tension (bars)

The mean A.W.S.C. for the Similkameen waste rock material, less than 2 mm fraction, was found to be 0.21 cm^3 per cm^3. When corrected for the nearly 85% coarse fragments in this material the whole soil A.W.S.C. drops to 0.03 cm per cm. Assuming a deep rooting plant with a rooting depth of 100 cm, 3.4 cm of water is available for plant use at field capacity. This value is extremely low and supports the initial premise that available water storage capacity is a major limitation.

Potential evapotranspiration demands for a somewhat similar north-eastern Californian site are described by Gianelli et al (1967). They report 36.9 inches potential maximum demand for a grass or pasture crop for the growing season or 0.39 cm per day. If one considers that our sites are somewhat north of this area but also that o.39 cm per day represents an average over the growing season, approximately ten days supply of water is available to satisfy this potential maximum demand.

The mean A.W.S.C. for the Copper Mountain tailings was found to be 0.152 cm^3/cm^3, assuming a deep rooting plant with a rooting depth of 100cm, 15.2 cm of water available for plant base at field capacity. Available water storage capacity does not appear to be a growth limiting factor from cursory laboratory analysis, however, the unusually sharp retention curve suggests drought conditions develop quickly as this material is drained at low water tensions.

Potential reserves of available water for adjacent soils are described in table IV. Site SM-7 classified as a Degraded Dystric Brunisol most closely approximates the water storage capacity of the Similkameen Mine waste rock dumps and is described in table A-6 of the appendix.

This site supports a vegetation component of aborescent or subaborescent species and pinegrass with a large portion of the understory consisting of needles on bare ground.

Particle size distributions for the Similkameen Mine waste rock dumps and Copper Mountain tails are given in table II.

The mean texture for all Similkameen waste rock samples is a very rocky, sandy loam with only 16.4% of the material being less than 2 mm. The surface 15 cm of material is 4% higher in less than 2 mm sized material than deeper samples while the deeper than 15 cm material is 1.2% higher in clay sized material and 1.9% higher in silt sized material than the top 15 cm. This reciprocal relationship quite possibly indicates active and rapid pedogenic illuviation.

The texture of the Copper Mountain tailings ranges from loamy sand to sandy loam. Combined silt and clay sized material increase with depth, again indicating active pedogenic illuviation.

Bulk densities and particle densities for both waste types are given in table III. The mean bulk density of the Similkameen Mine waste rock dumps is 1.9 gm per cm^3 while it is 1.45 gm per cm^3 for the Copper Mountain tailings.

The mean bulk density of the Similkameen Mine waste rock dumps exceed Buckman and Brady's upper limit for similarly textured soils.

However, it one considers the 85% coarse fragments with a rock density of 2.65 gm per cm^3 this value does not necessarily indicate the compaction that one would at first expect and may not indicate undue impairment to root growth.

Particle densities for both waste types are listed in table III. Particle densities are in both cases similar to the 2.65 gm per cm^3 normal for most soils.

Minimum aeration porosities of the Similkameen Mine waste rock dumps and Copper Mountain tails were found to be 21% and 30% respectively. In reference to Hank and Thorp (1956) aeration porosities for these materials seem adequate.

Cation exchange capacities for the Similkameen Mine waste rock dumps and Copper Mountain Tailings are listed in table IV. Attention is drawn to the extremely high values of the Similkameen Mine waste rock dump samples and extremely low values of the Copper Mountain tailings samples. Soil fertility problems will be present in reclamation attempts of the Copper Mountain tailings.

Table III

PARTICLE DENSITY AND BULK DENSITY OF SIMILKAMEEN MINE, BETHLEHEM MINE, AND LORNEX MINE WASTE MATERIALS

Sample #	Particle Density gm/cm^3	Bulk Density gm/cm^3
Similkameen Mine Waste Rock Dumps		
P-1	2.55	1.75
P-2	2.77	1.59
P-3	2.70	1.59
P-4	2.59	1.69
P-5	....	1.73
P-6	....	1.88
P-7	2.67	1.79
P-8	2.65	
P-11	2.68	1.98
P-12	2.65	1.84
P-13	2.74	1.98
P-14	2.66	1.85
Mean		1.91
74-P-10 (Sand berm)	2.68	
Bethlehem Mine Waste Rock Dumps		
B-1	2.63	1.79
B-2	2.67	1.60
B-3	2.88	2.05
B-4	2.79	1.26
B-5	2.74	1.77
Mean		1.79
Lornex Mine Waste Rock Dumps		
L-1	2.65	1.98
L-2	2.73	1.54
L-3	2.70	1.75
Mean		1.76
Bethlehem tailings sand	2.67	....
Lornex Temp. tailings 1	2.59	1.32
Lornex Temp. tailings 2	2.62	1.39

SUMMARY OF PHYSICAL PROPERTIES OF THE SIMILKAMEEN MINE

TABLE IV

WASTE ROCK DUMPS, COPPER MOUNTAIN TAILINGS AND ADJACENT SOIL SITES

Sample	Classification or Type	Layer or Profile	% 2 mm (mean)	Textural class (2 mm) (mean)	A.W.S.C. cm/cm (mean)	Bulk Density 0-15 cm g/cm^3 (mean)	Total Porosity 0-15 cm (mean)	Minimum aeration porosity 0-15 cm (mean)	C.E.C. Meg/100 gm <2mm fraction (mean)	A.W.S.C. 100 cm soil cm water
	Similkameen mine waste rock dumps	A	18.5	Sandy Loam	.034	1.91	.28	.21	20.04	3.4
		B	14.3	Sandy Loam	.....	....	...	...	21.98	...
	Copper Mountain tailings	A	100	Loamy Sand	1.68	1.46	.43	.30	2.16	15.2
		B	100	Loamy Sand	1.36	....	...	...	2.03	...
		C	100	Loamy Sand Sandy Loam	....	....	...	...	2.30	...
SM-1	Degraded Dystric Brunisol	Appendix	Appendix	Appendix	Appendix	1.20	.550	.39	Appendix	5.2
SM-4	Degraded Dystric Brunisol	Appendix	Appendix	Appendix	Appendix	1.25	.53	.40	Appendix	5.1
SM-5	Orthic Grey Brown Luvisol	Appendix	Appendix	Appendix	Appendix	1.27	.53	.39	Appendix	6.0
SM-6	Degraded Eutric Brunisol	Appendix	Appendix	Appendix	Appendix	1.34	.49	.37	Appendix	14.2
SM-7	Degraded Dystric Brunisol	Appendix	Appendix	Appendix	Appendix	1.20	.55	.39	Appendix	3.6
SM-8	Degraded Dystric Brunisol	Appendix	Appendix	Appendix	Appendix	1.11	.58	.47	Appendix	9.4
SM-20	Orthic Dark Brown Chernozem	Appendix	Appendix	Appendix	Appendix	1.00	.62	.49	Appendix	8.3

SUMMARY

Similkameen Mine Waste Rock Dumps

To summarize the physical properties of the Similkameen Mine waste rock dump material the following points may be made.

Less than 20 percent of the volume of the dump material is less than 2 mm in particle size and considered soil sized. The soil-sized material has a sandy loam textural class. The remainder of the volume of the dump material consists of coarse fragments.

Available water storage capacity is low because of the high proportion of fragments and is only 3.4 percent by volume.

Bulk density is high because of the high proportion of coarse fragments.

Particle density is comparable to that of normal natural soil.

Minimum aeration porosity is adequate for seedling emergence.

Cation exchange capacity is good, suggesting that nutrient status will improve as weathering progresses and that long term benefits may be realized from fertilization.

Pedogenic illuviation, evident by increased clay and silt content with depth, is ongoing and indicative of active soil processes.

Comparisons with surrounding natural soils show that coarse textured coniferous forest soils have physical properties similar to the waste dump materials. These sites typically have sparse understories dominated by woody species and a very low density of herbaceous species.

Copper Mountain tailings

To sumarize the physical properties of the Copper Mountain tailings the following points may be made.

All the material is soil-sized and with a sandy loam - loamy sand textural class.

Available water storage capacity is favourable being approximately 15 percent by volume. Retention curves suggest this material quickly dries as water is drained at low water tensions.

Bulk density is not excessive and particle density is similar to that of the normal soils found in the area.

Minimum aeration porosity is approximately 30 percent by volume and is ample for seedling emergence.

Cation exchange capacity is very low suggesting leaching losses will reduce both the beneficial effect of weathering on nutrient status and possible long term benefits gained through heavy fertilization. Some means of improving cation exchange capacity either through cultivation of a green manure crop or additions of organic matter should be considered to alleviate this condition.

SECTION 2

Mine Wastes of the Princeton Area.

(Similkameen Mine and Copper Mountain Mine)

F O R B S   I N V A D I N G   W A S T E   R O C K   D U M P
(B E T H L E H E M   M I N E)

S A M P L E   P I T   I N   W A S T E   R O C K   D U M P
(B E T H L E H E M   M I N E)

LORNEX AND BETHLEHEM MINES - HIGHLAND VALLEY, B.C.

WASTE ROCK DUMPS AND TAILINGS

INTRODUCTION

The Highland Valley is located north of Merrit and south of Kamloops B.C.. The region has been mined with varying intensities since the beginning of the century. Until the early 1970's mining was restricted to small underground operations but large scale open pit mining commenced at that time.

At the time of field work, the Lornex Mine processed 38,000 tons of ore a day and the Bethlehem Mine about 16,000 tons per day. A third Valley Copper Mine seems imminent.

GEOLOGY AND GEOMORPHOLOGY

These mines represent porphory copper operations with the main metals recovered being copper and molybdenum. The ore occurs as disseminated sulfides in granodiorite and quartz diorite intrusions. Sericite, chlorite, clay minerals and epidote occur as common alteration minerals with a significant proportion of pyrite occurring as an accessory mineral. The bedrock geology has been documented by White et al (1957), Carr (1960) and Cockfield (1961).

The area was glaciated in Pleistocene times and glacial overburden covers most of the land. Glacial till, glacial-fluvial sediments and colluvial material predominate. Smaller areas of lacustrine and organic material occur close to the mines. Surficial geology of the area has been described by Tipper (1971).

SOILS

Soils of the area are reported in a preliminary reconnaissance soil survey by the Soils Division British Columbia Department of Agriculture. (Provisional draft, 1974). Brunisolic and Luvisolic soils predominate with some Regosols occuring close to the mines.

Soil descriptions and natural vegetation of selected adjacent soils are described in tables A-14 to A-20 of the appendix. A summary of physical properties of the various soils is given in table VII.

CLIMATE

Climatic data for the area is summarized in table A-12 of the appendix. Annual precipitation for the area as reported by the Lornex Weather Station (1971) is 29.5 cm. Precipitation for the growing season, May to August, is 6.5 cm. Winter snow is about 15.8 cm. Average maximum temperatures for summer are 28°C. Temperatures near or below freezing are possible in any month of the year. As is the case at Princeton, moisture relationships become critical to vegetation establishment.

Table 5

DESCRIPTION OF BETHLEHEM MINE WASTE ROCK DUMPS

74-B-1, 2, 3, 4, 5

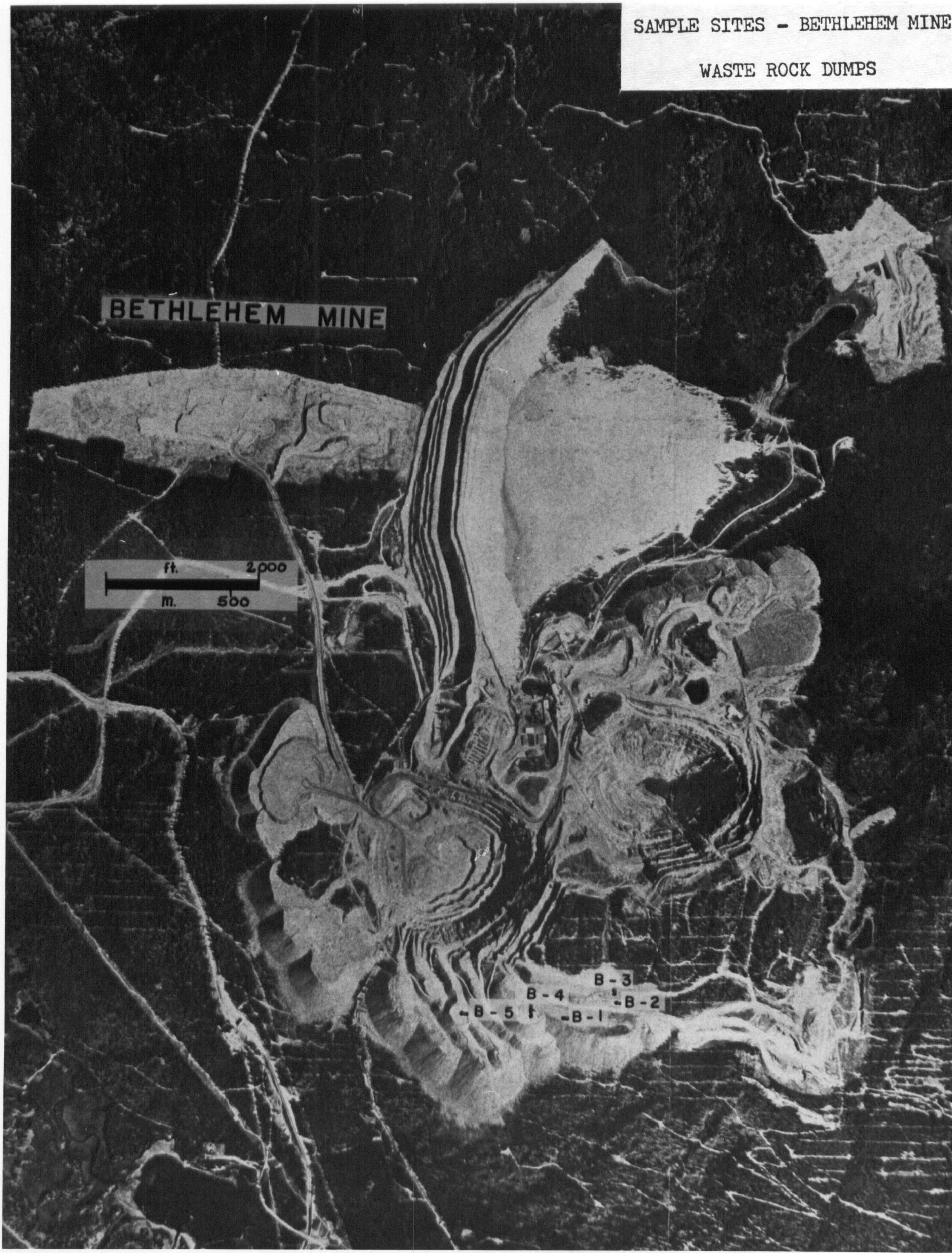
LAYER	Cm	
A	0 - 15	Light gray (10YR 6/1 - 6/2) very stony (less than 25% soil sized material)* sandy loam, compacted, fragments angular
	15 - 45	Light gray (10 YR 6/1 - 6/2) very strong (less than 25% soil sized material) sandy loam, compacted, fragments angular

DESCRIPTION OF LORNEX MINE WASTE ROCK DUMPS

74-L-1, 2, 3

LAYER	Cm	
A	0 - 15	Pale brown (10 YR 6/3), very stony (less than 25% soil sized material)* sandy loam, compacted, fragments angular
B	15 - 45	Pale brown (10 YR 6/3), very stony (less than 25% soil sized material) sandy loam, compacted, fragments angular
C	45 - 75+	Same as B above

* soil sized refers to fine earth fraction or less than 2 mm fraction of the material.


SAMPLE SITES - BETHLEHEM MINE
WASTE ROCK DUMPS
BETHLEHEM MINE
ft. 2000
m. 500
B-3
B-4
B-2
B-5
B-1

SAMPLE SITES - LORNEX MINE

WASTE ROCK DUMPS

DESCRIPTION OF SITES

The sample sites of the Bethlehem Mine and Lornex Mine are shown in Plates 4 and 5, respectively. The sample sites at adjacent soil and vegetation listings are shown in Figure A-13 of the appendix. Descriptions of the waste rock dumps are given in table V. Descriptions of the adjacent soil sites and species lists are given in tables A-14 to A-20 of the appendix.

RESULTS AND DISCUSSION

As in the case of the Similkameen Mine waste rock dumps, water stress was suspected of being the most probable growth limiting factor. Available water storage capacities were determined as outlined in the material and methods section of this report. Water retention data for the waste materials and natural soils are listed in tables A-21 and A-23 of the appendix. Mean water retention curves for the less than 2 mm fraction of the waste materials are shown in figures 4 and 5.

The mean A.W.S.C. for the Bethlehem and Lornex Mine waste rock dump materials, less than 2 mm fraction, is o.20 and 0.19 cm^3 per cm^3, respectively. When corrected for the high proportion of coarse fragments in the material the whole soil A.W.S.C. drops to 0.08 cm^3 and 0.05 cm^3 per cm^3 for the Bethlehem Mine and Lornex Mine waste rock dumps respectively. Mean A.W.S.C. for the Lornex temporary tailings

Figure 4

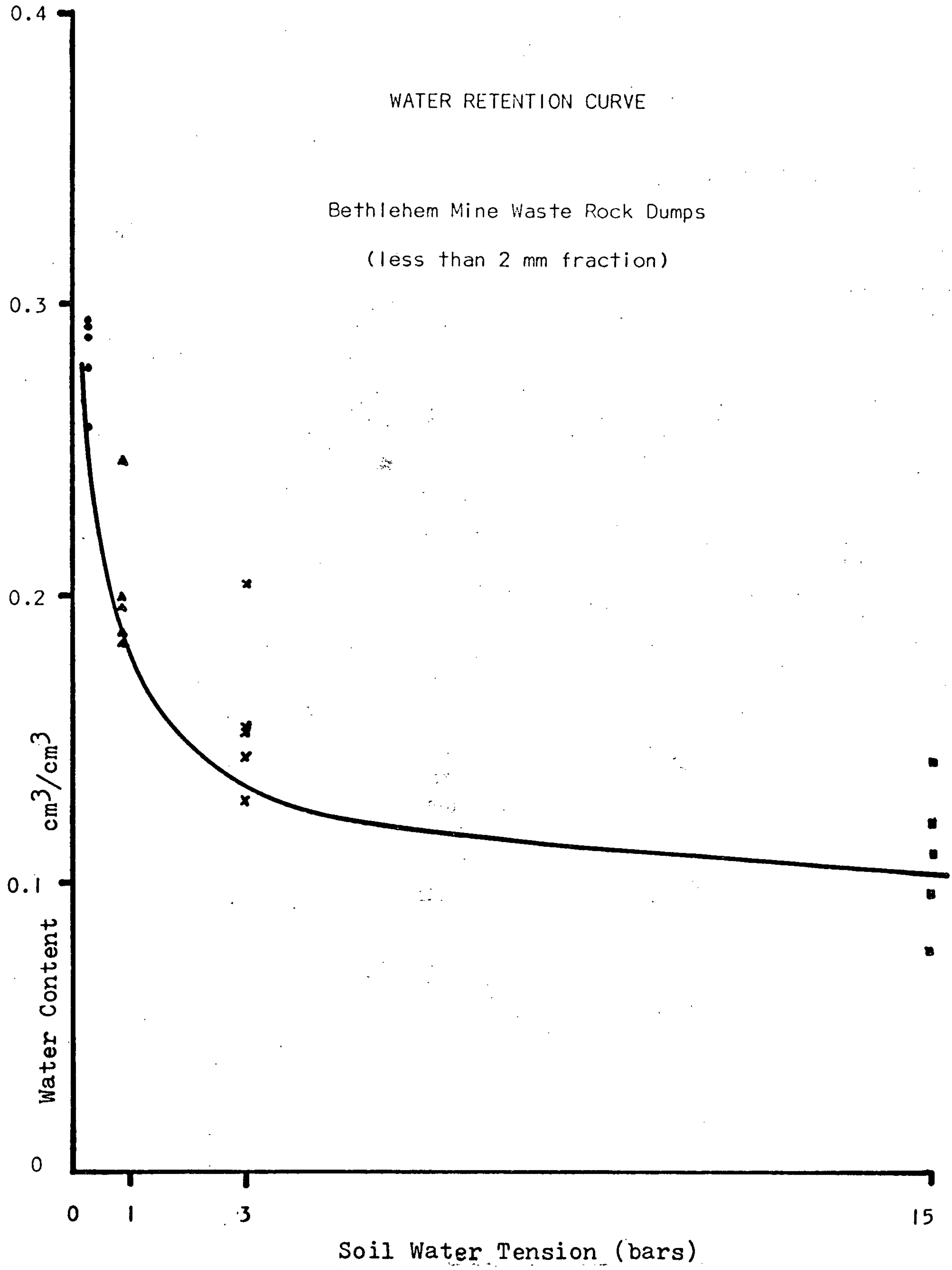
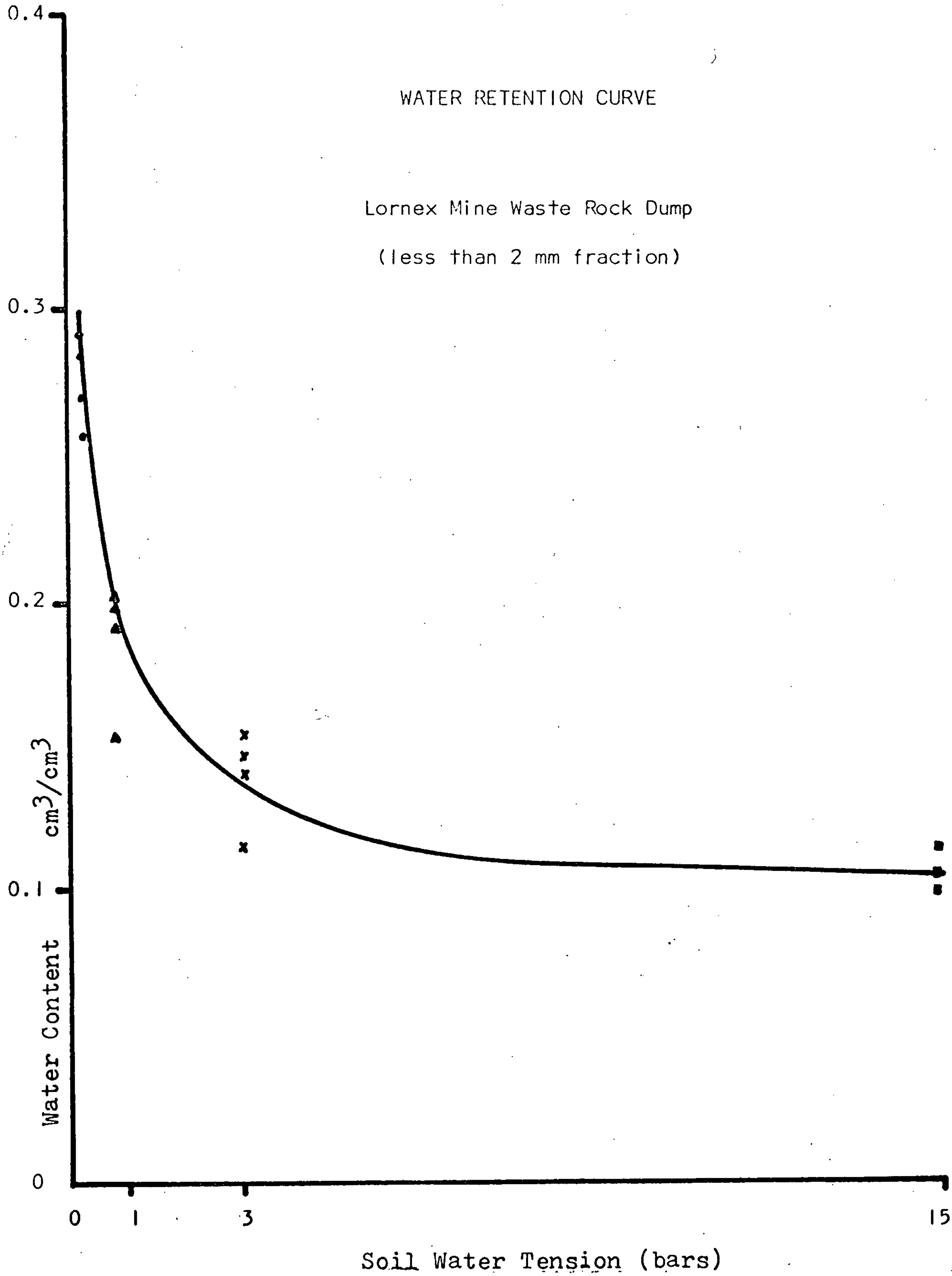

WATER RETENTION CURVE
Bethlehem Mine Waste Rock Dumps
(less than 2 mm fraction)
0.4
0.3
0.2
0.1
0
Water Content cm3/cm3
0
1
3
15
Soil Water Tension (bars)

Figure 5


WATER RETENTION CURVE
Lornex Mine Waste Rock Dump
(less than 2 mm fraction)
0.4
0.3
0.2
0.1
0
Water Content cm3/cm3
0
1
3
15
Soil Water Tension (bars)

pond is 0.19 cm per cm.

Assuming a deep rooting plant with a rooting depth of 100 cm, 4 cm and 5 cm of water is available for plant use in the dumps of the Bethlehem Mine and Lornex Mine, respectively and 19 cm is available in the temporary tailings.

If one considers a maximum evapotranspiration demand of 0.39 cm per day (see Similkameen Mine waste rock dumps), 10 to 13 days of maximum demand water storage is available in the waste rock dumps and 49 days in the temporary tailings; to a depth of 100cm.

Reserves of available water for adjacent soils are listed in table VII. Natural sites, HV-2 and HV-11 were found to have water retention capacities of the same order as those of the waste rock dumps. (Tables A-15 and A-20 of the appendix.) Both these soils were classified as Degraded Brunisols with sparce under stories dominated by woody species. Site HV-10 (Table A-19 of the appendix), classified as an Orthic Sombric Brunisol, has similar water retention values to the Lornex tailings. Its vegetation is dominated by graminoids with a thicker ground cover than HV-2 or HV-11.

Particle size distributions for waste materials of both the Bethlehem and Lornex mines are given in table VI. Waste rock dumps of both mines generally have less than 25% soil size material with the fine fraction having a sandy loam texture. Percentage of combined silt and clay sized material is equal at both depths in the Lornex dumps but is 2.5% higher in the deeper layers of the Bethlehem dumps. Pedogenic illuviation is considered an active process.

Bulk densities and particle densities for all of the waste materials of the two mines are given in table III. The mean bulk density of the Bethlehem Mine dumps is 1.8 gm per cm^3 and of the Lornex dumps is 1.7 gm per cm^3. Mean bulk density of the Lornex temporary tailings is 1.37 gm per cm^3.

Particle densities of the various waste materials are listed in table III and are in all cases similar to values attributed to normal soils.

Minimum aeration porosities for the Bethlehem Mine waste rock dumps, Lornex mine waste rock dumps and Lornex tailings were found to be 24%, 25% and 9% respectively. In reference to Hank and Thorp (1956) aeration porosities of the waste rock dumps seem adequate while those of the tailing may present difficulties in seedling establishment.

Cation exchange capacities of the various waste types are listed in table VII. Attention is drawn to the relatively low values for the tailings material but acceptable values for the waste rock dump fine material.

Table VI

PARTICLE SIZE ANALYSIS - LORNEX AND BETHLEHEM MINE WASTE ROCK DUMPS

(by weight)

Sample #	% 2mm	% Sand	% Silt	% Clay	Textural Class
L-1A	29	60	28	12	Sandy Loam
L-2A	35	63	24	13	Sandy Loam
L-3A	24	54	30	16	Sandy Loam-loam
Mean waste rock 0-15cm	29	59	28	13	Sandy Loam
L-1B	18	60	32	8	Sandy Loam
L-2B	22	61	30	9	Sandy Loam
L-3B	27	57	27	16	Sandy Loam-Sandy clay loam
Mean waste rock 15-40cm	23	59	30	11	Sandy Loam
L-1C	16	73	20	7	Sandy Loam-Loamy sand
B-1A	18	69	28	12	Sandy Loam
B-2A	32	64	26	10	Sandy Loam
B-3A	20	65	26	9	Sandy Loam
B-4A	41	57	27	14	Sandy Loam
B-5A	21	61	28	11	Sandy Loam
Mean waste rock 0-15cm	26	62	27	11	Sandy Loam
B-1B	13	60	30	10	Sandy Loam
B-2B	15	59	28	13	Sandy Loam
B-3B	15	55	30	15	Sandy Loam-Loam
B-4B	18	65	23	12	Sandy Loam
B-5B	14	57	31	12	Sandy Loam
Mean waste rock 15-40 cm	15	59	27	12	Sandy Loam
Lornex Tailings 1	100	62	31	7	Sandy Loam
Lornex Tailings 2	100	25	60	15	Silt Loam
Bethlehem Sand Tailings	100	90	7	3	Sand

SUMMARY OF PHYSICAL PROPERTIES OF THE BETHLEHEM MINE AND LORNEX MINE WASTE ROCK DUMPS AND TAILINGS AND ADJACENT SOIL SITES   Table VIII

Sample	Classification or Type	Layer or Profile	% 2 mm (mean)	Textural class (2 mm) (mean)	A.W.S.C. (cm/cm mean)	Bulk Density 0-15 cm g/cm^3 (mean)	Total Porosity 0-15 cm (mean)	Minimum aeration porosity 0-15 cm (mean)	C.E.C. Meg/100 gm <2mm fraction (mean)	A.W.S.C. 100 cm soil cm water
	Bethlehem mine waste rock dumps	A	26.5	Sandy loam	.039	1.79	0.32	.24	14.72	3.90
		B	14.9	Sandy Loam	....	....	....	...	15.57	....
	Lornex mine waste rock dumps	A	29.4	Sandy Loam	0.050	1.76	0.34	.25	6.61	5.00
		B	23.0	Sandy Loam	....	....	....	...	-8.51	....
	Lornex tailings	A	100.0	Loam	0.194	1.37	0.48	.09	4.70	19.4
	Bethlehem tailings sand	A	100.0	Sand	0.075	....	....	...	5.60	7.5
HV-1	Degraded Dystric Brunisol	Appendix	Appendix	Appendix	Appendix	0.91	0.66	.53		6.1
HV-2	Orthic Eutric Brunisol	Appendix	Appendix	Appendix	Appendix	1.53	0.42	...	Appendix	3.4
HV-3	Orthic Regosol	Appendix	Appendix	Appendix	Appendix	0.94	....	....	Appendix	18.4
HV-4	Degraded Dystric Brunisol	Appendix	Appendix	Appendix	Appendis	1.13	0.57	....	Appendix	...
HV-5	Orthic Grey Luvisol	Appendix	Appendix	Appendix	Appendix	1.24	0.53	.27	Appendix	13.6
HV-10	Orthic Sombric Brunisol	Appendix	Appendix	Appendix	Appendix	1.03	0.61	.26	Appendix	8.9
HV-11	Degraded Dystric Brunisol	Appendix	Appendix	Appendix	Appendix	1.15	0.57	.52	Appendix	3.0

SUMMARY

Lornex and Bethlehem Waste Rock Dumps

To summarize the physical properties of the Lornex and Bethlehem waste rock dump materials, the following points may be made.

Less than 25 percent of the volume of the dumps is less than 2 mm in particle size and considered soil-sized. The soil-sized fraction has a sandy loam textural class. The remainder of the volume of the dump material is occupied by coarse fragments.

Available water storage capacity is low because of the high proportion of coarse fragments and is only 4-5 percent by volume for the two mines.

Bulk density is high because of the high proportion of coarse fragments.

Minimum aeration porosity is adequate for seedling emergence.

Cation exchange capacity is good, suggesting that nutrient status will improve as weathering progresses and that long term benefits may be gained through fertilization.

Pedogenic illuviation, evident by increased clay and silt content with depth, is ongoing and indicative of active soil processes.

Comparisons with surrounding natural soils show that coarse textured coniferous forest soils have physical properties similar to the waste dumps. These sites support Douglas Fir and Lodgepole Pine forests with sparsely distributed shrubs on a bare needle covered forest floor. Density of grasses and forbs is low.

Lornex Temporary Tailings

To summarize the physical properties of the Lornex temporary tailings the following points may be made.

The tailings are completely soil-sized with a loam textural class.

Available water storage capacity is excellent being 19 percent by volume.

Bulk density is not excessive.

Minimum aeration porosity is low, less than 10 percent by volume. Previous agronomic research has shown such a low level may inhibit seedling emergence from thoroughly wetted sites (Hanks and Thorpe, 1956). Later spring seeding should be considered in view of this fact.

Cation exchange capacity is very low suggesting leaching may prevent nutritional status from improving with time and reducing long-term benefits from fertilization. Repeated light fertilizations may be required to attain stand establishment. Farming a green manure crop or adding organic matter may improve this situation.

Comparison with local natural soils points out that fine textured grassland soils have physical properties most like the tailings. Cultivation of a grass stand is the obvious path to reclamation of this material.

HORIZONATION IN IRON TAILINGS
(SULLIVAN MINE)

SURFACE CRUST ON IRON TAILINGS
(SULLIVAN MINE)

SULLIVAN MINE - KIMBERLEY, B.C.

IRON AND SILICA TAILINGS

INTRODUCTION

The Sullivan Mine is located on the edge of the town of Kimberley, British Columbia. It is the largest lead-zinc mine and largest underground mine in the province. As a lead-zinc producer it is one of the largest in the world.

Operation of the mine started in the late nineteenth century and present mill production is near 6,000 tons of ore a day. Much of the coarse waste material is used as backfill in the mining operation and as railway ballast. Extensive concentrator mill tailings have accumulated.

GEOLOGY AND GEOMORPHOLOGY

The ore body occurs as a layered sulfide deposit in sedimentary rocks. It is believed by Freeze (1966) to be of hydrothermal origin. The main products of the mining operation are lead, zinc, silver and iron sinter. Pyrite and other sulfides constitute a major proportion of the waste material.

Pleistocene glaciation has modified the landscape. Unconsolidated glacial overburden was left on most of the area. Glacial till, glacial-fluvial material and colluvial material predominate. Outcroppings of bedrock and areas of lacustrine sediment also occur. Minor recent alluvial sediments are found adjacent to the St. Mary's River. Surficial geology of the area is described by Fulton (1968) and Clague (1974).

SOILS

Soils of the area are described in a preliminary soil reconnaisance survey by the Soils Division, British Columbia Department of Agriculture. (Provisional draft, 1974.) Podzolic and Brunisolic soils predominate.

Soil descriptions, natural vegetation and physical properties of selected adjacent soils are described in tables A-25 to A-31 of the appendix and table XIII of the text.

CLIMATE

Climatic data for the area is summarized in table A-12. Mean annual precipitation as reported in 1965 and 1970 is 38 cm. Precipitation over the growing season, May to August, is 14 cm. Winter snow is 153 cm. Average maximum temperatures for this period are 28°C. Kimberley receives a much more favourable distribution of growing season precipitation than does the Highland Valley or Princeton areas.

DESCRIPTION OF SITES

The sample sites of the Sullivan Mine tailings are shown in Plate 7.

Sample sites of adjacent soil and vegetation sites are shown in Figure A-24 of the appendix. Typical descriptions of the Sullivan iron and silica tailings are given in tables XIII & XI. Diagrams of tailings materials are given in Figures 6 and 7. Descriptions of adjacent soil sites and vegetation lists are given in tables A-25 to A-31 of the appendix.

RESULTS AND DISCUSSIONS

It was difficult to predict characteristics for these materials by visual interpretation. Water retention data determined by laboratory analysis indicated that water retention was not a growth limiting factor. Water retention data is given in tables A-32 and A-34 of the appendix while curves are given in Figure 8 and 9 of the text. The mean A.W.S.C. for the iron tailings is 0.23 cm^3 per cm^3 and for the silica tailings is o.19 cm^3 per cm^3. Mean A.W.S.C. for silt loam soils is listed as 0.20 cm^3 per cm^3 in the British Columbia Irrigation Guide (Calver et al). Available water storage capacity is evidently not a problem.

Particle size distributions for these materials are possibly not as meaningful as for other areas because of the severe surface iron cementation that is often present. Distributions for the deeper and usually non-cemented material are probably more diagnostic.

Particle size distributions for the iron and silica tailings are given in table X. Both tailings types tend to have silt loam textures.

Table VIII

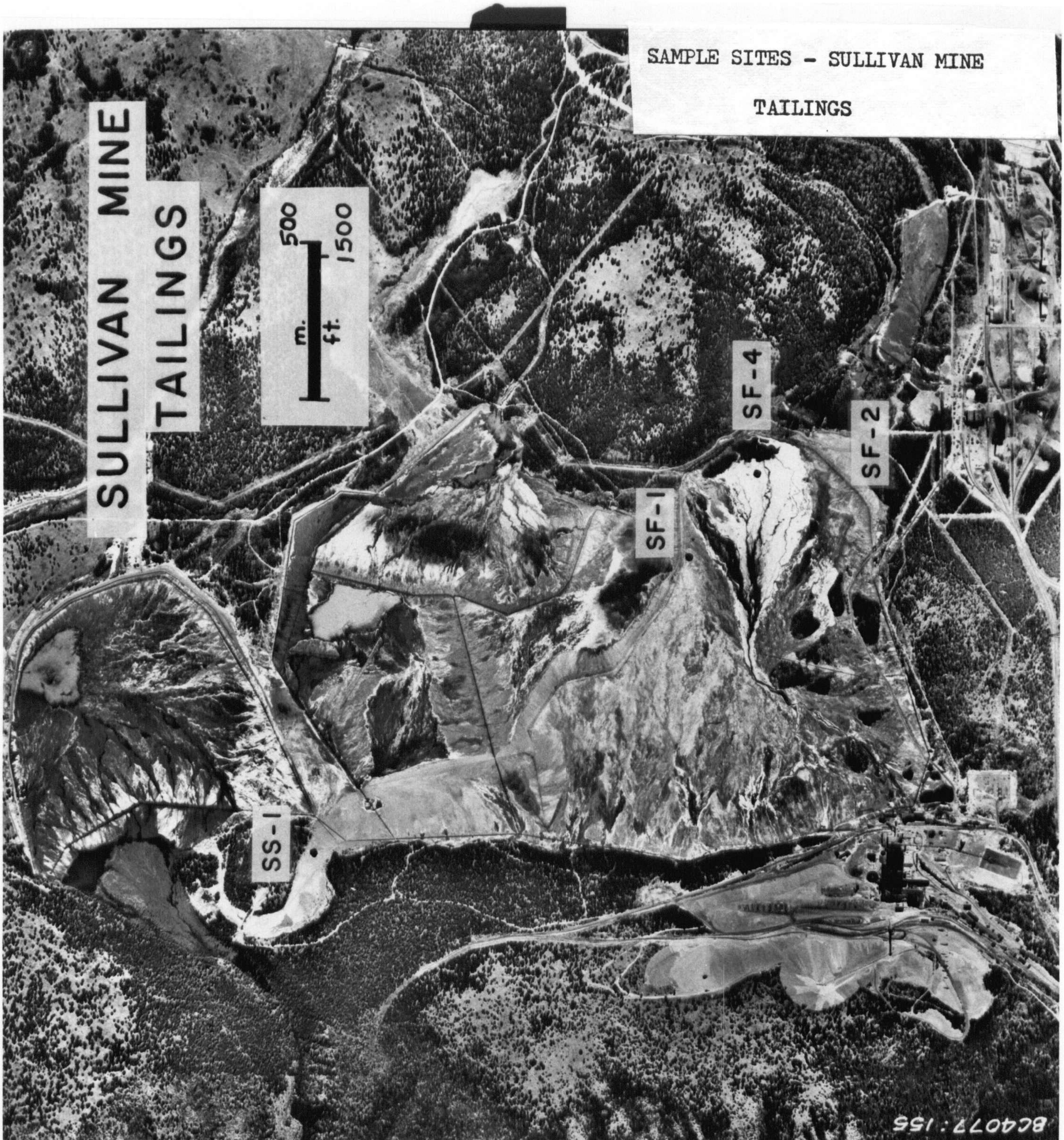
DESCRIPTION OF SULLIVAN MINE IRON TAILINGS

Cms	LAYER	
0-15	A	Strong brown (7.5 YR 5/8), loam - clay loam, very strongly cemented, full of small round gas holes, possibly a relic of gaseous release before cementation.
15-38	B	Light olive gray (5 YR 6/2), with some strong brown (7.5 YR 5/8), silt loam, sticky when wet.
38-51	C	Strong brown (7.5 YR 5/8), interfingered with some light olive grey (5 YR 6/2) and some black (5 YR 2/1) material, silt loam, developing into an iron pan (ortein)
51-70	D	Black (7.5 YR 2/0), loam - silt loam, induration.
70-90	E	Black (7.5 YR 2/0), banded with olive (5 YR 4/4), loam, below water table and completely saturated.

Table IX

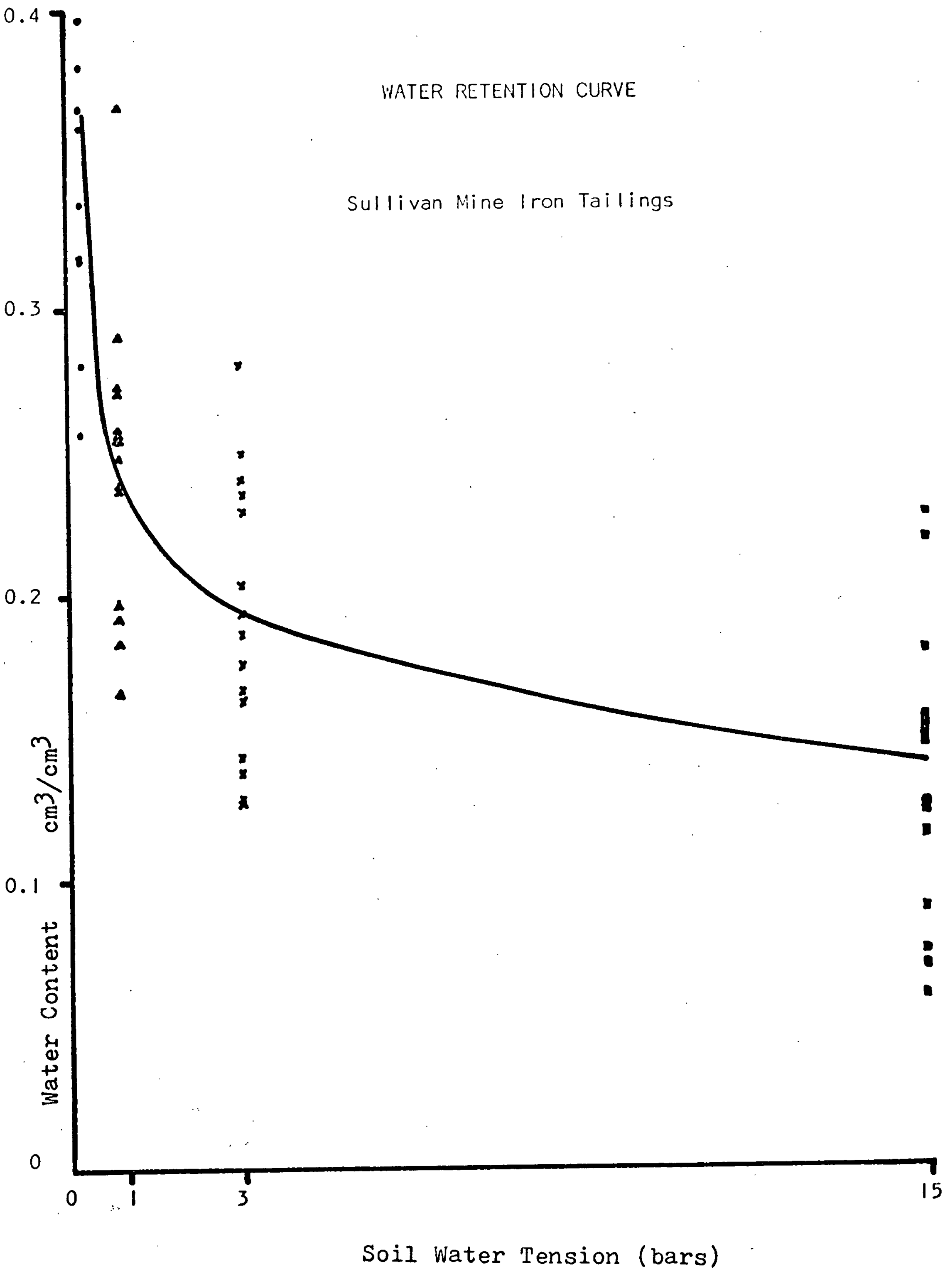
DESCRIPTION OF SULLIVAN MINE SILICEOUS TAILINGS

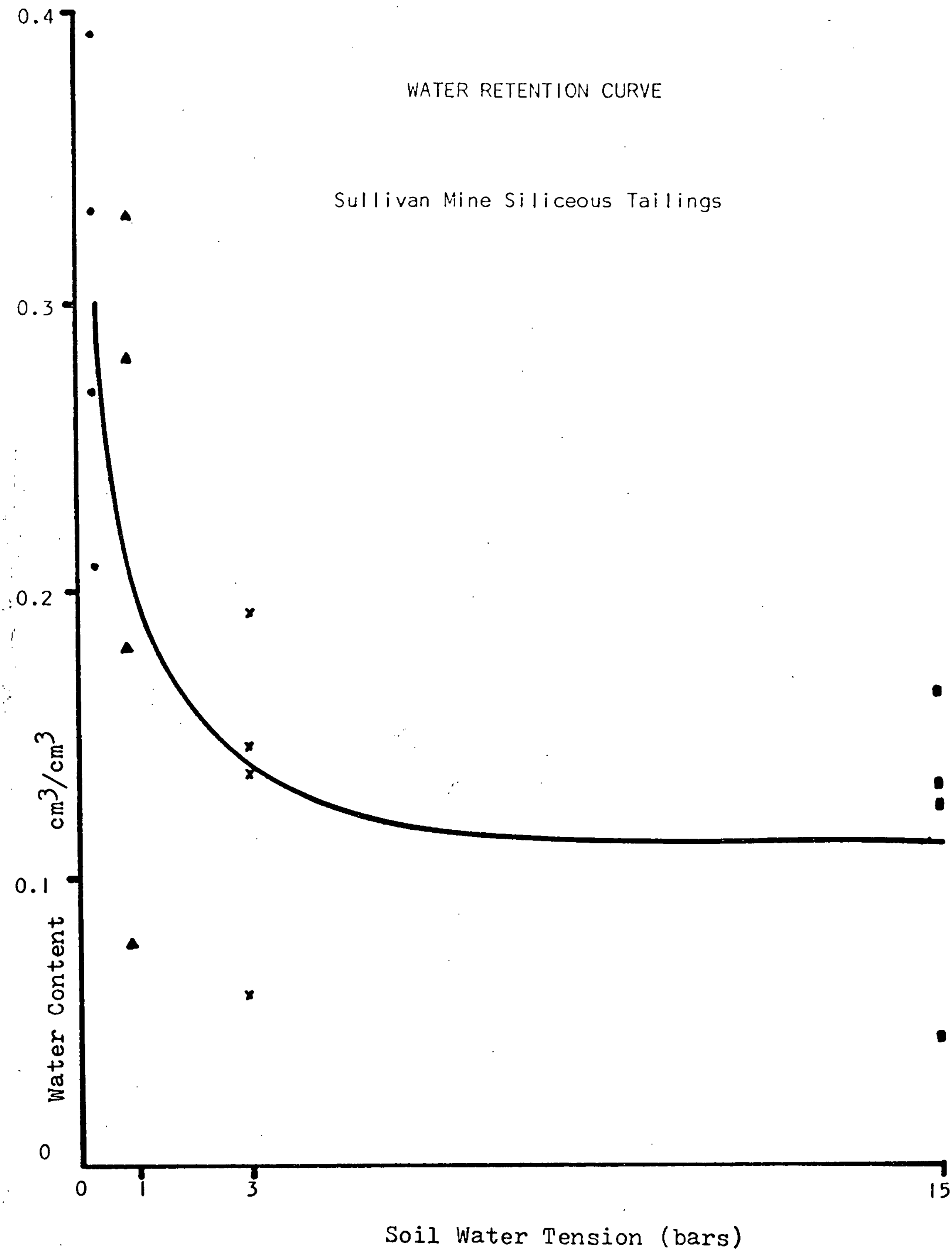
Cms	LAYER	
0-20	A	Dark grey (7.5 YR 4/0), sandy loam-loam, structureless.
20-25	B	Silt, indurated, much like an "ortstein" interfingered with silty material.
25-46	C	Brown (7.5 YR 4/4), sandy loam, structureless.
46+	D	Dark brown (7.5 YR 3/2), silt loam, somewhat indurated.



SAMPLE SITES - SULLIVAN MINE TAILINGS

Figure 8


WATER RETENTION CURVE
Sullivan Mine Iron Tailings
0.4
0.3
0.2
0.1
0
Water Content cm3/cm3
0
1
3
15
Soil Water Tension (bars)


WATER RETENTION CURVE
Sullivan Mine Siliceous Tailings
0.4
0.3
0.2
0.1
0
Water Content cm3/cm3
0
1
3
15
Soil Water Tension (bars)

UNDISTURBED NON-VEGETATED SULLIVAN MINE IRON TAILINGS

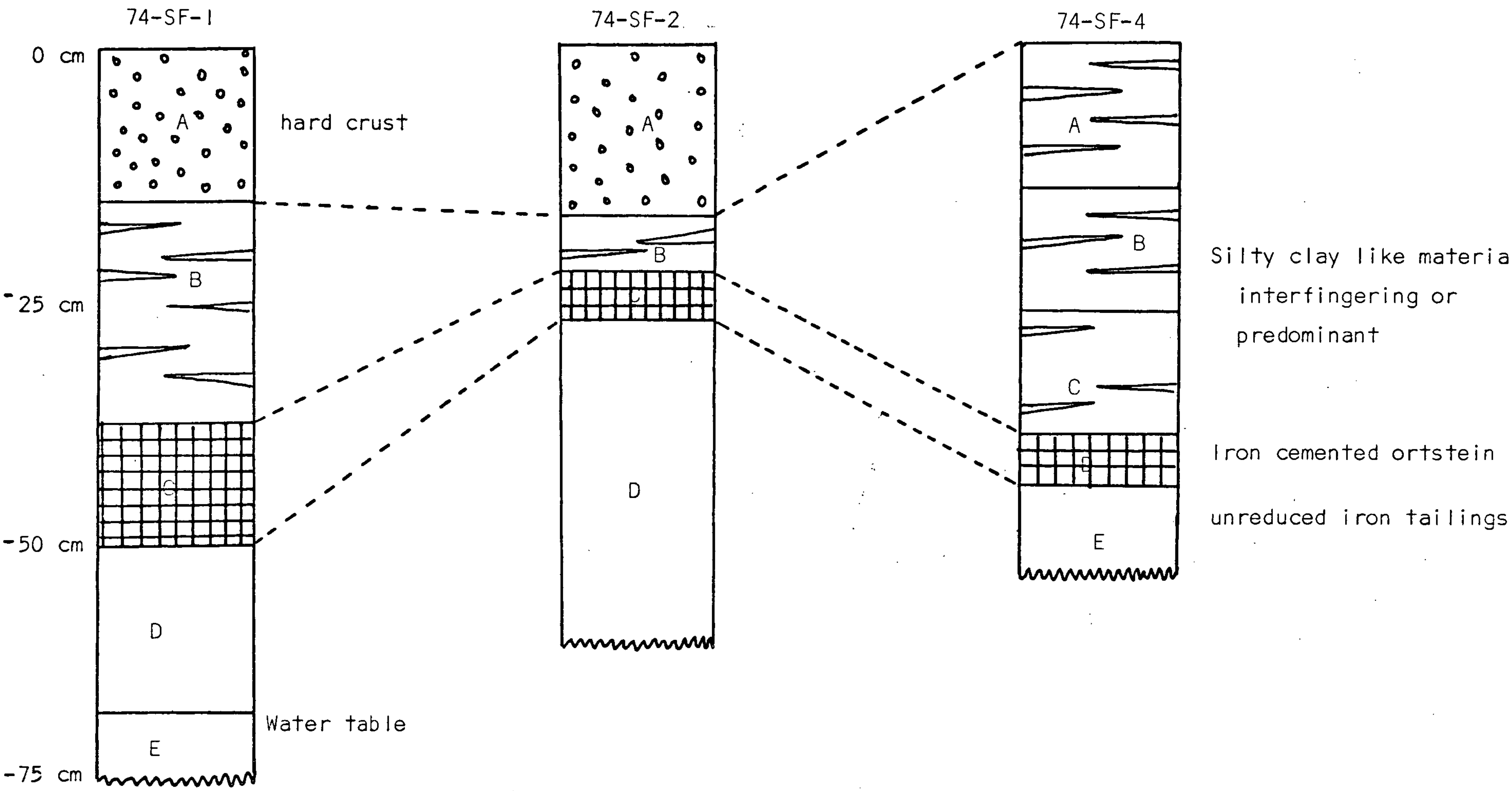


Figure 6

SULLIVAN MINE SILICEOUS TAILINGS

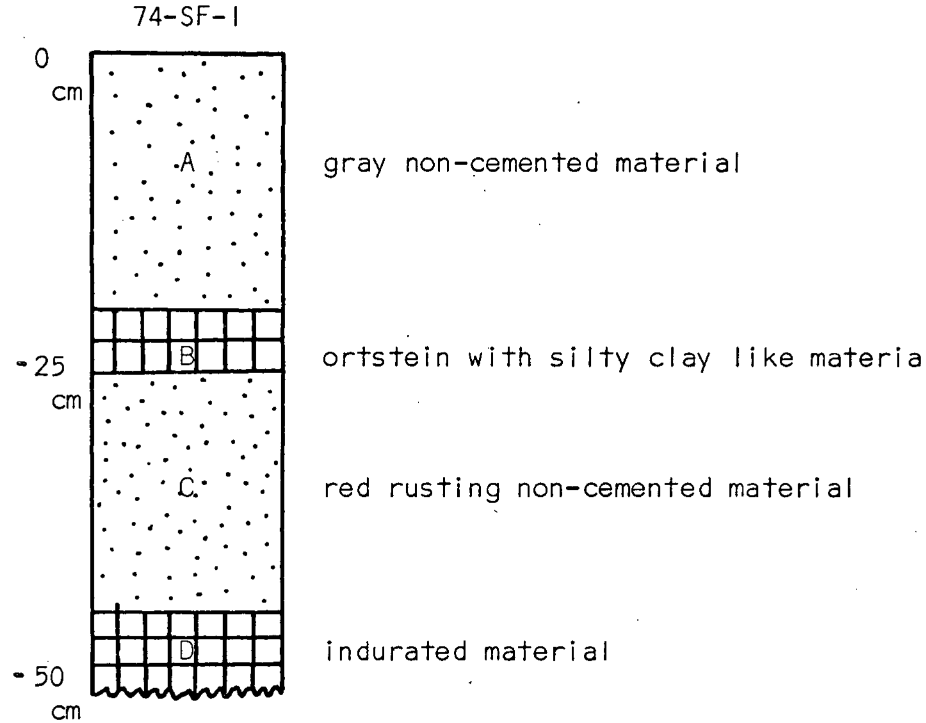


Figure 7

The silica tailings are higher in sand-sized material and lower in clay-sized material than are the iron tailings.

Severely cemented samples were found to retain their cementation despite immersions of up to two months in water.

Pre-treatment of a few samples with citrate dithionite solution resulted in dramatic increases in clay sized material. This increase in clay sized material indicates that untreated particles are actually cemented aggregates of smaller particles.

Unlike the other areas studied, which were fairly uniform throughout their profile, the Sullivan sites were found to be differentiated into layers much like classic horizonation in natural soils. The hard cemented surface layer is sometimes absent and in such places would render the tailings more amenable to seeding and other cultural practices. (See figure 6.)

The iron tailings formed from the 1948 "spill" on the bank of the St. Mary's River were found to lack cementation in the surface iron oxide layer. It is not known whether this can be attributed to 26 years of weathering or the periodic flooding to which this area is prone or to other conditions that might have prevailed at this site.

Bulk densities are listed in table XI. Mean bulk densities of the top 15 cm of the iron tailings was found to be 1.15 gms per cm^3, and of the top 15 cm of the silica tailings to be 1.36 gms per cm^3.

Particle density determinations are listed in table XIII. Mean particle densities for both materials are 2.80 gms per cm^3. Particle density is somewhat lower than originally anticipated for such a minerological assembleage and possibly reflects the intense oxidation and resulting amorphous crystalline structure of the particles.

Minimum aeration porosity of the silica tailings is 21% and of the iron tailings is 22%. In reference to Hank and Thorp (1956) aeration porosities for these materials appear adequate.

Cation exchange capacity is moderate for both tailings types, 8.8 me./100gm. for the iron tailings and 6.4 me./100gm. for the siliceous tailings. Considering the high proportions of iron, aluminium and amorphous crystalline material and the extreme acidity of the tailings, fertility problems will almost invariably be very real.

Hydraulic conductivities for these materials are listed in table XI. Iron cementation appears to be a critical factor influencing this property. Mean hydraulic conductivities for the silica tailings were found to be 60 cm per day and for the iron tailings to be 14 cms per day. Attention is drawn to the tremendous variability in hydraulic conductivity depending on the degree of cementation. Mean values indicate the fate of water ponded on the tailings surface. Schwals _et al_ (1971) list hydraulic conductivity ranges for representative loams as 12-49 cm per day and for clay loams as 3-12 cm per day.

PARTICLE SIZE ANALYSIS - SULLIVAN MINE TAILINGS

(by weight)

Sample #	% 2 mm	% Sand	%Silt	% Clay	Textural Class
SS-1A	100	49	46	5	Sandy Loam - Loam
SS-1B	100	7	84	9	Silt
SS-1C	100	59	37	6	Sandy Loam
SS-1D	100	27	59	14	Silt Loam
Mean silica tailings	100	35	56	9	Silt Loam
SF-1A	100	29	45	26	Loam-clay loam
SF-1B	100	18	68	14	Silt Loam
SF-1C	100	30	57	13	Silt Loan
SF-1D	100	44	51	5	Loam-silt loam
SF-1E	100	45	47	8	Loam
SF-2A	100	46	44	10	Loam
SF-2B	100	35	52	13	Silt Loam
SF-3A	100	29	51	20	Silt Loam-loam
SF-3B	100	47	39	14	Loam
SF-3C	100	21	62	17	Silt Loam
SF-3D	100	18	64	18	Silt Loam
SF-4A	100	23	47	30	Clay loam-silty clay loam
SF-4B	100	20	60	20	Silt Loam
SF-4C	100	5	76	17	Silt Loam
SF-4D	100	62	31	7	Sandy Loam
SF-4E	100	10	77	13	Silt Loam
Mean Iron Tailings	100	30	55	15	Silt Loam

BULK DENSITY AND HYDRAULIC CONDUCTIVITY

MEASUREMENTS BY CORE SAMPLE METHODS OF

SULLIVAN MINE TAILINGS

Sample Location	Sample Type	Hydraulic Conductivity cm/day	Bulk Densi (gm/cm^3)
Sullivan Silica Tailings			
SS-1	non cemented	113	1.41
"	non cemented	74	1.33
"	partially cemented	48	1.62
"	strongly cemented	3	1.10
MEAN		60	1.36
Sullivan Iron Tailings			
SF-1A	crusted surface	...	1.17
"	crusted surface	4	1.24
"	crusted surface	...	1.33
SF-4A	silty surface	28	1.03
"	silty surface	14	1.07
"	silty surface	10	1.07
MEAN		14	1.15

Table XII

PARTICLE DENSITY - SULLIVAN MINE TAILINGS

Sample Location	Sample #	Particle Density gm/cm^3
Siliceous tailings area	SS-A	2.90
"	SS-B	2.72
"	SS-C	2.78
"	SS-D	2.82
Iron Tailings area	SF-1A	2.75
"	SF-1B	2.84
"	SF-1C	2.67
"	SF-1D	3.17
"	SF-1E	3.03
"	SF-2A	2.67
"	SF-2B	2.60
"	SF-2D	2.91
"	SF-3A	2.59
"	SF-3B	3.16
"	SF-3C	2.75
"	SF-3D	2.71
"	SF-3E	3.14
"	SF-4A	2.55
"	SF-4B	2.75
"	SF-4C	2.67
"	SF-4D	2.66
"	SF4E	2.81
Mean Iron Tailings		2.80
Mean Silica Tailings		2.80

SUMMARY OF THE PHYSICAL PROPERTIES OF THE SULLIVAN MINE TAILINGS MATERIALS AND ADJACENT SOIL SITES

Table XIII

Sample	Classification or Type	Layer or Profile	% 2 mm (mean)	Textural class (2 mm) (mean)	A.W.S.C. cm/cm (mean)	Bulk Density 0 - 15 cm g/cm^3 (mean)	Total Porosity 0-15 cm (mean)	Minimum aeration porosity 0-15 cm (mean)	C.E.C. Meg/100gm <2mm fraction (mean)	A.W.S.C. 100 cm soil cm water
	Sullivan iron tailings	Mean	100	silt loam	.227	1.15	.59	.22	8.8	22.7
	Sullivan silica tailings	Mean	100	silt loam	.187	1.36	.51	.21	6.4	18.7
SV-1	Orthic humo-ferric podzol	Appendix	Appendix	Appendix	Appendix	1.37	.46	...	Appendix	12.2
SV-2	Orthic Humo-ferric podzol	Appendix	Appendix	Appendix	Appendix	1.24	.53	...	Appendix	2.5
SV-3	Orthic humo-ferric podzol	Appendix	Appendix	Appendix	Appendix	0.98	.63	.43	Appendix	8.7
SV-4	Sombric eutric brunisol	Appendix	Appendix	Appendix	Appendix	1.35	.49	.25	Appendix	8.9
SV-5	Orthic humo-ferric podzol	Appendix	Appendix	Appendix	Appendix	1.26	.52	.29	Appendix	13.9
SV-6	Orthic humo-ferric podzol	Appendix	Appendix	Appendix	Appendix	1.26	.52	...	Appendix	13.1
SV-7	Orthic humo-ferric podzol	Appendix	Appendix	Appendix	Appendix	1.26	.52	.33	Appendix	7.3

SUMMARY

Sullivan Mine Iron and Siliceous Tailings

To summarize the physical properties of the Sullivan Mine tailings the following points may be made.

All the material is soil sized i.e.$<$2mm. However, the top 15 cm. of the iron tailings can become so severely cemented that if crusted it cannot be considered soil sized, rather it becomes a continuous crust broken irregularly from heaving. Tailings material below the crust in the iron tailings and all of the siliceous tailings have a silt loam textural class. Shallow iron pans occur in some areas of both tailings types.

Available water storage for non-cemented tailings material is excellent ranging from 19 to 23 percent by volume for the two types.

Bulk densities are not excessive for either tailings types.

Particle densities are 2.80 gm. per cm^3 for both tailings types, slightly heavier than normal natural soils.

Minimum aeration porosity is ample for seedling emergence.

The cation exchange capacity of the iron tailings is about 6-9me per 100 gm. It is conjectural whether or not these values are adequate for nutritional requirements in view of the extremely acidic conditions and high concentrations of iron and amorphous minerals that exist.

The main limiting physical property is the severely crusted surface of the iron tailings and presence of shallow cemented iron pans, particularly in the siliceous tailings.

Revegetation of severely cemented regions of the tailings may necessitate additions of soil material above the crust to obtain satisfactory physical conditions for the establishment of vegetation.

JERSEY MINE (CANEX MINE) - SALMO B.C.

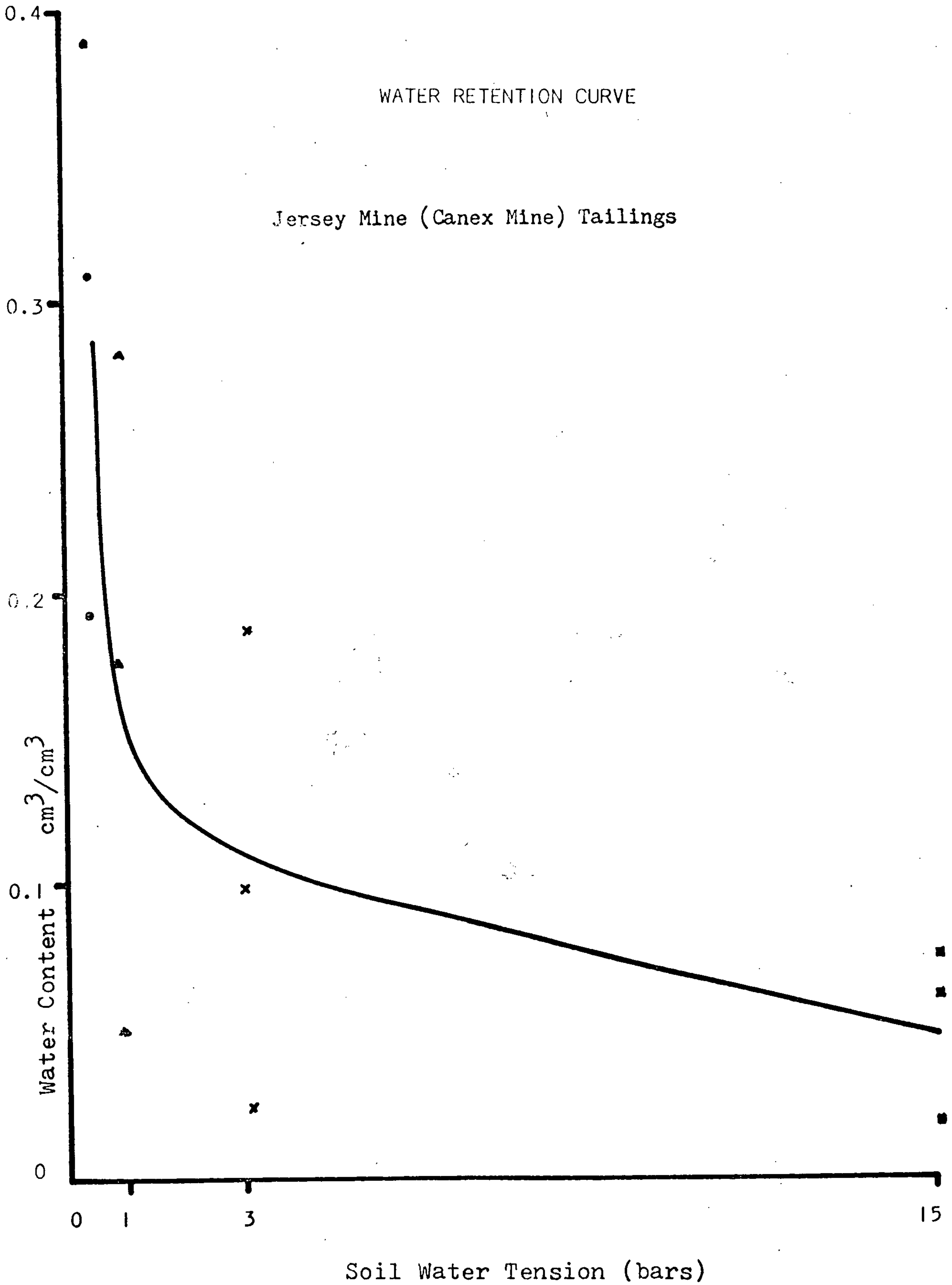
TAILINGS

INTRODUCTION AND DISCUSSION

The Jersey Mine (Canex Mine) is located a few miles south-west of Salmo, British Columbia on the southern Trans-Canada Highway. The mine is no longer operational but was mined by underground methods in past years. The mine is described by Green (1954). Mineralization occurred as sphalerite and galena in a dolomitic limestone body. Mill tailings were deposited in a tailings area adjacent to the mine and were drained and "dried up" at the end of mining. They were then successfully revegetated with grasses over a period of a few years (Weston, 1973).

Although not a centre of research in the scope of this project, samples of the tailings materials were collected. Descriptions and physical properties of these materials are given in tables XIV and XV. The water retention curve for these materials is given in figure 10.

It is noted that water storage capacity is adequate for vegetation requirements and that vegetation was eventually established despite exchange capacities that are extremely low.


WATER RETENTION CURVE
Jersey Mine (Canex Mine) Tailings
0.4
0.3
0.2
0.1
0
Water Content cm³/cm³
0
1
3
15
Soil Water Tension (bars)

DESCRIPTION OF JERSEY MINE TAILINGS (CANEX MINE)

(Salmo, B.C.)

LAYER	CMS	
A1	0 - 13	Dark brown (7.5 YR 3/2), sandy loam, structureless, abundant fine distinct roots (natural soil addition)
B11	13 - 30	Dark grey (7.5 YR 4/0), sandy loam, structureless, many fine distinct roots
C11	30 - 46+	Very dark grey (7.5 YR 3/0) with strong brown (7.5 YR 5/6) mottles, silt loam, structureless, few fine distinct roots

Table XV

PHYSICAL PROPERTIES - JERSEY MINE (CANEX MINE)

PARTICLE SIZE ANALYSIS

	% 2 mm	% Sand	% Silt	% Clay	Textural Class
A	63	65	31	4	Sandy Loam
B	100	68	27	5	Sandy Loam
C	100	11	74	15	Silt Loam

Note A is assumed to include soil material spread on surface at time of revegetation.

WATER RETENTION DATA

	-/10 bar gm/gm	-1/3 bar gm/gm	-9/10 bar gm/gm	-3 bar gm/gm	-15 bar gm/gm	A.W.S.C. gm/gm	A.W.S.C. cm^3/cm^3
A	.276	.212	.120	.068	.053	.159	.147
B	.159	.132	.034	.014	.010	.149	.219
C	.305	.263	.101	.127	.055	.208	.306

Mean bulk density gm/cm^3 (0 - 15 cm)		1.47
Mean Total Porosity (0 - 15 cm)		0.45
Mean Minimum Aeration Porosity (0 - 15 cm)		0.19
Mean C.E.C. Meg./100 gm 2 mm fraction	A	10.53
	B	0.98
	C	1.35
A.W.S.C. cm water (100 cm soil)		26.3

CONCLUSIONS

Waste Rock Dumps

To summarize the physical properties of waste rock dumps the following points may be made.

Less than 25 percent of the volume of the dumps is less than 2mm and considered soil-sized material. The soil-sized material has a sandy loam textural class. The remainder of the volume of the dump is occupied by coarse fragments.

Available water storage capacities are low because of the high proportion of coarse fragments and are only 3-5 percent by volume.

Bulk densities are high because of the high proportion of coarse fragments.

Particle densities are comparable to those of normal natural soils.

Minimum aeration porosities are ample for seedling emergence.

Cation exchange capacities are generally favourable suggesting that nutrient status will improve as weathering progresses and that long-term benefits may be realized from fertilization.

Pedogenic illuviation, evident by increased clay and silt content with depth, is ongoing and indicative of active soil processes.

Comparisons with local natural soils show that coarse textured coniferous forest soils have physical properties most like the waste dumps. These sites typically support Douglas Fir and Lodgepole Pine forests with understories consisting of sparsely distributed low or medium height shrubs growing on bare needle-covered forest floors. This comparison suggests that eventual revegetation will be by aborescent species and not herbaceous species. Grass growth although difficult may be beneficial in achieving immediate aesthetic improvement, surface stabilisation and soil improvement until more edaphic aborescent species are established.

CONCLUSIONS

Mill Tailings

To summarize the physical properties of the mill tailings the following points may be made.

All of the material is finer than 2 mm and is considered soil-sized. Textural classes for mill tailings are variable amongst mines.

Available water storage capacities are generally good to excellent being 15-25 percent by volume and comparable to irrigated agricultural soils, (Calvert *et al*).

Bulk densities are generally acceptable for vegetation establishment.

Particle densities of most tailings are comparable to those of normal soils excepting some highly metaliferous tailings which are heavier.

Minimum aeration porosities are usually adequate for seedling emergence. An exception on some finer textured tailings that show low aeration porosity values when thoroughly wet.

Cation exchange capacities of non iron sulfide-rich tailings are generally low, being less than 5 me/100 gm, tailings. Both the Copper Mountain tailings and the Lornex temporary tailings may require repeated fertilization to compensate for this fact. The cation exchange capacities of the Sullivan Mine iron and siliceous tailing (iron sulfide rich) range from 6-9 me/100 gm tailings. It is conjectural whether or not they are adequate for nutritional requirements in view of the extremely acidic conditions and high concentrations of iron and amorphous minerals that exist. Cultivation of an annual green manure crop or additions of organic matter will help improve this property.

Pedogenic horizonation is sometimes obvious as is the case in the Sullivan Mine tailings.

Comparisons with local natural soils show that grassland soils with high water storage capacities most closely approximate the properties of the tailings materials. This comparison suggests that eventual revegetation will be by grasses or forbs and that cultivation to establish this type of vegetation may be successful.

DISCUSSION

A hypothetical reclamation project for a dry climate mine might, on the basis of the physical properties of the waste materials, devise a reclamation scheme as follows.

The waste rock dumps would be initially seeded with grass attempting to get immediate aesthetic improvement, surface stabilization and soil improvement. The dumps could be seeded at a light rate in the fall to ensure that melt water moisture did not escape the germinating seeds in the spring. The surface of the dumps should be mechanically scarified, the seed broadcast and then packed in an attempt to get better seed-soil contact for germination. Fertilizer should be applied in the fall or winter but not summer to ensure that osmotic stresses were not added to drought stresses. Massive applications should be avoided for the same reason. More edaphic drought tolerant shrubs would be planted in accordance with their ultimate greater suitability to the dump environment.

The tailings would be cultivated in the same fashion as an arable soil. Irrigation should be considered for stand establishment, if water is available. Seeding should be done with conventional agricultural implements in the spring, to ensure that germination was not inhibited by low aeration porosity resulting from early season wet conditions. For tailings with low aeration porosities, special tolerant species such as Timothy could be considered. An initial annual crop would be sown to be turned under to improve cation exchange capacity and as a soil conditioner. Organic additives might be added for the same reason. Fertilization should be done repeatedly at short intervals in light applications in view of the low cation exchange capacity of the material. If irrigation was employed, fertilization might be conducted through the system. At such time as a vigorous stand is established fertilization would be tapered off hoping that nutrient cycling and improved soil conditions would have come into play.

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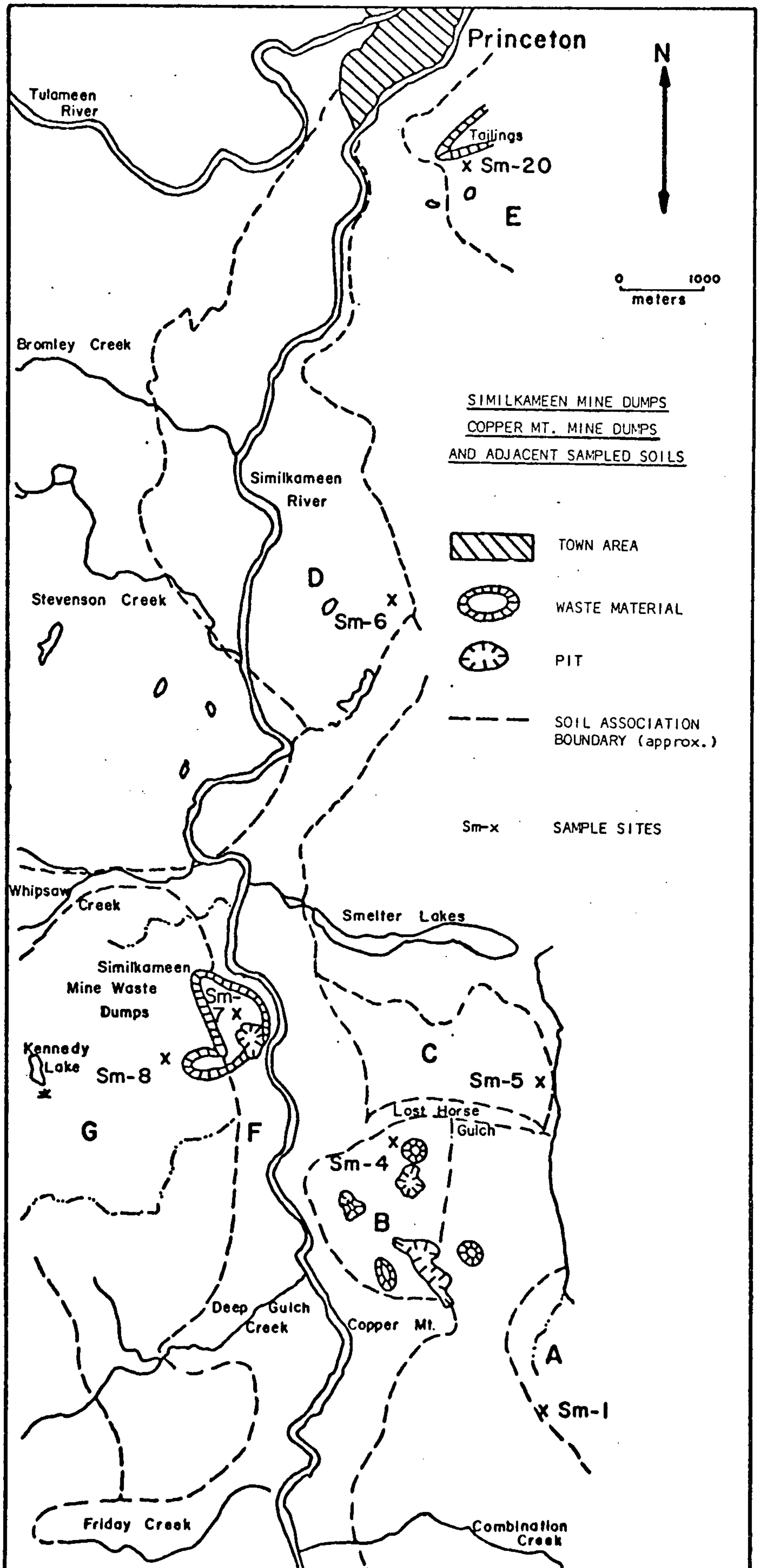
SECTION 8

Appendix

Sm	Princeton Area Soil
HV	Highland Valley Area Soils
SV	Kimberley Area Soil

Figure A-1


Princeton
N
Tulameen River
Tailings
x Sm-20
E
0 1000 meters
Bromley Creek
SIMILKAMEEN MINE DUMPS
COPPER MT. MINE DUMPS
AND ADJACENT SAMPLED SOILS
Similkameen River
TOWN AREA
D
Sm-6
Stevenson Creek
WASTE MATERIAL
PIT
SOIL ASSOCIATION BOUNDARY (approx.)
Sm-x SAMPLE SITES
Whipsaw Creek
Smelter Lakes
Similkameen Mine Waste Dumps
Sm-7
Kennedy Lake
Sm-8
C
Sm-5
Lost Horse Gulch
G
F
Sm-4
B
Deep Gulch Creek
Copper Mt.
A
Sm-1
Friday Creek
Combination Creek

SM-1

Classification	Degraded Dystric Brunisol
Location	SE Copper Mountain Mine
Elevation	1530 m
Slope and Aspect	20% E
Parent material	Glăcial till - colluvial material
Landform	Steep land
Drainage class	Moderately well

HORIZON	Cm	
LFH	3 - 0	
Ae	0 - 5	Light yellowish brown (10 YR 6/4), sandy loam, structureless, many fine distinct roots
Bm	5 - 25	Brown (10 YR 5/3), sandy loam, structureless, many fine distinct roots
BC	25 - 60	Yellowish brown (10 YR 5/4), silt loam, structureless, few fine distinct roots
C	60+	Yellowish brown (10 YR 5/4), sand structure-less

DOMINANT VEGETATION

Douglas fir	Buffalo berry	Grouseberry	Pinegrass	Feathermoss
Engleman spruce	Red twin berry	Blackmountain huckleberry		
Lodgepole Pine	Rose	False-box		

SM 4

Classification	Degraded Dystric Brunisol
Location	Top of Copper Mountain Mine Adjacent to waste dump
Elevation	1300 m
Slope and Aspect	10 20% N
Parent Material	Glacial till and rock
Landform	Colluvial slope and rock
Drainage Class	Well drained

HORIZON	Cm	
LFH	2 - 0	
Ae	0 - 5	Light yellowish grey (10 YR 6/2), silt loam structureless, many fine distinct roots
BM	5 - 23	Pale brown (10 YR 6/3), gravelly silt loam, structureless, many fine distinct roots
BC	25 - 50	Pale brown (10 YR 6/3), gravelly silt loam, structureless, few fine roots
C	50 - 65	Yellowish brown (10 YR 5/4), gravelly sandy loam, structureless
R	65+	

DOMINANT VEGETATION

Lodgepole Pine	Willow	Bearberry	Pinegrass
	Juniper	Twinflower	Sedge
	Grouseberry	False-box	
	Buffalo berry		

SM 5

Classification	Orthic Grey Brown Luvisol
Location	North of junction of Wolf Creek and Lost Horse Gulch
Elevation	1100 m
Slope and aspect	0 - 5% N
Parent Material	Galcial till
Landform	Drumlinized slope
Drainage class	Moderately well drained

HORIZON	Cm	
LFH	2 - 0	
Ae	0 - 8	Pinkish grey (7.5 YR 6/2), loam, structureless many fine distinct roots
B+	8 -32	Brown (10 YR 4/3), sandy loam, weak subangular, blocky, few distinct roots
C	32 - 50	Dark brown (10 YR 3/3), gravelly sandy loam, structureless

DOMINANT VEGETATION

Lodgepole Pine	Willow	Bearberry	Pinegrass
Trembling Aspen	Buffalo berry	Timber milk vetch	Canada bluegrass
Douglas Fir	Rose	Pussy_toes	Downy brome

SM 6

Classification	Degraded Eutric Brunisol
Location	Near Old Princeton Power House
Elevation	870 m
Slope and aspect	40 - 50% W
Parent material	Glacial till and colluvial
Landform	Till slope
Drainage class	Well

HORIZON	Cm	
LFH	2 - 0	
Ae	0 - 5	Greyish brown (10YR 5/2), loam, structureless, many fine distinct roots
BM	5 - 25	Brown (10 YR 5/3), loam, structureless, few fine distinct roots
C	25+	Yellowish brown (10 YR 5/4), sandy loam, structureless

DOMINANT VEGETATION

Douglas fir	Saskatoon berry	Spirea	Idaho fescue
	Creeping mahonia	Arnica	Bluebunch wheatgrass
		Aster	Canada wild-rye
			Annual bluegrass

SM 7

Classification	Degraded Dystric Brunisol
Location	A knoll within the Similkameen Mining operation
Elevation	1170 m
Slope and aspect	0 - 5%
Parent material	Glacial till and rock
Landform	Rock knob
Drainage class	Moderately well

HORIXON	Cm	
LFH	2 - 0	
Ae	0 - 2	Greyish brown (10 YR 5/2), sandy loam, structureless, many fine distinct roots
Bhm	2 - 5	Greyish brown (10 YR 5/2), loam, weak subangular blocky, few find distinct roots
BC	5 - 30	Pale brown (10 YR 6/3), weak subangular blocky, few find distinct roots
C	30 - 42	Pale brown (10 YR 6/3), loamy sand, structureless
R	42+	

DOMINANT VEGETATION

Douglas Fir	Rose	False-box	Pinegrass
Lodgepole Pine	Buffalo berry	Bearberry	Western wheatgrass
			Sedge

SM 8

Classification	Degraded Dystric Brunisol
Location	Kennedy Lake Road
Elevation	1170
Slope and aspect	5 - 10% S
Parent material	Colluvium and glacial till
Landform	Till slope
Drainage class	Moderately well

HORIZON	Cm	
LFH	3 - 0	
Ae	0 - 2	Light brownish grey (10 YR 6/2), sandy loam, structureless, abundant fine distinct roots
Bm	2 - 25	Brown (10 YR 5/3), gravelly sandy loam, weak subangular blocky, many fine distinct roots
BC	25 - 58	Pale brown (10 YR 6/3), gravelly sandy loam, structureless, few find distinct roots
C	58+	Brown (10 YR 4/3), gravelly sandy loam, structureless

DOMINANT VEGETATION

Engleman Spruce	Rose	Flasebox	Pinegrass
Douglas Fir		Twinflower	
Lodgepole Pine			

Table A-8

SM 20

Classification	Orthic Dark Brown Chernozem
Location	N.E. Princeton townsite adjacent Granby tailings
Elevation	780 m
Slope and aspect	2 - 5% N.W.
Parent material	Galcial till
Landform	Hummock till plain
Drainage class	Well drained

HORIZON	Cm	
Ah	0 - 20	Very dark greyish brown (10 YR 3/2), gravelly silty clay loam, medium granular - medium blocky, abundant fine distinct rooting
B+	20 - 55	Brown (10 YR 5/3), gravelly silty clay loam, medium granular - medium blocky, many fine distinct roots
Cca	55+	Pale brown (10 YR 6/3), gravelly silt loam, structureless.

DOMINANT VEGETATION

Lower grassland

Table A-9

WATER RETENTION DATA

SIMILKAMEEN AND COPPER MOUNTAIN TAILINGS

WASTE ROCK DUMPS (FINE FRACTION)

Sample	-1/10 bar gm.gm	-1/3 bar gm/gm	-9/10 bar gm/gm	-3 bar gm/gm	-15 bar gm/gm	A.W.S.C. gm/gm
Similkameen mine waste rock dumps						
P-1A	.281	.216	.176	.127	.112	.169
P-2A	.171	.130	.112	.083	.076	.095
P-3A	.176	.140	.110	.085	.072	.104
P-4A	.174	.136	.108	.083	.074	.100
P-5A	.174	.131	.108	.082	.068	.106
P-6A	.147	.136	.107	.084	.068	.079
P-7B	.178	.154	.119	.087	.081	.097
P-8A	.173	.152	.111	.081	.077	.096
P-11A	.174	.155	.121	.081	.072	.102
P-12A	.201	.157	.110	.088	.075	.126
P-13A	.212	.156	.115	.094	.080	.132
P-14A	.205	.144	.121	.094	.090	.115
Sand Berm						
P-10A	.100	.074	.050	.039	.038	.062
Copper Mountain Tailings						
Layer A	.143	.084	.038	.028	.027	.116
Layer B	.115	.065	.032	.024	.022	.093
Layer C	.160	.123	.043	.031	.027	.133

Table A-10

PRINCETON AREA SOIL SITES

PARTICLE SIZE ANALYSIS

Sample #	Horizon	% . 2 mm	% Sand	% Silt	% Clay	Textural Class
SM-1	Ae	74	69	28	3	Sandy loam
	Bm	59	71	27	2	Sandy loam
	BC	--	--	--	-	----------
	C	37	93	4	3	loam
SM-4	Ae	71	41	51	8	Silt loam
	BM	35	45	52	3	Silt loam
	BC	37	50	48	2	Silt loam
	C	68	57	35	8	Sandy loam
SM-5	Ae	57	50	38	12	Loam
	Bt	73	52	41	7	Sandy loam
	C	37	71	23	6	Sandy loam
SM-6	Ae	77	51	39	10	Loam
	BM	65	50	41	8	Loam
	C	78	56	34	10	Sandy loam
SM-7	Ae	--	--	--	--	----------
	Bhm	88	54	37	9	Sandy loam
	BC	76	48	40	12	Loam
	C	52	56	29	15	Sandy loam
SM-8	Ae	69	55	36	9	Sandy loam
	BM	54	61	25	14	Sandy loam
	BC	67	64	28	8	Sandy loam
	C	66	59	29	12	Sandy loam
SM-20	Ah	54	58	26	16	Sandy loam
	Bt	51	53	30	17	Sandy loam
	Cca	66	70	25	5	Sandy loam

Table A-11

PRINCETON AREA SOIL SITES

WATER RETENTION DATA AND CATION EXCHANGE CAPACITIES

nple and rizon		-1/10 bar gm/gm	-1/3 bar gm/gm	-15 bar gm/gm	A.W.S.C. gm/gm	A.W.S.C. gm/gm corrected for fragments	A.W.S.C. cm/cm	C.E.C. 2mm fractio Meg/100 gm
-1:	Ae	.332	.234	.140	.192	.142	.170	15.5
	Bm	.232	.164	.055	.177	.104	.125	7.4
	BC	.114	.096	.039	.075	.037	.044	----
	C	.045	.037	.030	.015	.005	.007	4.9
-4:	Ae	----	.392	.085	.307	.218	.273	13.6
	Bm	----	.296	.072	.224	.078	.098	13.8
	BC	----	.172	.060	.112	.041	.051	----
	C	----	.117	.071	.046	.031	.039	10.8
-5:	Ae	----	.200	.066	.134	.076	.096	10.7
	Bt	.272	.185	.084	.188	.137	.174	14.3
	C	.206	.138	.085	.121	.044	.056	19.1
-6:	Ae	----	.253	.089	.164	.126	.169	----
	Bm	----	.158	.106	.052	.034	.046	----
	C	.222	.137	.063	.159	.124	.166	----
-7:	Ae	.343	.256	.079	.264	.232	.278	----
	Bhm	.200	.158	.060	.140	.106	.127	----
	BC	.176	.146	.073	.103	.053	.064	----
	C	.108	.031	.025	.083	.042	.053	----
-8:	Ae	.217	.164	.059	.158	.109	.121	10.7
	Bm	.177	.135	.069	.108	.058	.064	11.5
	BC	.225	.155	.062	.163	.109	.121	----
	C	.222	.162	.076	.146	.096	.106	13.1
-20:	Ah	.244	.159	.084	.160	.086	.086	16.1
	Bt	.223	.140	.081	.142	.072	.072	12.6
	Cca	.222	.159	.063	.159	.105	.105	10.8

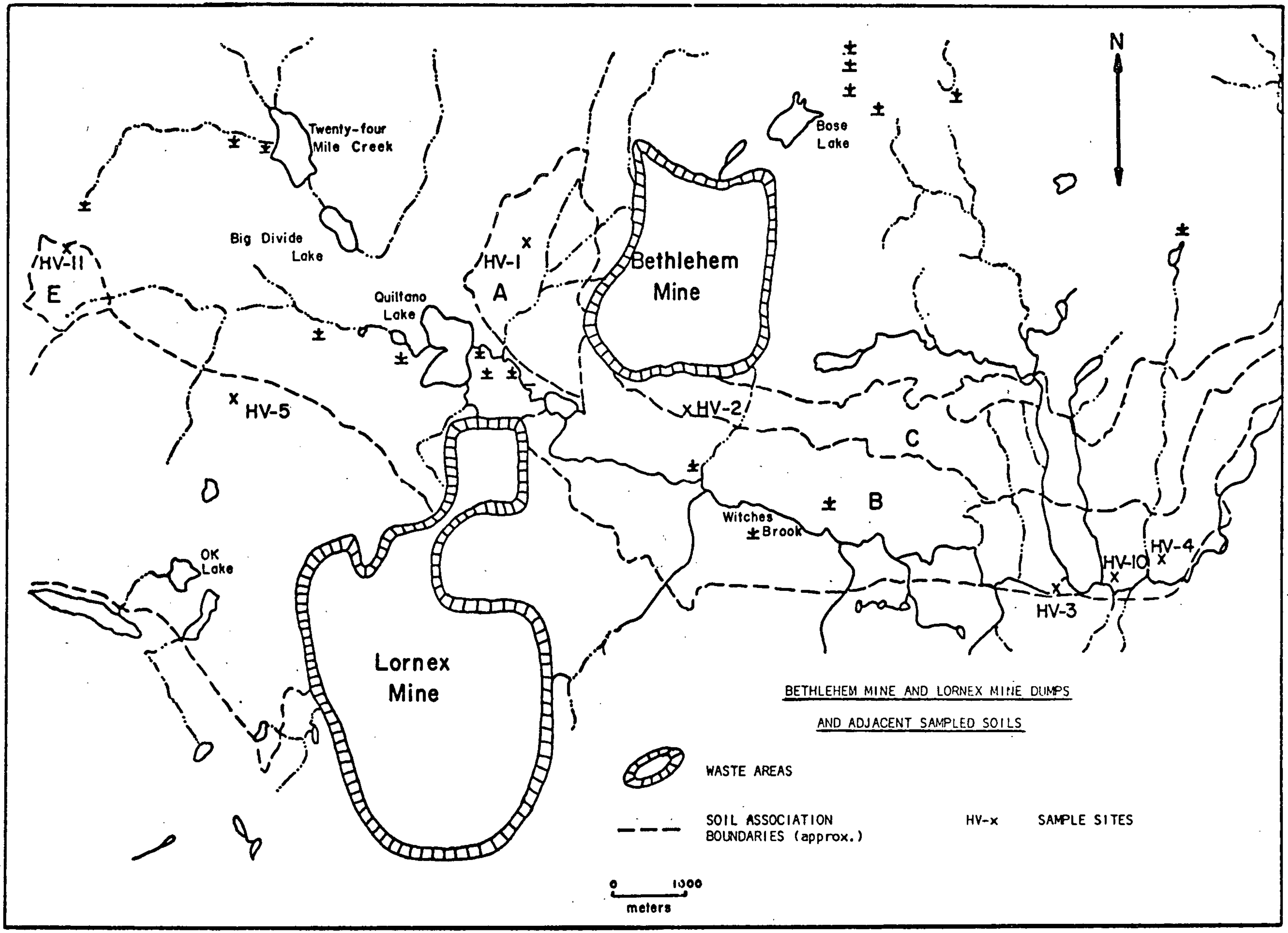
SELECTED CLIMATIC DATA*

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	Winter Snow
Precipitation (mm)															
Princeton		464	350	183	147	254	305	264	251	206	267	417	493	3,602	14,986
Highland Valley		259	38	132	206	196	213	10	142	419	79	635	610	2,939	15,773
Kimberley		412	292	221	183	320	523	218	330	252	274	348	424	3,797	15,290
Mean Temperature (^{o}C)															
Princeton		-7.8	-3.3	-0.5	6.7	11.1	.4.4	17.8	16.6	12.8	6.7	-1.1	-5.2	5.5	---
Highland Valley		07.8	-1.1	-0.5	2.8	7.2	13.9	15.5	15.0	8.9	3.9	-3.3	-7.8	3.9	
Kimberley		-6.5	-4.9	-1.7	5.5	10.5	14.4	17.8	16.6	11.7	5.5	2.2	-6.7	5.0	
Monthley Extremes (^{o}C)															
Princeton	Max	5.5	8.3	15.5	23.8	27.2	31.1	36.6	36.6	26.1	21.6	13.9	5.0	--	--
	Min	-22.2	-15.0	-16.1	-5.5	-4.4	1.6	2.8	0.5	-5.0	-5.0	-10.5	-23.9	--	--
Highland Valley	Max	5.0	9.4	7.2	12.2	21.6	28.9	30.0	31.6	25.0	23.9	12.8	4.4	--	--
	Min	-27.2	-15.0	-18.9	-8.9	-3.9	-1.1	0.5	2.8	-5.0	-10.0	-27.2	-22.8	--	--
Kimberley	Max	3.3	11.7	10.0	18.9	23.3	28.3	30.0	32.2	22.2	20.5	12.8	6.7	--	--
	Min	-17.2	-18.9	-21.1	-3.9	-3.3	-	6.1	0.5	-5.0	-2.2	-13.9	-18.9	--	--

* Taken from Climate of British Columbia, Report for 1965 and 1970.

Table A-12

Figure A-13


N
Twenty-four
Mile Creek
Bose
Lake
Big Divide
Lake
Quiltano
Lake
HV-11
E
HV-1
A
Bethlehem
Mine
xHV-2
C
x HV-5
B
Witches
Brook
OK
Lake
HV-4
HV-10
HV-3
Lornex
Mine
BETHLEHEM MINE AND LORNEX MINE DUMPS
AND ADJACENT SAMPLED SOILS
WASTE AREAS
SOIL ASSOCIATION
BOUNDARIES (approx.)
HV-x
SAMPLE SITES
0
1000
meters

HV 1

Classification	Degraded Dystric Brunisol
Location	West of Bethlehem Mine
Elevation	1400 m
Slope and Aspect	3 - 5% S
Parent material	Glacial fluvial outwash
Landform	Outwash fan
Drainage class	Moderately well drained

HORIZON	Cm	
LFH	5 - 0	
Ae	0 - 3	Light grey (10 YR 6/1) gravelly silt loam, structureless, abundant fine distinct roots
Bm1	3 - 10	Pale brown (10 YR 6/3), gravelly silt loam, very weak subangular blocky, abundant fine distinct roots
Bm2	10 - 80	Light brownish grey (10 YR 6/2), gravelly sandy loam, structureless, few fine distinct roots
C	80+	Dark yellowish brown (10 YR 4/4), gravelly sandy loam, structureless

DOMINANT VEGETATION

Lodgepole	Willow	Bearberry	Pinegrass
Douglas Fir	Buffalo berry	Twinflower	
Trembling Aspen	Rose	Timber milk vetch	

Table A-15

HV 2

Classification	Orthic Eutric Brunisol
Location	North of Witches Brook
Elevation	1300 m
Slope and aspect	10 - 15% S
Parent material	Colluvium
Landform	Colluvial slope
Drainage class	Moderately well drained

HORIZON	Cm	
Ah	0 - 3	Dark greyish brown (10 YR 4/2), loam, very weak subangular blocky, many common fine roots
Bm	3 - 10	Greyish brown (10 YR 5/2), gravelly silt loam, very weak subangular blocky, few distinct fine roots
BC	10 - 20	Light brownish grey (10 YR 6/2), gravelly loamy sand, structureless
C	20+	Greyish brown (10 YR 5/2), gravelly loamy sand, structureless

DOMINANT VEGETATION

Douglas Fir	Rose	Bearberry	Pinegrass
Ponderosa Pine	Juniper	Pussytoes	Bluebunch wheatgrass
Lodgepole Pine			

Table A-16

HV 3

Classification	Orthic Regosol
Location	Floodplain at Witches Brook
Elevation	1280 m
Slope and aspect	..
Parent material	Alluvium
Landform	Floodplain
Drainage class	Poorly drained

HORIZON	Cm	
H	12 - 0	Very dark brown (10 YR), structureless, many fine distinct roots
C1	0 - 38	Yellowish, brown (10 YR 5/6), mottled, sandy loam, structureless, few coarse banded H layers
C2	38+	Greyish brown (10 YR 5/2), mottled, sandy loam, structureless

DOMINANT VEGETATION

Bog birch	Avens	Annual bluegrass
Willow	Chickweed	
	Strawberry	
	White clover	

HV 4

Classification	Degraded Dystric Brunisol
Location	Knoll protruding into Witches Brook
Elevation	1300 m
Slope and aspect	5% W
Parent material	Outwash
Landform	Kame
Drainage Class	Moderately well drained

HORIZON	Cm	
LFH	2 - 0	
Ae	0 - 1	Grayish brown (10 YR 5/2), gravelly sandy loam, structureless, abundant fine distinct roots
Bm	1 - 10	Brown (10 YR 5/3), gravelly loamy sand, structureless, abundant fine distinct roots
BC	10 - 32	Light brownish gray (10 YR 6/2), gravelly loamy sand, structureless, many fine distinct roots
C	32+	Yellowish brown (10 YR 5/4), gravelly sand, structureless

DOMINANT VEGETATION

Lodgepole Pine	Buffalo berry	Bearberry	Pinegrass
Engleman Spruce	Juniper	Twinflower	
		Timber milk vetch	

Table A-18

HV 5

Classification	Orthic Gray Luvisol
Location	Near O.K. Mine
Elevation	1900 m
Slope and aspect	3 - 6% W
Parent material	Glacial till
Landform	Till slope
Drainage class	Moderately well drained

HORIZON	Cm	
LF	8 - 0	
Ae	0 - 5	Grayish brown (10 YR 5/2), gravelly silt loam, structureless, many coarse distinct roots
Bt	5 - 35	Grayish brown (10 YR 5/2), gravelly clay loam, weak subangular blocky, few coarse distinct roots
Cgj	35+	Brown (10 YR 4/3), gravelly clay loam, structureless

DOMINANT VEGETATION

Lodgepole Pine	Willow	Twinflower	Pinegrass
Engleman Spruce	Alder	Lupine	
	Rose		

HV 10

Classification	Orthic Sombric Brunisol
Location	Lacustrine plain adjacent Witches Brook
Elevation	1250 m
Slope and aspect	--
Parent material	Lacustrine sediments
Landform	Lacustrine plain
Drainage class	Moderately well

HORIZON	Cm	
Ah	0 - 12	Dark grayish brown (10 YR 5/2), silty loam, weak subangular blocky, many fine distinct roots
Ahe	12 - 25	Light brownish gray (10 YR 6/2), silty loam, weak subangular blocky, many fine distinct roots
Bm	25 - 30	Dark yellowish brown (lo YR 4/4), silty loam, blocky, few fine distinct roots
BCgj	30 - 42	Light gray (10 YR 6/1), loam, structureless
Cgj	42+	Light gray (10 YR 6/1), loam, structureless

bluegrass	white clover
wheatgrass	dandelion
sedge	pasture sage
	cinquefoil

Table A-20

HV 11

Classification	Degraded Dystric Brunisol
Location	Sand cut on O.K. mine road
Elevation	1500 m
Slope and aspect	10 - 20% N
Parent material	Glacial fluvial outwash
Landform	Outwash Delta
Drainage class	Well drained

HORIZON	Cm	
LF	1 - 0	
Ae	0 - 3	Light brownish gray (10 YR 6/2), gravelly sandy loam, structureless, many fine distinct roots
Bm	3 - 32	Brown (7.5 YR 5/4), gravelly sandy loam, structureless many fine distinct roots
C	32+	Yellowish brown (10 YR 5/4), gravelly sandy loam, structureless

DOMINANT VEGETATION

Lodgepole Pine	Gooseberry	Arnica	Feather moss
Engelmann Spruce	Black twin berry	Twinflower	

WATER RETENTION DATA

BETHLEHEM AND LORNEX MINE DUMPS AND TAILINGS

(Fine Fraction)

Sample	-1/10 bar gm/gm	-1/3 bar gm/gm	-9/10 bar gm/gm	-3 bar gm/gm	-15 bar gm/gm	A.W.S.C. gm/gm
B-1A	.178	.167	.112	.084	.066	.112
B-2A	.170	.146	.103	.114	.061	.100
B-3A	.189	.163	.112	.082	.078	.111
B-4A	.171	.165	.139	.078	.063	.107
B-5A	.174	.158	.102	.072	.054	.120
L-1A	.167	.154	.108	.081	.059	.108
L-1C	.152	.144	.086	.064	.057	.095
L-2A	.188	.164	.115	.081	.064	.124
L-3A	.167	.159	.113	.078	.057	.110
Lornex Tailings 1	.223	.178	.159	.057	.052	.171
Lornex Tailings 2	.352	.326	.231	.134	.098	.218
Bethlehem Talings Sand	.074	.074	.027	.021	.019	.055

Table A-22

HIGHLAND VALLEY AREA SOILS

PARTICLE SIZE ANALYSIS

Sample #	Horizon	% 2 mm	% Sand	% Silt	% Clay	Textural Class
HV-1	Ae	68	73	22	5	Sandy loam
	Bm1	68	69	27	4	Sandy loam
	Bm2	34	73	15	12	Sandy loam
	C	53	72	15	13	Sandy loam
HV-2	Ah	95	78	19	3	Loamy sand
	Bm	90	..	..	..	....
	BC	90	..	..	..	....
	C	95	80	17	3	Loamy sand
HV-3	H	100	..	..	..	....
	C1	100	74	18	8	Sandy loam
HV-4	Ae	75	66	27	7	Sandy loam
	Bm	65	..	..	..	....
	BC	61	73	21	6	Sandy loam
	C	55	71	18	11	Sandy loam
HV-5	Ae	75	..	..	..	....
	Bt	77	57	35	8	Sandy loam
	Cgj	74	46	32	22	Loam
HV-10	Ah	100	..	..	..	....
	Ahe	100	46	43	11	Loam
	Bm	100	45	44	11	Loam
	BCgj	100	66	16	18	Sandy loam
	Cgj	100	45	37	18	Loam
HV-11	Ae	58	22	63	15	Silt loam
	Bm	30	71	15	15	Sandy loam
	C	32	75	10	15	Sandy loam

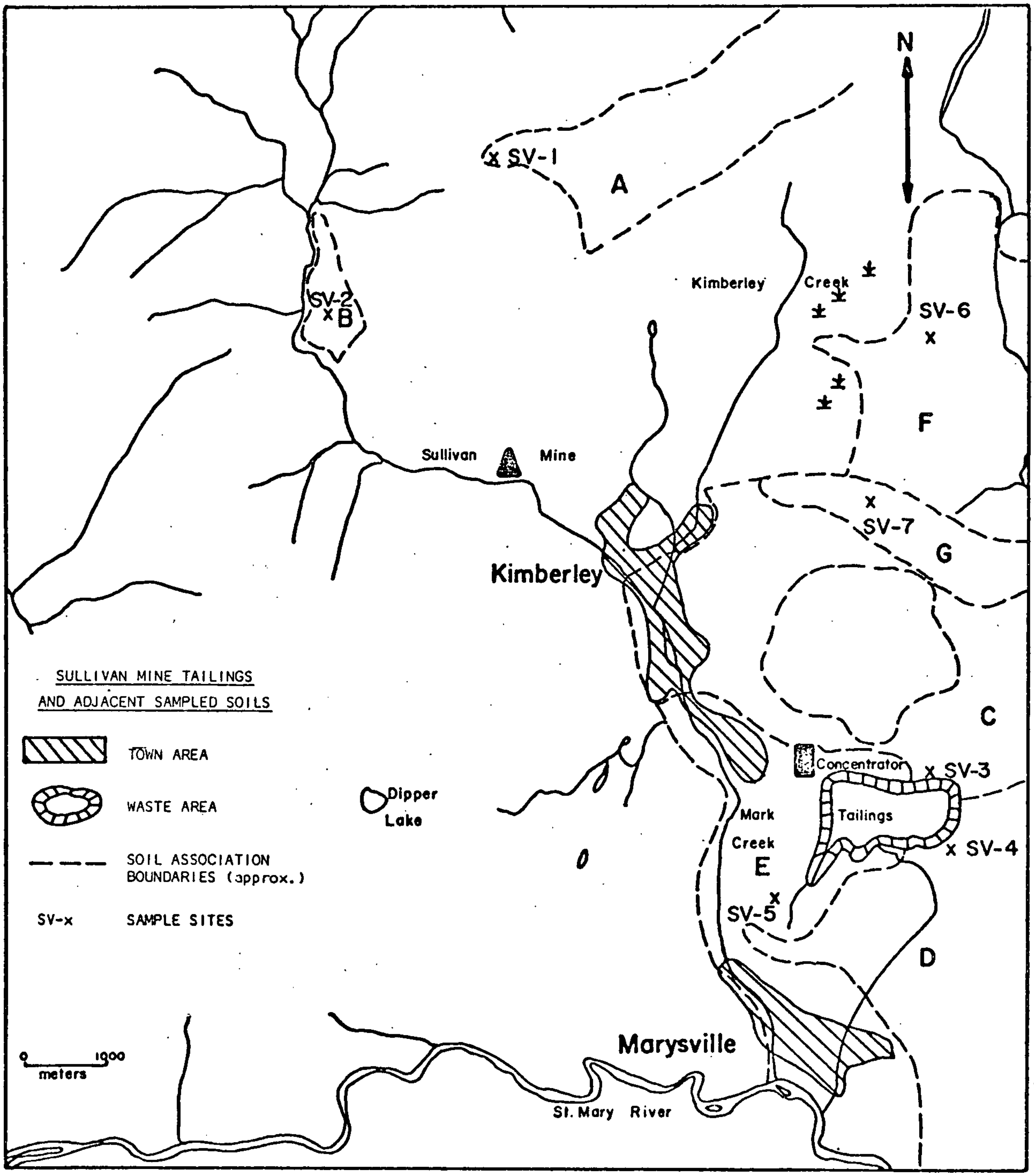
Table A-23

HIGHLAND VALLEY AREA SOIL SITES

WATER RETENTION DATA AND CATION EXCHANGE CAPACITIES

ample and orizon	-1/10 bar gm/gm	-1/3 bar gm/gm	-15 bar gm/gm	A.W.S.C. gm/gm	A.W.S.C. gm/gm corrected for fragments	A.W.S.C. cm/cm	C.E.C. 2mm fractic Meg/100 gm
IV-1: Ae	.234	.143	.072	.162	.110	.100	----
Bm	.215	.141	.067	.148	.101	.092	----
C	.111	.092	.039	.072	.038	.035	----
IV-2: Ah	.239	.148	.076	.163	.155	.237	15.8
C	.116	.062	.032	.084	.080	.122	5.5
V-3: H	----	1.018	.685	.333	.330	.310	114.5
C1	.154	.116	.060	.094	.094	.147	8.2
V-5: Bt	.267	.128	:098	.169	.130	.161	13.9
Cgj	.247	.183	.116	.131	.097	.120	32.8
V10: Ahe	----	.343	.210	.133	.133	.137	----
Bm	----	.386	.229	.157	.147	.162	27.2
Cgj	----	.123	.067	.056	.056	.058	9.2
V11: Bm	.156	.107	.066	.090	.027	.031	13.9
C	.115	.081	.055	.060	.019	.022	10.6

Figure A-24


N
x SV-1
A
SV-2
x B
Kimberley
Creek
SV-6
x
F
Sullivan
Mine
x
SV-7
G
Kimberley
C
SULLIVAN MINE TAILINGS
AND ADJACENT SAMPLED SOILS
TOWN AREA
WASTE AREA
SOIL ASSOCIATION
BOUNDARIES (approx.)
SV-x
SAMPLE SITES
Dipper
Lake
Concentrator
x SV-3
Mark
Creek
Tailings
x SV-4
E
x
SV-5
D
0
1000
meters
Marysville
St. Mary River

SV 1

Table A-25

Classification	Orthic Humo-Ferric Podzol
Location	N.E. Sullivan Hill
Elevation	1430 m
Slope and aspect	3 - 5% S
Parent material	Till and residual rock
Landform	Till slope
Drainage class	Moderately well

HORIZON	CM	
LFH	1 - 0	
Ae	0 - 8	Pale brown (10 YR 6/3), gravelly silt loam, platey structure, many fine distinct roots
Bf	8 - 25	Brownish yellow (10 YR 6/6), gravelly silt loam, weak subangular blocks, few fine distinct roots
BC	25 - 40	Light yellowish brown (10 YR 6/4), gravelly silt loam, very weak subangular blocks, few fine distinct roots
C	40+	Light brownish grey (10 YR 6/2), gravelly silt loam, structureless

DOMINANT VEGETATION

Lodgepole Pine	Sitka alder	Buffalo berry	Grouseberry	Pinegrass
		Juniper	Twinflower	

SV 2

Table A-26

Classification	Orthic Humo-ferric Podzol
Location	S,W. of Sullivan Hill
Elevation	1500 m
Slope and aspect	5 - 8% N.W.
Parent material	Glacio-fluvial outwash
Landform	Hummocky outwash
Drainage class	Well drained

HORIZON	CM	
LFH	2 - 0	
Ae	0 - 8	Light brownish (10 YR 6/2), sandy loam, structureless, many coarse distinct roots.
Bf	8 - 18	Yellowish brown (10 YR 5/6), very weak sub-angular blocks, few fine distinct roots
BC	18 - 30	Light brownish grey (10 YR 6/2), sandy loam, structureless, few fine roots
C	30+	Greyish brown (10 YR 5/2), loamy sand, structureless

DOMINANT VEGETATION

Lodgepole Pine	Sitka Alder	Red twinberry	Pinegrass
Western Larch		Grouseberry	

SV 3

Classification	Orthic Humo-ferric Podzol
Location	Adjacent to Siliceous tailings
Elevation	1130 m
Slope and aspect	0 - 2%
Parent material	Till
Landform	Till plain
Drainage class	Moderately well
Note	Affected by dust from silica tailings

HORIZON	Cm	
LFH	3 - 0	
Bf	0 - 20	Yellowish brown (10 YR 5/6), silt loam, very weak structural blocks, many fine distinct roots
BC	20 - 32	Yellowish brown (10 YR 5/4), silt loam, structureless
C	32+	Pale brown (10 YR 6/3), silt loam, structureless

DOMINANT VEGETATION

Ponderose Pine	Tall mahonia	Bearberry	Pinegrass
Douglas Fir			
Western Larch			

SV 4

Classification	Sombric Eutric Brunisol
Location	South of tailing area
Elevation	1100m
Slope and aspect	0
Parent material	Glacio-fluvial outwash
Landform	Outwash plain
Drainage class	Well drained

HORIZON	Cm	
Ah	0 - 20	Very dark grayish brown (10 YR 3/2), gravelly loam, weak crumbs, abundant fine distinct roots
Bm	20 - 40	Yellowish brown (10 YR 5/4), gravelly sandy loam, very fine medium subangular blocks, many fine distinct roots
C	40+	Light brownish gray (10 YR 6/2), gravelly loamy sand, structureless, few fine roots

<u>DOMINANT VEGETATION</u>

Ponderosa Pine	Fleabane	Idaho fescue
	Bearberry	Columbia needlegrass
	Penstemon	Annual bluegrass

SV 5

Classification	Orthic Humo-ferric Podzol
Location	South of iron tailings
Elevation	1130 M
Slope and aspect	0 - 2 S
Parent material	Glacial-fluvial outwash and aeolian
Landform	Outwash plain
Drainage class	Well drained

HORIZON	Cm	
LFH	2 - 0	
Bf1	0 - 10	Yellowish brown (10 YR 5/6), gravelly sandy loam, structureless, many fine distinct roots
Bf2	10 - 30	Brownish yellow (10 YR 6/6), gravelly sandy loam, structureless, few fine distinct roots
BC	30 - 50	Yellowish brown (10 YR 5/4), very gravelly sandy loam, structureless, few fine distinct roots
C	50+	Pale brown (10 YR 6/3), very gravelly sandy loam, structureless

<u>DOMINANT VEGETATION</u>

Western Larch	Buffalo berry	Bearberry	Pinegrass
Lodgepole Pine		Arnica	Idaho fescue
		Spirea	

Table A-30

SV 6

Classification	Orthic Humo-Ferric Podzol
Location	North of Kimberley off old Cherry Creek railway
Elevation	1270 m
Slope and aspect	5% S
Parent Material	Till
Landform	Till slope
Drainage class	Moderately well

HORIZON	Cm	
LFH	7 - 0	
Ae	0 - 1	Dark grayish brown (10 YR 4/2), gravelly silt loam, structureless, many distinct roots
Bf	1 - 20	Yellowish brown (10 YR 5/6), gravelly silt loam, weak subangular blocks, many distinct roots
BC	20 - 35	Yellowish brown (10 YR 5/4), gravelly sandy loam - loam, structureless, few roots
C	35+	Pale brown (10 YR 6/3), gravelly sandy loam - silt loam, structureless

DOMINANT VEGETATION

Lodgepole Pine	Saskatoon berry	Bearberry	Pinegrass
Engleman Spruce	Buffalo berry	Twinflower	Quack-grass
Western Larch	Rose	Heart-leaf arnica	

SV 7

Classification	Orthic Humo-Ferric Podzol
Location	South of Kimberley - Windermere Highway
Elevation	1230 m
Slope and aspect	3 - 5% S
Parent material	Glacial-fluvial outwash
Landform	Outwash plain (hummocky)
Drainage class	Well drained

HORIZON	Cm	
LFH	3 - 0	Abundant coarse roots
Ahe	0 - 1	Pale brown (10 YR 6/3), sandy loam, structureless, many coarse discontinuous roots
Bf	1 - 16	Brownish yellow (10 YR 6/6), sandy loam, very weak subangular blocks, many coarse discontinuous roots
C1	16 - 32	Light gray (10 YR 7/1), gravelly loamy sand - sandy loam, structureless
C2	32+	Very pale brown (10 YR 8/4), very gravelly loamy sand, structureless

DOMINANT VEGETATION

Lodgepole Pine	Willow	Spirea	Western wheatgrass
Western Larch	Buffalo berry	Vetch	Annual bluegrass
	Juniper	Bearberry	Pinegrass
	Rose		Columbia needle grass

Table A-32

WATER RETENTION DATA - SULLIVAN MINE TAILINGS

Sample	-1/10 bar gm/gm	-1/3 bar gm/gm	-9/10 bar gm/gm	- 3 bar gm/gm	- 15 bar gm/gm	A.W.S.C. gm/gm
SF-1A	--	.332	.218	.166	.189	.143
SF-1B	--	.397	.237	.212	.157	.240
SF-1C	--	.316	.235	.131	.128	.188
SF-1D	--	.321	.173	.158	.108	.213
SF-1E	--	.276	.251	.247	.123	.153
SF-3A	--	.291	.215	.208	.078	.212
SF-3B	--	.275	.148	.112	.051	.224
SF-3C	--	.347	.206	.143	.067	.280
SF-3D	--	.392	.321	.220	.133	.259
SF-4A	--	.383	.169	.202	.196	.187
SF-4B	--	.242	.206	.114	.129	.113
SF-4C	--	.371	.222	.172	.132	.239
SF-4D	--	.223	.162	.121	.105	.118
SF-4E	--	.292	.223	.147	.099	.193
SS-1A	.301	.152	.056	.042	.031	.121
SS-1B	.456	.293	.223	.143	.119	.174
SS-1C	.327	.197	.134	.109	.095	.102
SS-1D	.390	.243	.206	.102	.090	.153

Table A-33

KIMBERLEY AREA SOIL SITES

PARTICLE SIZE ANALYSIS

Sample #	Horizon	% 2 mm	% Sand	% Silt	% Clay	Textural Class
SV-1	Ae	90	24	67	9	Silt loam
	Bf	62	35	58	7	Silt loam
	BC	--	--	--	--	---------
	C	71	20	66	14	Silt loam
SV-2	Ae	62	62	36	2	Sandy loam
	Bf	39	72	22	7	Sandy loam
	BC	--	--	--	--	----------
	C	27	85	9	6	Loamy sand
SV-3	Bf	62	25	65	10	Silt loam
	BC	64	28	66	6	Silt loam
	C	49	35	54	11	Silt loam
SV-4	Ah	57	52	37	11	Loam
	Bm	36	66	27	7	Sandy loam
	C	41	77	20	3	Loamy sand
SV-5	Bf1	91	73	22	5	Sandy loam
	Bf2	75	69	25	6	Sandy loam
	BC	95	73	22	5	Sandy loam
	C	--	--	--	--	----------
SV-6	Ae	--	--	--	--	----------
	Bf	88	43	51	6	Loam
	BC	47	48	44	8	Loam
	C	49	43	48	9	Loam
SV-7	Ahe	--	--	--	--	----------
	Bf	69	66	32	2	Sandy loam
	C1	85	78	18	4	Loamy sand
	C2	37	84	11	5	Loamy sand

Table A-34

KIMBERLEY AREA SOIL SITES

WATER RETENTION DATA AND CATION EXCHANGE CAPACITIES

Sample and horixon	-1/10 bar gm/gm	-1/3 bar gm/gm	-15 bar gm/gm	A.W.S.C. gm/gm	A.W.S.C. gm/gm corrected for fragments	A.W.S.C. cm/cm	C.E.C. 2mm fraction Meg/100gm
SV-1: Ae	...	.311	.070	.241	.217	.297	13.0
Bf	...	.296	.063	.233	.144	.197	9.8
BC	...	.191	.043	.148	.096	.132	....
C	...	.124	.048	.076	.054	.074	3.2
SV-2: Bf	.115	.084	.080	.035	.014	.016	31.8
C	.065	.056	.023	.042	.015	.017	6.7
SV-3: Bf	...	.324	.079	.245	.152	.149	...
BC	...	.206	.064	.142	.091	.089	...
C	...	.078	.064	.014	.007	.007	...
SV-4: Ah	...	.314	.132	.182	.104	.140	26.1
Bm	.196	.130	.044	.152	.054	.073	4.9
C	.172	.107	.031	.141	.058	.078	2.8
SV-5: Bf1	.201	.127	.043	.158	.144	.181	...
BC	.231	.183	.063	.168	.126	.159	...
C	.135	.085	.038	.197	.092	.116	...
SV-6: Bf	...	.156	.110	.046	.041	.051	17.1
BC	.264	.185	.052	.212	.106	.133	...
C	.293	.136	.038	.255	.124	.155	2.0
SV-7: Bf	.216	.185	.069	.147	.101	.126	...
C1	.114	.185	.035	.079	.067	.084	...
C2	.150	.070	.027	.123	.046	.058	...