RECLAMATION IN THE HIGHLAND VALLEY : THE CLASSIFICATION OF DISTURBED AREAS FOR EVALUATION AND PLANNING

by

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ABSTRACT

The Highland Valley has the greatest concentration of open-pit hardrock mines in Western Canada. It is anticipated that the reclamation of 8,000ha of disturbed land will eventually be necessary. This study was undertaken to evaluate existing reclamation methods and objectives and to predict the effects of reclamation upon land-use in the area.

Physical characteristics of disturbed materials and the effect of aspect on moisture conditions in disturbed materials were investigated. Natural vegetation, natural revegetation and land-use were surveyed. Reclamation trials were assessed.

Disturbed materials differed significantly in texture. Aspect did not affect moisture conditions in disturbed materials but sites exposed to wind were significantly drier than sheltered sites.

The factors texture, exposure, topography and elevation were used to classify disturbed areas into 13 reclamation site-types. Each reclamation site-type had characteristic reclamation requirements. Existing and anticipated reclamation site-types were delineated on maps.

Information acquired from surveys and from assessment of reclamation trials and results of reclamation research in other regions were used to propose suitable reclamation techniques and land-use objectives for each reclamation site-type. A plan of the predicted land-use of the Highland Valley resulting from adoption of these techniques and objectives was compiled.

Methods of reclaiming two of the reclamation site-types have been developed in the Highland Valley but reclamation trials have not been located in the disturbed areas which present more difficult conditions for plant establishment and growth. Future research should be directed towards solving the problems caused by steep slopes, exposure and the peculiar characteristics of tailings.

The potential impact of reclamation on land-use is large. The amount of rangeland in the Highland Valley could be increased by 4400ha. An over-abundance of wildlife may result from temporary increases in the amount of habitat available.

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1.. Introduction

1.1. Background

The Highland Valley has the greatest concentration of open-pit hardrock mines in Western Canada. Three mines are currently operating in the area and a fourth is expected to come into production soon. Mining activity started in 1962 and is expected to continue until at least the end of this century. Mining and related activities occur within an area of approximately 25,000ha and it is anticipated that the total surface disturbance will cover almost one-third of this.

As required by law, each mining company has instituted and is carrying out "a program for the protection and reclamation of the surface of the land and watercourses affected by it ....." (Mining Regulation Act, 1979). Reclamation reports, describing the reclamation programme and land-use objectives, are submitted annually by each company to the Ministry of Energy, Mines and Petroleum Resources.

Because of the nature of open-pit mining operations, continual and progressive reclamation of <u>all</u> the land affected by mining is not always possible. Waste-rock is placed on top of previously dumped material throughout the life of each mine and dumps will not achieve final configuration until mining ceases. Operational reclamation is carried out only on small areas of disturbance and reclamation programmes have been largely concerned with research into reclamation techniques.

1.2. Aims and objectives

The aims of the study were to evaluate existing reclamation methods and objectives for the Highland Valley and to predict the effects of reclamation upon land-use in the area.

For the purposes of this study, reclamation is defined as "the return of disturbed land to a productive state or to a state in which its potential for productive use is maintained". The reclamation and conservation of water bodies, though important in the Highland Valley, is not considered in this study.

The first objective was to classify all disturbed areas into "reclamation site-types". Each reclamation site-type would identify and describe disturbed areas having similar conditions for plant establishment and growth and characteristic reclamation requirements.

The second objective was to use the classification scheme:-

1) to identify those reclamation site-types for which suitable land-use objectives and reclamation techniques had been developed by the mining companies in the Highland Valley;

2) to propose land-use objectives for each site-type. The distribution of natural vegetation and information on past and present land-uses in the Highland Valley would be used to develop these proposals;

3) to propose reclamation techniques to achieve the

land-use objectives for each site-type. Proposals would incorporate knowledge of natural vegetation in the area, as well as results of reclamation trials in the Highland Valley and of other relevant reclamation research;

4) to identify those site-types requiring more reclamation research;

5) to compile a "final land use plan" of the Highland Valley and use it to predict the effects of reclamation on land-use in the area.

2.. Description of Mining Operations

2.1. Bethlehem Copper Corporation

Bethlehem Copper Corporation ("Bethlehem") operated a copper-mining complex on the north side of the Highland Valley. Molybenum was produced as a by-product. Bethlehem is now owned by Cominco Ltd. and, as part of Cominco Copper Division, is mining the "Valley ore zone" at a rate of 20,000tonnes/day. (In this study the old names will be used to distinguish the old Bethlehem property from Cominco's property in the valley bottom (see section 2.4)). The Bethlehem pits and concentrator are located at an elevation of approximately 1470m to 1600m.[1] Tailings are deposited in a disposal area nearby. This disposal area is bounded by the main dam to the west and by the Bose Lake Saddle Dam to the northeast. The elevation of the tailings surface is at present 1440m and the dams have recently been raised to increase the storage capacity. Waste-rock dumps are located at an elevation of 1230m to 1560m on the Bethlehem property. There are 3 pits in the complex; the Iona pit, the Huestis pit and the Jersey and East Jersey expansion pit. Mining began in the East Jersey pit in 1962 and continued with

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[1]All heights are given in meters above sea level.

exploitation of the Jersey, Huestis and Iona pits. The Jersey pit was depleted in 1973 and the Huestis pit in 1976. The Iona pit was reactivated in 1975 and was mined-out in 1979. Development of a Jersey pit extension began in 1974, was curtailed in 1975 for economic reasons but resumed in 1977. Waste from the Jersey mine extension was placed in the mined-out Huestis pit. This practice has been discontinued and the mined-out volume of the Huestis pit is now being used for tailings storage. A second dam (the Trojan dam) is being constructed to provide an additional tailings disposal area (Bellamy, 1979; Bethlehem Copper Coroporation, 1979, 1981).

2.2. Lornex Mining Corporation

Lornex Mining Corporation, ("Lornex"), a member of the Rio Algom-Rio Tinto group of companies, operates a copper mine on the south side of the Highland Valley. The concentrator and plant areas are at an elevation of approximately 1350m; the perimeter of the pit is at about 1600m. Mining began in 1972; and current mill throughput is approximately 80,000tonnes/day. Copper and molybdenum are produced. Waste-rock dumps are found in the elevational range 1350-1600m. Glacial till and overburden have been stockpiled on the higher elevation waste dumps. Tailings are deposited in the valley bottom tailings area 3.6km from the plant site. This is a conventional tailings impoundment area bounded by an upstream and a downstream dam, 1203m and 1163m high respectively. An emergency tailings pond (the 7-day pond) is located below the concentrator. Water is pumped from the Thompson river, stored in the reservoir and used in the processing operation and in tailings disposal. Water is recycled through the system and only losses caused by evaporation need be replaced by water from the Thompson (Lornex Mining Corporation, 1981)

2.3. Highmont Operating Corporation

Highmont Operating Corporation, ("Highmont"), owned by Teck Corporation, began operating a copper mine on the south side of the Highland Valley in 1980. The property is located on the northwest slope of Gnawed Mountain; the mine and concentrator are at approximately 1620m elevation. Two pits are mined; copper and molybdenum are produced and the estimated mill throughput is 23,000tonnes/day. Waste-rock is currently used for construction purposes but eventually will be dumped at an elevation of approximately 1570m. Final elevation of the waste dumps is expected to be 1676m. Overburden has been stockpiled near the proposed waste dump. Tailings are deposited in a disposal area 7km from the concentrator. Temporary and starter dams have been built for water impoundment and tailings disposal respectively. Main dams and seepage recovery dams are being constructed (Highmont Operating Corporation, 1980, 1981).

2.4. Valley Copper Mines

Valley Copper Mines, ("Valley Copper"), owned by Cominco Ltd., (and now part of Cominco Copper Division) is considering the establishment of a copper mine in the bottom of the Highland Valley between Lornex's and Bethlehem's operations. The pit will be developed at approximately 1200m elevation. Waste-rock will be stored at 1200m (the original valley floor) to 1370m elevation. At present, however, ore from the Valley ore zone is milled in the Bethlehem concentrator.

A summary of the mining operations in the Highland valley is presented in Table 1. Figure 2 shows the location of the mining operations.

Table 1. Mining operations in the Highland Valley

NAME	OPERATING PERIOD beg.	end	VOLUME OF MILL THR'-PUT tonnes/day	AREA DISTURBED TO DATE (ha)	AREA RECLAIMED TO DATE (ha)	TOTAL ANTICIPATED DISTURBANCE (ha)	ELEVATION OF DISTURBED AREAS m.a.s.l.
Bethlehem	1962	198?	20,500	878.9	22	932	1200 - 1550
Highmont	1981	?	25,000	976	14	1160	1450 - 1700
Lornex	1972	1993?	85,000	1341	221	5100	1200 - 1550
Valley Copper	1983	2024?	100,000	384 (exploration)	-	750	1160 - 1370

SOURCES: Reclamation Reports (various dates)

3. Description of Study Area

3.1. Location

The Highland Valley is located in southcentral British Columbia, approximately 30km southeast of Cache Creek and 20km northwest of Merritt. The location of the study area is shown on the accompanying map (Figure 1).

3.2. Topography and Drainage

The Highland Valley is situated within the Thompson Plateau (Holland, 1964), which is part of the Interior Plateau landform. The Thompson Plateau is a gently rolling upland of low relief lying between 1300 and 1660m elevation with some peaks rising to over 3200m.

Four lakes are located in the valley bottom at an elevation of 1200m. Over most of the study area the valley sides rise to about 1870m in the north and 1700m in the south. South Forge Mountain, on the north side, and Gnawed Mountain, on the south side, are 1870m and 1890m high respectively.

The Highland Valley trends northwest-southeast. Prior to the construction of the valley bottom tailings area, Pukaist Creek drained the valley to the northwest. Witches Brook drains it to the southeast. The valley sides are drained by creeks

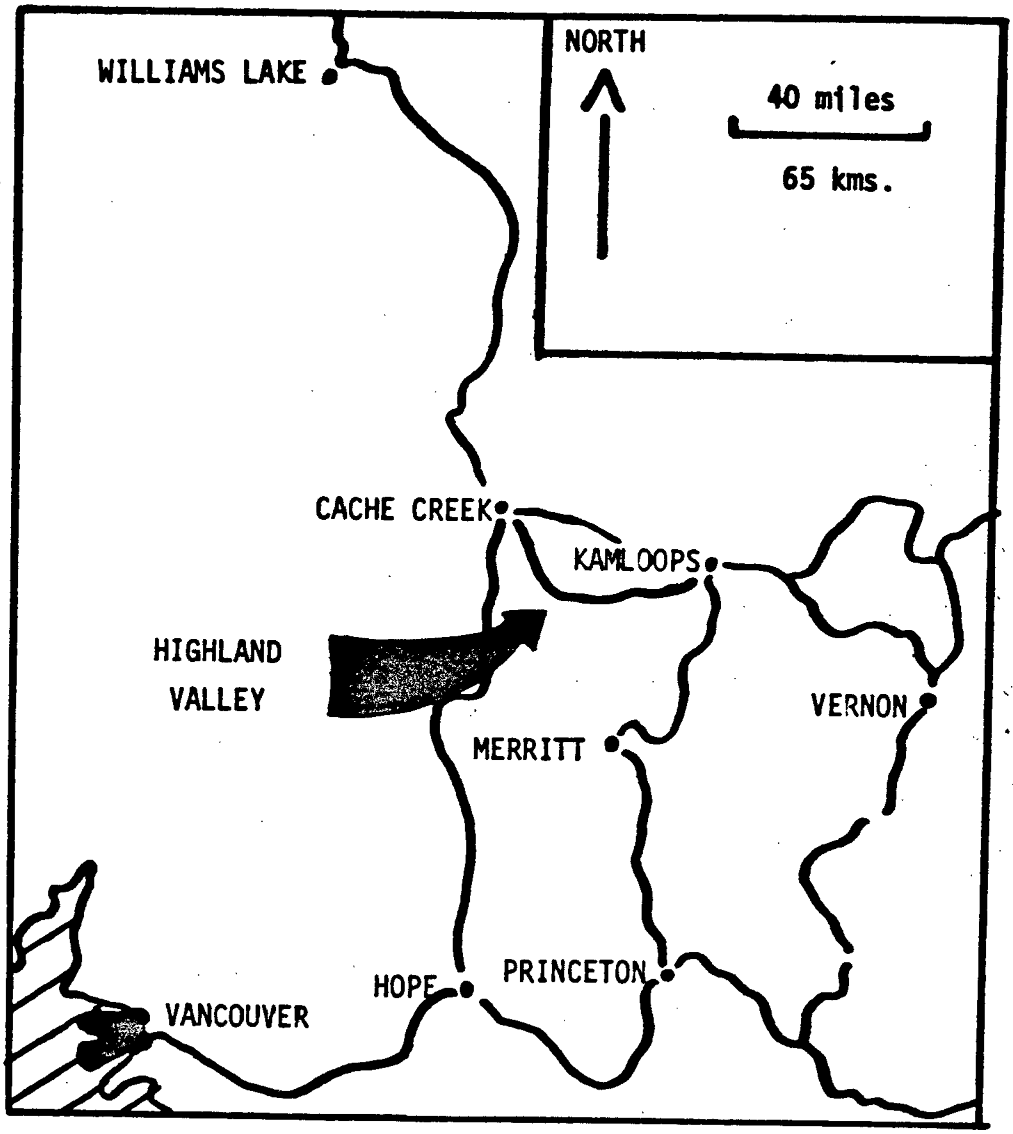

Fig. 1. The location of the Highland Valley, British Columbia

which flow into the lakes or into Witches Brook, or which have been intercepted and diverted by mining operations.

3.3. Geology

The geology of the Highland Valley has been documented by White *et al.* (1957) and Carr (1960), and mapped by Macmillan (1971).

The area is underlain by the Guichon Creek batholith which is composed of quartz diorite, granodiorite and local gabbroic phases. The batholith was successively intruded by granite, granodiorite, younger quartz diorite and porphyry. Porphyry intrusion was accompanied by explosive brecciation, faulting and rock alteration. This resulted in copper mineralization in localized zones of repeated fracturing and brecciation. (Quartz diorite grades to quartz monzonite and to granodiorite with varying quartz and potassium feldspar content).

On the north side of the valley, the prevailing rock types are Guichon quartz diorite, granite, Bethlehem quartz diorite/granodiorite, two varieties of porphyry, and breccia. The host rocks for the copper minerals are the Guichon quartz diorite, Bethlehem quartz diorite, dacite porphyry and breccia (Bellamy, 1979; Bethlehem Copper Corporation, 1981). On the south side, Guichon quartz diorite, Bethsaida quartz diorite/granodiorite and Skeena quartz diorite/granodiorite are present. (Skeena quartz diorite/ granodiorite is intermediate in texture and composition between the Bethlehem and Bethsaida phases). On the Lornex and Highmont property the ore zones are situated within the Skeena quartz diorite/granodiorite and are associated with quartz porphyry dykes. The Highmont dyke contains zones of brecciation (Highmont Operating Corporation, 1981). On the Lornex property, 20% of the Skeena quartz diorite is composed of a heterogeneous material known as fault gouge (Lornex Mining Corporation, 1981). The Valley Copper orebody occurs entirely within the Bethsaida quartz diorite/granodiorite (Valley Copper Mines, 1980).

All mined deposits in the Highland Valley are the copper porphyry type. Bornite and chalcopyrite are the dominant copper-bearing minerals; other minerals, including pyrite, are found in minor amounts especially on the peripheries of the deposits. Molybdenite is also found, commonly as a coating on fault planes.

3.4. Surficial Geology and Soils

The Highland Valley has been subjected to repeated glaciation. The direction of ice-movement during the last period of glaciation was southwest (B.C. Natural Resources Conference, 1956). Ninety percent of the upland surface exhibits drumlin and swell-and-swale topography and bedrock is covered by up to 16m of ground moraine (White *et al.* , 1957).

Soils of the area have been surveyed and mapped by the Dept. of Soil Science (1975) and the Resource Analysis Branch (1978). Soils have developed in colluvium and in morainal, fluvioglacial and fluvial material. Dominant and significant soils are :-

orthic humo-ferric podzols
orthic dystric brunisols
degraded dystric brunisols
degraded eutric brunisols
orthic gray luvisols
podzolic gray luvisols
orthic dark gray chernozems
gleyed cumulic regosols
regosols (Dept. of Soil Science, 1975)

3.5. Climate

The Highland Valley is located within the Interior Dry Belt in British Columbia's Southwest Interior Climatic Region (B.C. Natural Resources Conference, 1956). Typically, in the Interior Dry Belt, the "rain shadow effect" of the coast mountains, combined with the relatively high elevation, creates a climate of fairly extreme temperature ranges and precipitation between 30 and 63mm annually, most of which is in the form of snow. In addition, early and late frosts are probable (Pinkerton, 1972). The estimated range of the length of the freeze-free period is 20 - 100 days (Agriculture Canada, 1976).

Weather recording stations are located at the Bethlehem and Lornex mine sites. Data from these stations for the period 1977-80 are given in Appendix 1. Summarized values are given in Tables 2a and 2b. Temperatures are slightly lower at the Lornex station but there is little difference in precipitation.

No records of wind speed or direction are kept. At high elevations, winds follow the prevailing wind pattern which is westerly; in the valley winds are directed by the topography

Table 2.a) Mean monthly temperatures and mean monthly total precipitation, 1977-79, at Bethlehem.

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	UNITS	YEARS MEASD.	TOTAL
MEAN T.	- 7.0	2.0	2.0	3.0	5.0	11.6	14.6	14.0*	8.5*	4.5*	4.6	- 9.0	^{0}C	77-79	
RANGE	-13/-4	-5/0	-3/2	0/5	4/6	10/13	13/16	13/15	7/10	4/5	-5/-4	-11/-7	^{0}C	77-79	
PRECIP.	30.6	14.0	19.7	21.1	18.9	18.3	18.0+	20.7*+	36.8	12.5	43.1'	19.0	mm	77-79	m
RANGE	18/48	9/20	5/39	6/42	5/32	14/24	10/27	-	15/59	4/17	2/83	14/24	mm	77-79	

mean longest period with minimum above $0^{0}C$: 64* days
" " " " " " $-2^{0}C$: 76* "
" " " " " " $-4^{0}C$: 98* "

Table 2.b) Mean monthly temperatures and mean monthly total precipitation, 1977-79, at Lornex.

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	UNITS	YEARS MEASD.	TOTAL
MEAN T.	- 9.6	- 3.6	1.0	4.0	5.0	12.0	11.6	14.3	8.6	4.6	- 4.0	-12.0	^{0}C	77-79	
RANGE	-13/4	-6/-1	-2/1	3/6	5/8	11/13	12/16	13/15	7/11	3/6	-5/-3	-14/-9	^{0}C	77-79	
PRECIP.	12.4	58.6	9.5	19.0	8.0	11.0	5.3	11.7	35.2	54.0	7.3	129.8	mm	79	361.8

mean longest period with minimum above $0^{0}C$: 74 days
" " " " " " $-2^{0}C$: 124 "
" " " " " " $-4^{0}C$: 145 "

* '77 data missing + '78 data missing ' '79 data missing m data missing

from either the northwest or southeast (Pinkerton, 1972). Walmsley (1977) reports that strong southwesterly winds are prevalent in April and June.

3.6. Vegetation

The Highland Valley is within the Montane forest region (Rowe, 1972). According to Krajina (1976) it is within the Interior Douglas-fir and the Engelmann Spruce - Subalpine Fir Biogeoclimatic Zones.

The vegetation was surveyed in 1970 by B.C.Research (B.C.Research, 1971a). Six major plant communities were identified:-

1) burned areas carrying various ages of lodgepole pine,
2) burned areas carrying various ages of lodgepole pine with an overstorey of Douglas-fir,
3) grassland or open forest and grassland,
4) valley bottom meadows,
5) valley bottom grassland and willow communities,
6) valley side creek communities.

3.7. Pre-mining Land-use

Ranching was the major land-use in the Highland Valley before mining began. The ranches were purchased by Lornex, Bethlehem and Cominco. Indian reservations in the valley had been used primarily for grazing and very limited ranching (Lornex Mining Corporation, 1981).

The area has been logged commercially at intervals since the end of the last century. More widespread clearing of forest cover has since occurred as a result of mining activity (B.C. Forest Service, Ashcroft Field Office, personal communication).

Fish and wildlife in the area were surveyed and described by B.C.Research in 1970 (B.C. Research, 1971b). (At this time the Bethlehem mine had been in operation for 8 years) The maximum wintering population of deer and moose was 10 and 12 per square mile respectively (4 and 4.5 per square kilometre). Competition with cattle for forage may have limited big game use. According to B.C.Fish and Wildlife (personal communication) deer and elk used the area for spring and fall range before mining began but wintered further west in the lower Pukaist Creek area.

Limited populations of ruffed and blue grouse existed in the area. A single common loon was the only waterfowl observed on Quiltanton Lake in 1970. Rainbow trout were found in Pukaist Creek, Witches Brook, Guichon Creek and Quiltanton Lake. The productivity of the lake was described as low (B.C.Research, 1971b).

Other animals observed in the area were rabbits, yellow-bellied marmots, skunks and porcupine. Beaver, mink, squirrel, muskrat and coyote were trapped in the area until 1968. Trapping probably ceased due to poor economic returns (B.C.Research, 1971b)

Little recreational hunting or fishing took place prior to mining and access to the Highland Valley was restricted (B.C.C., 1979, 1981).

3.8. Land Tenure

Most of the Highland Valley is Crown Land. In addition to the deposits held under lease by the mining companies described in section 2, various mineral claims are held by them and by other companies.

4.. Study Procedures

4.1. Selection of possible classification factors

Numerous methods of classifying land are described in the literature (e.g. Hills, 1961; Krajina,1965; Environment Canada, 1970a). To meet the objectives of this study the classification scheme had to fulfill three requirements:-

1) it had to be at a scale suitable for management purposes;

2) it had to be based on information that could be acquired from the available maps and air photographs of the area;

3) it could not incorporate natural vegetation as a factor (since it was to be applied to areas denuded of natural vegetation).

Review of Hills' classification method and of reclamation research done previously in the Highland Valley (Walmsley, 1977) and elsewhere, indicated that the following factors might be used to classify disturbed areas:-

-elevation

-topography

-aspect

-exposure

-depth of disturbed materials,

-physical characteristics (bulk density and texture) of disturbed materials.

These factors were selected on the assumption that the local climate and the retention of moisture and nutrients in the soil would be the most important factors affecting reclamation because of their effect on plant establishment and growth. Topography and physical characteristics also affect the stability of disturbed areas; reclamation techniques may therefore be modified by the need to control erosion and by constraints on the operation of machinery.

The effects of aspect and exposure on reclamation in the Highland Valley were investigated in the course of this study. Aspect is commonly assumed to affect soil temperature and soil moisture content. However, in semi-arid areas, differences due to aspect may not be significant. Aspect had no apparent effect on germination or survival of conifer seedlings planted in mineral soil where long periods of drought were common in July and August, but topography, exposure, vegetation and shade were important (Clark, 1969). At Bethlehem, exposure to prevailing winds affects the success of reclamation (Walmsley, 1977). Harrison (1977) found that southwest exposures of coal wastes supported fewer trees than southeast exposures although both attained approximately the same temperature. He suggested that the cause was wind. Nicholson and Bell (1981) found that on a tailings pond with ridge-and-furrow microtopography, average total grass and herb cover in hollows was significantly greater than that on ridges and west exposures. North, south and east exposures were intermediate although highest temperatures were recorded on south exposures. They suggested that wind and warmer afternoon air temperatures caused the decreased vegetation cover on west exposures and that south exposures had relatively high cover because the hottest summer days did not occur until after the vegetation was developed.

Information on all factors except physical characteristics and depth of material could be acquired directly from existing maps and air photographs of the area. Although physical characteristics could not be determined from air photographs, distinct kinds of disturbed materials were visible. Once the physical characteristics of these were known, it would be possible to infer physical characteristics from air photographs.

Chemical characteristics of materials (pH, available nutrients etc.) were not included because:-

1) research by Lornex (Lornex Mining Corporation, 1973 & undated), Dept. of Soil Science (1975;1976-77) and Valley Copper (Valley Copper Mines, 1980) on disturbed materials in the Highland Valley has shown that levels of available nutrients are generally limiting to plant growth. Fertilization has therfore been required wherever seeding has taken place. Topography and physical characteristics affect the retention of fertilizer in disturbed materials and therefore their artificially-created chemical characteristics;

2) chemical characteristics are not readily identified or inferred from maps or air photographs.

4.2. Collection of information in the field

The objectives of the field work and associated laboratory work were:-

1) to survey the natural vegetation of the study area. The information collected would be used to propose land-use objectives and reclamation techniques for disturbed areas and to compile a final land-use plan for the Highland Valley.

2) to investigate the physical characteristics of the disturbed materials (and also of a few natural soils for comparative purposes). This information would be used in classifying disturbed areas;

3) to investigate the effect of aspect on moisture and temperature conditions in disturbed areas in order to select the appropriate factor(s) for the classification scheme;

4) to assess the reclamation trials carried out by the mining companies in the Highland Valley in order to identify the factors which have affected their success and to evaluate the techniques and species used.

5) to survey the extent and nature of natural revegetation of disturbed areas in the Highland Valley;

6) to acquire information on current land-uses in the Highland Valley that would be used to propose land-use objectives for the reclaimed areas.

All field work was carried out in the period June 1st - September 1st 1980. The methods used to acheive these objectives are described below.

4.2.1 Natural vegetation survey

Many methods of vegetation survey are described in the literature (Daubenmire, 1968). For this study a method was devised which would:-

a) produce an easy-to-visualize description of the vegetation and land-uses;

b) describe the distribution of plant species in different topographic and soil conditions and

c) be simple and quick to apply over a large area.

PREFIELD: Air photographs of the study area were examined stereoscopically. Thirteen vegetation "types" (visually similar areas of vegetation) were distinguished and their boundaries were marked on overlays. Preliminary identification of the plant communities represented by some of these types was possible using the results of a vegetation survey of the Highland Valley done previously (B.C.Research, 1971).

FIELD: Following procedures described by the Resource Analysis Branch (1980), a $20m^2$ plot was positioned in selected areas of each vegetation type (Figure 2). Location, macro-position, slope and aspect of each plot were recorded.

To describe the plant community, the vegetation in each plot was stratified as follows:-

-upper tree layer; containing tall trees, usually mature or over-mature,

-lower tree layer; containing young, often second-growth trees,

-upper shrub layer; containing tall shrubs and some young tree seedlings,

-lower shrub layer; containing small shrubs and tree seedlings,

-herb layer; containing young shrubs, herbs, grasses, mosses, and also rocks, stumps and bareground.

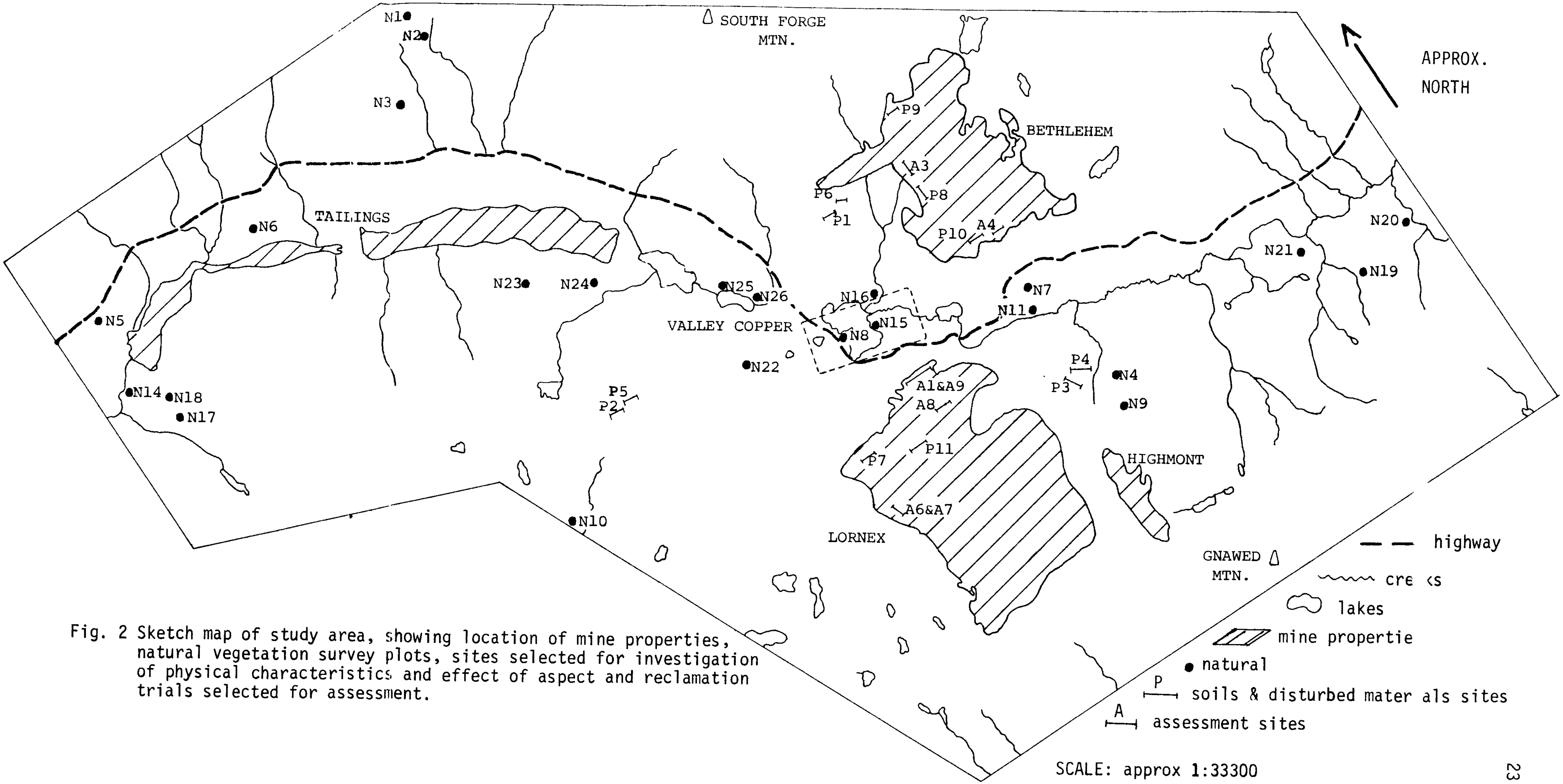

Fig. 2 Sketch map of study area, showing location of mine properties, natural vegetation survey plots, sites selected for investigation of physical characteristics and effect of aspect and reclamation trials selected for assessment.

Many methods of describing plant communities entail the stratification of the vegetation (Richards, 1952; Christian and Perry, 1953; Poulton and Tisdale, 1961; Resource Analysis Branch, 1980). For this study, layers which would be identifiable in a variety of vegetation types under different topographic conditions were defined. No absolute height limits were set for each layer since communities in different localities may be quite similar in structure though of differing heights (Christian and Perry, 1953).

Within each layer, percent cover (the percent of the plot area covered by a vertical projection of the foliage) of each species was estimated visually and recorded. Visual estimation of plant cover is a quick method of vegetation description but it is subject to bias (Kershaw, 1964). Observer bias was minimized by recording the mean of two independent estimates made by the author and assistant. Visual estimates can be influenced by the size, branching habit and degree of clumping of different species. By estimating the percent cover within each layer, bias due to, for example, over-estimation of tree cover and underestimation of herb cover was reduced.

A soil pit was dug in each plot to 100cm depth or to bedrock. The following features were recorded, using the methods described by Resource Analysis Branch (1980) :-

-position and depth of major soil horizons

-soil texture

-soil structure

-sol structure grade

-soil moisture and drainage

-soil colour

-depth of root penetration.

Soil descriptions were based on those characteristics which could be used to compare natural soils with disturbed materials when proposing reclamation techniques and land-use objectives for disturbed materials.

Descriptions of the plant communities in each plot were compared. The 13 vegetation types were regrouped and 10 characteristic "vegetation community-types" that comprised the natural vegetation of the area were defined. Previously delineated boundaries of the vegetation types were adjusted to become boundaries of vegetation communities. The positions of these boundaries were ground-truthed in all accessible areas, using field glasses where necessary.

4.2.2 Investigation of physical characteristics of disturbed materials

PREFIELD: Disturbed materials were initially grouped according to differences in appearance on air photographs. Eight kinds of disturbed material could be distinguished-

1) glacial till lacking a natural soil covering,
2) free-dumped waste-rock piles,
3) compacted waste-rock dumps,
4) areas of end-dumped waste-rock,
5) tailings disposal areas,
6) access roads,
7) plant sites and machinery dumps,
8) stock-piled overburden.

End-dumped waste-rock will probably not remain after mining operations end (Munroe, personal communication). Access roads will not be reclaimed (Highmont Operating Corporation, 1980) or will be ripped (Valley Copper Mines, 1980). They and the plant sites, once cleared, will probably revert to a condition similar to the compacted waste-rock dumps or to the glacial till. Free dumped waste-rock piles may be covered with a thin layer of overburden as part of the reclamation operation.

Therefore, four kinds of disturbed materials were selected for field investigation:-

1) glacial till (referred to hereafter as "raw till"),

2) waste-rock piles covered with overburden ("overburden/rock"),

3) compacted waste-rock ("compacted rock"),

4) tailings.

FIELD: Sites sampled for this investigation are shown in Figure 2. Sites are listed in Table 3. The sampling procedure is described in section 4.2.3.

LABORATORY: The textures of the materials (disturbed materials and natural soils) sampled were analysed using the hydrometer method of particle size analysis (Day, 1950; Dept. of Soil Science, 1978). Particle densities were determined by the pycnometer method (Blake, 1965). Percent composition of particles and bulk density were calculated and mean values for each site and each type derived.

Percent composition data were transformed to create a normal distribution of values with standardized sample variances. Nested analyses-of-variance (sites being nested within types) were carried out on transformed percent composition and bulk density data. Analysis-of-variance using the statistical package ANOVAR (Analysis of Variance and Covariance) showed that for some variables differences between sites-nested-within-types were significant. A second analysis using GENLIN (General Least Squares Analysis of Variance Program), which allows selection of the correct divisor used to calculate the F-ratios when the nested term is significant, was therefore carried out. The significance of differences between mean values of each variable was tested using the New Duncan's Multiple Range Test. The package GENLIN carries out the multiple range test when the numbers of samples in each treatment are unequal.

4.2.3 Investigation of the effect of aspect on moisture conditions in disturbed materials

PREFIELD: One hundred psychrometers were tested in distilled water. Only those recording a water potential of 0.5bars or less were used in this study. The remainder were discarded.

FIELD: The sites selected for the investigation of the effect of aspect are described in Table 3. Comparable sites (indicated by brackets) are those where psychrometers were installed. Comparable sites had to have different aspects but had to be at similar elevations and apparently unaffected by anomalies in local drainage patterns, shade by trees or nearby slopes, or the presence of unusually high or "perched" water tables. Since daily precipitation records were to be used in

Table 3. Sites selected for investigation of physical characteristics and effect of aspect

SITE NO.	MATERIAL	LOCAL ASPECT	ELEVATION m a.s.l	VALLEY SIDE	EXPOSURE
P1	natural soil	190	1320	north	sheltered
P2	natural soil	020	1320	south	sheltered
P3	natural soil	010	1320	south	sheltered
P4	raw till	000	1320	south	sheltered
P5	raw till	022	1230	south	sheltered
P6	raw till	180	1320	north	sheltered
P7	compacted rock	flat	1570	south	exposed*
P8	overburden/rock	200	1440	north	sheltered
P9	overburden/rock	044	1440	north	sheltered
P10	overburden/rock	180	1570	north	exposed
P11	overburden/rock	000	1570	south	sheltered
P12	tailings	flat	1140	-	exposed
P13	tailings	flat	1500	north	exposed+

* comparable site was too compacted to be sampled
\+ no psychrometers installed

interpretation of the results obtained from the psychrometers, the proximity of sites to rain gauges was also considered.

On most sites, a 20m transect was positioned randomly. On the overburden/rock slopes, a 20 m transect was placed parallel to and 2m below the top of the slope. This minimized the risk of psychrometers being damaged by movement of material downslope. Installation of psychrometers to take account of variation due to slope position was not possible. Eight soil pits were dug to 20cm depth at randomly selected positions along each transect. Bulk density was measured using a modification of the field method described by the Dept. of Soil Science, replacing water with sand. One gravimetric sample was taken per transect. (More intensive gravimetric sampling was limited by lack of oven-drying facilities in the field and of watertight containers). Material from each pit was weighed and passed through a 25mm sieve. Weight of the greater-than-25mm fraction was recorded. A representative sample of the less-than-25mm fraction was taken for textural analysis. Sampling of specific horizons and/or at greater depths was impossible because of the poorly-consolidated nature of the materials.

One psychrometer was installed in each of four of the soil pits. (Greater sampling intensity was limited by availability of usable psychrometers). Installation followed procedures outlined by Nmyamah and Black (1977) with the following modifications:-

1) Each psychrometer was installed 15cm below the surface to reduce the effect of air temperature fluctuations on soil temperature measurements and hence on calculated soil water potential. At 15cm depth, diurnal soil temperature fluctuations are minimized (Brady, 1974).

2) Particular care was taken during installation to avoid the creation of a channel in which moisture would collect and surround the thermocouple.

3) Each psychrometer was inserted 15cm into the wall of the pit.

Psychrometer readings were taken from comparable sites on the same day to minimize variation caused by day-to-day fluctuations in moisture content. Variation caused by diurnal fluctuations was minimized by taking readings in random order between comparable sites during the period 1200-1500 hours.

The timing and frequency of readings was severely limited by lack of transport to sites, blocked access and thunderstorms. Climatic data for the Highland Valley indicated that drought conditions would be expected to develop in mid-late summer. Therefore, during June and July readings were taken at 10-14 day intervals but the frequency was reduced after August 1st when other field work had been completed.

LABORATORY: Psychrometers were retested first in distilled water and then in a salt solution of known osmotic potential. Field measurements made with psychrometers that subsequently measured the osmotic potential of the test solutions with an error of 0.5bars or more were not included in the results.

Differences in soil water potential between comparable sites were tested for significance using the t-statistic at a probability level of 0.1. Composition of particles and bulk density of materials at each site were analysed using ANOVAR. Differences between comparable sites were tested for significance using the New Duncan's Multiple Range Test.

4.2.4 Assessment of reclamation trials

PREFIELD: Numerous reclamation trials have been started in the Highland Valley. There are approximately 200 test plots on the Lornex property alone. Trials were selected for assessment using the following criteria:-

1) age: newly reclaimed sites give little evidence of the long-term suitability of the techniques employed.

2) nature of material: sites were selected on as many

of the kinds of disturbed material as possible.

3) size: where possible, large areas were assessed to eliminate errors due to edge effects.

4) topography: sites were selected on slopes and on flat ground.

5) accessibility.

The 11 sites selected are shown in Figure 2. All sites were within the elevation range 1300-1400m.

At each site, the assessment was carried out in plots positioned along a transect. The length of transect and size of plot chosen depended on the size of the site. On sloping sites, the transect was positioned diagonally across the slope to take account of variation due to position on the slope.

At site A3, permanent plots set up in 1977 by the Ministry were assessed. Assessment at all sites followed the procedure developed by the Ministry (Ministry of Energy, Mines and Petroleum Resources, 1980) but only the following features were recorded:

plot size (m)	soil value
slope (°)	soil chroma
aspect (°)	humus cover (%)
elevation (m)	total cover (%)
texture	moss cover (%)
pH	individual species cover (%)
pellets (no.)	individual species seed heads (%)
calcareousness	individual species height (cm)
soil hue	individual species vigour

The prescence of other important features on the site but not within the plots was also noted. Such features were shrub invasion, soil erosion and mass-movement.

One tree planting trial was assessed at approximatley 1500m on the Lornex property. Species age, height and vigour were recorded.

Treatment records for each trial were obtained where possible from the mining companies.

4.2.5 Natural revegetation survey

PREFIELD: A number of cleared areas (i.e. still covered by soil but lacking normal vegetative cover) where natural revegetation was occurring were identified on the air photographs. A cleared area of 384ha and ranging from 1380m to 1530m in elevation was selected for detailed survey. (Figure 2).

FIELD: The cleared area was surveyed along a 2000m transect positioned so as to include as much of the variation in altitude and topography as possible. The transect was followed using a compass and $16m^2$ plots were centred on it at 100m intervals. At each plot each species present was identified and its percentage cover estimated.

Other disturbed areas were surveyed and assessed visually.

4.2.6 Additional land-use information

Records of wildlife observed and reported were kept. Observations on other land-uses in the study area were made.

4.3 Compilation of topographic base map

A topographic base map was compiled specifically for this study to render a more accurate classification of the reclamation site-types than would have been achieved by using existing, but out-of-date, N.T.S. maps which could not be aligned with air photographs.

The topographic base map was constructed at a scale of 1:15000 from the following maps and plans:-

1) Highland Valley Project topographic maps (National Topographic System (N.T.S.) sheet 92/I, numbers 6h, 7f, 10d, 11a and 11b) compiled at 1" to 1320ft. by the Topographic Division, Surveys and Mapping Branch, Dept. of Lands, Forests and Water Resources from 1965 air photographs and updated in 1969.

2) Highland Valley topographic map published in revised form by Bethlehem in 1980 at a scale of 1" to 400ft.

3) Topographic map compiled by Pacific Survey Corporation for Bethlehem in 1979 at a scale of 1" to 200ft.

4) Dumps and pit composite topographic map (with spot heights) prepared by the Survey Dept. at Lornex in 1981 at a scale of 1" to 400ft.. (Contours were drawn on this map using spot height measurements and information from 1980 B.C. government air photographs at 1:10000).

5) Outline plan of tailings lake drawn from 1980 B.C. government air photographs at 1:10000.

6) N.T.S. map sheet 92/I, numbers 7,6,10 and 11, produced at 1:50000 in 1975 by Surveys and Mapping Branch, Dept. of Mines and Technical Surveys, from air photographs taken in 1971.

The Highland Valley Project map was used as a reference base map. Other maps and plans were aligned on this using features such as lakes and streams as reference points. Some adjustments were necessary to account for the distortion inherent in air photographs.

5. Results

5.1. Natural Vegetation

The natural vegetation of the Highland Valley is composed of many vegetation communities which have been grouped into 10 community-types:-

1: Lodgepole pine/spruce

2: Douglas-fir

3: Lodgepole pine

4: Spruce/alder

5: Aspen meadow

6: Open forest/grassland

7: Valley bottom meadow

8: Willow/birch

9: Willow

10: Sedge marsh

Communities of the same community-type are defined as those which have similar vegetation structure, similar species composition and which are located in sites of similar topography. The distribution of vegetation communities in the Highland Valley is shown in Plan 1. Details of the species found in the plots located in examples of each community are given in Appendix 111. The vegetation structure, species composition and location of each community-type are summarized in the following descriptions. Species described as "common and typical" occupied 5% or more of the cover (in the layer in which they were found) in all the plots in that community-type. "Typical" species were present in all plots. Species described as "abundant" occupied 40% or more of the cover in any one layer. All taxonomy follows Hitchcock and Cronquist (1973).

1: Lodgepole pine/spruce communities are found at high elevations. Below 1500m the abundance of spruce decreases and there is a gradual transition to Douglas-fir and lodgepole pine communities. (Because of this transition, no boundary between lodgepole pine/spruce and Douglas-fir communities is shown on Plan 1). Tree layers typically contain spruce (*Picea* spp. A. Dietr.), (white spruce (*P. glauca* (Moench.) Voss), Engelmann spruce (*P. engelmannii* Parry and their hybrids), lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) and minor amounts of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) are also present. A variety of shrubs is found in these communities but cover is generally low. Much of the herb layer is typically bare or moss- and lichen-covered. Grasses and herbs are scarce.

Soils are coarse- or moderately coarse-textured, dry to moist and contain many coarse fragments. Depths of mineral soil and of fine root penetration are shallow but organic matter, much of it partly decomposed, has accumulated on the surface. In some communities (plots 9 and 10) finely comminuted charcoal is visible both as a distinct layer and intermingled with the A horizon which is consequently lighter in colour.

2: Douglas-fir communities are located on the middle slopes of the valley. Their distribution has been affected by fire, logging and mining activity but they are found in the elevational range 1300-1500m. Douglas-fir is common and typical in the upper tree layers; lower tree layers contain Douglas-fir and lodgepole pine. Young Douglas-fir growth is evident in the shrub layers; a variety of shrub species is found but soapberry (Shepherdia canadensis L. Nutt.), rose (Rosa spp. L.) and bearberry (Arctostaphylos uva-ursi (L.) Spreng.) are typical. Pinegrass (Calamagrostis rubescens Buckl.) is abundant, many herbs are present and heartleaf arnica (Arnica cordifolia Hook.) is typical.

Soil textures vary from coarse to fine (apparently causing variation in structure also) but all contain very many coarse fragments. Organic horizons, when undisturbed, are thick while A horizons are 8cm deep or less. However, the brown to very dark grayish brown A horizons and gray to grayish brown B horizons indicate that organic matter is accumulating in the mineral soil. Fine roots have penetrated to a maximum depth of 24cm. Soils in these communities are well-drained.

3: Lodgepole pine communities are found within the same elevational range as Douglas-fir communities. They have developed as a result of fire. Lodgepole pine is typical and common in the tree layers. Common juniper (Juniperus communis L.), soapberry and grouseberry (Vaccinium scoparium Leiberg) are typical in the shrub layers. Herbs are less widespread than in the Douglas-fir communities; pinegrass is abundant. Mosses, lichens and bare-ground are typical and common.

Soils supporting these communities are variable. They have granular structure with many coarse fragments but range in texture from coarse to moderately fine. There is wide variation in thickness of soil horizons and depth of fine root penetration. This variation is probably due to differences in stand history (date and frequency of fires, previous vegetation cover etc.) as well as differences in texture and drainage. Organic horizons are less thick than those in the Douglas-fir/lodgepole pine communities while the colours of the A and B horizons suggest that little organic matter has accumulated in the mineral horizons. Fire may be the reason for this.

4: Spruce/alder communities are located on the edges of creeks draining the valley sides. Spruce is typical and common in the shrub layers and mountain alder (*Alnus incana* (L.) Moench) is typical and common in the tree or shrub layers. Many herbs are found in these communities. Pinegrass is typical.

They are associated with poorly-drained, medium-textured soils. A horizons are black and can be very deep, indicating much organic matter accumulation.

5: Aspen meadow communities are found in small, flat areas that have apparently originated from natural infilling of bogs and/or small ponds that developed in depressions on the valley sides. These communities are characterized by their location and topography. Trembling aspen (*Populus tremuloides* Michx.) is typical of the tree and shrub layers; the herb cover is diverse and fowl bluegrass (*Poa palustris* L.) is abundant.

Soils are deep and medium-textured but contain no coarse fragments. A horizons are thick and fine roots have penetrated to at least 28cm depth. The colour of the A horizons (very dark gray or very dark brown) indicates much organic matter accumulation. Soils are moist, have granular structure and may be compact.

6: _Open forest/grassland communities_ are found on the lower slopes of the valley in the approximate elevation range 1200-1300m. Some of these communities are old logging areas where only sparse regeneration of forest cover has occurred. Douglas-fir and trembling aspen are typical and common in the tree layers which also contain some lodgepole pine. Many shrubs are present; bearberry is typical and common. The herb layers contain abundant pinegrass and a wide variety of herbs. Wild strawberry (_Fragaria virginia_ Duchesne), heart-leaf arnica and dandelion (_Taraxacum officinale_ Weber) are typical.

Soils supporting these communities show considerable variation in depth and texture. They contain some coarse fragments and are well-drained. Fine roots have not penetrated deeper than 20cm. Boundaries between A and B horizons are indistinct but the former are shallow and dark grayish brown or dark brown while B horizons are slightly lighter in colour. A horizons are thicker and darker but organic horizons are shallower than those of Douglas-fir/lodgepole communities. Before logging, some of these communities were probably the more productive Douglas-fir/lodgepole pine communities.

7: _Valley bottom meadows_ are located on the level areas in the valley bottom. They have been (or still are) used for grazing cattle. Kentucky bluegrass (_Poa pratensis_ L.) is abundant and some herbs are also found .

Soils are coarse-textured (sandy loams) but contain few coarse fragments. They contain little undecomposed or partly decomposed organic matter but both A and B horizons are enriched with organic matter. Mineral horizons can be thick with deep fine root penetration but these communities are also found on shallow, compacted soils with impeded drainage.

The willow/birch, willow, and sedge marsh communities represent stages in the hygric succession of the valley bottom.

8: Willow/birch comunities have developed furthest from water bodies in the hummock-and-hollow topography formed by the infilling and raising of peat bogs. Soils are moderately fine and have deep, black A horizons. Organic horizons , especially H horizons, are narrow. Willow (Salix sp. L.) is common and typical; swamp birch (Betula glandulosa Michx.) is abundant in the shrub layers. Kentucky bluegrass is the typical grass found in the herb layer which typically contains sedges (Carex sp. L.) and a wide variety of herbs.

9: Willow communities border the lakes and marshes. The water-table is within 18-20cm of the ground surface and undecomposed plant remains can be seen scattered throughout the upper 20cm of the profile. Willow is abundant and swamp gooseberry (Ribes lacustre (Pers.) Poir) is typical in the shrub layer. The herb layer typically contains a wide variety of herbs; bluejoint reedgrass (Calamagrostis canadensis (Michx.) Beauv.) is abundant and sedges are typical.

10: Sedge marshes are found where changes in the drainage pattern have partially emptied lakes or on the edges of existing lakes and ponds. Sedges grow in 10-30 cm of water.

5.2. Investigation of physical characteristics of disturbed materials and natural soils

The variation in physical characteristics within all types of disturbed material was high (Table 4) and significant differences between sites-within-types were shown by 8 of the 11 variables measured (Table 5). When within-type differences were taken into account in the analysis, significant differences between types were shown by 10 of the 11 variables measured. (Analysis of variance tables are shown in Appendix IV).

The significant variables were used to identify differences between each type of material (Table 6). Compacted rock and overburden/rock did not differ significantly in any characteristic. Tailings contained no particles greater than 2mm diameter and contained significantly more fine sand and less coarse sand than any other material. There were no significant differences in percent composition of particles greater than 25mm, 4.76-10mm or 2-4.76mm diameter between natural soil, compacted rock and overburden/rock but natural soil contained significantly less particles 10-25mm diameter. Handling of compacted rock and overburden/rock materials may be the cause of the more uniform distribution of particles in size classes greater than 2mm diameter. Raw till and natural soil did not differ significantly in percent composition of particles greater than 25mm or 2-4.76mm diameter, nor in percent composition of fine sand, silt or clay while amounts of all other particle sizes except 4.76-10mm diameter did not differ widely.

Natural soil, compacted rock and tailings were sandy loams, raw till a loamy sand and overburden/rock a loam (marginally). The U.S. Department of Agriculture Classification System considers only particles of 2mm diameter or less. The distribution of all particle sizes is shown in Figure 3.

Bulk density did not differ significantly between types of material. The bulk density measurements do not reflect the differences in penetrability observed in the field between types of materials. The measurement technique used in this study gives values that are affected by the prescence of coarse fragments. Use of a technique that determines only the bulk density of the soil-sized fraction might have given a better indication of differences in the porosity of the soil volume occupied by roots.

5.3. Effect of aspect on moisture conditions

This investigation did not provide as much information as anticipated because 15 psychrometers malfunctioned or were accidentally buried under tailings and because readings could not be taken on each occasion as planned. At each of the sites P5, P6 and P7, only 1 psychrometer functioned correctly so these sites could not be compared with any others.

Mean soil water potentials (SWPs) in the south-facing natural area (P1) were not consistently higher or lower than those recorded in sites P2 or P3, which were north-facing

Table 4. Physical characteristics of materials

MATERIAL	% COMPOSITION OF PARTICLES										BULK DENSITY g/m^3	
	25mm diam.		10-25mm diam.		4.7-10mm diam		2-4.7mm diam.		Organic matter			
	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.
Natural soil	29.6	24.07	6.4	5.54	7.7	4.32	15.0	7.30	2.2	0.82	1.9	0.81
Raw Till	26.1	18.34	14.2	6.93	13.1	4.62	14.4	4.79	1.5	2.21	2.4	0.81
Compacted Rock	22.2	16.93	25.4	8.00	10.2	8.02	10.8	7.69	1.2	0.18	2.2	0.26
Overburden/rock	25.0	14.13	20.3	8.73	10.0	3.70	10.0	3.00	2.4	1.26	2.4	1.45
Tailings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.09

MATERIAL	% COMPOSITION OF PARTICLES (soil-sized)										TEXTURAL CLASS*
	coarse sand*		fine sand*		total sand*		silt*		clay*		
	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	
Natural soil	47.5	8.26	14.6	3.24	62.2	-	26.9	13.56	4.8	5.31	sandy loam
Raw Till	67.8	12.94	16.0	10.72	83.7	-	11.5	5.47	4.8	1.84	loamy sand
Compacted Rock	40.9	3.48	20.0	1.18	60.9	-	28.5	2.41	10.6	1.7	sandy loam
Overburden/rock	32.0	8.49	20.5	4.83	52.5	-	34.1	6.48	13.4	4.73	loam
Tailings	15.6	9.22	49.1	16.70	64.8	-	31.3	19.64	3.9	4.29	sandy loam

* according to the U.S. Department of Agriculture Classification System

Table 5. Results of F-tests on variables for physical characteristics

PHYSICAL CHARACTERISTIC	DIFFERENCES BETWEEN SITES-WITHIN-TYPES	PROBABILITY	DIFFERENCES BETWEEN TYPES	PROBABILITY
Percent composition of particles greater than 25mm diam.	N.S.	0.31098	SIG.	0.00000
Percent composition of particles 10-25mm diameter	SIG.	0.00152	SIG.	0.00101
Percent composition of particles 4.74-10mm diameter	SIG.	0.00263	SIG.	0.00113
Percent composition of particles 2-4.76mm diameter	SIG.	0.00396	SIG.	0.00090
Percent composition of soil-sized particles	SIG.	0.00018	SIG.	0.00000
Percent composition of coarse sand	SIG.	0.00289	SIG.	0.00019
Percent composition of fine sand	N.S.	0.18406	SIG.	0.00000
Percent composition of silt	SIG.	0.00587	SIG.	0.01747
Percent composition of clay	SIG.	0.00002	SIG.	0.02858
Percent composition of organic matter	SIG.	0.00000	SIG.	0.04706
Bulk density	N.S.	0.34041	N.S.	0.19521

N.S.=not significant at 95% probability level
SIG.=significant at 95% probability level

Table 6. Results of Duncan's New Multiple Range Tests on materials

(Each line indicates a homogeneous subset, no pair of which differs by more than the shortest significant range (a=0.05) for a subset of that size).
Mean values (percent) are given for each material.

Composition of particles greater than 25mm diameter:

tailings	compacted rock	overburden/rock	raw till	natural soil
0.0	22.200	24.961	26.138	29.617

Composition of particles 10-25mm diameter:

tailings	natural soil	raw till	overburden/rock	compacted rock
0.0	6.431	14.204	20.305	25.440

Composition of particles 4.76-10mm diameter:

tailings	natural soil	compacted rock	overburden/rock	raw till
0.0	7.734	9.984	10.155	13.085

Composition of particles 2-4.76mm diameter:

tailings	compacted rock	overburden/rock	natural soil	raw till
0.0	9.969	10.753	14.377	14.592

Composition of soil-sized particles:

compacted rock	raw till	overburden/rock	natural soil	tailings
31.452	32.029	35.182	41.958	100.00

Composition of coarse sand:

tailings	overburden/rock	compacted rock	natural soil	raw till
15.640	32.037	40.862	47.536	67.755

Composition of fine sand:

natural soil	raw till	compacted rock	overburden/rock	tailings
14.635	15.963	20.023	20.462	49.144

Composition of silt:

raw till	natural soil	compacted rock	tailings	overburden/rock
11.477	26.898	28.544	31.288	34.087

Composition of clay:

tailings	natural soil	raw till	compacted rock	overburden/rock
3.928	4.746	4.805	10.570	13.414

Composition of organic matter:

tailings	compacted rock	raw till	natural soil	overburden/rock
0.0	1.196	1.468	2.152	2.431

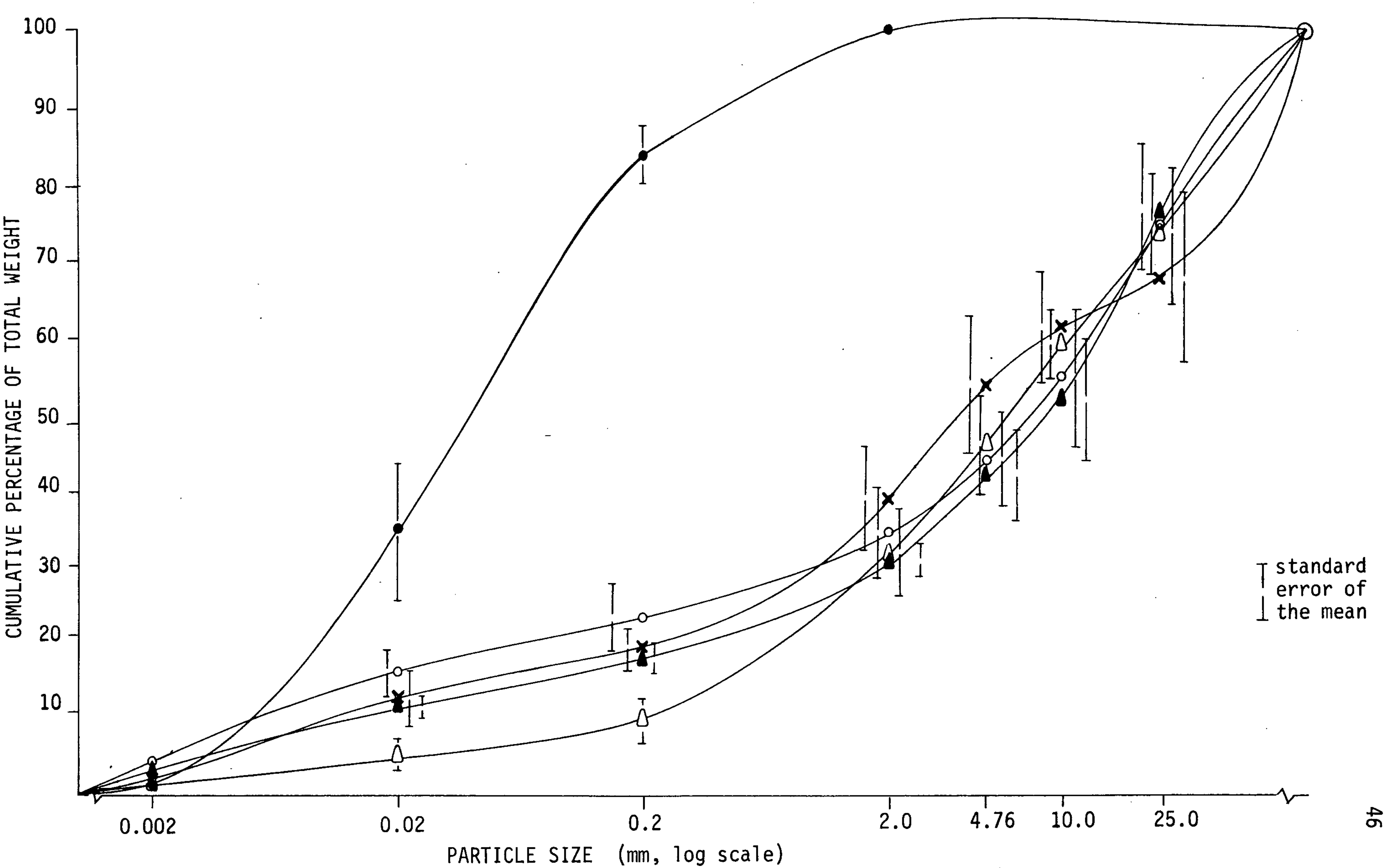

Fig. 3. Distribution of particle sizes in natural soils and disturbed materials. (✖ natural soil, n=24; △ raw till, n=24; ▲ compacted rock, n=8; ○ overburden/rock, n=32; ● tailings, n=8).

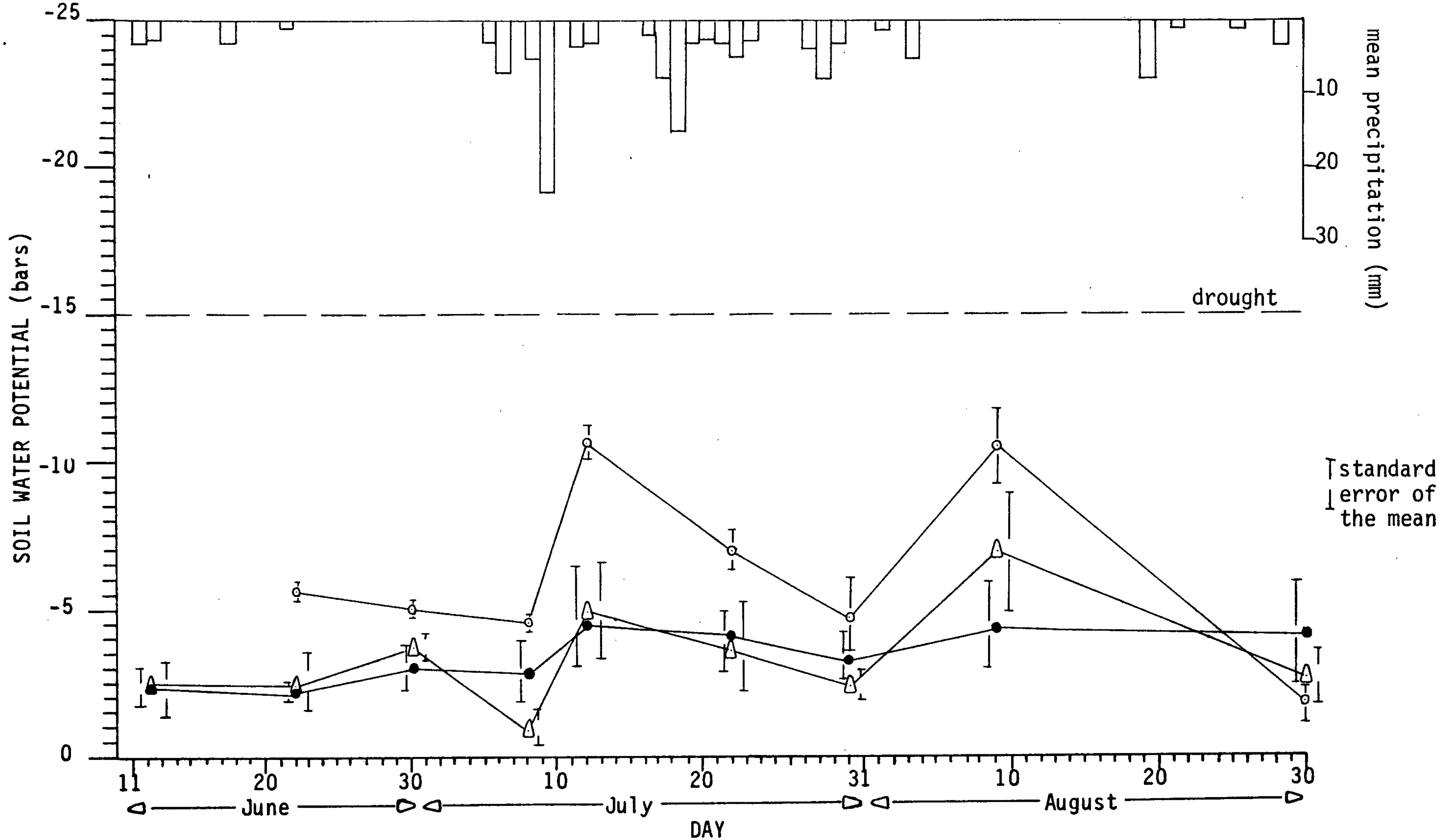

Fig. 4. Mean soil water potentials at site P1 (natural area, south-facing) (●,n=4), site P2 (natural area, north-facing) (o,n=4) and site P3 (natural area, north-facing) (Δ,n=3).

(Figure 4). Mean SWPs at site P2 were lower than those at sites P1 and P3 in 7 out of 8 comparisons.

The northeast-facing and southwest-facing sheltered overburden/rock slopes (P9 and P8) showed no consistent difference in mean SWPs and no differences were significant (Figure 5).

The south-facing exposed overburden/rock slope (P10) showed consistently lower mean SWPs than the sheltered, north-facing overburden/rock slope (P11) (Figure 6).

When the SWPs of overburden/rock sites P8, P9 and P11 were compared with the SWPs of raw till sites P5 and P6 the mean SWP of the raw till sites was lower in each of the 9 comparisons but the difference was significant in only 4 of the 7 comparisons (Figure 7). (These comparisons were made using means of measurements all taken within any 3-day rainless period. SWPs of raw till sites could not be compared with those of site P10, the south-facing exposed overburden/rock slope, because measurements were not made at comparable times).

Water held at tensions of -15bars or less is said to unavailable to plants (Brady, 1974). Drought conditions developed during the study period in all disturbed materials but not in natural soil. Drought conditions developed earliest and were most prevalent on the south-facing exposed overburden/rock site (P10) (Table 7).

Differences in soil moisture content at comparable sites could have been caused by differences in local precipitation, texture, aspect or exposure. Local drainage, though very uniform in disturbed materials at 15cm depth, could have affected sites

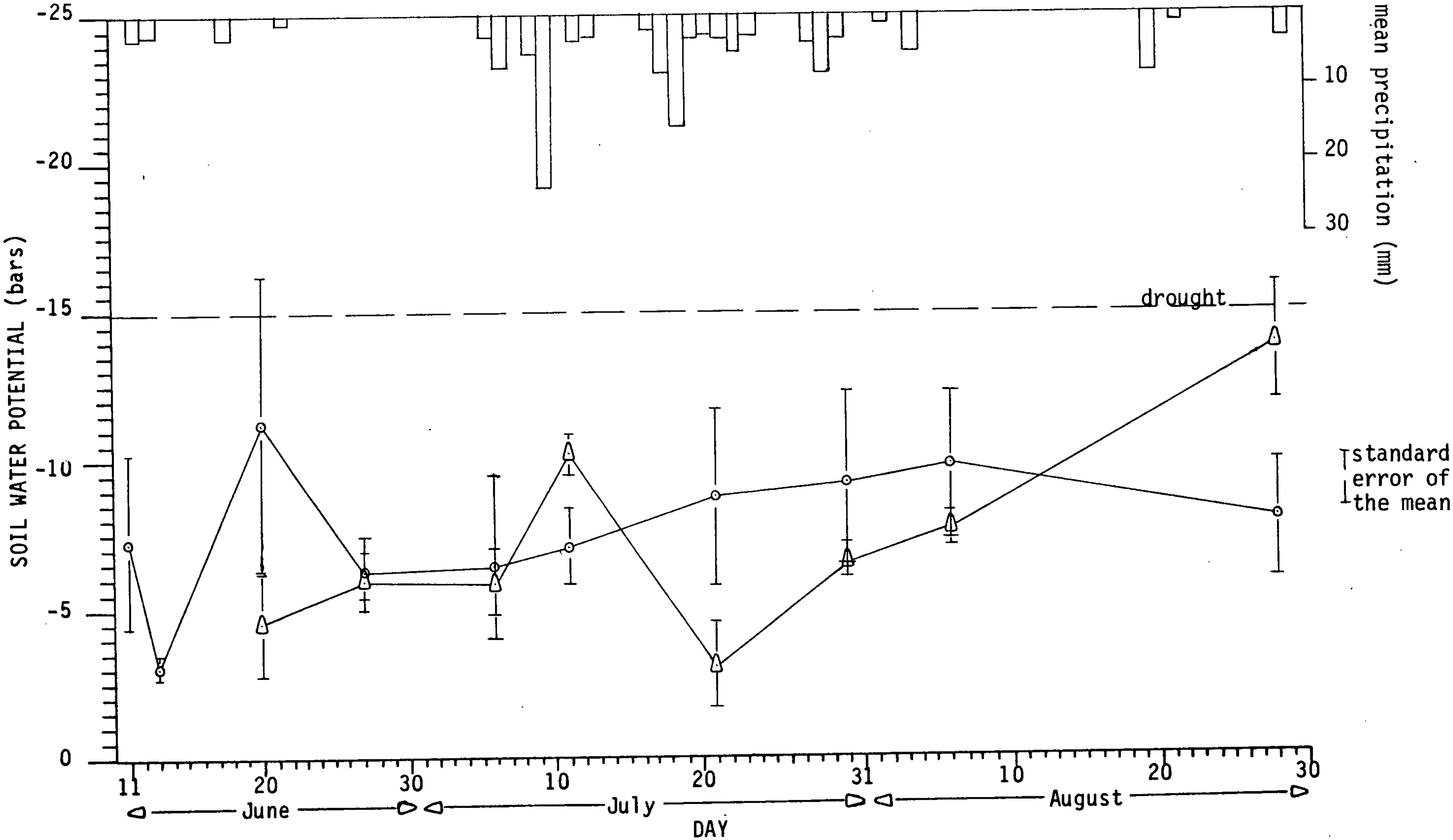

Fig. 5. Mean soil water potentials at site P9 (northeast-facing, sheltered, overburden/rock) (o, n=3) and site P8 (southwest-facing, sheltered, overburden/rock) (Δ, n=4).

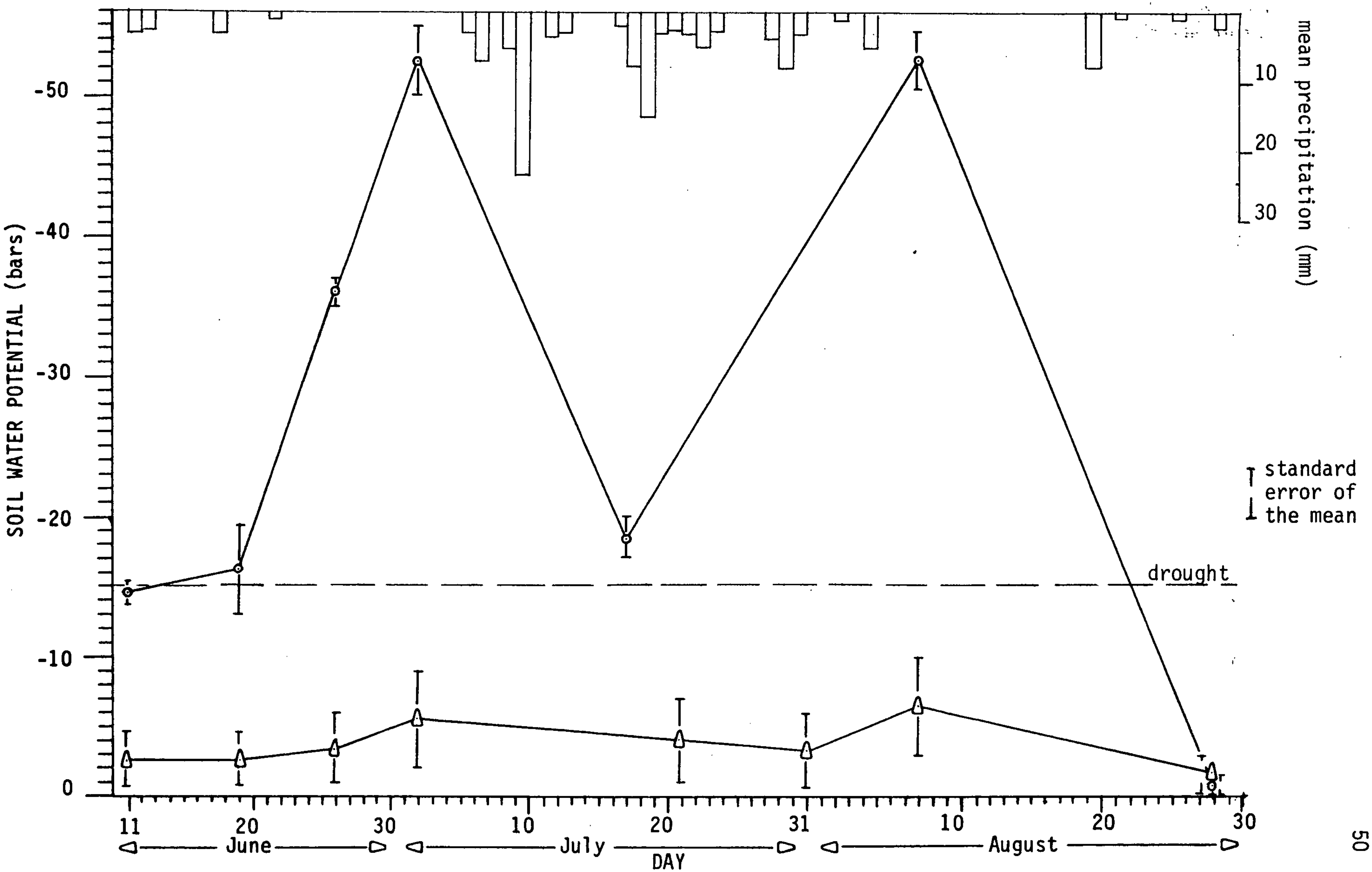

Fig. 6. Mean soil water potentials at site P11(north-facing,sheltered, overburden/rock) (Δ, n=3) and site P10(south-facing, exposed, overburden/rock) (○, n=3).

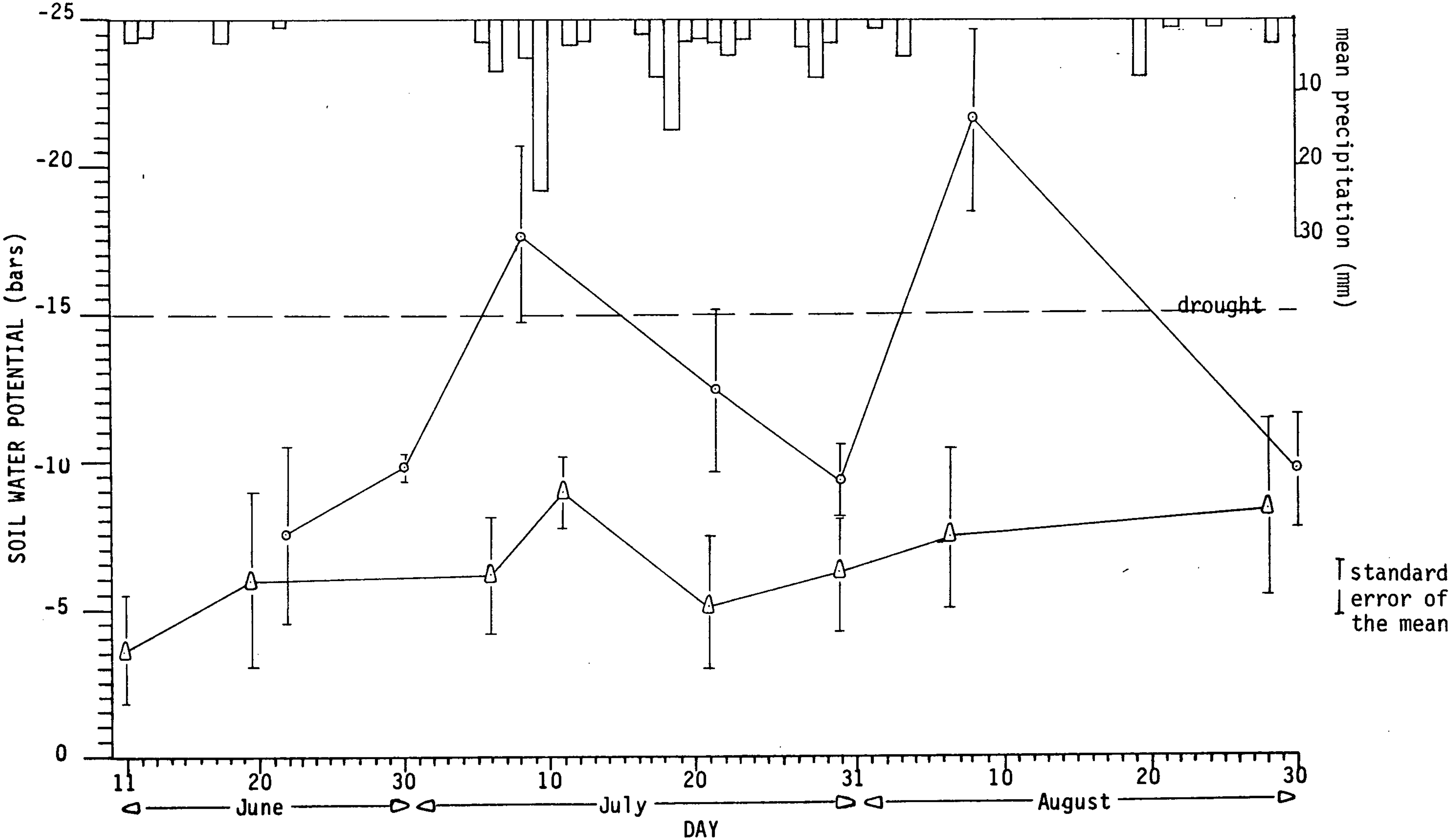

Fig. 7. Mean soil water potentials at raw till sites P5 and P6 (o, n=3) and at overburden/rock sites P8, P9 and P11 (Δ, n=10).

Table 7. Moisture and temperature conditions in materials

NO.	MATERIAL	ASPECT	EXPOSURE	NO. OF OCCASIONS MEAN TEMPS. 15°C OR GREATER (TOTAL NO.)	NO. OF OCCASIONS MIN. SWP OF -15bars OR LESS RECORDED	DATE SWP OF -15bars. OR LESS RECORDED DAY/MONTH
P1	natural soil	south	sheltered	0 (9)	0 (9)	-
P2	natural soil	north	sheltered	0 (8)	0 (8)	-
P3	natural soil	north	sheltered	0 (9)	0 (9)	-
P4	raw till	north	sheltered	1 (9)	4 (9)	8/7
P8	overburden/rock	s-west	sheltered	3 (8)	1 (8)	28/8
P9	overburden/rock	n-east	sheltered	1 (10)	3 (10)	30/7
P10	overburden/rock	south	exposed	2 (7)	6 (7)	19/6
P11	overburden/rock	north	sheltered	1 (8)	2 (8)	2/7
P12	tailings	flat	exposed	0 (5)*		

* during the period June 11th - July 30th; psychrometers not tested after use

located in natural soils.

Daily precipitation falling at the Bethlehem and Lornex stations during the period June 11th - September 1st is shown in Figures 8a and 8b. Differences in the time of occurrence and quantity of rain were very small and do not account for differences in soil moisture content at comparable sites located on opposite sides on the valley. Daily precipitation averaged between the two stations is shown in Figures 4,5,6 and 7. Materials at site P3 contained significantly less clay and less particles 4.76-10mm diameter than those at sites P2 and P1. Less stoniness could be a reason for the difference in soil moisture content between sites P2 and P3 but since P2 was drier than sites P3 and P1, the difference is more likely due to the location of P2 on a small ridge.

Differences in texture between materials at sites P8 and P9 were not significant. A difference in aspect did not cause differences in soil moisture content between these two sheltered sites although soil temperatures were higher at site P8. A possible explanation for this is that air temperatures at both sites were similar throughout much of the day and so higher soil temperatures at 1200-1500 hours did not cause significantly greater drying of the site exposed to the southwest. Also, if high soil temperatures were attained for short periods, soil moisture loss may have been limited by some other factor such as the rate of water movement to the surface.

Materials at site P10 contained significantly more silt and clay and less coarse sand and gravel than site P11. Despite this, site P10 was drier than site P11. It appears that exposure

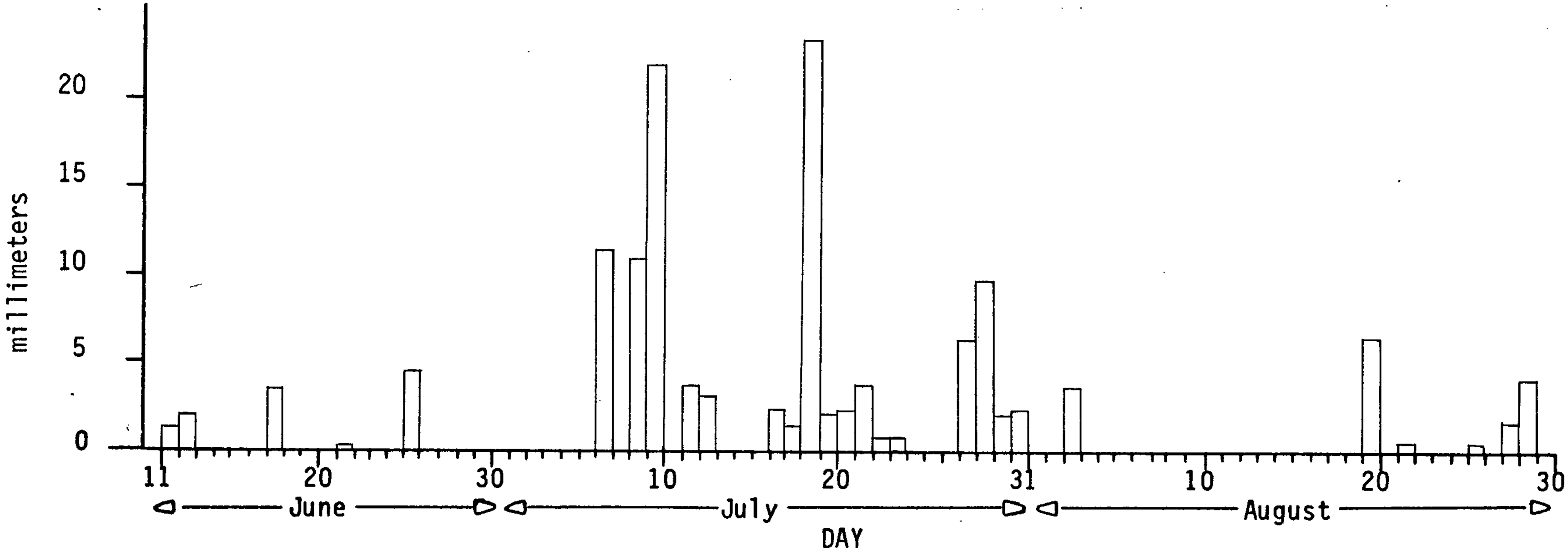

Fig. 8a). Daily precipitation at Bethlehem, June 11th - August 30th, 1981

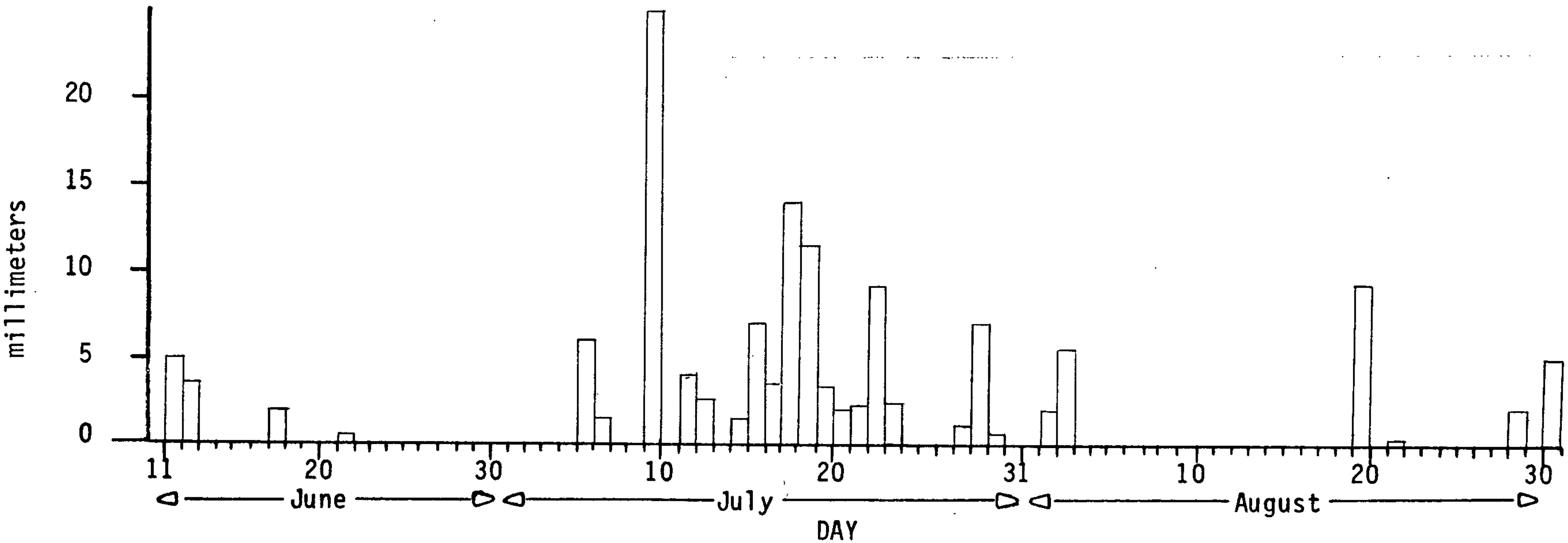

Fig. 8b). Daily precipitation at Lornex, June 11th - August 30th, 1981.

to wind (possibly combined with southwest aspect) was the cause of greater loss of moisture from site P10.

Although differences in physical characteristics of disturbed materials do not account for differences in soil moisture content at comparable sites, they do account for the differences in SWPs between raw till and overburden rock sites. Physical characteristics of sites are described in Appendix V.

Interpretation of the results is complicated by the unusually wet and cold weather experienced in the Highland Valley during the study period. Monthly precipitation totals in June,July and August were 20, 109 and 24mm respectively at the Lornex climatological station. Mean totals for the same months in the period 1977-79 were 11,15 and 11mm. At Bethlehem, mean precipitation totals for June, July and August during the period 1977-79 were 18, 18 and 20mm respectively. In 1981, 23mm of rain fell in June and 110mm in July although only 4mm of rain were received in August.

In June, July and August at the Bethlehem station and in June at the Lornex station, mean monthly temperatures in 1981 were lower than previously recorded mean monthly minimum temperatures. In July and August 1981 mean monthly temperatures at the Lornex station were greater than the mean of those previously recorded but mean monthly minima for these months were lower in 1981 than in previous years.

When longer periods of hot, dry weather are experienced differences in soil moisture content caused by aspect alone may become evident although they were not observed in this study.

Soil temperature measurements were made at 15cm depth for the purpose of calculating soil water potentials. The data also give an indication of soil temperature conditions in the different materials. At 1200-1500 hours in summer it is expected that soil temperatures will decrease with depth to about 15 cm (Brady, 1974). It is suggested that temperatures of 15°C or greater at 15cm depth would inhibit root growth and would be accompanied by surface temperatures lethal to germinating seedlings. The number of occasions on which mean temperatures were 15°C or greater in each material is shown in Table 7. The date on which mean temperatures of 15° C or greater were recorded in each material is also shown. (Because psychrometers installed in tailings were not recovered, the measurements of soil water potential and temperature could not be validated by testing psychrometers after use in the field. However, since no errors in temperature measurement were detected in the psychrometers that were tested, the probability of the measurements made in tailings being incorrect is low).

5.4. Assessment of reclamation trials

The interpretation of these results is limited because many treatment records were incomplete.

5.4.1 Identification of successful species

Eighteen commercial grass and legume species were observed in the reclamation trials. Ten naturally invading species were also identified. Mean values of percent cover, percent seed heads, height and vigour for each species are given in Appendix

V1. Because each trial had been treated differently, and some species had only been used in one trial, these results cannot be used to detect differences in suitability between species. However, the results show that the following species have been successfully established:-

yellow sweet clover (Melilotus officinales)
crested wheatgrass (Agropyron cristatum)
red fescue (Festuca rubra)
tall fescue (Festuca arundinacea)
smooth brome (Bromus inermis)

Also, alsike clover (Trifolium hybridum) and alfalfa (Medicago sp.) have been established on a grazed and irrigated area.

5.4.2 Establishment of cover on different areas

The lowest mean, maximum and minimum percent ground cover occurred on the exposed sites A3 and A4. Mean and maximum cover were highest on site A10, which was irrigated, but minimum cover was very low. This was probably a result of trampling and overgrazing. Variation in cover was high at all sites and was not related to date of establishment (Table 8). pH was the same at all sites and soil textures were not markedly different. Variation in calcareousness was high at all sites and was not related to humus cover, ground cover or age. This indicated the presence of only small, poorly distributed amounts of organic matter.

Interpretation of the data in Table 8 is limited because no two sites were given the same treatment. Differences in rates of

Table 8. Results of assessment of reclamation trials

SITE NO.	MATERIAL	ASPECT	EXPOSURE	DATE OF ESTABL-MENT	PERCENT GROUND COVER			
					min.	max.	mean	S.E.
A1	overburden/rock	north	sheltered	1972	15	35	22	7.5
A2	overburden/rock	flat	sheltered	1979	25	40	31	5.4
A3	overburden/rock	west	exposed	1972-77?	6	35	19	11.7
A4	overburden/rock	south	exposed	1970	7	30	21	10.1
A5	raw till	north	m	m	m	m	m	m
A6	overburden/rock	flat	sheltered	1977	25	65	38	16.4
A7	overburden/rock	west	sheltered	1977	30	50	38	7.5
A8	overburden/rock	north	sheltered	1972	7	60	34	27.1
A9	overburden/rock	north	sheltered	1972	20	40	32	8.3
A10	raw till*+	flat	sheltered	?	8	80	59	17.4
A11	raw till*	north	sheltered	?	35	40	24	11.5

* grazed
\+ irrigated

fertilizer application could have affected the density of the cover established. However, it is unlikely that differences were sufficiently large to cause the low cover at sites A3 and A4. Exposure is the likely explanation for these results.

In semi-arid zones many grass (especially bunchgrass) communities exhibit patchy cover even when mature. Mean and maximum cover are probably better indicators of the success of cover establishment than minimum cover.

5.4.3 Shrub invasion

Native shrubs were naturally invading sites where reclamation trials had been set up. On site A1 the following shrubs and trees were observed:-

mountain alder (*Alnus incana*)
willow (*Salix spp.*)
soapberry (*Shepherdia canadensis*)
trembling aspen (*Populus tremuloides*)

On site A2:-

mountain alder
willow

Cover was very low on both sites, approximating 1 shrub/100m².

5.4.4 Erosion and mass movement

Gully erosion and ravel (gravity-induced movement of small, dry soil particles) were observed on all steep-sloping sites and on many other slopes. During the extended dry period in August ravel appeared to be most severe on the driest coarse-textured slopes. After heavy rainstorms, however, mass movement of material was observed on the overburden/rock slopes.

5.4.5 Tree planting trials

Treatment records for the reclamation trials using conifer seedlings were not available. Twenty lodgepole pine and 3 spruce seedlings with average heights of 20 and 15cm respectively were observed. Trees were approximately 7 years old, stems were bent and needles showed symptoms of nitrogen and phosphorus deficiency.

Wildling lodgepole pine, aged 6-8 years, were observed growing on overburden/rock at an elevation of 1600m on the Lornex property.

5.5. Natural revegetation survey

The species composition of each plot surveyed is given in Appendix VII. Many of the species are members of the vegetation communities of the undisturbed areas surrounding the denuded area (Appendix 111). These species were probably present in the area before it was cleared and have reestablished from seed or vegetative parts left in the ground. Weedy species which may have invaded the area since it was denuded are :-

goldenrod (*Solidago occidentalis*)
daisy (*Erigeron spp*)
foxtail barley (*Hordeum jubatum*)
downy oat-grass (*Trisetum spicatum*)

Some lodgepole pine seedlings were observed as well as older cone-bearing trees. Many of the seedlings were clustered around the older trees. In semi-arid areas lodgepole pine cones can open and release seed when surface temperatures on mineral soil become high enough to melt the resinous coating (U.S.D.A., 1965). Hence the seedlings could have originated from seed left in the ground after clearing or from the cone-bearing trees.

In other revegetated (previously cleared) areas, invasion by grasses, herbs, shrubs and trees, apparently from adjoining undisturbed areas, had occurred. Revegetation was sparse in the centres of pipeline clearings, hydro right-of-ways and borrow pits but the number of invaders increased with increasing proximity to undisturbed vegetation.

5.6. Present land-use

5.6.1 Range

About 20 head of cattle, owned by a local rancher, grazed a reclaimed and irrigated area around the Lornex access road. Throughout the period of field work cattle were herded between this area and adjoining forest grazing land at two- to three-week intervals.

5.6.2 Forestry

The only forestry operations carried out in the Highland Valley during the period of field work were the clearing of hydro right-of-ways and of areas where construction of dams was taking place.

5.6.3 Wildlife

Wildlife in the Highland Valley observed by or reported to the author during the period June 1st - September 1st is listed in Tables 9a and 9b.

5.6.4 Recreation and tourism

On average, 20 groups were camped by Quiltanton Lake throughout the period June 1st - September 1st. Of these, 10 were connected with the mines; the remainder chose to stay in the area because of the fishing. Fishing at Quiltanton Lake was described as "excellent". No reports of fishing on Bose Lake were obtained but Bethlehem Copper Corporation (1981) describe it as "active". During the period of field work vehicles were frequently seen travelling the road to Pimainus Lake with fishing equipment. Hunting is prohibited on the mine properties but is "active" in other parts of the Highland Valley in season (Bethlehem Copper Corporation, 1981). Ducks and geese which breed in reedy lakes in the Kamloops area are hunted in season (B.C. Lands Service, 1971).

A survey of traffic on the Highland Valley road between Bethlehem and Logan Lake was conducted in October, 1980. A total of 2300 vehicles was recorded in a 10-hour period. It was estimated that 5% of this traffic was holiday traffic, the remainder was connected with the mines (Dept. of Highways, Merritt District, personal communication).

During the period June 1st - September 1st approximately half of the vehicles observed on the road, outside periods when mine shifts were changing, were recreational vehicles. During the summer both Bethlehem and Lornex ran tours of their mills twice a week for tourists.

Table 9a). Mammals in the Highland Valley, June - September, 1981

COMMON NAME	SPECIFIC NAME*	FREQUENCY OF OBSERVATIONS	SOURCE
Mule deer	Odocoileus hemionus hemionus	occasional	
Elk	Cervus canadensis nelsoni	occasional	
Moose	Alces alces andersoni	occasional	1
Coyote	Canis latrans	occasional	
Yellow-bellied marmot	Marmota flaviventris	very frequent	
Chipmunk	Eutamias spp	frequent	
Groundsquirrel	Spermophilus spp.	very frequent	
Fieldmouse	Microtus spp.	occasional	
Squirrel	Tamiasciurus spp.	frequent	
Rabbit	Lepus spp.	reported	2
Cougar	Felis concolor	reported	2
Lynx	Lynx spp.	reported	2
Muskrat	Ondatra zibethica	reported	3
Porcupine	Erethizon dorsatum	reported	3
Beaver	Castor canadensis	reported	3
Black bear	Ursus americanus	reported	3

Table 9b). Birds in the Highland Valley, June - September, 1981

COMMON NAME	SPECIFIC NAME *	FREQUENCY OF OBSERVATIONS
Commom loon	Gavia immer	nesting
Western grebe	Aechmophorus occidentalis	nesting
Mallard	Anas platyrhynches	nesting
Green-winged teal	Anas carolinensis	nesting
Blue-winged teal	Anas discors	nesting
American widgeon	Mareca americana	nesting
American coot	Fulica americana	nesting
Sparrow hawk	Falco sperverius	frequent
Red-tailed hawk	Buteo jamaicensis	occasional
Spruce grouse	Canachites canadensis	occasional
Killdeer	Charadrius vociferus	very frequent
Spotted sandpiper	Actitis macularia	frequent
Baird's sandpiper	Erolia bairdii	frequent
Dunlin	Erolia alpina	frequent
Western sandpiper	Ereunetes mauri	frequent

Table 9b). continued

Horned owl	Bubo virginianus	reported	4
Flicker	Colaptes spp.	very frequent	
Red-breasted sapsucker	Sphyrapicus varius	frequent	
Western kingbird	Tyrannus verticulis	frequent	
Bank swallow	Riparia riparia	frequent	
Cliff swallow	Petrochelidon pyrrhonota	frequent	
Skylark	Alauda arvensis	frequent	
Gray jay	Perisoreus canadensis	frequent	
Black-billed magpie	Pica pica	frequent	
Common raven	Corvus corax	frequent	
Common crow	Corvus brachyrhynchos	frequent	
Robin	Turdus migratorius	occasional	
Mountain bluebird	Sialia currucoides	occasional	
Yellow warbler	Dendroica petechia	occasional	
Western meadowlark	Sturnella neglecta	occasional	
Red-winged blackbird	Agelaius phoenicens	occasional	
Savannah sparrow	Passerculus sandwichensis	occasional	

* according to Cowan and Giguet (1978) and Peterson (1961)
1 three killed on highway in June
2 reported by Highmont Operating Corporation,(1980)
3 reported by hunters
4 reported by Bethleham Copper Corporation, (1981)

6.. Discussion

6.1. Selection of factors for classification scheme

The following factors were used to classify disturbed areas in the Highland Valley into reclamation site-types:-

-topography

-exposure

-type of disturbed material

-elevation

6.1.1 Topography

The topography of many disturbed areas in the Highland Valley is both more uniform and more extreme than natural areas. Topography can therefore affect the reclamation and ultimate use of disturbed areas. Three topographic classes can be identified.

Flat areas are those with a 0-4° slope. Examples are rockdump terraces, abandoned plant sites, and tailings ponds. Drainage may be impeded, causing periodic flooding, particularly when there are impermeable compacted horizons in the soil profile. (Small pools of water were observed on flat, disturbed areas in the Highland Valley up to 6 days after the last recorded rain event). Cultivation with machinery is possible.

Sloping areas are those with long slopes of 25° or greater, e.g. rock dump faces, dams. In these areas drainage of water and nutrients through the disturbed material will be more rapid. The potential for surface erosion and ravel, causing loss of silt- and clay- sized particles, seed and fertilizer, is increased. On slopes of 18° or greater machine drilling is not possible (U.S. Dept. of Agriculture, 1979). Dry broadcast seeding is possible on slopes of 145° (Carr, 1980). Machine broadcasting is often limited when slopes are long.

Undulating areas are those whose topography is similar to or the same as the original natural topography. Examples are roads and small clearings. The topography is varied; though it may include some steep slopes and some flat areas, none are extensive enough to warrant modification of the reclamation technique.

6.1.2 Exposure

In this study, two exposure classes which separate disturbed areas with different reclamation requirements are identified.

Exposed areas are disturbed areas with aspect in the range 160-260° (or which are flat) and which are not sheltered by terrain of greater elevation within 1/2 mile (800m) in the direction 160-260°. Drought develops rapidly and is very severe. In this study the drought period lasted for 8-9 weeks at an exposed site. Wind erosion of silt- and clay- sized particles, seed and fertilizer may occur. Germinating seedlings may be abraded by wind-borne material. Aboveground plant parts may be stunted.

Sheltered areas are those disturbed areas not classified as exposed. Although drought may develop in these areas, the period during which moisture is available to plants is longer. Wind erosion and wind damage are not likely to occur.

Although Pinkerton (1972) reports that winds in the valley bottom are directed from the northwest or southeast, winds detected during the period of field work were from the south and west. Additional "exposed" areas may be identified over a period of years.

Although results showed aspect to have no direct affect on moisture conditions in disturbed materials, it can affect exposure indirectly because many slopes with south or west aspects are exposed to the prevailing winds.

A difference in the density of natural vegetation between the north and south sides of the valley is visible on the air photographs. Delay in snow-melt probably increases the amount of moisture available to plants on the south side of the valley. Aspect may therefore affect the density of cover which eventually develops on reclaimed disturbed areas.

6.1.4. Type of disturbed material

Types of disturbed material differ from each other in characteristics that affect water retention, aeration and root penetration. The depth of most disturbed materials is a function of their type. Three classes of disturbed material are identified.

<u>Tailings</u> differ more markedly from natural soil than do other types of disturbed material. Tailings produced by the Lornex and Bethlehem mines have been analysed and described in detail by Dept. of Soil Science (1976/77). Lornex tailings at 0-10cm depth contained 8.07, 43.89 and 48.04% and fresh Bethlehem tailings 4.28, 27.32 and 68.42% clay-, silt- and sand-sized particles respectively. Bulk densities of Lornex tailings from 0-95.5cm depth ranged from 1.09-1.30gm/cc. (These values are all similar to those obtained in this study). The effects of these physical characteristics on vegetation establishment have been described by Dept. of Soil Science (1976/77) and Morton (1976). Water stress is a major problem, especially in summer. Aeration at field capacity of Lornex tailings is low although total porosity is sufficient for plant growth. The layered structure of tailings material (caused by variation in bulk density and particle size with depth) can inhibit drainage and effect chemical properties. Sand- and silt- sized particles are susceptible to wind erosion (Dept. of Soil Science, 1976-77). Available water storage capacities are 14-25% by volume (Morton, 1976).

The total depth of tailings is far greater than the maximum possible penetration of grass and herb roots. However, root penetration may be restricted by the layered structure of tailings material. The depths at which these layers occur are very variable, depending on the method and time of tailings disposal. At 0 to 15cm depth, tailings materials were noticeably colder than other materials when sampled in June and were cooler than other materials at 15cm depth during June and July. Low temperatures could delay the start of root growth in spring.

Raw till materials are coarse-textured and contain many stones and cobbles. Water stress develops very rapidly; available water storage capacity may be very low. Drainage of water and nutrients through the profile may be rapid but aeration would not be a problem. (In this study average moisture conditions in raw till sites represented two periods of drought, 13 and 19 days long). Wind erosion of the small amounts of fine particles exposed at the surface may occur initially, but would not be a persistent problem. Stones and cobbles may create sheltered microsites where seed and fertilizer would collect but ravel erosion may occur on steep slopes. High surface temperatures may occur on the dry surfaces of mineral particles.

The depth of raw till materials is very variable and vertical root penetration may therefore be restricted by an underlying C horizon. However, the zone above the C horizon may be supplied with sub-surface drainage from surrounding areas and therefore permit better plant growth once roots are established.

Overburden/rock materials contain more silt- and clay-sized particles than raw till materials. Rooting volumes will be larger and moisture and nutrients should be retained longer in the profile. The fine particles, and applied seed and fertilizer, may be subject to erosion by wind. Surface run-off may also occur if the infiltration capacity of the materials is exceeded during heavy storms.

The overburden/rock materials sampled for this study were approximately 30cm deep. Observation of other areas of overburden/rock materials indicated that this was typical. On slopes, these materials are underlain by large fragments of loosely-packed rock. Penetration by roots may improve anchorage but would not increase water supply. On flat areas, overburden/rock materials overlie rock fragments that have been crushed and heavily compacted by the traffic of dump trucks and spreaders. These materials may be impenetratable by plant roots, but may increase water retention in the overlying materials.

In this study, only one area of the compacted rock type of materials could be sampled. This was oxidised granodiorite. It had physical characteristics very similar to those of the overburden/rock types, and is therefore included in the class described as "overburden/rock". However, other compacted/rock areas (which were not sampled) are composed of different rock types.

Some of these rock types have been characterized previously by Lornex. Rock types varied significantly in rate and degree of breakdown due to blasting , traffic and weathering. They were ranked as follows in order of most to least rapid breakdown to soil-sized particles:- fault gouge; oxidised quartz diorite and granodiorite; quartz diorite and granodiorite in various stages of alteration; quartz porphyry (Lornex Mining Corporation, undated). Bethlehem granodiorite/quartz diorite has not been characterized but is considerably harder than the Skeena and Bethsaida phases found on the Lornex property .

The mining companies have all stockpiled overburden for future use, if necessary, in reclamation. In defining classes of disturbed material for this classification scheme it is assumed that other areas of compacted rock will be similar to the area sampled or that they will be covered with overburden. In both cases, they are classed as "overburden/rock" materials. Sampling of other areas of compacted rock would identify the areas requiring treatment with overburden and might identify additional classes of disturbed materials.

6.1.4 Elevation

The maximum elevation of disturbed areas in the Highland Valley will be approximately 1700m (5500ft.). Natural vegetation communities in the Highland Valley exhibit differences in species composition, many of which are caused by differences in elevation. The most notable example is the transition from grassland to forest that occurs with elevation, presumably as a result of changes in the precipitation:evaporation ratio. Many commercial grass and legume species have low germination percentages, poor vigour and reduced ability to persist at elevations of greater than 1530m (5000ft.) (Hubbard and Bell, 1977).

Since all reclamation trials were established below 1500m, no data on the effect of elevation on the success of reclamation trials in the Highland Valley is available. Many species e.g. pinegrass, mountain alder, juniper, rose, bearberry and lodgepole pine, grow at all elevations in natural vegetation communities. In southern B.C. the significant effect of elevation change occurs at about 2100m (7000ft.) (Errington, personal communication).

It seems unlikely that an increase in elevation from 1500m to 1700m would cause sufficient changes in plant growth conditions to justify significant modification of the reclamation techniques employed in the initial stages of a reclamation programme.

However, in many instances elevation will influence the choice of a land-use objective for a disturbed area. The factor elevation is included in the classification scheme because of its influence on the choice of a land-use objective and its possible effect on reclamation techniques.

6.2. Identification of reclamation site-types

The classification scheme was applied to the study area using the topographic base map and standard B.C. government stereo color photographs, taken in June 1980 at a scale of 1:20000. The following reclamation site-types were identified in the Highland Valley:-

low elevation, flat exposed tailings
low elevation, flat, sheltered overburden/rock
high elevation, flat, sheltered overburden/rock
low elevation, sloping, sheltered overburden/rock
high elevation, sloping, sheltered overburden/rock
low elevation, flat, exposed overburden/rock
high elevation, flat, exposed overburden/rock
low elevation, sloping, exposed overburden/rock
high elevation, sloping, exposed overburden/rock
low elevation, undulating, sheltered raw till

high elevation, undulating, sheltered raw till

low elevation, undulating, exposed raw till

Cleared and revegetated areas

In addition to the disturbed areas classified into reclamation site-types, mining and related activities have created other disturbed areas, that do not require reclamation, but which are shown on Plan 1.

Cleared areas are those which have been cleared of all natural vegetation but which are still covered with natural topsoil. These, if not buried by waste rock, will become revegetated naturally (as discussed in section 5.5).

Revegetated areas are those which were probably cleared several years ago but on which some natural revegetation has already occurred.

Cleared and revegetated areas associated with hydro rights-of-way are maintained so as to prevent the reestablishment of forest cover. They will be used by cattle and/or wildlife, depending on accessibility. Other denuded and revegetated areas will provide cattle and wildlife forage initially but will eventually become reforested.

The distribution of natural vegetation, reclamation site-types, cleared and revegetated areas in 1981 is shown in Plan 1. The plan also shows the approximate predicted distribution of reclamation site-types when mining operations cease. Predictions were made using information supplied by the mining companies and some assumptions based on observation of the mining techniques used in the Highland Valley. The information and assumptions were as follows.

Bethlehem have described a projected development schedule for the period 1982-1987. The main tailings and Bose Lake dams are being raised by 3m (10ft.) and 6m (20ft.). respectively. The Huestis pit will be used for tailings disposal and waste rock will go to existing waste dumps. Projected additional disturbed areas will be primarily in the Trojan Pond area (Bethlehem Copper Corporation, 1981). In Plan 1 it is assumed that the Huestis pit will be filled with tailings to the maximum possible height and that tailings in the Trojan Pond will cover the previously cleared area upstream of the Trojan Dam. The surface area of the main tailings pond will increase slightly. Surfaces of all tailings disposal areas will be flat.

Lornex estimate that surface disturbance by waste dumps and low-grade stock-piles will total 141ha by 1986; all waste disposal areas are currently active (Lornex Mining Corporation, 1981). No predictions have been made beyond 1986. At present, further dumping on the northwest dumps is not anticipated; the lack of space for waste rock disposal within the property boundary is a problem at Lornex (Lornex reclamation staff, personal communication).

In Plan 1 it is assumed that Lornex waste dumps will be expanded to the limits imposed by the property boundary and that final dump configuration will be similar to that at present.

The final elevation of the waste dumps at Lornex and Bethlehem may be greater than that shown in Plan 1, depending on mine developments. The high elevation site-types may therefore be under-represented.

Plan 1 shows the final configuration and elevation of the Highmont waste dumps and pit anticipated by Highmont. When the mine is completed, the tailings disposal area will consist of a beached area and a pond (Highmont Operating Corporation Property Engineering, 1981), bounded by dams. The predicted size of the tailings disposal area shown in Plan 1 is an estimate based on the planned height of the dam and the underlying relief.

On both the Highmont and Valley Copper properties, it is assumed that a small area around the perimeter of the pit will be disturbed as has happened at Lornex. It is also assumed that small areas between waste dumps, around plant sites etc. will be disturbed.

The final configuration, size and elevation of the valley bottom tailings disposal area shown in Plan 1 is an estimate based on Valley Copper's prediction that the final tailings surface will be 1820 ha and that the JJ dam will be 1292m (4200ft.) high. It is assumed that tailings disposal will not necessitate relocation of that portion of the Highland Valley road that was relocated a few years ago. Although the shape of the tailings area predicted in Plan 1 is somewhat conjectural, the surface area is approximately 1820ha and any inaccuracies in predicting the shape will not greatly affect the elevation of the tailings.

6.3. Land-use Options

When mining ceases, the Highland Valley could be used for a number of purposes, depending upon political, economic and social conditions. The construction of an industrial park has been proposed (Ministry of Lands, Parks and Housing, personal communication). However, consideration of all possible land-use options is beyond the scope of this study.

Considering only pre-mining and current land-uses in the Highland Valley and the surrounding area, the following are possible objectives for reclaimed land in the Highland Valley.

6.3.1 Range

The provincial supply of rangeland is depleted by factors including land alienation for competing uses. There is a continous decrease in areas used for range in the southern interior. In this region, the park-like open timber zone (equivalent to the open forest/grassland community-type) is the most productive but the lower elevation open grasslands (valley bottom meadows) are the most valuable because they are available for grazing earlier in spring and later in fall. Meadow openings on organic wetland soils (aspen meadows) are highly productive and, if accessible, valuable because animals are more easily controlled. Bunch grasses, which are dominant on most good-condition grasslands, supply good quality feed late in the season but 'soft' grasses, such as pinegrass, are of relatively low value in all seasons except early and mid-summer. In the Ashcroft-Lilloet subregion of the Thompson region, the open range is in poor-fair condition and overstocked; the open forest is in fair condition. Mining developments in the Highland valley have removed some minor productive valleys. Temporary increases in the supply of rangeland are available on logged areas before regeneration growth becomes too dense (Select Standing Committee on Agriculture, 1979).

Grassland ranges are often of critical importance to a ranching operation in B.C. because their use in the late fall and early spring shortens the expensive winter feeding period. Rangelands in B.C. are, in general, producing much less than maximum (van Ryswyk et al. , 1966).

In the Highland Valley, remaining open forest/grassland and valley bottom meadow communities are currently usable for range, Only a few areas of the aspen meadow community-type are usable because access to the meadows is limited. Sedge marshes can be grazed by cattle in winter.

New rangelands could be created on reclaimed land by establishing forage plants in areas where cattle access is possible. At higher elevations, additions to the forage supply may be of little value because the limiting feed source is generally in spring, fall or winter. Slopes of 26° or more would be little used by cattle unless forage were in very short supply (Pitt, personal communication). Natural barriers, such as steep hillsides, can simplify stock control but may cause access and management problems (Select Standing Committe on Agriculture, 1979).

6.3.2 Agriculture

Because of the importance of ranching in the Ashcroft-Nicola area, cultivation of forage crops is the principal agricultural activity in the low elevation valley bottoms. For ranches using the upland plateaux for summer grazing, the winter feeding period may be as long as 4-5 months (B. C. Lands Service, 1971). Shortage of winter feed adds to the restrictions on range use imposed by poor spring/fall ranges but water supply problems restrict the production of forage crops (Select Standng Committee on Agriculture, 1979)

To date, existing natural vegetation communities of the Highland Valley have not been used for agriculture. Removal of the natural vegetation, seeding and irrigating of forage crops would require huge capital outlay. In 1970, the capability of land in the valley bottom (now mostly covered by tailings) was class 6, ("capable of producing only perennial forage crops and improvement practices are not feasible") (Environment Canada, 1976).

However, the climate for agriculture at the west end of the Highland Valley is class 3 , with drought or aridity between May 1st and September 30th being the major limitation to growth. If irrigated it would be class 2, the limitation being minimum temperatures near freezing adversely effecting plant growth during the growing season. At the east end of the valley the climate for agriculture is class 3, with insufficient accumulation of heat units above 5°C during the growing season being the limitation to growth (Environment Canada, 1966).

If there were sufficient demand (for instance generated by expansion of the local ranching industry), dryland or irrigated forage crops could be grown on flat or gently sloping reclaimed areas at low elevations. Irrigation might be feasible for areas close to sources of water, where soils and surrounding topography would maximise water retention.

6.3.3 Forestry

It is predicted that 5% of the total provincial Crown forest land base will be alienated over the next 20 years. Forest development is being forced into marginal areas to offset losses caused by alienation of good-site forest land. Access to these marginal areas can be costly. A falldown in timber supply by the Kamloops Forest Region is forecast for 20-60 years from now even if trends toward using smaller trees and less desirable species continue (B.C. Ministry of Forests, 1980).

Existing forest sites in the Highland Valley are classed as "poor" or "medium" (B.C Forest Service, 1970). The area is classed by the Canada Land Inventory as "having very severe or severe limitations for forestry". Limitations are chiefly lack of moisture (Environment Canada, 1970b). However, records of pre-mining logging activity suggest that the area has greater forestry potential than this classification suggests (B.C.Forest Service, Ashcroft Field Office, undated).

Spruce/lodgepole pine, Douglas-fir and lodgepole pine communities could all be used for timber production to offset predicted falldowns. Mature stands, once logged, could be replaced by more productive immature stands. Dense, stagnant lodgepole pine stands may be made merchantable by silvicultural treatment and changes in utilization standards. Roads constructed for mining will reduce the cost of access for harvesting and site preparation (Ministry of Forests, 1980)

It is impossible to predict what the eventual economic benefits of planting trees on disturbed areas in the Highland

Valley will be. But, faced with a decreasing forest land base and trends towards use of less productive forest land, the need to establish commercial species on those disturbed areas which show the greatest potential for timber production and the least potential for any other land-use is growing. The intangible aesthetic values resulting from afforestation of large tracts of disturbed land will add to the eventual value of timber produced. Some of the mining companies have expressed intentions to return the land to a state similar to that which existed prior to mining (see section 6.4). Where no better land-use can realistically be achieved, a return to the "natural land-use" (in this case largely forestry) is a desirable reclamation objective.

6.3.4 Wildlife

The value of wildlife is becoming an increasingly important factor in making decisions for Crown ranges. Benefits from wildlife include hunting and recreational uses, aesthetic benefits and "existence values" (Select Standing Committee on Agriculture, 1979). Deer habitat in B.C. has declined in quantity as a result of land-use practices (including mining) and in quality because of plant maturation and improved forest fire control. Deer-hunting is a traditional sport in B.C. and there is also public demand for opportunities to view deer in their natural habitat (B.C. Fish and Wildlife, 1980). In winter, moose feed almost exclusively on browse (Van Drimmelen, 1979). Loss of tree and shrub cover is therefore critical.

All existing natural vegetation communities in the Highland

Valley have some value for wildlife, because they provide food and/or habitat. Communities which have the greatest value, and little value for other land-uses, are willow communities (moose browse) and willow/birch communities (elk, deer and moose browse, elk grazing). Sedge marsh communities may provide wildfowl nesting grounds and feed for moose if not used by cattle. As the volume of traffic on the Highland Valley road will be greater when mining operations cease than it was in the pre-mining period, use of these communities may be limited or may create traffic hazards. Also, natural succession on these communities may reduce their value for wildlife. In the remaining valley bottom meadow communities and open forest/grassland communities, competition between wild and domestic ungulates may develop (Select Standing Committee on Agriculture, 1979).

Since vegetation produced in the first 20 years of seral succession provides food most valuable for wild ungulates (Van Drimmelen, 1979), reclaimed disturbed areas have obvious potential for wildlife use. Proximity to cover is important, especially for mule deer and elk.

Disturbed areas have little obvious potential for wildfowl habitat. Olson (1981) has reviewed the factors which determine the wetland plant community composition and resulting wildlife habitat quality of Northern Great Plain strip-mine ponds. He concludes that there is little ecological information available and only limited future research interest in these ecosystems. Creation of wetland plant communities and wildfowl habitat in the Highland Valley would require extensive research, and probably the importation of organic soils and vegetation. Such an approach is not practical for the Highland Valley; protection of existing ponds and wetlands from unnecessary or accidental destruction is a more realistic and cost-effective approach.

6.3.5 <u>Recreation</u>

The Canada Land Inventory describes the area as "lacking the natural quality and significant features to rate a higher capability for recreation but having the natural capability to engender and sustain low annual use based on dispersed activities" (Environment Canada, 1970c). In the future, however, the changes in landscape and ease of access may significantly change the rating of this area for recreation.

A more realistic assessment perhaps is that of the Ministry of Forests which describes the Kamloops Region as a whole as "having the greatest potential of any Region for providing a full complement of recreational activities". Horseback riding, trail bike riding, camping, fishing and hunting are some of the potential facilities. It is expected that this region will be the first to see the demand for recreation approximate the physical supply. Management of landscape values is expected to require particular attention (B.C. Ministry of Forests, 1980).

Existing natural vegetation communities that have potential for recreational use are the valley bottom meadow communities adjacent to lakes which are suitable for camping. The potential of the Highland Valley area for hunting will increase, when mining ceases, as a result of improved access. The open and varied communities in the valley bottom would be suitable for horseback-riding if facilities were developed.

The greatest potential for developing recreational facilities on disturbed areas lies in the creation of artificial ponds and lakes and camping facilities adjacent to these. The practice of flooding disturbed land created by surface mining and using the lakes for recreation is common in the U.S. (Schultz, 1971; U.S Dept. of the Interior/Bureau of Outdoor Recreation, 1974; Illinois Dept. of Conservation, 1977; Shaw, 1980). However, there are no cases, known to the author, of open-pit mines being used for recreation.

Access for hunting purposes should be maintained.

Current interest in the mining operations could be maintained by preserving selected areas of mined-out land, constructing look-out points, exhibiting relics of the mining industry and providing information on past, present and future land-uses of the Highland Valley.

6.4. Summary of post-mining land-use objectives proposed by mining companies

6.4.1 Bethlehem Copper Corporation

Bethlehem aims to provide a food source for domestic or wild ungulates by developing "a self-propagating strain of grasses". Some deciduous trees or shrubs will be planted to speed up natural invasion of disturbed areas by lodgepole pine and other conifers. Bose Lake will continue to be restocked (Bethlehem Copper Corporation, 1979, 1981).

6.4.2 Lornex Mining Corporation

Land-use objectives for the abandoned Lornex property, 20-30 years in the future, will be developed as reclamation research continues. The reclaimed land must be practically and visually complementary with the surrounding terrain. Ultimate use will depend upon final topography, surface materials and vegetation. Possible uses are wildlife habitat, grazing land and low yield forestry. The open-pit will be flooded to create a lake. The valley bottom tailings area will be reclaimed for a use to be agreed upon with the Ministry (Burge, 1971; Lornex Mining Corporation, 1979 and 1981).

6.4.3 Highmont Operating Corporation

Highmont aims to return the area to a close approximation of its pre-mining use, that is, a wooded area, but with improved access for possible recreation utilization. No long-term objectives are given for the areas where this will not be possible, e.g. the open-pit, waste dumps and tailings disposal area. In the near-term the objectives are to reclaim as much of the disturbed area as possible by re-planting with a suitable seed mixture, or transplanting native-type trees onto the large disturbed areas (Highmont Operating Corporation, 1980, 1981).

6.4.4 Valley Copper Mines

The reclamation objectives for disturbed areas at the Valley Copper mine include establishing self-sustaining plant communities which will support a type and level of use similar to that which existed prior to mining. Plant communities which provide forage for wildlife and merchantable timber will be established. The feasibility of flooding the pit to create a lake will be investigated. Water levels are expected to return to the former elevation of Quiltanton Lake (Valley Copper Mines, 1980).

6.5. Reclamation research, objectives and techniques for each reclamation site-type

This section treats each reclamation site-type individually and discusses:-

a) previous and current reclamation research undertaken in the Highland Valley in areas of the site-type under consideration;

b) previous reclamation research, not undertaken in the Highland Valley but relevant to the site-type under consideration;

c) suitable reclamation objectives and reclamation techniques for the site-type under consideration.

6.5.1 Flat, exposed tailings

a) Single species test-plots were established on low elevation tailings by Lornex in 1978. Grass-legume mixes were established in 1979. No results or conclusions have been presented yet. A 1ha plot was established on low elevation tailings in July 1981. Windrows and furrows were created on the plot to improve the microclimate. Unfortunately, this plot was flooded by an accidental discharge of tailings but initial growth appeared to be good (Lornex Mining Corporation, 1981). The plot is to be re-established in 1982. Irrigation and wind breaks (constructed with snow fencing) were used by Bethlehem to help establish vegetation on tailings. Plants grew well for two seasons but are now buried by tailings (Bethlehem Copper Corporation, 1979).

Chemical analysis of tailings from a number of mines including Lornex and Bethlehem has been undertaken by Dept. of Soil Science (1976-77). Available nutrients in Lornex and Bethlehem tailings were variable. It was noted that correlation between plant response and results of soil tests on tailings is often poor. Available phosphorus (P) was low, especially in the Bethlehem tailings; it was slightly higher in some of the Lornex tailings sampled but tailings from both mines gave poor plant response unless fertilizer potassium (K) was added. Magnesium (Mg) did not appear to be a severe limiting factor in the Lornex or Bethlehem tailings but nitrogen (N) was consistently very low. Organic matter is thought to be the single most important amendment for tailings from a number of mines including Lornex and Bethlehem because of its effect on chemical and physical properties of tailings (Dept. of Soil Science (1976-77).

Copper:molybdenum ratios in plants of less than 2.0 have been associated with symptoms of molybdenum-induced copper deficiency; this finding is supported by some, but not all, of the literature (Miltmore and Mason, 1971). No immediate problem was identified in a situation where ruminants were expected to browse only for a short period on vegetation grown on tailings but further research into the ultimate potential of tailings for forage production was recommended (Dept. of Soil Science, 1976-77).

b) Alfalfa has been successfully established on tailings at the Princeton mine (approximately 120km southeast of the Highland Valley) using fall rye as a cover crop and sewage water for irrigation (Lane and McDonald, 1979). At the Craigmont mine (approximately 25km southeast of the Highland Valley) research on tailings has shown that a grass-legume cover can be established under dryland conditions but a stronger growth was established using irrigation. On another test plot at Craigmont, a grass-legume cover has been established after an intensive site preparation programme which included fertilizing, irrigating, green manuring and compacting. Both reclaim water and cooling water from the compressors have been used.

The addition of organic matter, in the form of poultry manure, cow manure and sewage sludge, to tailings from the Sullivan mine greatly increased yields of orchard grass (Dactylis glomerata) in a greenhouse study (Dept. of Soil Science, 1976-77).

c) Areas of low elevation tailings could be used for range. The intensity of use will depend on the demand for rangeland by local ranchers; the Highmont tailings pond may be too inaccessible to be useful. The intensity of grazing that will be suitable will depend on results of research into possible toxicity problems. If toxicity is proven not to be a problem, areas of this site-type could be used for fall and spring grazing of cattle and/or hay production under irrigation.

Reclamation for range would require establishment of grass-legume cover. Use of a cover crop or a green manure would increase water retention and natural soil fertility; it might also reduce wind erosion and help maintain the windrows and furrows created by site preparation. Addition of organic amendments, if available, would also be beneficial. Grasses would provide early cover for legumes which are slower to establish. Ploughing would improve aeration and drainage by destroying layers; seed should be packed to improve contact and fertilizer should be applied. Further research into the fertilizer requirements of tailings used for range (and hay) is required.

Hay production on reclaimed low elevation tailings would require irrigation. The available water storage capacity of tailings is comparable to that of irrigated agricultural soils (Calver, 1965 IN: Morton, 1976). The surrounding topography of the valley bottom tailings disposal area would help retain water. Possible sources of water are the Thompson (via the Lornex pipeline) and local creeks. Water from Big Divide Lake (which will be drained when Valley Copper comes into production), if not used in mine processing, could be used for a period of time to establish ground cover. However, enhancing the growth of water-demanding species at the expense of drought-resistant ones should be avoided. If irrigation cannot be maintained permanently, ground cover established under irrigated conditions could be used as a green manure and more drought-resistant species seeded subsequently.

6.5.2 Low elevation, flat, sheltered overburden/rock

a) Results of the assessment of sites A2 and A6 (see table 8) and Appendix VI) indicate that grass or grass-legume cover can be established and maintained on these sites when fertilizer is applied annually. Other reclamation trials (not assessed) have been carried out by Lornex and Bethlehem on areas of this site-type, but there is no evidence that a self-sustaining cover has been established.

b) Grasses and legumes have been established on overburden-covered waste-rock terraces in many areas of B.C.. At Craigmont mine such an area will be used for cattle grazing in 1982 (Gavelin, personal communication). Little research has been done on the persistence of grasses and legumes established on reclaimed areas. Self-sustaining reclamation plant communities can be identified. In some reclaimed areas, communities become "mature". The mature phase in the development of a reclamation community is characterized by the development of a large root-soil-root exchange system which obviates the need for maintenance fertilization (Ziemkiewicz,1979).

c) Areas of this site-type should eventually be used for range. Existing rangeland in the Highland Valley is found on many different soils, some of which, though richer in organic matter, are in other characteristics similar to overburden/rock. Seeding of desirable forage species and fertilization could provide rangeland of equal, if not greater, productivity than existing rangeland which supports only pinegrass or is colonized by weeds. (Use for hay production would be restricted by problems of supplying irrigation water to these areas). Legumes should be established because of their effect on nutrient reserves of the material and because they provide nutritious forage. Grasses may be established as well to prevent the supply of too rich a forage.

Potassium is needed for legume establishment but heavy applications of nitrogen can reduce legume growth by inhibiting nodulation and favouring vigorous growth of competing grasses. To etablish grass-legume cover, initial fertilization with 13-16-10 at 400kg/ha would be suitable. Maintenance fertilizer, for instance, 10-20-0, should be applied subsequently at 200kg/ha. A suitable seeding rate is 40kg/ha. Seed should be applied in spring and the surface harrowed and packed if possible. This programme of site preparation, seeding and fertilizing is siutable for the establishment of grass-legume cover on other overburden/rock site-types where required.

6.5.3 <u>High elevation, flat, sheltered overburden/rock</u>

a) Of the reclamation trials that were assessed, none were above 1500m except for the conifer trials. Elevations of other test plots on the Lornex property are not known. There is no clear indication that methods for the reclamation of high elevation site-types have been or are being developed. The choice of species for use at high elevations may be important.

Results of another conifer planting trial have been reported. The percent survival of lodgepole pine planted on a revegetated overburden/rock site averaged 94% after 11 growing seasons . Height ranged from 15 to 105cm and averaged 48cm. The conifers were apparently nitrogen deficient (Lornex Mining Corporation, 1981). Bethlehem have noted that lodgepole pine is sufficiently hardy to grow on waste dumps in the Highland valley, but no trials at elevations of greater than 1500m are reported.

b) There are many reports in the literature of research into reclamation of waste-rock areas at high elevations. Some species of commercially-available grasses and legumes which are known to establish and persist in the elevation range 1500-1850m in dry conditions are given in table 10. Research into tree establishment has been less extensive and apparently less successful (Dick, 1972). Many studies have shown that seedlings originating from local stock establish better than nursery stock from a different provenance. Engelmann spruce and lodgepole pine were successfully established on coal mine spoils at 1530m and 1076-1530m respectively in the S.E.Kootenays. Lodgepole pine was particularly desirable because it reacted well to browsing (Lowenberger, 1967). White spruce was successful in trials at 1500m in the Green Zone of Alberta (Selner, 1974). Percent survival of Douglas-fir, Engelmann spruce and lodgepole pine after 2 seasons on high elevation waste rock in the S.E.Kootenays was 99% (Fording Coal Ltd., 1981). Research into the use of native shrubs for reclamation is currently very active.

c) Areas of this site-type could be reclaimed for wildlife or for forestry. (Productivity would not be high enough to justify use of this site-type for range and access would be difficult). Reclamation for wildlife use should be the objective for small areas of this site-type which are surrounded by mature forest cover. Wildlife use of extensive areas would be restricted to the peripheries; forestry is a more desirable reclamation objective for these areas.

Trees and shrubs grow naturally in the Highland Valley on coarse-textured soils which contain some humus. Overburden/rock materials would differ from natural soils only in their ability to maintain a supply of the nutrients required for tree growth. By adding fertilizer and establishing grass-legume cover, supplies of both readily- and slowly-available nutrients would be created.

Research into the choice of grass and legume species for high elevation areas in the Highland Valley may be required. Species which could be tested are listed in table 10. Ground cover would also reduce the high surface temperatures in summer that could damage tree seedlings and shrub cuttings or seedlings. Competition between ground cover and trees and/or shrubs may be a problem. Some control methods which could be tested are the use of low-growing grasses, reduction in fertilization and clearing of planting sites.

Reclamation for forestry would require planting of seedlings of local origin. Lodgepole pine and spruce should be used. Without planting, invasion of extensive areas of this site-type would be slow. High quality planting of 2+3 (or older) stock with wide spacing would be more cost-effective than planting many younger seedlings. Larger seedlings would also compete more effectively with ground cover. Since lodgepole pine can bear viable seed when only 5-10 years old and its seed disperses up to 70m from source (U.S. Dep. of Agriculture, 1965), extensive areas could become well stocked within a short time.

Grass-legume cover would provide some forage for wildlife. To create good wildlife habitat, however, shrubs should be established. Local shrubs should be propagated; suitable species are given in table 11. It may prove to be easier to establish N-fixing shrubs than legumes in high elevation areas, in which case they should also be established in the areas which are to be reclaimed for forestry.

6.5.4 Low elevation, flat, exposed overburden/rock

a) No reclamation trials have been established on areas of this site-type.

b) Methods of controlling wind erosion of fine soil particles have been reported in the literature. Creation of ridges in the seedbed reduced wind erosion from grass seedbeds (Marlatt and Hyder, 1970). Chemical soil binders have been used to hold seed and surface particles in place. They are best for temporary stabilization and usually disintegrate within 6-8 months (Murray, 1971; Carr, 1980). Mulches such as straw, bark residues, wood chips, jute nettings etc. have been used in a number of reclamation trials (Schietl, 1964; Brown et al. ,1971; Aldon and Springfield, 1973). Both beneficial and detrimental effects are reported. Excessive mulching is detrimental to seedling germination (Murray, 1971). There appears to be little promise with hydroseeding and mulching in low precipitation areas (Tresler, 1974).

c) Suitable land-use objectives for this site-type are the same as for the low elevation, flat, sheltered overburden/rock site-type (see section 6.5.2). The reclamation technique should be modified to reduce the problems caused by exposure. Areas of this site-type should be cultivated to create soil ridges perpendicular to the direction of the prevailing wind. Seed should be packed after application. Where possible, small banks of rock should be left on the edges of terraces and berms to provide some shelter. Decomposition of mulches would be slow in the Highland Valley climate; their use should be avoided as much as possible.

6.5.5 <u>High elevation, flat, exposed overburden/rock</u>

a) No reclamation trials have apparently been established on areas of this site-type.

b) After a high mortality (caused by wind, south aspect, dark spoil and lack of protection by snow) of seedlings planted with regular spacing at 1530m in the S.E. Kootenays was observed, seedlings were planted in sheltered microsites with irregular spacing. A greater percentage of seedlings planted survived, but the total number/unit area was the same because the availability of microsites was limited (Dick, 1972).

c) Land-use objectives (wildlife and forestry) and reclamation techniques are the same as those proposed for the high elevation flat, sheltered, overburden/rock site-type (section 6.5.3) but establishment of trees and shrubs would require sheltered planting sites. If small depressions are not already present in the overburden/rock materials, they should be created mechanically. The ability of ground cover to provide shelter (as well as to improve nutrient status) for the tree seedlings without adverse competitive effects should be evaluated in trials.

6.5.6 Low elevation, sloping, sheltered overburden/rock

a) Several areas of this site-type have been reclaimed. Results of the assessment of sites A7, A8 and A9 indicate that methods for the establishment of ground cover on this site-type have been developed. Both dry and hydraulic seeding methods have been used (Bethlehem Copper Corporation,1981; Lornex Mining Corporation,1979; 1981). Cover is still sparse, however, and persistence of species when fertilization is discontinued has not been tested. Planting of lodgepole pine, spruce and Douglas-fir on mine waste dumps (location not specified) where no vegetation was present resulted in "poor" survival of seedlings. Planting of Douglas-fir, white spruce, Manitoba maple and birch species on the Bose Lake Saddle dam (an area of the low elevation, sloping, sheltered overburden/rock site-type) after ground cover had been established produced "excellent" survival (Bethleham Copper Corporation, 1979).

b) Many reports describe the importance of microsites, where seed, fertilizer and moiture can collect, for developing adequate ground cover (Etter, 1971; Berg, 1974).

c) Areas of this site-type would be of little value for range, because of their slope. If the surrounding areas were used by cattle in spring and fall (as proposed in section 6.5.2), use by wildlife would be restricted to areas not covered by snow in winter .

The reclamation objective for this site-type should be to prevent erosion and to improve appearance. Grass-legume cover would provide some forage for wildlife but these areas would be of greater aesthetic and wildlife value if shrubs were established. Shrubs are also more effective in preventing sloughing. The use of shrubs for reclamation is discussed in section 6.5.8. On areas of this site-type grasses and legumes should be etablished initially; if shrubs are to be planted subsequently and the density of microsites is high, seeding rates should be less than those recommended for site-types where permanent grass-legume cover is to be established (section 6.5.2).

6.5.7 High elevation, sloping, sheltered overburden/rock

a) Again, no reclamation trials established above 1500m are reported from the Highland Valley.

b) Research on species selection of high elevation areas is discussed in section 6.5.3.

c) The reclamation objectives and possible techniques for this site-type are the same as those for the low elevation, sloping, sheltered overburden/rock site-type, but it may be necessary to use some of the grass and legume species recommended for high elevation areas in Table 10.

6.5.8 Low elevation, sloping, exposed overburden/rock

a) Results of assessment of trials A3 and A4 illustrate the problems of reclaiming areas of this site-type. It is not known if the sparse cover established so far is able to persist without maintenance fertilization. Bethlehem have described the problems caused by wind erosion of seed. They achieved "satisfactory" results on an area of this site-type when a hydroseeder and a peat moss mulch were used (Bethlehem Copper Corporation, 1979). The plot has apparently been buried.

b) Grass and legume cover has been established on steep slopes subject to strong winds using a hydroseed slurry containing seed, fertilizer and a soil binder in areas of heavy rainfall (Carr and Marchant, undated). Research on the use of mulches, and soil stabilizers was discussed above (see section 6.5.4). Little research has been done on the problems of reclaiming steep, exposed slopes in semi-arid areas.

c) The reclamation objectives for this site-type is to establish cover (the same as that for low elevation, sloping, sheltered overburden/rock (section 6.5.6)). Because of the exposure, (and consequently less snow cover) these areas might be valuable for wildlife in winter. Grasses prevent surface erosion but deep-rooted plants are required to prevent sloughing. The feasibility of using shrubs for this site-type should be investigated. By planting rooted shrub cuttings, the problems of wind erosion, germination failure and mortalty of very young seedlings (caused by rapid drying of surface materials) would be avoided. Woody cuttings would be better able to withstand the high surface temperatures which develop on areas of this site-type. Shrubs with a prostrate growth-habit, such as bearberry, will reduce evaporation of moisture from the disturbed materials; this should promote decomposition of the detritus they produce.

Many research projects involving shrub propagation and use are currently in progress. Table 11 gives some of the species worthy of investigation; many others, for example from semi-arid regions of the United States, could also be tested. It may prove necessary to use shrubs propagated from local stock to ensure persitence; this is particularly important for those areas far from sources of invading tree and shrub species. (Those adjacent to existing forest will eventually become forested).

The desirability and feasibilty of establishing grass-legume cover before, concurrently with, or after the shrubs should be investigated. The cost-effectiveness of mulches and shelter fences should also be evaluated.

6.5.9 High elevation, sloping, exposed overburden/rock

a) No reclamation trials have been established on areas of this site-type.

b) Research on species selection for high elevation areas is dicussed in section 6.5.3.

c) Again the reclamation objective should be erosion control and improved appearance (and possibly wildlife use). The need for research into species selection and reclamation techniques was discussed in sections 6.5.3 and 6.5.8.

6.5.10 Low elevation, undulating, sheltered raw till

e by Lornex and, in 1981, by Highmont. (Lornex Mining Corpor One example of this site-type was assessed (A11); under grazing conditions a grass-legume cover has been established. Fertilizer records for this trial were not available. It is not known if this cover would be able to persist without maintenance fertilization.

b) Ziemkiewicz's (1979) study of the development of self-sustaining reclamation plant communities is relevant to the problems of this site-type (section 6.5.2).

c) Most areas of this site-type are small and isolated. They would be valuable for wildlife grazing and browsing. Grasses and legumes should be established; planting of shrubs favoured by wildlife (Table 11) would create a better habitat than one which resulted from natural invasion of shrubs growing close to the disturbed area. The persistence of grass-legume cover on areas of this site-type will be less important if grasses and herbs invade from the adjacent forest communities. (Some areas of this site-type should be retained as access routes for recreation and fire control).

Extensive areas of this site-type are suitable for use as range. Again, grasses and legumes should be seeded; harrowing and packing, where possible, would be advantageous. Because of the coarse texture, establishment of adequate ground cover on raw till will be more difficult and take longer than on overburden/rock and compacted rock. On all raw till areas it may be necessary to apply fertilizer in the fall as well as in the spring to counteract the losses that are likely to occur as a result of coarse texture and low colloidal content. However, fertilizer should only be applied if fall rains accur. Self-sustaining reclamation communities must be developed on extensive areas. Grasses that develop a dense turf, e.g. the fescues and bluegrasses, should be favoured in the mix.

6.5.11 High elevation, undulating, sheltered raw till

a) Some reclamation work has been done recently on areas of this site-type (Lornex Mining Corporation, 1971; Highmont Operating Corporation, 1981) but there is no evidence that a method of establishing permanent vegetative cover has been developed.

b) Trials of grass and legume species at high elevations are relevant (see table 10).

c) Areas of this site-type are generally small, e.g.pipelines, exploration areas and borrow pits. They would be suitable, at least in the early stages of reclamation, for wildlife grazing (in summer) and browsing. A grass-legume mix should be seeded initially; a patchy cover would likely develop because of the temperature and moisture conditions. This would permit the invasion of native trees and shrubs from surrounding natural areas. Establishment of too dense a ground cover (for instance in shaded areas) should be prevented by modifying the seeding and fertilizing rates. Some areas may be kept clear for access.

6.5.12 <u>Low elevation, undulating, exposed raw till</u>

a) No reclamation trials have been established on areas of this site-type. Some operational reclamation work was carried out in 1981 (Lornex Mining Corporation,1981; Highmont Operating Corporation, 1981).

b) Methods for the reduction of erosion are discussed in section 6.5.3.

c) Range is the most suitable land-use objective for areas of this site-type. Because they are generally extensive, wildlife use would be restricted to the peripheries. Grass-legume cover should be established (see section 6.5.10); mechanical site preparation, if not prevented by the high content of coarse particles, would aid establishment.

6.5.13 <u>High elevation, undulating, exposed raw till</u>

a) No reclamation trials have been established in areas of this site-type.

b) Again, trials of grass and legume species at high elevation are relevant (Table 10)

c) Areas of this site-type, which are generally extensive, are suitable for return to forest cover. Techniques similar to those recommended for the high elevation, flat, exposed overburden/rock site-type should be used (section 6.5.5).

Table 10. Some recommended grass and legume species for the Highland Valley

	GRASSES FOR LOW ELEVATION AREAS	GRASSES FOR HIGH ELEVATION AREAS	LEGUMES FOR LOW ELEVATION AREAS	LEGUMES FOR HIGH ELEVATION AREAS
TESTED AND PROVEN SUCCESSFUL IN HIGHLAND VALLEY	crested wheatgrass red fescue tall fescue smooth brome		yellow sweet clover alfalfa	
RECOMMENDED FOR MORE TESTING AND EVALUATION	Canada bluegrass meadow foxtail timothy		sainfoin	
RECOMMENDED FOR TESTING. PROVEN SUCCESSFUL UNDER CONDITIONS SIMILAR TO THOSE IN THE HIGHLAND VALLEY		"Manchar" smoothbrome red fescue timothy Canada bluegrass perennial ryegrass*' bluebunch wheatgrass meadow foxtail + native species		alfalfa* red clover sainfoin + native species

* winter hardy species
' may not be readily available in Canada

<u>Sources</u>: Hubbard and Bell, 1977
Watson et al., 1980
and others.

Table 11. Some recommended shrub and tree species for the Highland Valley.

	SHRUBS/TREES VALUABLE BECAUSE OF N-FIXING ABILITY	SHRUBS/TREES VALUABLE FOR WILDLIFE BROWSE	OTHER SHRUBS WITH POTENTIAL FOR RECLAMATION
NATIVE TO HIGHLAND VALLEY	*Alnus* spp. *Shepherdia canadensis*	*Populus tremuloides* *Betula* spp. *Salix* spp. *Rosa* spp. *Vaccinium* spp.	*Arctostaphylos uva-ursi* *Amelanchier* spp. *Cornus stolonifera* *Juniperus communis* *Picea* spp. *Pinus contorta* *Spiraea* spp. *Lonicera involucrata*
NON-NATIVE BUT PROVEN SUCCESSFUL UNDER CONDITIONS SIMILAR TO THOSE IN THE HIGHLAND VALLEY	*Ceanothus* spp.*	*Symphoricarpus alba*	

* may not tolerate high pH

Sources: Watson et al., 1980
Van Drimmelen, 1979
Carr and Marchant, undated.

6.6 Compilation of land-use plan

Proposed land-uses for the Highland Valley are shown in Plan 2. The plan is based upon the predicted distribution of reclamation site-types shown in Plan 1.

For individual areas of each reclamation site-type, one or two land-uses have been selected according to the rationale decribed in section 6.5, and so as to incorporate the land-use objectives of the mining companies (section 6.4). Land-uses for natural vegetation communities (discussed in section 6.3) are also shown. Where two land-uses are equally appropriate for an area, e.g. range or hay production, they are shown as alternatives. Selection of one of the alternatives will depend on cost and demand factors not considered in this study. In some areas, two or more land-uses may be possible at the same time or at different times in each year e.g. range and wildlife. These are shown on the plan as mutually compatible land-uses.

Areas which have potential for recreation (as opposed to those with known recreational value, such as Bose Lake) have not been indicated on the plan. Hunting is a recreational activity which cannot be associated with any particular reclamation site-type or natural vegetation community. Hunting will probably be important within those wildlife areas adjacent to forest cover, remote from the highway and yet accessible by vehicles. However, much will depend on the pattern of wildlife use that develops in the Highland Valley when mining operations cease. Areas which are to be used for camping should be selected after consultation between the mining companies, ranchers, and, possibly, members of the Ministries of Forests, Environment and Lands, Parks and Housing. The success of establishing fishing and/or boating facilities on the lakes will influence the selection. Recreational use of newly-constructed lakes has not been indicated on the plan because there is so little information on this subject. Horseback-riding is a recreational activity which cannot be associated with any particular reclamation site-type or natural vegetation community. It will probably be mutually compatible with range, wildlife and small forest areas in the valley bottom and on the lower valley slopes.

The plan shows the proposed use of disturbed areas 20 years after operational reclamation takes place. Because the timing of mining operations is very unpredictable, differences in the nature and degree of use of areas undergoing transition from one land-use to another are not shown. Such differences, which would be caused by differences in the timing of the reclamation operations, should be taken into account when interpreting the plan.

Site preparation assocated with the planned Valley Copper mine began in spring 1982. The mine has an anticipated life of 20 years (Valley Copper Mines,1980). If it is assumed that start-up takes place in 1984 and that the other 3 mines will be mined-out in less than 20 years, all the land-uses for the Highland Valley proposed in Plan 2 could be achieved by the year 2024. However, any changes in the economy could shorten or lengthen the duration of mining activities.

In making the land-use plan, it is assumed that the distribution of all natural vegetation communities except the open forest/grassland communities will not change between now and 20 years after operational reclamation takes place. This assumption may not be valid but no information on successional trends in the Highland Valley is available. It is assumed that the open forest/grassland communities created by logging will be fully restocked and regain their value for forestry use.

It is assumed that the Lornex open pit will be filled with water to the maximum level possible given the configuration of the pit walls, and that flooding of both the Lornex and Valley Copper pits will be completed 20 years after operational reclamation takes place. Since knowledge of the potential of open pits to become lakes is lacking these assumptions are questionable. No predictions regarding the future use of the Highmont pit have been made in Plan 2.

Access roads which should not be reclaimed in order to enable certain land-uses are shown in the plan.

7.. Conclusions

7.1. Evaluation of reclamation programme

So far, operational reclamation in the Highland Valley has been carried out in small areas only. This is, to a large extent, a result of the nature of the mining operations.

Reclamation research undertaken by Bethlehem and Lornex has been in the form of species trials and test plots. These have not been located in sites which represent the full range of environmental conditions that will be encountered in the course of operational reclamation. Assessment of trials and test plots has tended to be short-term in nature; this is probably a consequence of the high turnover rate of reclamation personnel, the destruction of research sites by mining activities and, most noticeably, a failure to define and document clearly the objectives of each series of species trials or test plots. Hence, the research programmes are not producing as much information as they could.

Considerable progress has been made by Bethlehem and Lornex in developing techniques for the reclamation of areas of the low elevation flat and sloping sheltered site-types. These areas could now be used to extend reclamation research into the topics recommended below; Lornex's experiences with methods of seeding slopes will be particularly valuable.

The seeding of high elevation areas undertaken recently by Lornex and Highmont will, if adequately assessed, contribute to the solution of the problems posed by these areas. Accidental destruction of the tailings reclamation test plot was very unfortunate; the technique was well suited to the problem.

Evaluation of the long-term success of the shrub and tree planting programme initiated by Bethlehem has been prevented by destruction of the site, but the preliminary results have been informative.

Opportunities to reclaim land for wildlife, grazing and recreational use are acknowledged by the mining companies but, with the exception of Bethlehem, land-use objectives are not explicit. By considering the suitability of different areas of disturbance for different land-uses, the reclamation programmes could be made more successful, less costly and more valuable to other land-users.

Although the restoration of disturbed land to a state similar to that which existed prior to mining is intrinsically appealing, such an objective is not always feasible, can be very costly and should not exclude opportunities to improve land-use in the area.

7.2. Recommendations for further research

1) The surface area of tailings in the Highland Valley will be almost 2000ha when mining ceases. An intensive research programme should start immediately to ensure that 2000ha of unproductive or toxic land will not be created. This programme should incorporate weathering studies, fertilizer trials and vegetation analysis. (Weathering studies and vegetation analysis have been recommended previously by Dept. of Soil Science (1976-

77)). Methods of site preparation and sources of organic matter should also be investigated. The cost-effectiveness of organic matter amendments and green manures should be compared (section 6.5.1).

2) The ability of already-established grass and legume cover to persist without maintenance fertilization will be crucial to the long-term success of reclamation in the Highland Valley. Research into this topic could span 10 or more years, but once the optimum length of the fertilization programme is known, the programme will be applicable to areas of many different site-types. It is particularly important to know when grass-legume communities become suitable for grazing use. An already proven method of developing self-sustaining cover will serve to shorten the interval between cessation of mining activity and repayment of the reclamation bond.

3) The use of shrubs for reclamation is an important topic for research in the Highland Valley. It is likely that they will aid the reclamation of areas of the low and high elevation, sloping, exposed overburden/rock site-types. They will provide forage for wildlife, improve slope stability and improve the appearance of the landscape. They could also improve the reclamation of low and high elevation, sloping, sheltered overburden/rock, high elevation, flat sheltered overburden/rock and low elevation, undulating, sheltered raw till areas. Competition between ground cover and shrubs may be a problem; this and methods for its reduction, should also be considered (sections 6.5.3, 5, 6, 7, 8 and 10 and Table 11). Site preparation will be an important factor in the reclamation of

all exposed areas (section 6.5.4, 5, 8 and 9). Methods of creating microsites to aid grass, legume, shrub and tree establishment should be investigated. Only if such methods are unsuccessful should the use of expensive mulches be considered.

4) In conjunction with evaluation of seeding already undertaken by Lornex and Highmont, a research project to identify grass and legume species suitable for use in all high elevation areas should be started (Table 10).

5) Different rock types throughout the Highland Valley should be sampled and, if necessary, mapped to identify areas where overburden will be most needed. Selective dumping may reduce the demand for the limited quantities of overburden available.

6) The mining companies share many of the reclamation problems in the Highland Valley. A coordinated, cooperative approach to reclamation research would prevent unnecessary and costly duplication of reclamation projects. A few, well-planned, carefully-located cooperative projects would provide information that is needed by all the companies. To ensure that compatible land-uses are proposed for different areas, each company should consult with the others before developing its reclamation plan.

7) The demand for range and/or irrigated hay production, access for fire control, temporary increases in wildlife forage, hunting access routes, camping sites and fishing facilities will be significant factors in determining land-use objectives for reclamation. Consultation with local interest groups, as required by the Mining Regulation Act (1979), must accompany all research and operational reclamation.

7.3. Land-use changes resulting from mining and reclamation

If the reclamation techniques and land-use objectives recommended in section 6.5. are adopted, significant changes in land-use in the Highland Valley will result. Table 12 shows the amount of land available for each land-use in 1970 and the amount of new land that will be made available after reclamation. (Recreation and mutually compatible wildlife use are not shown for the reasons discussed in section 6.6.) Table 13 shows the amount occurring on each mine property.

In Table 12, comparison is made with the situation in 1970 using the results of the vegetation survey of the Highland Valley by B.C. Research (1971a). The northwest-southeast boundaries of the survey coincide almost exactly with those of this study. Since the portion of the area of this study not covered by B.C. Research is largely forested, with some lakes and aspen meadows, only minor inaccuracies result from adjusting the figures to make the survey area and study area comparable. Descriptions by B.C.Research suggest that their "open forest and grassland, and grassland communities" were usable for range and that their "valley bottom meadows and grassland and willow communities" were useful only for wildlife. The rest of the survey area was apparently forested. No mention is made of communities equivalent to the aspen meadow community-type described in this study.

The greatest change could be in the amount of land made available for range. If toxicity is not a problem, 2507ha of new range land could be provided by reclamation. A further 1794ha could be used for range or hay production and an additional 251ha could be used for range or wildlife, depending on demand. In 1970, 202ha of rangeland was available; only 93ha of this will remain after mining operations cease.

In 1971 forest, with some lakes and aspen meadows, covered 24830ha of the study area. Mining has removed 6737ha of this. Reclamation could provide 495ha of newly planted forest land and a further 291ha would be created by the gradual invasion of areas initially more valuable for wildlife. Natural invasion of areas reclaimed to provide cover could eventually add a maximum of 449ha of steep-sloping sites to the total forest area.

Areas providing cover, with little potential for any other use (except possibly wildlife grazing) will account for 486ha of the reclaimed area. No areas similar to this existed before mining.

Forty-six hectares of land of long-term value for wildlife could be made available as a result of reclamation. Approximately half of this will result from the prevention of forest invasion on hydro rights-of-way. A further 291ha will be available during the early stages of succession on reclaimed areas (approximately 20 years) and 251ha could be used for range or wildlife. Estimation of the total area available for wildlife in 1971 is difficult. Four hundred and four hectares were available in the valley bottom; 266ha of this will remain after mining ceases but may never be fully used because of disturbance by the highway. The 24830ha of forest, including lakes and aspen meadows, must have included areas valuable to wildlife for food or cover. Since 6737ha have been removed, reclamation will

Table 12. Pre- and post-mining land-uses in the Highland Valley

	1970			FINAL			
LAND - USE	area (ha)	% of total area	remaining area (ha)	new area (ha)	total (ha)	% of total area	net change (ha)
Range	201.9	0.8	93.0	2507.2	2600.2	10.2	+2398.3
Range/Wildlife	-	-	-	251.0	251.0	1.0	+ 251.0
Range/Hay	-	-	-	1794.0	1794.0	7.0	+1794.0
Total Range	201.9	0.8	93.0	4552.2	4645.2	18.2	+4443.3
Forestry	24830.2	96.9	18191.7	494.6* 291.0' 449.4' 1235.0	19426.7	75.8	-5403.5
Wildlife	404.3 +?	1.6	266.4 usable?	46.4	312.8	1.2	- 91.5?
Cover	-	-	-	486.0	486.0	1.9	+ 486.0
Lakes	162.8	0.6	64.5	403.6	468.1	1.8	+ 305.3
Pits@	?	?	?	261.2	?	?	+ 261.2
Total	25600.0				25600.0		

* immediate reforestation

' natural reforestation of wildlife areas

' natural reforestation of cover areas

@ Bethlehem pits

Table 13. Amounts of potential new land on each mine property

LAND-USE	Bethlehem	Lornex	Highmont	Valley Copper	Lornex & Valley	B.C. HYDRO	TOTAL
Range	570.4	616.4	-	1217.6	102.8	-	2507.2
Range/Wildlife	-	14.6	213.4	-	-	23.0	251.0
Range/Hay	-	11.0	-	-	1783.0	-	1794.0
Forestry	107.4	387.2	-	-	-	-	494.6
Wildlife Forestry	-	266.6	24.4	-	-	-	291.0
Cover Forestry	84.2	125.0	177.8	36.0	26.4	-	449.4
Wildlife	-	21.2	-	-	-	25.2	46.4
Cover	196.4	236.8	1.4	21.8	9.0	20.6	486.0
Lake	-	52.0	-	351.6	-	-	403.6
Pit	122.6	-	138.6	-	-	-	261.2
Total	1081.0	1730.8	555.6	1627.0	1921.2	68.8	6984.4

probably not result in a net long-term increase in land of value to wildlife. There is therefore a danger that during the early stages of succession of reclaimed areas, an abundance of forage will increase wildlife populations to levels that will not be sustainable on a long-term basis. It may therefore become necessary to reduce numbers of wildlife in the Highland Valley or to allow greater wildlife use of range areas.

New lakes and pits will account for 404ha and 261ha of reclaimed areas respectively.

7.4. Summary conclusions

While some progress in developing reclamation techniques has been made, many potential problems have not yet been approached. This study, using a classification scheme, field observations and a review of reclamation research, has identified steep topography, exposure and the peculiar characteristics of tailings as the principal barriers to reclamation. Research should therefore be directed towards the problems caused by these factors.

The potential impact of reclamation on land-use in the Highland Valley is large. Steps should be taken now to ensure that the impact will be beneficial, with particular attention being given to range and wildlife use of the area.

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APPENDIX I

Climatic data

9217NW HIGHLAND VALLEY BCCL 1123468

Y MO	MONTHLY TOTAL PRECIPITATION (MM) MANUAL OBSERV	RECORDING GAUGE	DAYS WITH PRECIP	DAYS MISSED	ACCUMULATED PRECIPITATION (MM) STORAGE GAUGE 1	2	INTERVAL	MONTHLY SNOWFALL (CM)	SNOW PACK DEPTH (CM)	COVER (%)	DATE
77 01	25.4		6	0				22.6	M		JAN31
77 02	9.0		4	0				9.0	M		FEB28
77 03	39.6		21	0				39.6	0		MAR31
77 04	6.2		5	0				5.4	M		APR30
77 05	32.4		8	0				2.5	0		MAY31
77 06	24.6		5	0				.0	0		JUN30
77 07	26.5		9	0				.0	0		JUL31
77 08	M		M	31				M	M		AUG31
77 09	M		M	19				.0	0		SEP30
77 10	16.7		8	0				.0	0		OCT31
77 11	83.6		12	0				59.0	M		NOV30
77 12	M		M	31				M	M		DEC31
ANNUAL	M		M	81				M			
78 01	48.0		8	0				48.0	M		JAN31
78 02	20.0		5	0				17.0	M		FEB28
78 03	14.5		5	0				11.0	M		MAR31
78 04	42.0*		9*	0				8.0*	M		APR30
78 05	19.8		6	0				1.5	M		MAY31
78 06	17.0*		3*	0				.0	0		JUN30
78 07	M		M	7				.0	0		JUL31
78 08	20.7		4	0				.0	0		AUG31
78 09	58.5		8	0				.0	0		SEP30
78 10	4.3		2	0				T	0		OCT31
78 11	2.6		2	0				2.6	M		NOV30
78 12	14.0*		7*	0				14.0*	M		DEC31
ANNUAL	M		M	7				102.1*			
79 01	18.6		6	0				18.6	M		JAN31
79 02	13.0		4	0				13.0	M		FEB28
79 03	5.0		2	0				5.0	M		MAR31
79 04	15.2		3	0				15.2	M		APR30
79 05	4.9		1	0				4.9	M		MAY31
79 06	14.0		4	0				.0	0		JUN30
79 07	9.5		4	0				T	0		JUL31
79 08	M		M	6				.0	0		AUG31
79 09	15.0		3	0				.0	0		SEP30
79 10	16.5*		3*	0				T	0		OCT31
79 11	M		M	30				.0	0		NOV30
79 12	24.0		3	0				24.0	M		DEC31
ANNUAL	M		M	36				80.7			

7217N# HIGHLAND VALLEY BCCL 1123468									DAYS BELOW MINIMUM					DEGREE DAYS		
Y MO	MEAN MAX	MEAN MIN	MONTHLY MEAN	EXTREME MAX	EXTREME MIN	MISSING MAX	MISSING MIN	0	-5	-10	-20	-30	ABOVE 5	BELOW 18	EFFECTIVE ABOVE 5
77 01	-1	-8	-4	7.8	-18.9	0	0	30	20	10	0	0	0	692	0
77 02	4	-3	0	8.3	-7.8	0	0	25	9	0	0	0	0	496	0
77 03	0	-7	-3	4.4	-12.2	0	0	31	25	3	0	0	0	661	0
77 04	10	0*	5*	23.9*	-6.7*	3	5	14*	7	0	0	0	64*	327*	17*
77 05	9	1	5	16.7	-3.3	0	0	10	0	0	0	0	38	396	6
77 06	17	7	12	25.0	1.7	0	0	0	0	0	0	0	217	176	84
77 07	18	7	13	27.8	2.2	0	0	0	0	0	0	0	242	170	102
77 08	M	M	M	M	M	31	31	M					M	M	M
77 09	M	M	M	10.6*	-1.1*	20	21	M					M	M	M
77 10	M	-2	M	12.5*	-9.5	13	0	21	7	0	0	0	M	M	M
77 11	3	-12	-5	11.5	-26.5	0	0	30	29	18	6	0	0	682	0
77 12	0	-17	-9	6.0	-33.0	0	0	31	31	26	11	1	0	822	0
ANNUAL	M	M	M	27.8*	-33.0*	67	57	M					M	M	M

LONGEST 1977 PERIOD WITH MINIMUM ABOVE: 0 M DAYS
-2 M DAYS
-4 M DAYS

PERIOD BETWEEN FIRST AND LAST OCCURENCES
OF FIVE CONSECUTIVE DAYS ALL WITH
MEAN TEMPERATURE ABOVE 5 IN 1977: M DAYS

DEGREE DAYS ABOVE 5 FOR SAME PERIOD: M

Y MO	MEAN MAX	MEAN MIN	MONTHLY MEAN	EXTREME MAX	EXTREME MIN	MISSING MAX	MISSING MIN	0	-5	-10	-20	-30	ABOVE 5	BELOW 18	EFFECTIVE ABOVE 5
78 01	-3*	M	M	4.5*	-29.5*	4	9	M	M	M	M	M	M	M	M
78 02	0	-7*	-4	8.5	-19.0*	0	0	26*	19*	9*	0*	0*	0	607	0
78 03	4	-5	-1	9.5	-15.0	0	0	26	16	4	0	0	0	577	0
78 04	7	-3	2	15.0	-10.0	0	0	25	8	2	0	0	21	472	4
78 05	10	-1	4	20.0	-10.0	0	0	20	12	1	0	0	43	424	11
78 06	18	7	13	27.0	-3.0	0	0	4	0	0	0	0	228	170	106
78 07	22	11	16	27.0	2.0	0	0	1	0	0	0	0	351	75	201
78 08	17	9	13	28.0	4.0	0	0	0	0	0	0	0	255	169	130
78 09	11	4	7	21.5	-5.0	0	0	3	1	0	0	0	80	319	16
78 10	10	1	5	17.5	-9.5	0	0	13	4	0	0	0	69	393	15
78 11	0	-9	-5	12.0	-23.5	0	0	27	25	14	2	0	5	675	1
78 12	-6	-16	-11	3.0	-35.0	0	0	31	31	30	6	3	0	901	0
ANNUAL	8	-2	3	28.0*	-35.0*	4	9	198*	133*	70*	12*	3*	1052*	5341*	484*

LONGEST 1978 PERIOD WITH MINIMUM ABOVE: 0 66 DAYS JUL 12 - SEP 15
-2 66 DAYS JUL 12 - SEP 15
-4 108 DAYS MAY 31 - SEP 15

PERIOD BETWEEN FIRST AND LAST OCCURENCES
OF FIVE CONSECUTIVE DAYS ALL WITH
MEAN TEMPERATURE ABOVE 5 IN 1978: 155 DAYS MAY 17 - OCT 19

DEGREE DAYS ABOVE FOR SAME PERIOD: 1017

Y MO	MEAN MAX	MEAN MIN	MONTHLY MEAN	EXTREME MAX	EXTREME MIN	MISSING MAX	MISSING MIN	0	-5	-10	-20	-30	ABOVE 5	BELOW 18	EFFECTIVE ABOVE 5
79 01	-8	-19	-13	1.5	-28.0	0	0	31	31	29	9	0	0	964	0
79 02	1	-11	-5	3.5	-23.0	0	0	28	23	17	2	0	0	650	0
79 03	5	-7	-1	14.0	-15.0	0	0	30	21	13	0	0	2	601	0
79 04	6	-7	0	18.0	-15.0	0	0	26	23	11	0	0	21	551	3
79 05	13	-2	6	25.0	-8.0	0	0	22	13	0	0	0	60	387	15
79 06	16	3	10	24.0	-5.0	0	0	8	2	0	0	0	146	254	48
79 07	21	8	15	30.0	5.0	0	0	3	1	0	0	0	304	131	164
79 08	20	9	15	25.0	4.0	0	0	0	0	0	0	0	299	107	131
79 09	16	4	10	24.0	-4.0	0	0	1	0	0	0	0	159	234	50
79 10	11	-2	4	21.0	-8.0	0	0	19	11	0	0	0	71	421	15
79 11	2	-9	-4	9.0	-16.0	0	0	29	26	16	0	0	0	655	0
79 12	-1	-13	-7*	5.0*	-32.0*	2	3	28*	28*	19*	2*	2*	0*	678*	0*

1175W HIGHLAND VALLEY LORNEX 1123469

Y MO	MEAN MAX	MEAN MIN	MONTHLY MEAN	EXTREME MAX	EXTREME MIN	MISSING MAX	MISSING MIN	DAYS BELOW MINIMUM 0	-5	-10	-20	-30	DEGREE DAYS ABOVE 5	BELOW 18	EFFECTIVE ABOVE 5
77 01	-1	-12	-7	8.9	-21.7	0	0	31	30	21	1	0	0	762	0
77 02	5	-6	-1	10.6	-13.9	0	0	28	17	8	0	0	0	529	0
77 03	3	-7	-2	6.1	-14.4	0	0	30	24	9	0	0	0	634	0
77 04	12	-1	6	26.1	-9.4	0	0	18	10	0	0	0	88	374	26
77 05	11	-1	5	16.1	-5.0	0	0	16	2	0	0	0	32	401	3
77 06	18	5	12	27.2	.0	0	0	0	0	0	0	0	203	189	67
77 07	19	6	12	28.3	-.6	0	0	1	0	0	0	0	232	178	91
77 08	22	8	15	30.6	1.1	0	0	0	0	0	0	0	318	103	166
77 09	13	0	7	21.1	-5.0	0	0	11	1	0	0	0	57	343	8
77 10	10	-3	3	16.1	-7.2	0	0	29	10	0	0	0	14	461	2
77 11	0	-8	-4	9.0	-20.0	0	0	28	19	8	0	0	0	662	0
77 12	-6	-14	-10	5.0	-29.0	0	0	31	27	23	5	0	0	867	0
ANNUAL	9	-3	3	30.6	-29.0	0	0	223	140	69	6	0	944	5503	363

LONGEST 1977 PERIOD WITH MINIMUM ABOVE: 0 50 DAYS JUL 20 - SEP 07
-2 116 DAYS MAY 29 - SEP 21
-4 117 DAYS MAY 28 - SEP 21

PERIOD BETWEEN FIRST AND LAST OCCURENCES
OF FIVE CONSECUTIVE DAYS ALL WITH
MEAN TEMPERATURE ABOVE 5 IN 1977: 171 DAYS APR 03 - SEP 21

DEGREE DAYS ABOVE 5 FOR SAME PERIOD: 929

Y MO	MEAN MAX	MEAN MIN	MONTHLY MEAN	EXTREME MAX	EXTREME MIN	MISSING MAX	MISSING MIN	DAYS BELOW MINIMUM 0	-5	-10	-20	-30	DEGREE DAYS ABOVE 5	BELOW 18	EFFECTIVE ABOVE 5
78 01	-4	-11	-8	4.5	-28.0	0	0	31	24	13	6	0	0	793	0
78 02	1	-10	-4	10.5	-20.0	0	0	28	21	16	0	0	0	625	0
78 03	5	-5	0	12.5	-16.0	0	0	24	15	4	0	0	1	548	0
78 04	8	-2	3	17.5	-5.5	0	0	23	3	0	0	0	17	442	2
78 05	12	0	6	22.0	-5.0	0	0	10	1	0	0	0	62	364	10
78 06	20	7	13	28.5	-1.0	0	0	1	0	0	0	0	247	145	94
78 07	23	9	16	28.5	5.0	0	0	0	0	0	0	0	340	72	168
78 08	19	8	13	29.0	1.5	0	0	0	0	0	0	0	260	154	113
78 09	14	2	8	22.5	-1.5	0	0	5	0	0	0	0	90	301	13
78 10	12	-2	5	19.0	-7.5	0	0	19	4	0	0	0	46	404	5
78 11	0	-10	-5	14.5	-27.0	0	0	24	21	17	4	0	5	682	1
78 12	-5	-14	-9	4.5	-33.0	0	0	31	30	21	5	4	0	849	0
ANNUAL	9	-2	3	29.0	-33.0	0	0	196	119	71	15	4	1068	5379	406

LONGEST 1978 PERIOD WITH MINIMUM ABOVE: 0 84 DAYS JUN 15 - SEP 06
-2 129 DAYS MAY 25 - SEP 30
-4 141 DAYS MAY 24 - OCT 11

PERIOD BETWEEN FIRST AND LAST OCCURENCES
OF FIVE CONSECUTIVE DAYS ALL WITH
MEAN TEMPERATURE ABOVE 5 IN 1978: 179 DAYS APR 24 - OCT 20

DEGREE DAYS ABOVE 5 FOR SAME PERIOD: 1057

Y MO	MEAN MAX	MEAN MIN	MONTHLY MEAN	EXTREME MAX	EXTREME MIN	MISSING MAX	MISSING MIN	DAYS BELOW MINIMUM 0	-5	-10	-20	-30	DEGREE DAYS ABOVE 5	BELOW 18	EFFECTIVE ABOVE 5
79 01	-9	-20	-14	4.0	-31.0	0	0	31	31	31	13	1	0	997	0
79 02	0	-12	-6	5.5	-24.0	0	0	28	27	16	3	0	0	678	0
79 03	7	-5	1	16.5	-15.5	0	0	28	17	3	0	0	4	540	0
79 04	9	-4	3	20.5	-11.0	0	0	25	8	1	0	0	28	463	4
79 05	14	1	8	22.0	-3.0	0	0	13	0	0	0	0	89	322	18
79 06	18	4	11	26.5	-1.5	0	0	1	0	0	0	0	190	200	61
79 07	23	8	16	31.0	3.5	0	0	0	0	0	0	0	331	88	160
79 08	22	8	15	27.0	6.0	0	0	0	0	0	0	0	315	89	135
79 09	18	4	11	25.0	.0	0	0	0	0	0	0	0	176	214	44
79 10	12	0	6	22.0	-6.0	0	0	10	1	0	0	0	67	379	12
79 11	3	-8	-3	11.5	-15.0	0	0	30	27	7	0	0	0	616	0
79 12	2	-9	-4	7.0	-28.5	0	0	28	20	14	1	0	0	669	0
ANNUAL	10	-3	4	31.0	-31.0	0	0	194	131	72	17	1	1200	5255	434

921/SW HIGHLAND VALLEY LORNEX 1123469

Y MO	MONTHLY TOTAL PRECIPITATION (MM) MANUAL OBSERV	RECORDING GAUGE	DAYS WITH PRECIP	DAYS MISSED	ACCUMULATED PRECIPITATION (MM) STORAGE GAUGE 1	2	INTERVAL	MONTHLY SNOWFALL (CM)	SNOW PACK DEPTH (CM)	COVER (%)	DATE
79 01	73.2		8	0				73.2	M		JAN31
79 02	10.8		5	0				10.8	M		FEB28
79 03	15.2		3	0				15.2	M		MAR31
79 04	46.3		10	0				13.9	M		APR30
79 05	36.8		10	0				11.4	M		MAY31
79 06	11.6		2	0				.0	0		JUN30
79 07	24.2		6	0				.0	0		JUL31
79 08	45.4		12	0				.0	0		AUG31
79 09	35.5		10	0				.0	0		SEP30
79 10	62.7		7	0				60.7*	M		OCT31
79 11	6.9		4	0				6.9	M		NOV30
79 12	24.2		6	0				24.2	M		DEC31
ANNUAL	392.8		83	0				216.3*			

APPENDIX 11

Theory and operation of psychrometers

Thermocouple psychrometers measure the relative humidity of the environment in which they are placed. Relative humidity is linearly related to water potential in the range of 0 to approximately -50bars (Wescor, undated). Water potential in soils is the measure of the difference between the free energy of pure water and the free energy of soil water. It has two components; matric potential and osmotic potential. Osmotic potential has little effect on soil moisture retention or on mass soil water movement. The relative humidity of the environment is therefore related to the soil matric potential. This potential is recorded as a negative value because it represents a difference between two water potentials and may be regarded as a tension force. Alternatively, the soil matric potential, expressed as a positive value, may be regarded as the energy required to extract water from the soil matrix (Brady, 1974).

Thermocouple psychrometers may be operated using the the psychrometricmethod or the dewpoint method. In this study a Wescor HR33T dewpoint microvoltmeter was used; this instrument allowed readings to be taken using both methods. In addition, soil temperatures could be measured also using the thermocouple.

With the psychrometric method, the junction is cooled to below the dew point so that water condenses on the junction. Upon discontinuing the current, the condensed water evaporates back into the atmosphere and this evaporation cools the junction. The temperature of the junction is measured electrically before cooling and during evaporation. The difference in temperature is a function of the relative humidity of the atmosphere; the relationship is typically 0.47uvolts/bar at 25° C. This value may corrected for ambient temperature which is measured at the same time.

With the dew point method, the junction is cooled so that it becomes wet. Its temperature is then below that of its surroundings and heat flows into it. A counter-current can be created to balance this low exactly and to maintain the dew point temperature. However, other heat transfer mechanisms as well as evaporation and condensation are also involved here. If, at the beginning of the measurement, a balanced condition is set up on a dry thermocouple, the current required to create a balanced condition on a wet thermocouple will be a function only of the amount of water on the junction. Each thermocouple therefore has a cooling coefficient which is set at the beginning of the measurement. The relationship between the current required to maintain the dew point temperature and the water potential is typically 0.75uvolts/bar at 25° C. Again, correction due to ambient temperature is required.

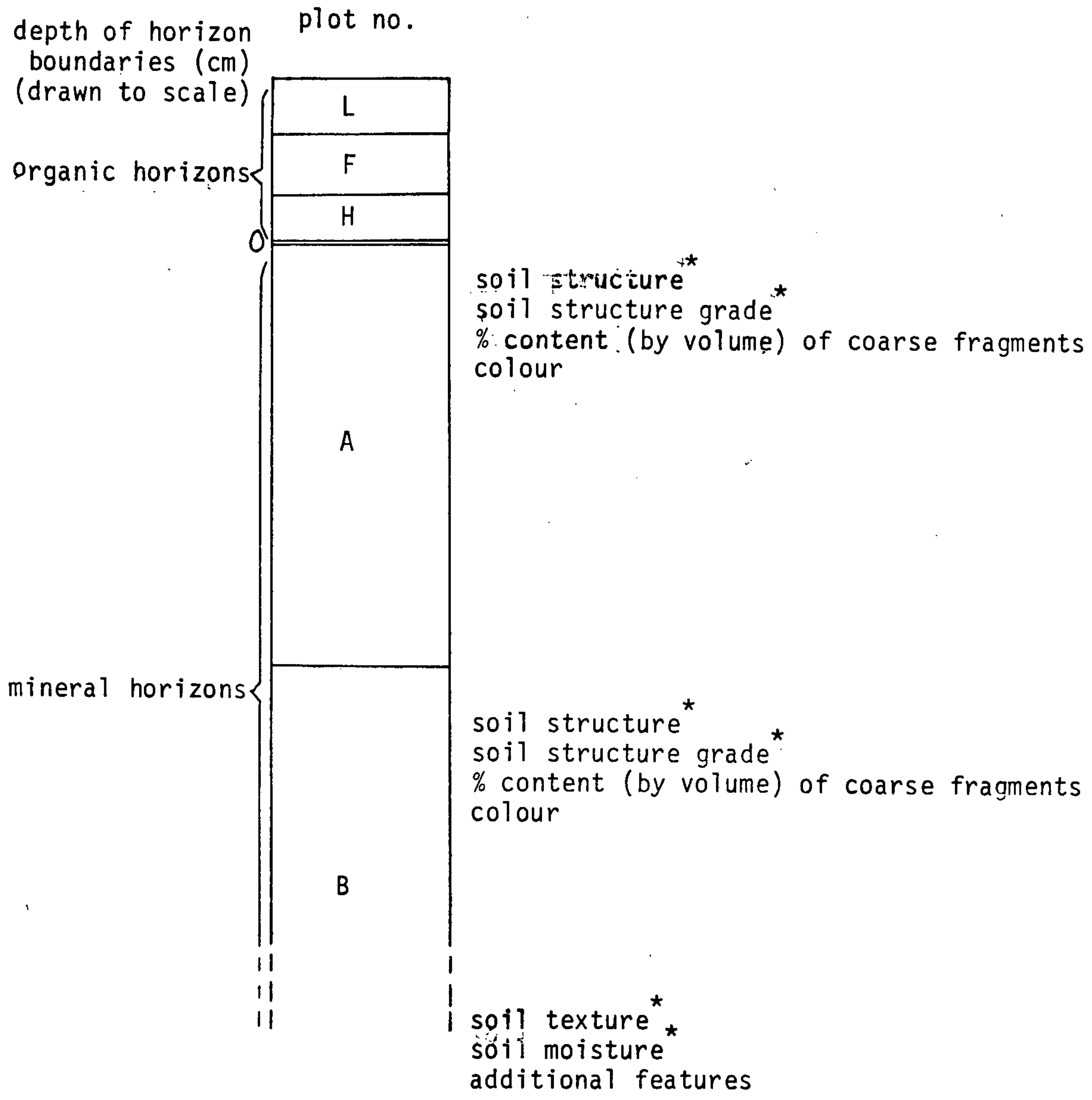
The dew point method is regarded as the more accurate of the two. In this study, measurements were made using both methods as a precaution against erroneous readings.

APPENDIX III

Species composition and soil profile diagrams for plots surveyed within each community-type.

(Species composition reported as percent cover in each layer; + = less than 5 percent)

KEY TO SOIL PROFILE DIAGRAMS



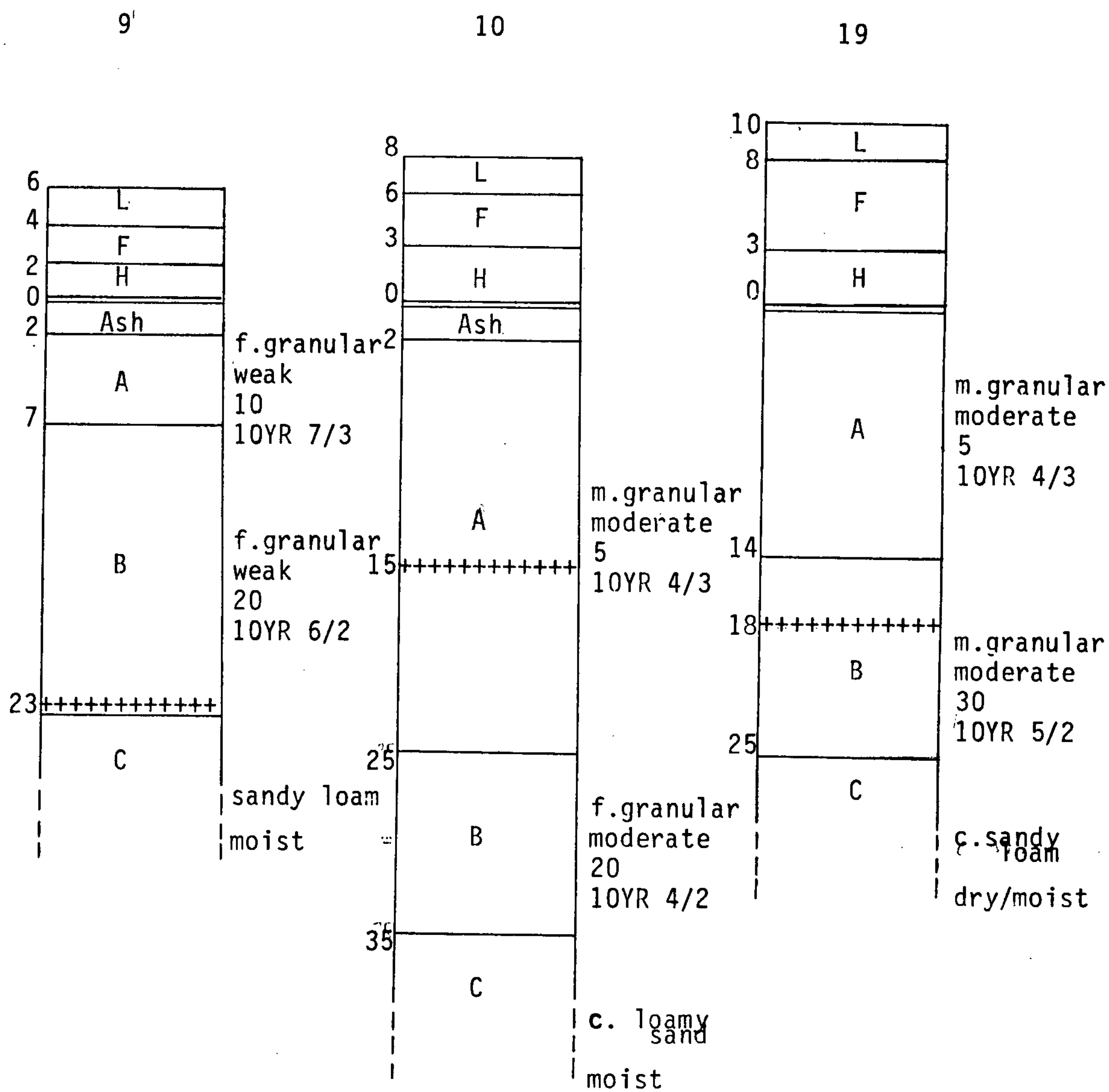
—— distinct horizon boundary
---- indistinct " "
++++ maximum depth of root penetration
\- feature not recorded
W.T. water table

* Classes according to Resource Analysis Branch (1980)

f.=very fine m=medium
f.=fine c.=coarse

LODGEPOLE PINE/SPRUCE COMMUNITIES

LAYER	SPECIES	PLOT NUMBER		
		09	10	19
upper tree	*Picea* sp.	10	05	15
	Pinus contorta	25	20	
	Pseudotsuga menziesii var. *glauca*	05	+	15
lower tree	*Picea spp*	05	05	10
	Pinus contorta	+	05	
	Pseudotsuga menziesii var. *glauca*	05		+
upper shrub	*Alnus incana*	15		10
	Pseudotsuga menziesii var. *glauca*	+	+	
	Rosa nutkana var. *nutkana*			+
	Salix sp.	+		
lower shrub	*Alnus incana*	05		
	Arctostaphylos uva-ursi		+	+
	Juniperus communis	+	+	
	Ledum sp.	+		
	Linnaea borealis		+	05
	Rosa sp.			+
	Spiraea betulifolia		05	05
	Vaccinium scoparium		10	
herb	*Spiraea betulifolia*	+		
	Vaccinium scoparium	+		
	Arnica cordifolia			+
	Calypso blubosa			+
	Goodyera oblongifolia			+
	Lupinus bicolor		+	
	Pryola minor			+
	Pyrola secunda		+	
	Calamagrostis rubescens		10	+
mosses		05	05	35
lichens		+	10	15
ground		40	30	20
stumps		30	30	05



Lodgepole pine/spruce communities

DOUGLAS-FIR/LODGEPOLE PINE COMMUNITIES

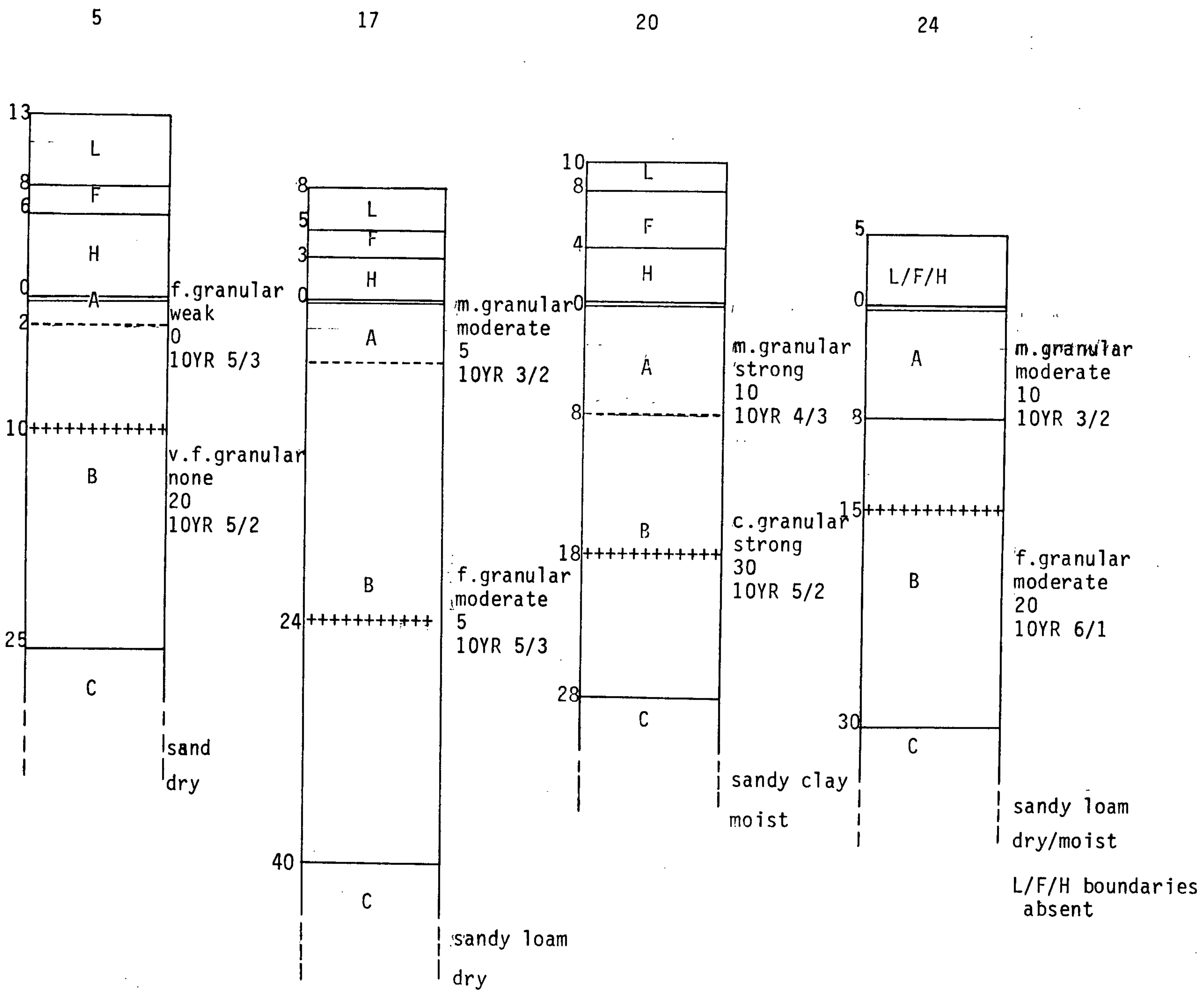
LAYER	SPECIES	PLOT NUMBER 05	17	20	24
upper tree	*Pseudotsuga menziesii* var. *glauca*	25	08	20	10
upper shrub	*Pinus contorta*	10	05	+	05
	Populus tremuloides		05		
	Pseudotsuga menziesii var. *glauca*	02	05	07	+
	Salix sp.		+		
upper shrub	*Pinus contorta*		+	+	
	Populus tremuloides		+		
	Pseudotsuga menziesii var. *glauca*	30	25	07	05
	Juniperus communis	+			
	Rosa nutkana var. *nutkana*			+	
	Salix sp.		+	+	+
	Shepherdia canadensis		10	10	+
lower shrub	*Arctostaphylos uva-ursi*	15	+	+	10
	Juniperus communis			+	
	Linnaea borealis	+	+	+	
	Rosa nutkana var. *nutkana*	+	+	05	
	Spiraea betulifolia	05			
	Vaccinium scoparium			10	
	Vaccinium sp.			+	
herb	*Achillia millefolium*		+	+	
	Anaphalis margaritacea	+	+		
	Antennaria alpina var. *media*	07			
	Antennaria neglecta var. *attenuata*	+			
	Arabidopsis thaliana		+		
	Arnica cordifolia	10	05	+	+
	Aster radulinus	10		+	
	Astragulus miser var. *decumbens*	+	10	05	
	Castilleja sp.		+		
	Chimaphila sp.			+	
	Epilobium sp.			+	
	Fragaria virginiana	+	+	+	
	Galium boreale	+	+		
	Gentiana amarella	+			

Gentiana propinqua +
Goodyera oblongifolia +
Lilium columbianum +
Oxytropis campestris +
Plantago sp. +
Pyrola sp. +
Sedum lanceolatum +
Stellaria sp. +
Taraxacum officinale +

Agrostis sp. +
Calamagrostis rubescens 70 80 30
30
Festuca scabrella +

mosses 07 05 30

lichens + + 15
rocks/ground 05 05
35
stumps 10 05 05
05



Douglas-fir/lodgepole pine communities

LODGEPOLE PINE COMMUNITIES

LAYER   SPECIES   PLOT NUMBER

01 04   08
23

upper tree   *Pinus contorta*   20 45   30

lower tree   *Picea* sp.   +
Pinus contorta   +
35
Pseudotsuga menziesii var. *glauca*   + 05

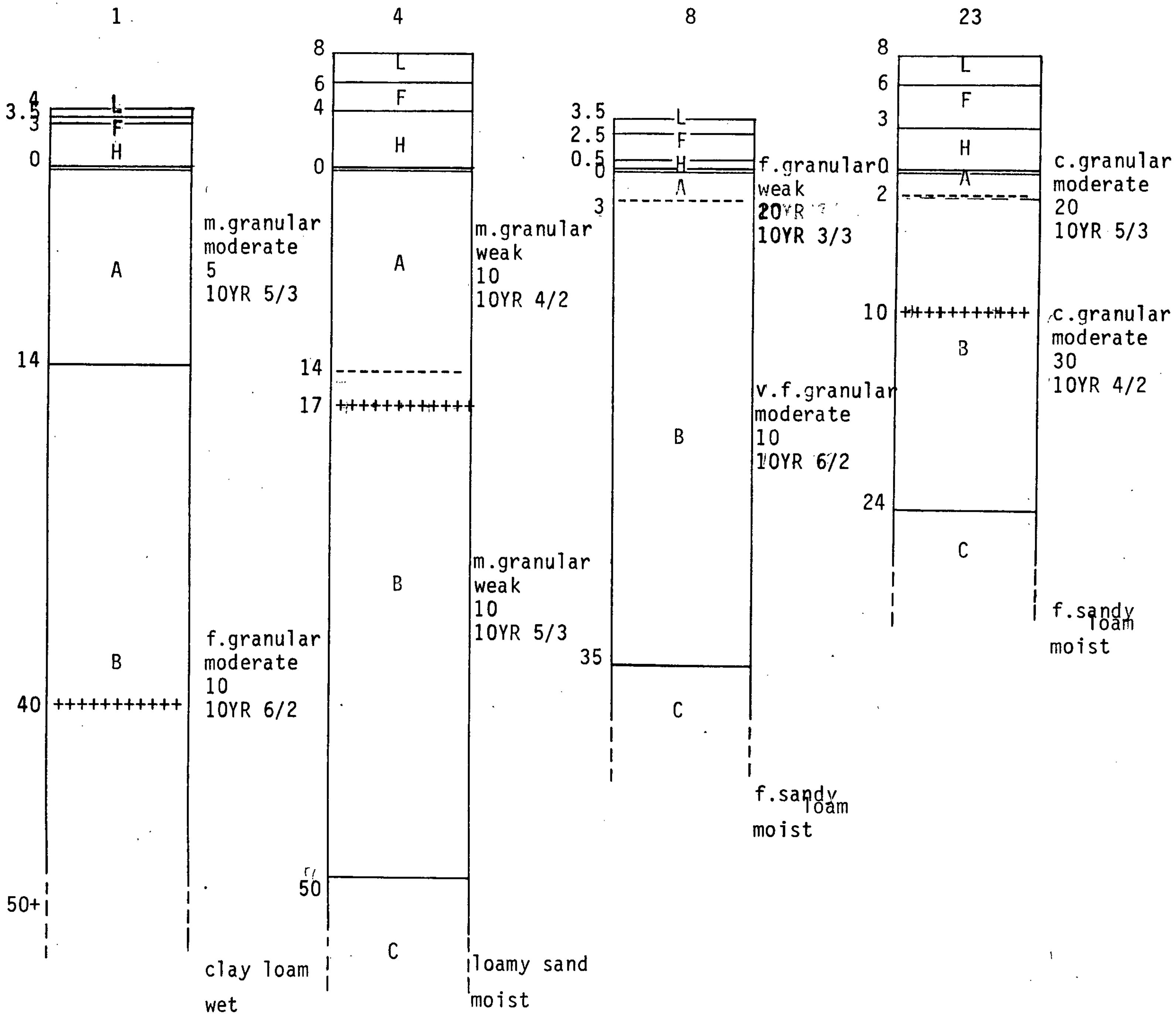
upper shrub *Pinus contorta*   +
+
Pseudotsuga menziesii var. *glauca*   +

Alnus sp.   +
Amelanchier sp.   +
Rosa nutkana var. *nutkana*   05
Rosa sp.   +
Salix sp.   +
Shepherdia canadensis   25   +   +
20
Spiraea betulifolia   +

lower shrub *Arctostaphylos uva-ursi*   40   15
Cornus stolonifera   +
Juniperus communis   10   +   +
+
Linnaea borealis   + 15
Rosa nutkana var. *nutkana*   05   +   05
Rosa sp. 10
Rosa woodsii   05   +
Spiraea betulifolia   05 10 10
Vaccinium scoparium   30 05   +
+

herb   *Achillea millefolium*   +
Arnica cordifolia   10 05   05
Astragalus miser var. *decumbens*   20
Calypso bulbosa   +
Coptis sp.   +
Daucus sp.   +
Epilobium sp.   +   +
Fragaria virginiana   +
Goodyera oblongifolia   +
Ledum sp.   +
Lilium sp.   +   +
Lupinus sp.   +
Pyrola chlorantha   +
Pyrola secunda   +
Pyrola sp.   +

Stellaria sp.		+			
Calamagrostis *rubescens*	60	50		35	40
Carex sp.	10				
mosses	10	10		+	+
lichens	20	05		+	05
rocks/ground		+	25		
stumps	10			05	10
unknown heather	05				



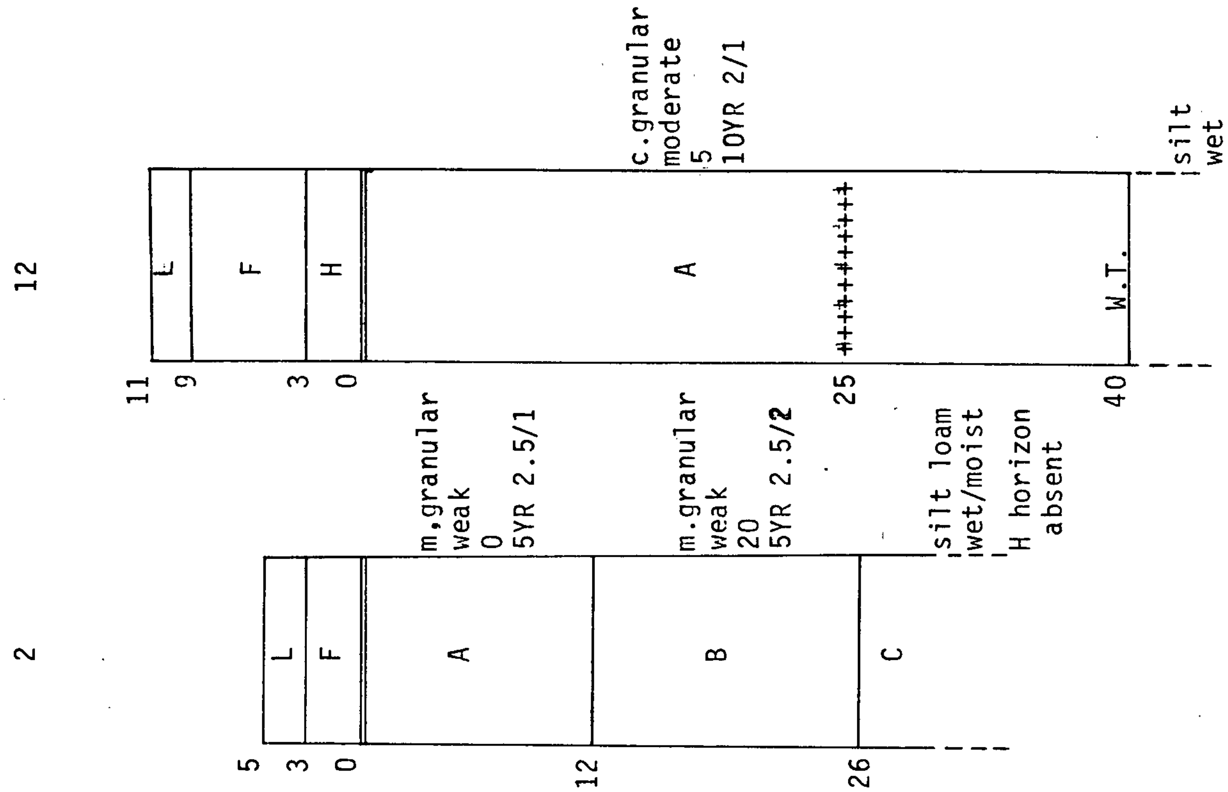
Lodgepole pine communities

SPRUCE/ALDER COMMUNITIES

LAYER	SPECIES	PLOT NUMBER 02	12
upper tree	*Picea* sp.	15	20
	Pinus contorta	20	
	Populus tremuloides		15
lower tree	*Alnus incana*	20	
	Picea sp.		10
	Populus tremuloides		05
	Pseudotsuga menziesii var. *glauca*	+	+
	Salix sp.	+	
upper shrub	*Alnus incana*		05
	Juniperus communis	+	
	Juniperus scopulorum	+	
	Lonicera involucrata		+
	Rosa nutkana var. *inutkana*	+	+
	Salix sp.	10	10
	Shepherdia canadensis	+	
lower shrub	*Arctostaphylos uva-ursi*	+	
	Juniperus communis	05	
	Juniperus scopulorum	+	
	Linnaea borealis	10	+
	Lonicera involucrata	+	10
	Ribes hudsonianum	+	+
	Ribes lacustre	+	05
	Rosa nutkana var. *nutkana*	05	05
	Vaccinium sp.	+	
herb	*Actea rubra*	05	+
	Aquilegia formosa	+	
	Arnica cordifolia	+	
	Astragulus canadensis var. *mortonii*	+	
	Castilleja rhexifolia		
	Cornus canadensis	05	
	Epilobium sp.	+	+
	Fragaria virginiana	05	+
	Galium aparine		+
	Galium boreale	+	+
	Goodyera sp.		+
	Lupinus bicolor	+	
	Mitella pentandra	+	+
	Pastinaca sativa		05
	Pyrola minor		+
	Pyrola uniflora	+	
	Ranunculus sp.	+	
	Senecio amplectrens		+
	Senecio pseudaureus		+
	Smilacina stellata		15

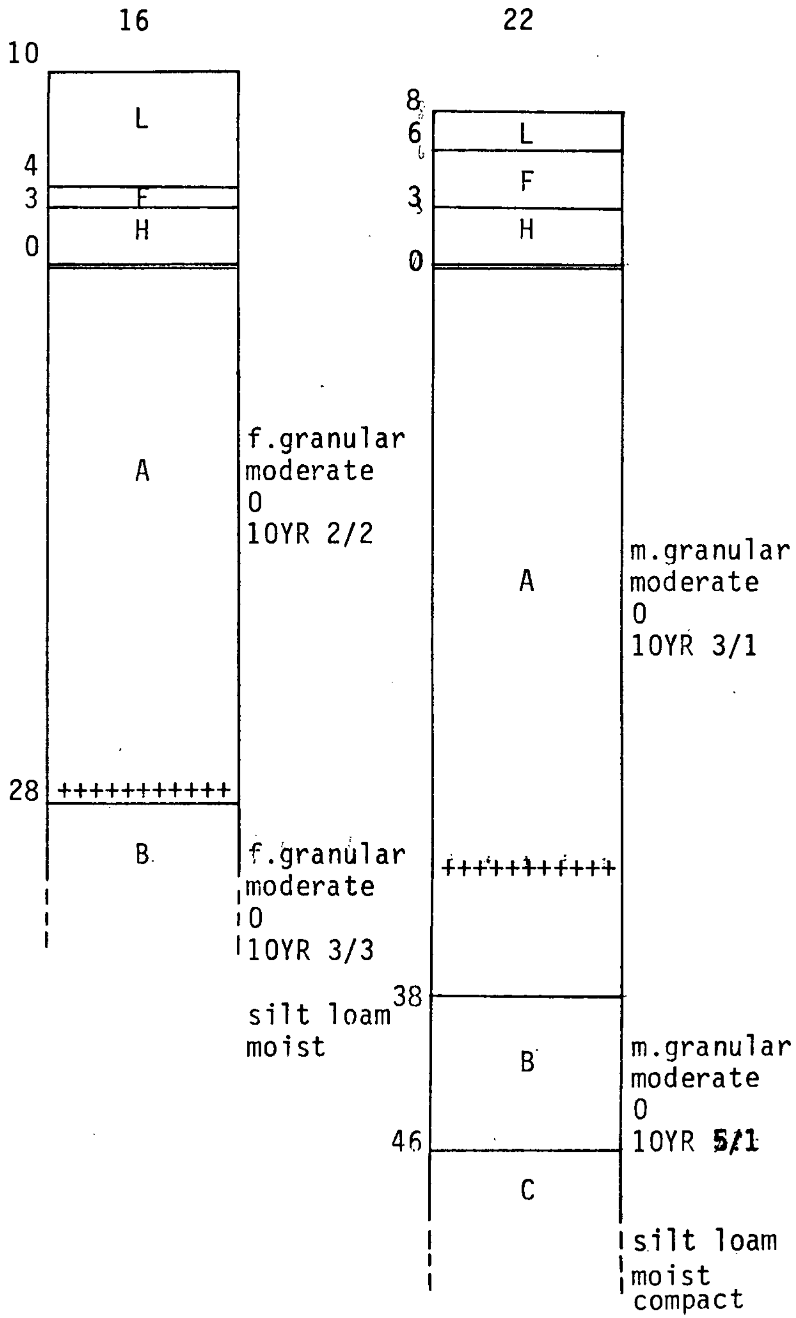
Stellaria sp.		+
Sreptopus amplexifolius	+	
Thalictrum occidentale	08	+
Calamagrostis rubescens	25	10
Equisetum arvense	10	
Equisetum pratense		+
Juncus gerardii	+	
Carex atherodes		+
Carex sp.		+
mosses		+
lichens	+	+
ground	08	35
stumps	05	
unknown *Graminid* sp.	10	+

Spruce/alder communities



ASPEN MEADOW COMMUNITIES

LAYER	SPECIES	PLOT NUMBER 16	22
upper tree	Populus tremuloides	+	
lower tree	Populus tremuloides	+	
upper shrub	Populus tremuloides	+	
lower shrub	Populus tremuloides		+
herb	Achillea millefolium	05	+
	Agoseris glauca	+	+
	Arabidopsis thaliana		+
	Delphinium occidentale	+	
	Fragaria virginiana		+
	Galium boreale	+	
	Potentilla gracilis		+
	Ranunculus sp.	+	
	Sonchus arvensis	+	
	Sonchus sp.	+	
	Stellaria aquatica	+	
	Stellaria longifolia	+	+
	Taraxacum officinale	+	12
	Trifolium hybridum		+
	Trifolium macrocephalum		+
	Trifolium repens		15
	Alopecurus pratensis	+	+
	Bromus inermis		35
	Festuca sp.		25
	Poa palustris	90	10
	Carex sp.	+	+

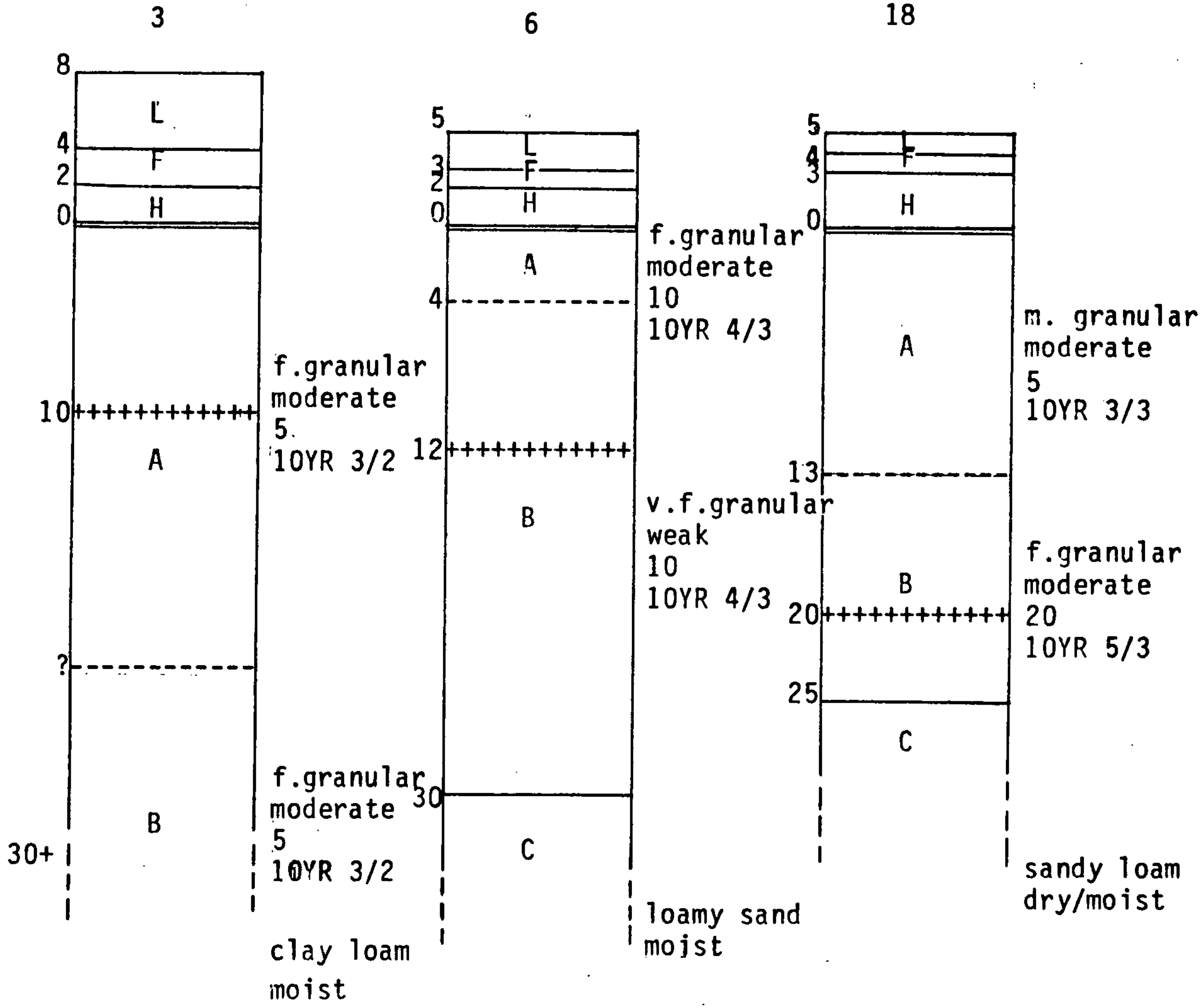


Aspen meadow communities

OPEN FOREST/GRASSLAND COMMUNITIES

LAYER	SPECIES	PLOT NUMBER 03	06	18
upper tree	*Pinus contorta*	+	02	
	Pseudotsuga menziesii var. *glauca*	15	08	
lower tree	*Pinus contorta*	10	+	+
	Populus tremuloides	05	08	05
	Pseudotsuga menziesii var. *glauca*			10
upper shrub	*Populus tremuloides*			05
	Juniperus communis		+	
	Shepherdia canadensis	10	+	10
lower shrub	*Arctostaphylos uva-ursi*	15	15	07
	Juniperus communis			+
	Juniperus scopulorum		+	
	Linnaea borealis		+	
	Rosa nutkana var. *nutkana*	10	10	+
	Rosa woodsii (var. *woodsii* ?)	+		
	Salix sp.	+		+
	Spiraea betulifolia	10	10	
	Vaccinium sp.	+		
herb	*Achillia millefolium*	+		+
	Agoseris glauca		+	
	Allium cernum		+	
	Antennaria microphylla		+	+
	Antennaria sp.		+	+
	Arabidopsis thaliana			+
	Arnica cordifolia			+
	Astragalus miser var. *decumbens*		+	+
	Castilleja sp.			+
	Epilobium (*angustifolium* ?)	+		
	Fragaria virginiana	+	+	+
	Galium boreale		+	+
	Penstemon procerus var. *procerus*		+	
	Plantago sp.			+
	Sonchus sp.			+
	Stanleya sp.			+
	Taraxacum officinale	+	+	+
	Thelypodium flexuosum			+
	Thelypodium howelli		+	
	Tragopogon dubius		+	
	Trifolium hybridum			+
	Trifolium repens			+
	Agrostis sp.			10
	Calamagrostis rubescens	75	40	35
	Poa pratensis		+	
	Poa sp.			10

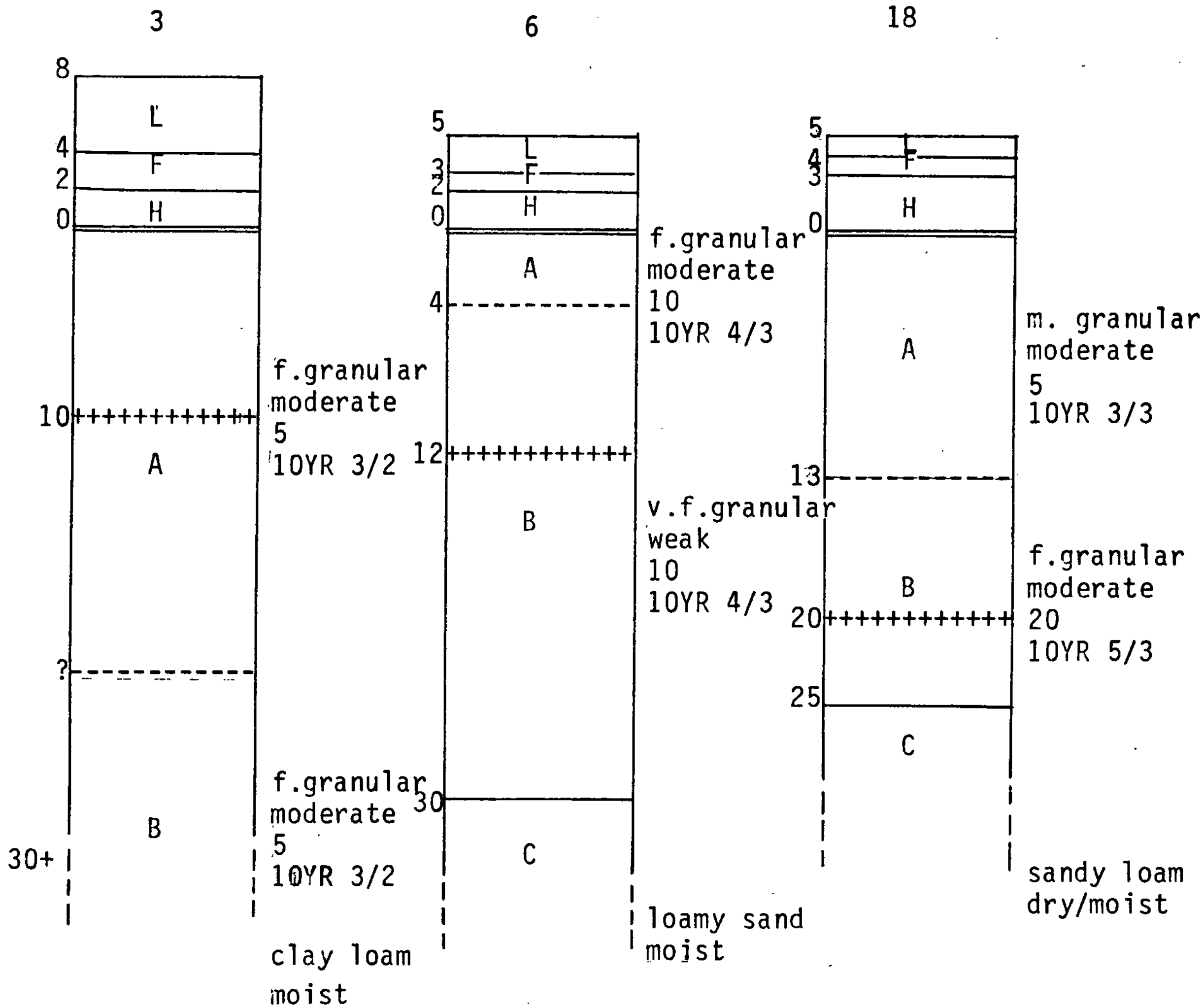
Carex sp.	+		
mosses	25	+	+
lichens	+	+	+
rocks/ground	10		10
stumps	15		10
unknown composite	10		
unknown legume	+		
unknown mint	+		



Open forest/grassland communities

VALLEY BOTTOM MEADOW COMMUNITIES

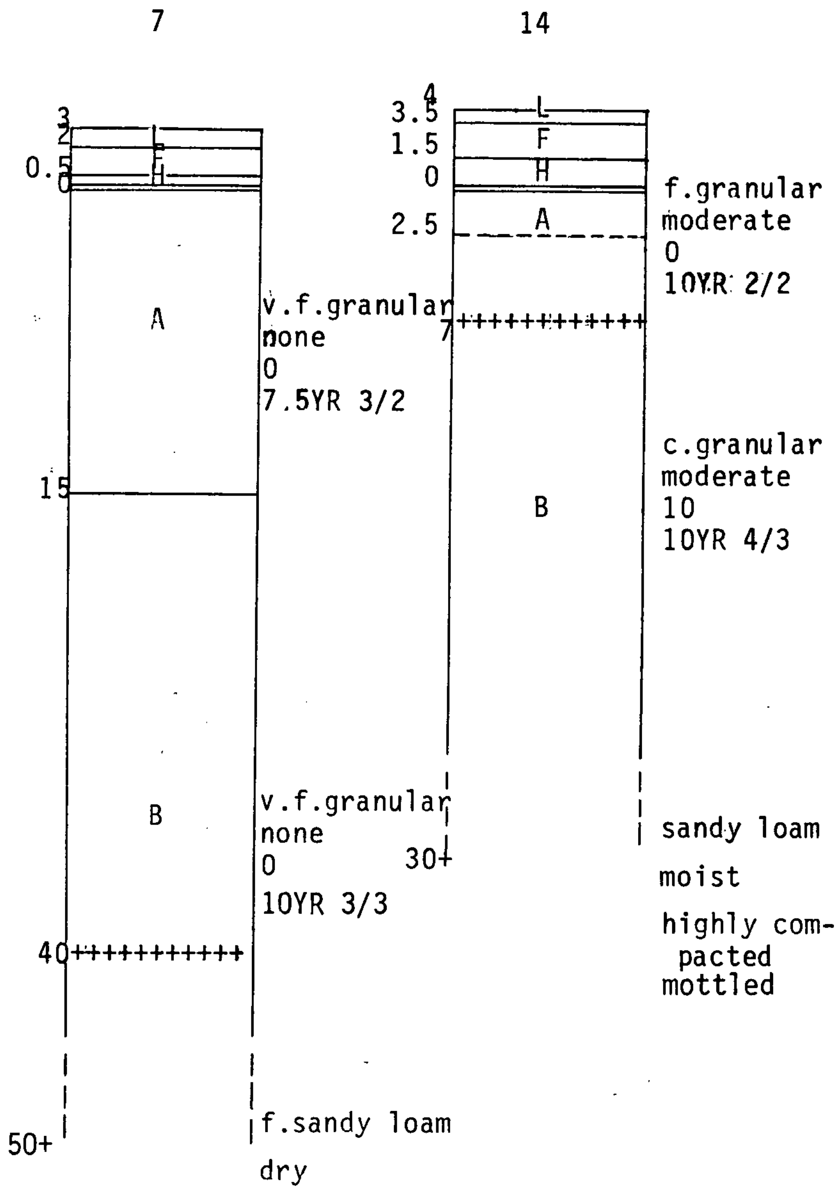
LAYER	SPECIES	PLOT NUMBER 07	14
upper tree			
lower tree			
upper shrub			
lower shrub			
herb	*Fragaria virginiana*	+	
	Oxytropis sericea var. *spicata*	+	
	Plantago sp.		+
	Ranunculus sp.	05	+
	Taraxacum officinale	+	10
	Trifolium parryi		+
	Trifolium repens		05
	Alopecurus sp.		+
	Festuca sp.	+	
	Poa compressa	+	
	Poa pratensis	80	35
	Poa trivialis		45
	Equisetum hyemale	+	
	Juncus sp.	+	
	Carex sp.	05	
bare ground		05	10



Open forest/grassland communities

VALLEY BOTTOM MEADOW COMMUNITIES

LAYER	SPECIES	PLOT NUMBER	
		07	14
upper tree			
lower tree			
upper shrub			
lower shrub			
herb	*Fragaria virginiana*	+	
	Oxytropis sericea var. *spicata*	+	
	Plantago sp.		+
	Ranunculus sp.	05	+
	Taraxacum officinale	+	10
	Trifolium parryi		+
	Trifolium repens		05
	Alopecurus sp.		+
	Festuca sp.	+	
	Poa compressa	+	
	Poa pratensis	80	35
	Poa trivialis		45
	Equisetum hyemale	+	
	Juncus sp.	+	
	Carex sp.	05	
bare ground		05	10

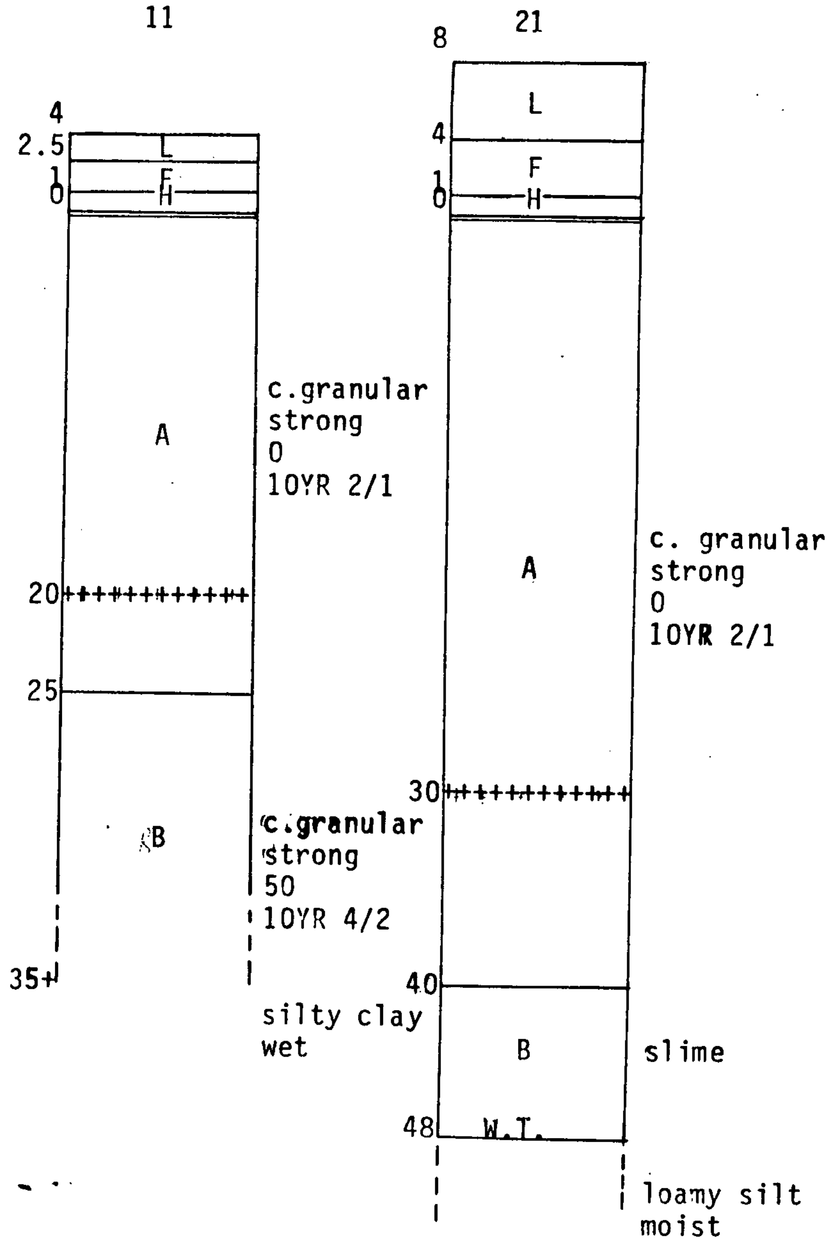


Valley bottom meadow communities

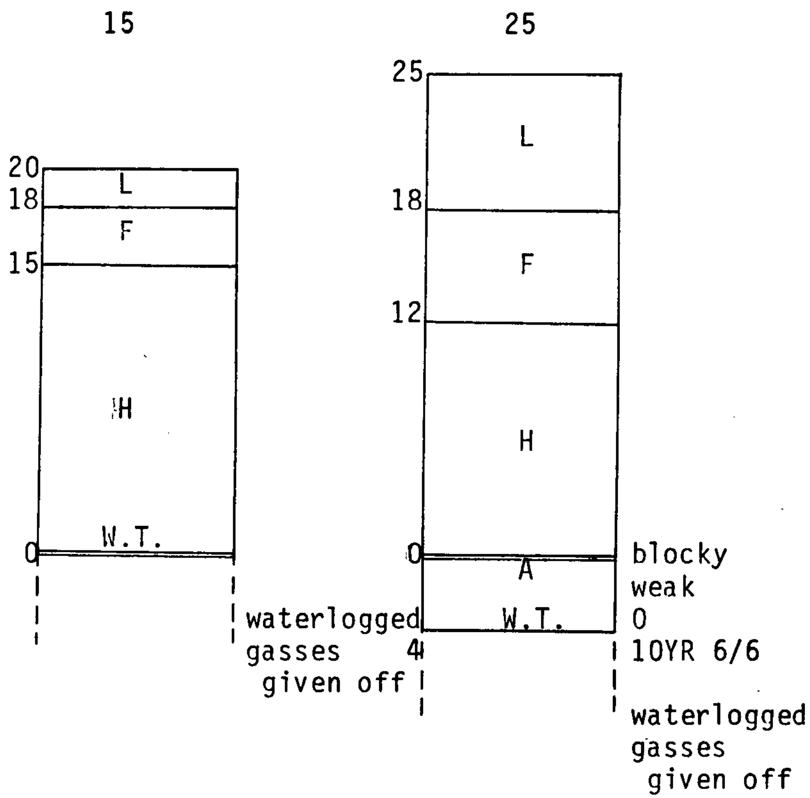
WILLOW COMMUNITIES

LAYER	SPECIES	PLOT NUMBER 15	25
upper tree			
lower tree	*Salix* sp.	60	60
upper shrub	*Betula glandulosum*		+
	Lonicera involucrata	05	
	Ribes hudsonianum	05	
	Ribes lacustre	+	
	Salix sp.	05	
lower shrub	*Picea* sp.		+
	Ribes lacustre		20
	Rosa nutkana var. *nutkana*		05
	Rubus acaulis	+	
	Rubus parviflorus	+	
	Rubus spectabalis	05	
	Salix sp.	+	
herb	*Epilobium angustifolium*	05	+
	Fragaria virginiana		+
	Galium aparine	+	
	Geum aleppicum		+
	Plantago sp.		+
	Potentilla flabellifolia		+
	Pyrola minor		+
	Ranunculus sp.	+	+
	Senecio pseudaureus		+
	Senecio sylvaticus	+	
	Smilacina stellata		+
	Stellaria aquatica	+	
	Stellaria longifolia	05	
	Taraxacum officinale		+
	Thalictrum sp.	+	+
	Trifolium repens		05
	Urtica dioica		05
	Viola sp.	+	
	Alopecurus pratensis		+
	Calamagrostis canadensis	60	40
	Catabrosa aquatica		20
	Equisetum arvense	+	
	Equisetum fluviatile		+
	Juncus sp.		+
	Carex sp.	15	+

mosses	05	
water	10	
unknown composite	08	+



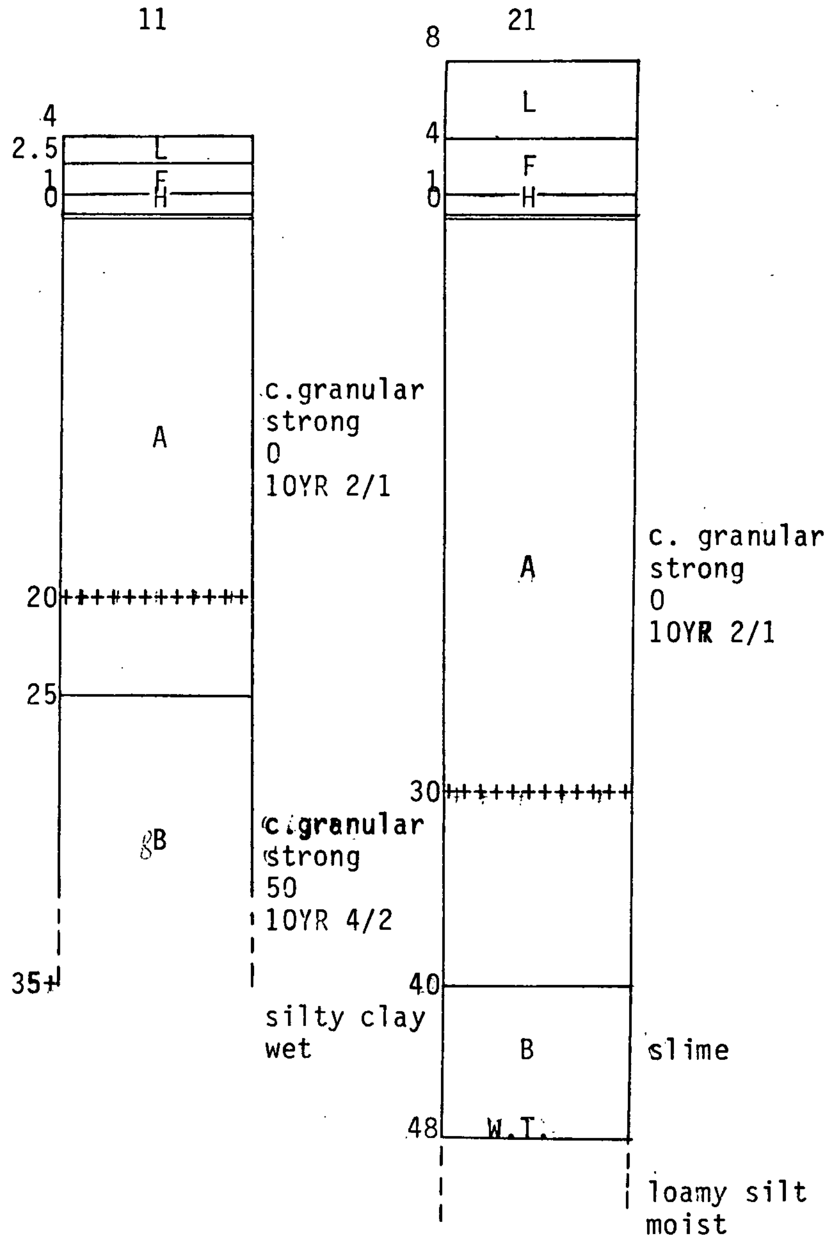
Willow/birch communities



Willow communities

WILLOW/BIRCH COMMUNITIES

LAYER	SPECIES	PLOT NUMBER 11	21
upper tree			
lower tree			
upper shrub	Betula glandulosa	40	40
	Salix sp.	08	+
lower shrub	Arctostaphylos uva-ursi	05	20
	Betula glandulosa	15	+
	Salix pedicellaris	10	05
	Salix sp.	+	05
herb	Achillia millefolium	+	05
	Anaphalis margaritacea	+	
	Antennaria media		+
	Arnica sp.	+	
	Epilobium sp.	05	
	Fragaria virginiana		05
	Galium boreale		+
	Oxytropis campestris		+
	Plantago sp.		+
	Potentilla sp.		+
	Ranunculus sp.	+	+
	Senecio amplectens		+
	Sisyrinchium angustifolium	+	+
	Stellaria longifolia	+	+
	Taraxacum officinale		+
	Trifolium repens	+	+
	Viola sp.		+
	Botrychium lunaria var. lunaria	+	
	Agropyron caninum sp. caninum var. latiglume		+
	Agrostis sp.		15
	Poa pratensis	10	15
	Poa sp.	10	
	Juncus gerardii	20	
	Juncus sp.		05
	Carex atherodes	+	+
	Carex sp.	+	
mosses		+	+
ground		+	+



Willow/birch communities

SEDGE MARSH COMMUNITIES

LAYER	SPECIES	PLOT NUMBER 13	26
upper tree			
lower tree			
upper shrub			
lower shrub			
herb	*Catabrosa aquatica*		10
	Equisetum fluviatile	+	
	Carex sp.(*oederi* ?)	60	60

APPENDIX IV

Analysis of variance tables for physical characteristics of types of material

Composition of particles greater than 25mm diameter

Source	Sum of squares	DF	Mean square	F-ratio	Probability	Test term
TYPE	7.9231	4.	1.9808	10.830	0.00000	RESIDUAL
SITE	1.7513	8.	0.21892	1.1969	0.31098	RESIDUAL
Residual	15.181	83.	0.18290			
Total	24.855	95.				

Composition of particles 10-25mm diameter

TYPE	7.8134	4.	1.9534	14.340	0.00101	SITE
SITE	1.0897	8.	0.13621	3.5147	0.00152	RESIDUAL
Residual	3.2167	83.	0.38756E-01			
Total	12.120	95.				

Composition of particles 4.76-10mm diameter

TYPE	3.3529	4.	0.83822	13.868	0.00113	SITE
SITE	0.48354	8.	0.60443E-01	3.2871	0.00263	RESIDUAL
Residual	1.5262	83.	0.18388E-01			
Total	5.3626	95.				

Composition of particles 2-4.76mm diameter

TYPE	4.0192	4.	1.0048	14.844	0.00090	SITE
SITE	0.54152	8.	0.67690E-01	3.1179	0.00396	RESIDUAL
Residual	1.8019	83.	0.21710E-01			
Total	6.3626	95.				

Composition of soil-sized particles

TYPE	9728.7	4.	2432.2	620.30	0.00000	SITE
SITE	31.368	8.	3.9210	4.4098	0.00018	RESIDUAL
Residual	73.799	83.	0.88915			
Total	9833.9	95.				

Composition of coarse sand

TYPE	11.408	4.	2.8520	23.028	0.00019	SITE
SITE	0.99078	8.	0.12385	3.2485	0.00289	RESIDUAL
Residual	3.1644	83.	0.38125E-01			
Total	15.563	95.				

Composition of fine sand

TYPE	3.8812	4.	0.97030	30.956	0.00000	RESIDUAL
SITE	0.38966	8.	0.48708E-01	1.5540	0.15147	RESIDUAL
Residual	2.6016	83.	0.31344E-01			
Total	6.8725	95.				

Composition of silt

TYPE	4.7962	4.	1.1990	5.7646	0.01747	SITE
SITE	1.6640	8.	0.20800	2.9548	0.00587	RESIDUAL
Residual	5.8427	83.	0.70394E-01			
Total	12.303	95.				

Composition of clay

TYPE	2.5885	4.	0.64712	4.8018	0.02858	SITE
SITE	1.0781	8.	0.13477	5.2543	0.00002	RESIDUAL
Residual	2.1288	83.	0.25648E-01			

Composition of organic matter

TYPE	0.65886	4.	0.16472	3.9362	0.04706	SITE
SITE	0.33477	8.	0.41647E-01	13.842	0.00000	RESIDUAL
Residual	0.25093	83.	0.30232E-02			
Total	1.2446	95.				

Bulk density

TYPE	6.6009	4.	1.6502	1.5507	0.19521	RESIDUAL
SITE	9.7767	8.	1.2221	1.1484	0.34041	RESIDUAL
Residual	88.327	83.	1.0642			
Total	104.70	95.				

APPENDIX V

Physical characteristics of materials at each site

SITE	NUMBER in SAMPLE	PG25MM MEAN	PG25MM STD DEV	PG10MM MEAN	PG10MM STD DEV	PG476MM MEAN	PG476MM STD DEV	PG2MM MEAN	PG2MM STD DEV	PCTOM MEAN	PCTOM STD DEV	PG500MU MEAN	PG500MU STD DEV
1	8	32.422	18.372	6.773	2.546	8.227	2.039	15.181	3.478	2.018	0.599	50.327	7.667
2	8	19.234	26.226	5.042	6.878	10.728	5.381	19.475	9.214	2.025	0.689	47.122	11.041
3	8	37.196	26.079	7.479	6.612	4.246	1.922	9.121	4.036	2.414	1.139	45.159	5.299
4	8	22.651	20.239	15.398	6.375	14.332	5.165	16.235	5.482	0.641	0.157	65.512	20.653
5	8	34.865	23.167	11.098	5.557	11.339	5.235	11.668	4.930	0.841	0.159	73.231	7.190
6	8	20.897	5.192	16.116	8.330	13.582	3.262	15.227	2.775	2.923	3.506	64.522	4.496
7	7	22.200	16.934	25.440	8.001	10.155	8.019	10.753	7.689	1.196	0.179	40.862	3.488
8	8	23.567	12.342	17.828	4.447	12.484	2.269	12.251	2.082	3.699	0.600	37.469	7.600
9	8	23.771	11.108	21.541	7.095	9.706	4.324	9.800	2.927	3.519	0.406	30.185	5.732
10	8	27.818	20.133	11.888	6.154	6.474	1.923	7.638	2.403	1.782	0.279	23.691	3.376
11	9	24.718	13.821	28.890	7.013	11.128	3.240	10.162	2.980	0.913	0.139	36.274	8.732
12	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.071	6.620
13	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	22.210	6.266

SITE	NUMBER in SAMPLE	PG50MU MEAN	PG50MU STD DEV	PG2MU MEAN	PG2MU STD DEV	PL2MU MEAN	PL2MU STD DEV	BD MEAN	BD STD DEV
1	8	12.325	2.786	26.339	12.126	7.644	6.286	1.774	0.119
2	8	14.665	3.156	32.169	7.576	6.044	4.525	1.839	0.874
3	8	16.915	2.216	22.186	18.496	0.551	1.039	2.180	1.131
4	8	19.740	17.982	8.763	3.414	5.985	2.716	2.549	1.118
5	8	14.878	4.981	7.933	2.655	3.959	0.939	2.250	0.659
6	8	13.271	1.911	17.735	3.450	4.472	0.613	2.334	0.663
7	7	20.023	1.188	28.544	2.414	10.570	1.700	2.227	0.263
8	8	18.660	3.538	31.391	4.160	12.480	2.138	2.121	0.511
9	8	19.715	2.780	37.028	6.791	13.072	6.000	2.150	0.449
10	8	17.331	1.896	40.461	1.801	18.517	3.094	1.896	0.386
11	9	25.511	5.493	28.203	3.790	10.012	2.381	3.183	2.606
12	4	45.847	24.137	39.650	24.599	5.432	6.056	1.587	0.118
13	4	52.442	6.370	22.925	10.434	2.423	0.462	1.537	0.072

APPENDIX VI

Results of assessment of reclamation trials

(Percent cover, percent seed heads and height of species in reclamation trials assessed)

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SPECIES	A01	A02	A03	A04	A06	A07	A08	A09	A10
A.V.F. CLOVER									[illegible]
ALFALFA COVER % / SEED HEADS % / HEIGHT CM			[illegible]				[illegible]	[illegible]	[illegible]
COMMON SAINFOIN COVER % / SEED HEADS % / HEIGHT CM			[illegible]					[illegible]	[illegible]
WHITE CLOVER COVER % / SEED HEADS % / HEIGHT CM		[illegible]							[illegible]
YELLOW SWEET CLOVER COVER % / SEED HEADS % / HEIGHT CM		[illegible]						[illegible]	[illegible]
STREAMBANK WHEATGRASS COVER % / SEED HEADS % / HEIGHT CM			[illegible]						
CRESTED WHEATGRASS COVER % / SEED HEADS % / HEIGHT CM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PUBESCENT WHEATGRASS COVER % / SEED HEADS % / HEIGHT CM		[illegible]	[illegible]						
INTERMEDIATE WHEATGRASS COVER % / SEED HEADS % / HEIGHT CM								[illegible]	
CANADA BLUEGRASS COVER % / SEED HEADS % / HEIGHT CM							[illegible]	[illegible]	
KENTUCKY BLUEGRASS COVER % / SEED HEADS % / HEIGHT CM			[illegible]						[illegible]
RED FESCUE COVER % / SEED HEADS % / HEIGHT CM		[illegible]			[illegible]	[illegible]			[illegible]
HARD FESCUE COVER % / SEED HEADS % / HEIGHT CM			[illegible]	[illegible]					
SHEEP FESCUE COVER % / SEED HEADS % / HEIGHT CM							[illegible]	[illegible]	
ORCHARDGRASS COVER % / SEED HEADS % / HEIGHT CM		[illegible]							
SMOOTH BROME COVER % / SEED HEADS % / HEIGHT CM	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]
COMMON TIMOTHY COVER % / SEED HEADS % / HEIGHT CM					[illegible]	[illegible]			[illegible]
AGROPYRON SPICATUM COVER % / SEED HEADS % / HEIGHT CM			[illegible]						
ACHILLEA MILLEFOLIUM COVER % / SEED HEADS % / HEIGHT CM		[illegible]	[illegible]				[illegible]	[illegible]	
ANTENNARIA COVER % / SEED HEADS % / HEIGHT CM	[illegible]								
AVENA FATUA COVER % / SEED HEADS % / HEIGHT CM		[illegible]							
BROMUS TECTORUM COVER % / SEED HEADS % / HEIGHT CM			[illegible]						
EPILOBIUM COVER % / SEED HEADS % / HEIGHT CM	[illegible]	[illegible]						[illegible]	
OXYTROPIS CAMPESTRIS COVER % / SEED HEADS % / HEIGHT CM	[illegible]								
PLANTAGO LANCEOLATA COVER % / SEED HEADS % / HEIGHT CM	[illegible]						[illegible]		
[illegible] OFFICINALE COVER % / SEED HEADS % / HEIGHT CM	[illegible]							[illegible]	
[illegible] COVER % / SEED HEADS % / HEIGHT CM							[illegible]		
UNKNOWN COMPOSITAE COVER % / SEED HEADS % / HEIGHT CM	[illegible]								

Leaf 167 missed in numbering.

APPENDIX VII

Species composition of plots surveyed within natural revegetation area

(Species composition reported as percent cover)

SPECIES	PLOT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Alnus incana																	+			
Alnus sinuata																		05		
Arctostaphylos uva-ursi	05	20	10	25	05	05	05	25	25	30	35	30	05	60		+	+		20	
Fragaria virginiana		+	+	+	+	+	+	+		+	+	+	+	+	+	+				
Juniperus communis								+		+			+							
Linnaea borealis													+		+		+	+	+	
Pinus contorta var. contorta		+		05	+	05	+	+			+		+	+			10	05	+	+
Populus tremuloides						10	05			05	+				05	+				+
Pseudotsuga menziesii var. glauca																				+
Ribes sp.																				+
Rosa nutkana var. hispida	10	05		+	05	+		+		05		05		+		+	+			
Rosa nutkana var. nutkana																+				
Rubus idaeus																				10
Rubus sp.																	05			
Salix pedicellaris																			+	
Salix sp.													20		05	+	+			
Shepherdia canadensis		+	25				+			+		+	+	10		+	05	05	10	+
Spiraea betulifolia														+	+			+	+	+
Achillea millefolium	+	+	+		+		+	+	+	+	+	+	+		+	+	+	+	+	
Agropyron caninum	+						+	+		+										
Agrostis alba var. alba		+	05	50		50	25	+	+	10		25	+	08	35	85	50	+	+	
Anaphalis margaritacea											+									
Antennaria alpina var. media					+		+													
Antennaria microphylla																		+		+
Arnica cordifolia																+	+			
Aster conspicuus							+													
Brassica sp.																				+
Calamagrostis rubescens														+		+	+		25	+
Castilleja sp.																		08		
Epilobium sp.			+			+							+							
Erigeron sp.				+	05	05												+		
Festuca ovina var. rydbergii			05	+	05	+	+	15	15	05	05	+			+					+
Festuca sp.																				+
Galium aparine																				+
Galium boreale								+			+									
Graminid sp.		+	+	+	+	10	+				+									
Hordeum sp.	10	+	+							+	10	+								+
Lilium columbianum									+											
Oxytropis sericea var. spicata										+			+							
Penstemon sp.																			+	08
Plantago sp.							+												+	+
Poa pratensis				+	05	05		+	+						+				+	+

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Poa sp.												10		+						
Poa trivialis											+									+
Polemonium humile	05	+								05										
Sedum sp.								+	+	+	+			+						+
Senecio (*crassulus*?)	+	+																		
Solidago occidentalis	+	+	05		05	+	+	05	+	+	+	+	+	+	+	+		+	+	+
Stellaria longifolia							+										+			
Taraxacum officinale	+	+				+	+	+								+		+	+	
Thelypodium howellii			+					+		+	+	+		+					+	+
Trifolium hybridum											+									
Trifolium repens											+									
PLOT NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

APPENDIX VIII

Alphabetical listing of species names and common names
(Hitchcock and Cronquist, 1973)

Achillia millefolium	Common yarrow
Actea rubra	Baneberry
Agropyron caninum	Awned wheatgrass
Agropyron caninum sp. *caninum* var. *latiglume*	Broadglumed wheatgrass
Agropyron cristatum	Crested wheatgrass
Agroseris glauca	Short-beaked false dandelion
Agrostis alba var. *alba*	Redtop
Agrostis sp.	Bentgrass
Allium cernum	Wild onion
Alnus incana	Mountain alder
Alnus sinuata	Wing-leaved alder
Alnus sp.	Alder
Alopecurus pratensis	Meadow foxtail
Alopecurus sp.	Foxtail
Amelanchier sp.	Serviceberry
Anaphalis margaritacea	Pearly-everlasting
Antennaria alpina var. *media*	Alpine pussy-toes
Antennaria microphylla	Rosy pussy-toes
Antennaria neglecta var. *attenuata*	Field pussy-toes
Antennaria sp.	Pussy-toes
Aquilegia formosa	Red columbine
Arabidopsis thaliana	Common wall-cress
Arnica cordifolia	Heart-leaf arnica
Arnica sp.	Arnica
Arctostaphylos uva-ursi	Kinnikinnick
Aster conspicuus	Showy aster
Aster radulinus	Rough-leaved aster
Astragulus canadensis var. *mortonii*	Canada milk-vetch
Astragalus miser var. *decumbens*	Weedy milk-vetch
Betula glandulosum	Scrub birch
Botrychium lunaria var. *lunaria*	Moonwort
Brassica sp.	Mustard
Bromus inermis	Smooth brome
Calamagrostis canadensis	Bluejoint reedgrass
Calamagrostis rubescens	Pinegrass
Calypos bulbosa	Fairy-slipper
Calypso sp.	Fairy-slipper
Carex atherodes	Awned sedge
Carex oederi	Green sedge
Carex	Sedge
Castilleja rhexifolia	Rhexia-leaved paintbrush
Castilleja	Indian-paintbrush
Catabrosa aquatica	Brookgrass
Chimaphila sp.	Prince's-pine
Coptis sp.	Goldthread
Cornus canadensis	Bunchberry
Cornus stolonifera	Creek dogwood
Dactylis glomerata	Orchard grass

Daucus sp.	Carrot
Delphinium occidentale	Western larkspur
Epilobium angustifolium	Fireweed
Epilobium sp.	Willow-herb
Equisetum arvense	Common horsetail
Equisetem fluviatile	Water horsetail
Equisetum hyemale	Common scouring-rush
Equisetum pratense	Shady horsetail
Equisetum sp.	Horsetail
Erigeron sp.	Daisy
Festuca arundinacea	Tall fescue
Festuca rubra	Red fescue
Festuca scabrella	Buffalo grass
Festuca sp.	Fescue
Festuca ovina var. rydbergii	Sheep fescue
Fragaria virginiana	Wild strawberry
Galium aparine	Cleavers
Galium boreale	Northern bedstraw
Gentiana amarella	Northern gentain
Gentiana propinqua	Four-parted gentian
Geum aleppicum	Yellow avens
Goodyera oblongifolia	Western rattlesnake-plantain
Goodyera sp.	Rattlesnake-plantain
Hordeum jubatum	Foxtail barley
Hordeum sp.	Foxtail barley
Juncus gerardii	Mud rush
Juncus spp	Rush
Juniperus communis	Common juniper
Juniperus scopulorum	Rocky mountain juniper
Ledum sp.	Labrador tea
Lilium columbianum	Tiger lily
Lilium sp.	Lily
Linnaea borealis	Twinflower
Lonicera involucrata	Bearberry honeysuckle
Lupinus bicolor	Two-color lupine
Lupinus sp.	Lupine
Melilotus officinales	Yellow sweet clover
Mitella pentandra	Alpine mitrewort
Oxytropis campestris	Field crazyweed
Oxytropis sericea var. spicata	Silky crazyweed
Pastinaca sativa	Common parsnip
Penstemon procerus var. procerus	Tiny-bloom penstemon
Penstemon sp.	Penstemon
Picea sp.	Spruce
Pinus contorta	Lodgepole pine
Plantago sp.	Plantain
Poa compressa	Canada bluegrass
Poa palustris	Fowl bluegrass
Poa pratensis	Kentucky bluegrass
Poa sp.	Bluegrass
Poa trivialis	Roughstalk bluegrass

Polemonium sp.	Jacob's ladder
Populus tremuloides	Trembling aspen
Potentilla flabellifolia	Fan-leaf cinquefoil
Potentilla gracilis	Graceful cinquefoil
Potentilla sp.	Cinquefoil
Pseudotsuga menziesii var. *glauca*	Douglas-fir
Pyrola chlorantha	Greenish wintergreen
Pyrola minor	Lesser wintergreen
Pyrola secunda	One-sided wintergreen
Pyrola sp.	Wintergreen
Pyrola uniflora	Woodnymph
Ranunculus sp.	Buttercup
Ribes hudsonianum	Stinking currant
Ribes lacustre	Swamp gooseberry
Ribes sp.	Currant
Rosa nutkana var. *hispida*	Bristly Nootka rose
Rosa nutkana var. *nutkana*	Nootka rose
Rosa sp.	Rose
Rosa woodsii	Wood's rose
Rubus acaulis	Nagoonberry
Rubus idaeus	Red raspberry
Rubus parviflorus	Thimbleberry
Rubus spectabalis	Salmonberry
Rubus sp.	Bramble
Salix pedicellaris	Bog willow
Salix sp.	Willow
Sedum lanceolatum	Lanceleaved sedum
Sedum sp.	Stonecrop
Senecio amplectens	Clasping groundsel
Senecio crassulus	Thick-leaved groundsel
Senecio pseudoaureus	Streambank butterweed
Senecio sylvaticus	Wood groundsel
Shepherdia canadensis	Soapberry
Sisyrinchia angustifolium	Eye-bright
Smilacina stellata	Starry Solomon-plume
Solidago occidentalis	Western goldenrod
Sonchus arvensis	Field milk-thistle
Sonchus sp.	Sow-thistle
Spiraea betulifolia	Shiny-leaf spirea
Stanleya sp.	Stanleya
Stellaria aquatica	Starwort
Stellaria longifolia	Longleaved starwort
Stellaria sp.	Starwort
Streptopus amplexifolius	Clasping-leaved twisted-stalk
Taraxacum officinale	Common dandelion
Thalictrum occidentale	Western meadowrue
Thalictrum sp.	Meadowrue
Thelypodium flexuosum	Thelypody
Thelypodium howellii	Howell's thelypody
Tragopogon dubius	Yellow salsify
Trifolium hybridum	Alsike clover
Trifolium macrocephalum	Big-head clover
Trifolium parryi	Parry's clover

Trifolium repens	White clover
Trisetum spicatum	Downy oat-grass
Urtica dioica	Stinging nettle
Vaccinium scoparium	Grouseberry
Vaccinium sp.	Bluberry
Viola sp.	Violet