BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

British Columbia Hydro and Power Authority - Hat Creek Project
1978 Environmental Field Programs - April 1979

ENVIRONMENTAL IMPACT STATEMENT REFERENCE NUMBER: 45

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1978 ENVIRONMENTAL FIELD PROGRAMS

THERMAL DIVISION

APRIL 1979

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1.0 SUMMARY AND INTRODUCTION

Numerous environmental studies related to the proposed Hat Creek thermal power development have been conducted over the past three years. To provide more detailed background environmental data, and to fulfill the requirements of our exploration permit, some of these studies have been continued. These include:

- air quality and surface and groundwater monitoring programs to better define existing conditions;
- leachate studies to assess characteristics of leachates from waste coal materials;
- trace element studies to define existing natural levels.

- During 1977 a reclamation test program was initiated using waste materials from the Bulk Sample Program. This program was designed to assess the revegetation potential of various waste overburden materials and to evaluate other variables pertinent to successful revegetation of these waste materials. The initial plant was carried out in the fall of 1977. The success of this work was assessed during 1978 and additional remedial measures were taken to improve the reclamation where necessary.

- The exploration drilling program continued during 1978. These drill sites related disturbances and those from previous years exploration were reclaimed during 1978.

This docoument reports on all environmental studies and field programs carried out in 1978. Detailed results are presented and discussed.

2.0 REVEGETATION PROGRAMS

2.1 ALEECE LAKE TEST PLOTS

2.1.1 Introduction

The Bulk Sample Program was carried out during 1977 to assess mining operations and to obtain coal samples for large scale combustion tests. During the mining program, overburden and waste materials that potentially would require reclamation were identified and analysed. Eight such materials were identified and revegetation test plots of these eight materials were established near Aleece Lake. These plots were fertilized and seeded with various types of plants in October 1977 commencing a program to assess the revegetation potential of the various waste materials to be expected from the full scale project. A complete description of the Aleece Lake revegetation test program is contained in the report prepared for B.C. Hydro in 1977 by Acres Consulting Services[1].

In the spring of 1978 soil samples were collected from the eight plots for nutrient and trace element analyses and the plots were fertilized as required. In July and August 1978 a counting and sampling program was conducted to assess germination success and plant growth during the first year and to obtain vegetation samples for trace element analyses. A description of the 1978 revegetation testing program, the results and a discussion of the results are presented in this section.

2.1.2 Soil Nutrient Analyses and Fertilizer Additions

The eight soil materials at Aleece Lake and soils at other test areas were sampled on 25 and 26 April 1978 to provide samples for nutrient and trace element analyses. At Aleece Lake each soil material was sampled on the non-topsoil treated side of the plot. Samples were obtained by first loosening the soil surface to a depth of approximately 20 cm with a shovel blade and sampling along the untouched surface with a heavy plastic scoop. Four individual samples were collected from each plot. Three samples were collected from the fly ash plot because of the smaller area of this plot. These were placed onto dry white paper sheets, thoroughly mixed, and sub-sampled. The samples for nutrient analyses were placed in plastic bags and sent to the Soils Testing Laboratory of the B.C. Department of Agriculture in Kelowna, B.C. The samples for mercury analyses were placed directly into white paper bags which were then placed in double clear plastic bags with twist tops. Excess air was drawn off with a straw. The samples for trace element analyses were spread out to air-dry and after six days were rebagged in white paper bags. The samples were stored in a cool, dry place prior to shipment for analysis.

The soils characteristics and nutrient content were determined using standard agricultural test procedures. These procedures are described in Acres' report to B.C. Hydro[8]. The results of the analyses are presented in Table 2-1.

The report from the Soils Testing Laboratory also recommended nutrient and soil amendments to be applied for good growth of a grass and legume crop based on the soils tests. The recommended nutrient additions were made 12 June 1978 with a hand-operated cyclone spreader using standard commercial fertilizers. The types and quantities that were added are summarized in Table 2-2.

2.1.3 Vegetation Sampling and Handling Methods

The Aleece Lake test plots contain 46 populations. There are eight plots of different soil materials. Half of each plot was treated with a layer of about 5 cm of topsoil. Seven of the eight plots were planted on both the topsoil treated and untreated

TABLE 2-1

ANALYSIS OF SOIL MATERIALS AT ALEECE LAKE

	Texture		Organic Matter	pH	Conductivity	Available Plant Nutrients kg/ha					S	B	Na
	>2mm %	<2mm Class	%		mmho/cm	N	P	K	Ca	Mg	(ppm)	(ppm)	(ppm)
Carbonaceous Shale	18	N.D.	18.0	4.5	3.70	93	22	365	6,882	1,120+	30+	1.44	70
Coal Waste	N.D.	Clay	30+	4.0	5.00	8	19	318	4,463	1,120+	30+	3.50	90
Bentonitic Clay	N.D.	Clay	0.7	8.1	3.80	8	53	870	10,000+	1,120+	30+	-	2,050
Gritstone	4	Loam	2.3	8.7	1.30	39	90	844	5,776	1,120+	30+	-	980
Colluvium	39	Sandy Clay Loam	3.0	7.9	3.50	21	63	631	10,000+	1,120+	30+	0.30	140
Baked Clay	44	Sandy Loam	0.7	8.0	0.90	3	49	812	10,000+	1,120+	30+	<0.20	150
Glacial Gravel	67	Silt Loam	2.0	8.3	0.56	53	80	507	10,000+	1,120+	5.0	0.38	50
Fly Ash	0	Silt Loam	1.2	9.1	0.32	9	43	124	3,471	239	17.6	11.09	20

Sampled: 25/26 April 1978
Analyzed: B.C. Department of Agricultural Soil Testing Laboratory, Kelowna.
N.D. - No Data.

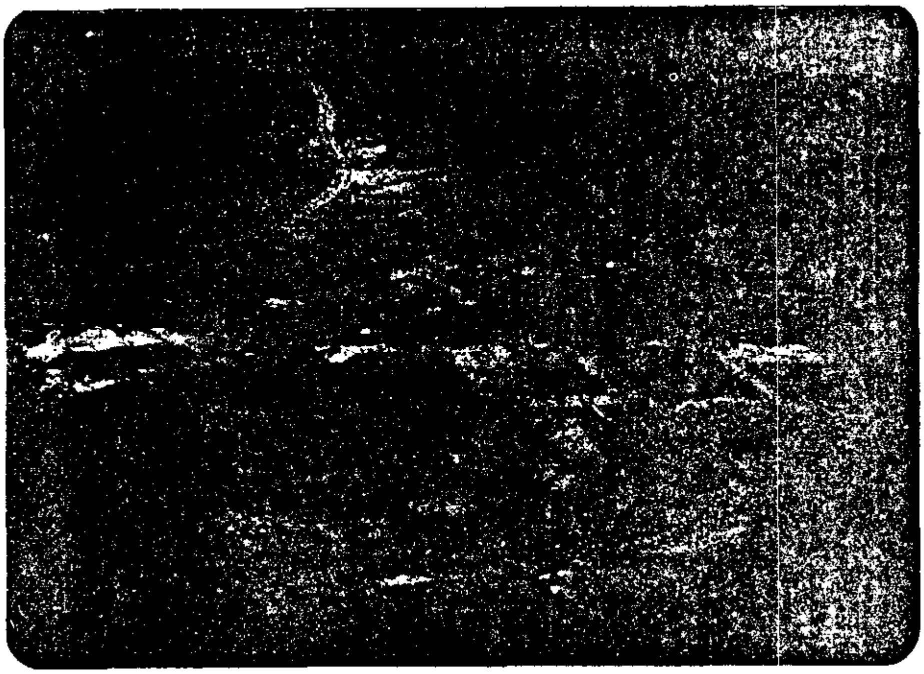
TABLE 2-2

FERTILIZER ADDITIONS AT ALEECE LAKE TEST PLOTS
June 12, 1978

Description	Fertilizer Additions (lb/acre)*				
	46-0-0	11-48-0	0-0-60	16-20-0-14	Borate 68 (21.1% boron)
Carbonaceous Shale	25	83	67	-	-
Coal Waste	20	167	67	-	-
Bentonitic Clay	45	-	-	-	-
Gritstone	55	187	-	-	-
Colluvium	50	83	-	-	19
Baked Clay	45	62	-	-	24
Glacial Gravels	16	104	67	143	19
Fly Ash	40		210*	-	-

* Standard fertilizer nomenclature where the number indicate percent by weight of N, P_2O_5, K_2O and S respectively.

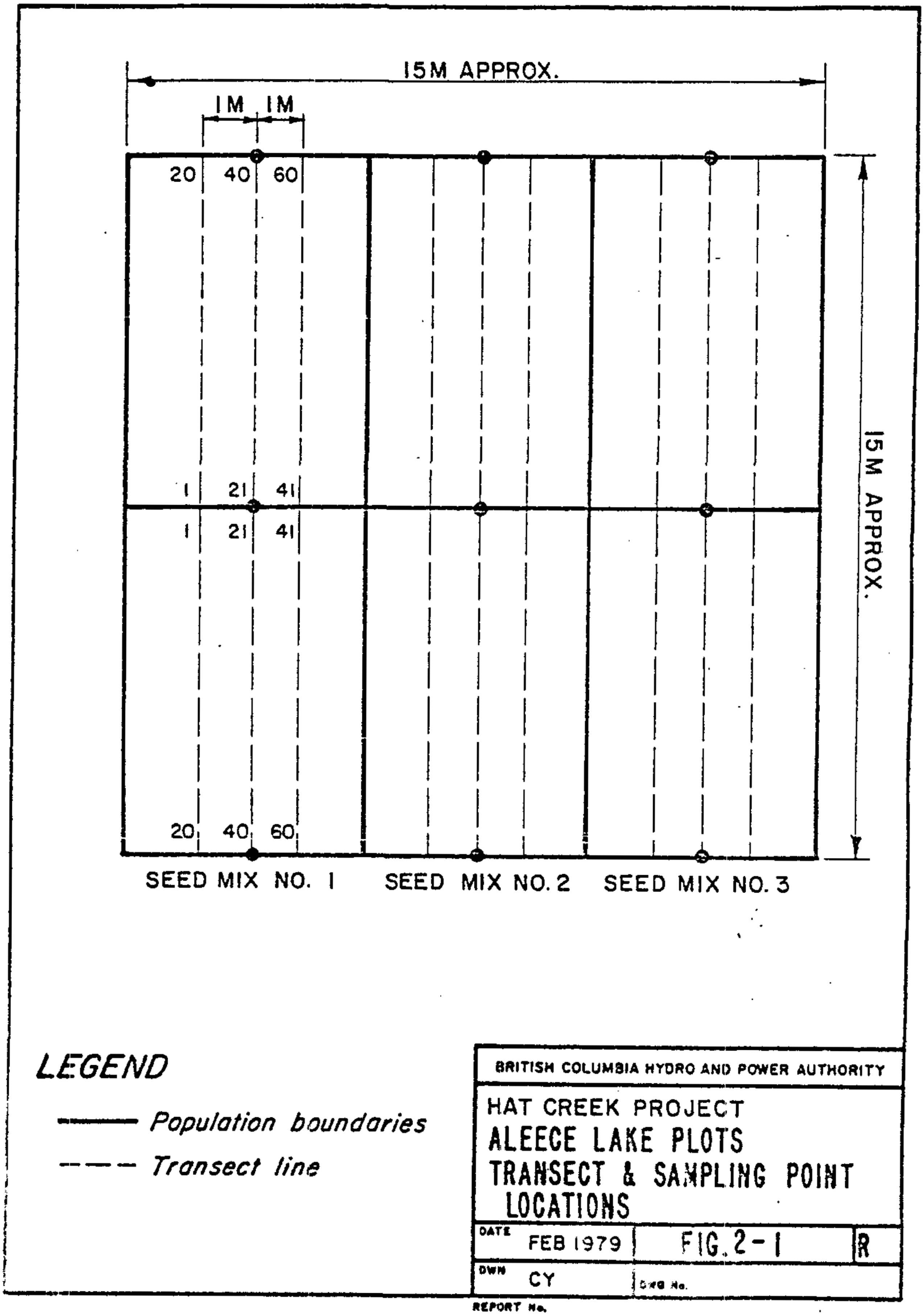
halves with three seed mixtures. The eighth plot is smaller and was planted with only two seed mixtures. These are shown in photograph 1.



Photograph 1 -
Aerial view of Aleece Lake Test Plots

Each population was sampled at eighteen randomly selected locations along three transects (A, B and C) spaced one meter apart. Marker stakes indicated the ends of each transect. Fluorescent orange stakes indicated the middle transect and purple stakes indicated the outside transects.

Twenty equidistant points were located along each transect after allowing for edge effects. The points were located 31.7 cm apart, equivalent to the inside dimension of the quadrat used for sampling. Sixty points were located for each population. Transect locations are shown in Figures 2-1 and 2-2 and point spacings are shown in Table 2-3. Photograph 2 shows the sampling points being located on the carbonaceous shale plot.


15M APPROX.
IM IM
20 40 60
1 21 41
1 21 41
20 40 60
15M APPROX.
SEED MIX NO. 1
SEED MIX NO. 2
SEED MIX NO. 3
LEGEND
Population boundaries
Transect line
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
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ALEECE LAKE PLOTS
TRANSECT & SAMPLING POINT LOCATIONS
DATE FEB 1979
FIG. 2-1
R
DWN CY
DWG No.
REPORT No.

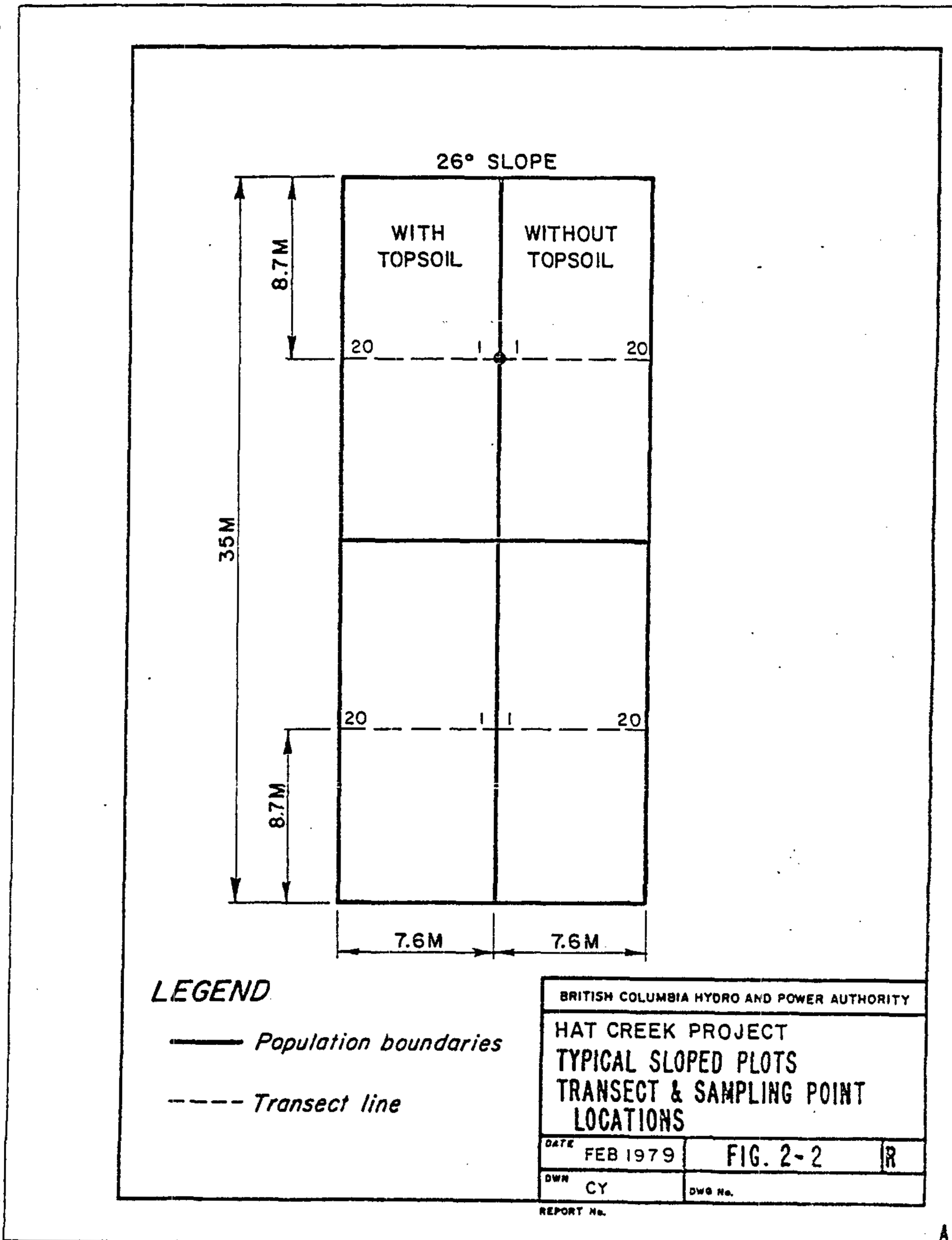
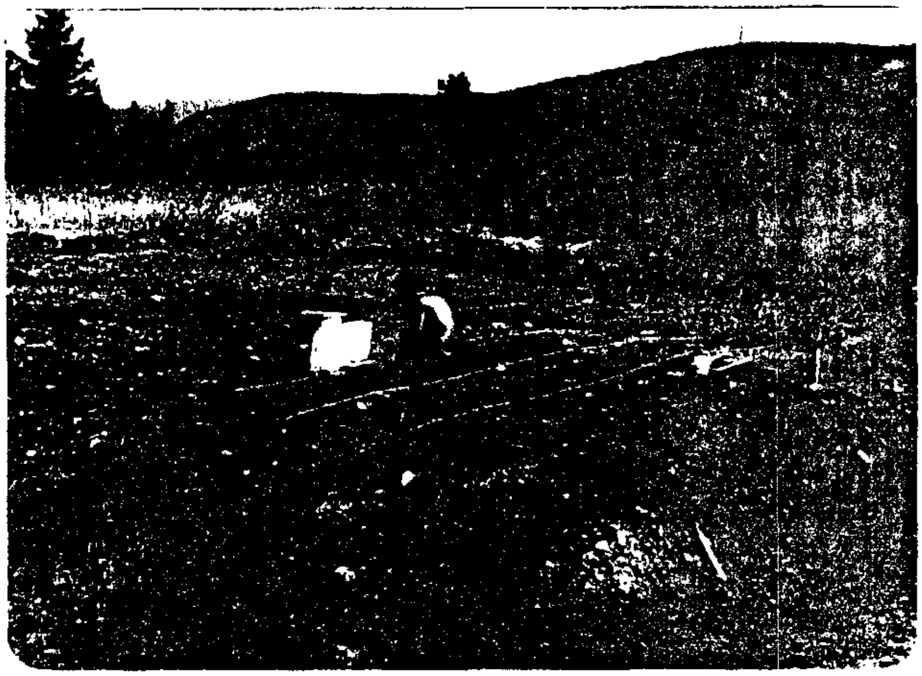

26° SLOPE
WITH TOPSOIL
WITHOUT TOPSOIL
8.7M
35M
20
1
1
20
20
1
1
20
8.7M
7.6M
7.6M
LEGEND
Population boundaries
Transect line
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
TYPICAL SLOPED PLOTS
TRANSECT & SAMPLING POINT LOCATIONS
DATE FEB 1979
FIG. 2-2
R
DWN CY
DWG No.
REPORT No.
A

TABLE 2-3

POINT SPACING ALONG TRANSECTS

POINT NUMBER			Distance From End of Transect
Transect A	Transect B	Transect C	cm
01	21	41	80.0
02	22	42	111.7
03	23	43	143.4
04	24	44	175.1
05	25	45	206.8
06	26	46	238.5
07	27	47	270.2
08	28	48	301.9
09	29	49	333.6
10	30	50	365.3
11	31	51	397.0
12	32	52	428.7
13	33	53	460.4
14	34	54	492.1
15	35	55	523.8
16	36	56	555.5
17	37	57	587.2
18	38	58	618.9
19	39	59	650.6
20	40	60	682.3
EDGE	EDGE	EDGE	720.0



Photograph 2 -
Sampling on Carbonaceous Shale Plot.
Note Transect Lines.

It was decided based on review of literature references that useful germination and plant growth information could be obtained by sampling about 5% of the total area of the plots[2]. Thus eighteen 0.12m quadrats were sampled in each population. The eighteen sampling points in each population were randomly selected from the sixty numbered points using a method described by Zar[3]. This method involved generating six sets of eighteen numbers by random selection from the sixty numbered points. The six sets of randomly selected numbers are shown in Table 2-4. These numbers were used to locate the centre of each 31.7m square quadrat for vegetation sampling. The six sets of random numbers were employed to sample the six populations in each of the eight test plots as shown in Table 2-5.

Vegetation collection and handling methods were based on those recommended by the B.C. Ministry of Environment[4]. Samplers

TABLE 2-4

RANDOM SELECTION OF SIX SETS OF SAMPLING POINTS

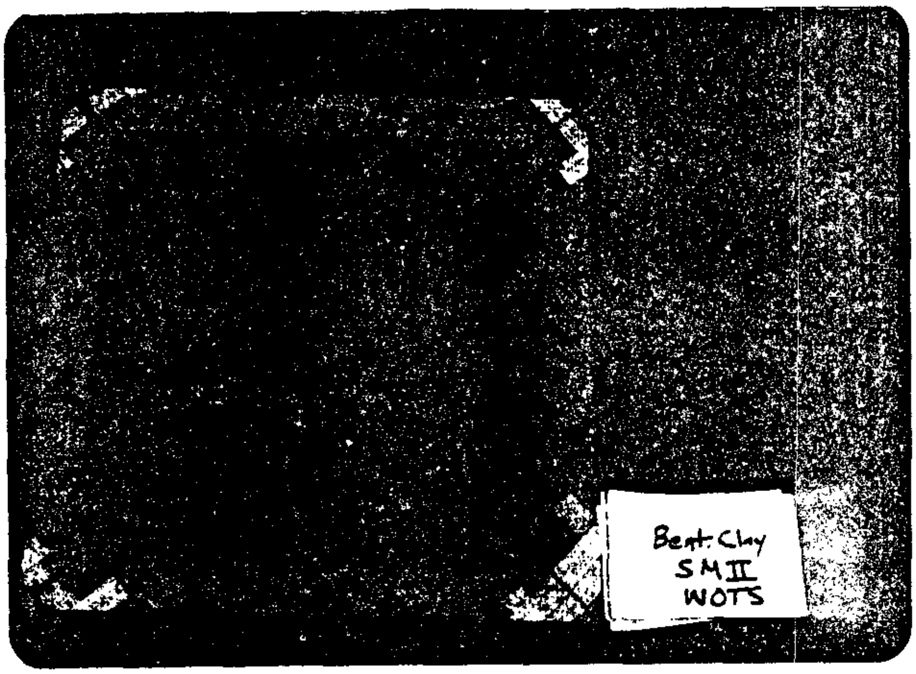
Quadrat Number	SAMPLING POINTS SELECTED Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
1	08	02	03	05	05	01
2	09	08	05	10	10	05
3	11	09	09	17	11	08
4	12	12	10	23	12	09
5	15	15	14	24	13	15
6	19	16	16	28	15	17
7	21	30	17	29	17	26
8	22	40	20	31	19	31
9	24	44	21	32	21	37
10	28	45	28	35	29	39
11	36	46	36	36	38	43
12	39	47	39	42	39	44
13	41	49	45	43	40	46
14	43	50	48	46	47	47
15	44	54	50	47	50	48
16	49	55	52	53	51	50
17	54	58	54	57	53	53
18	56	59	58	58	59	56

TABLE 2-5

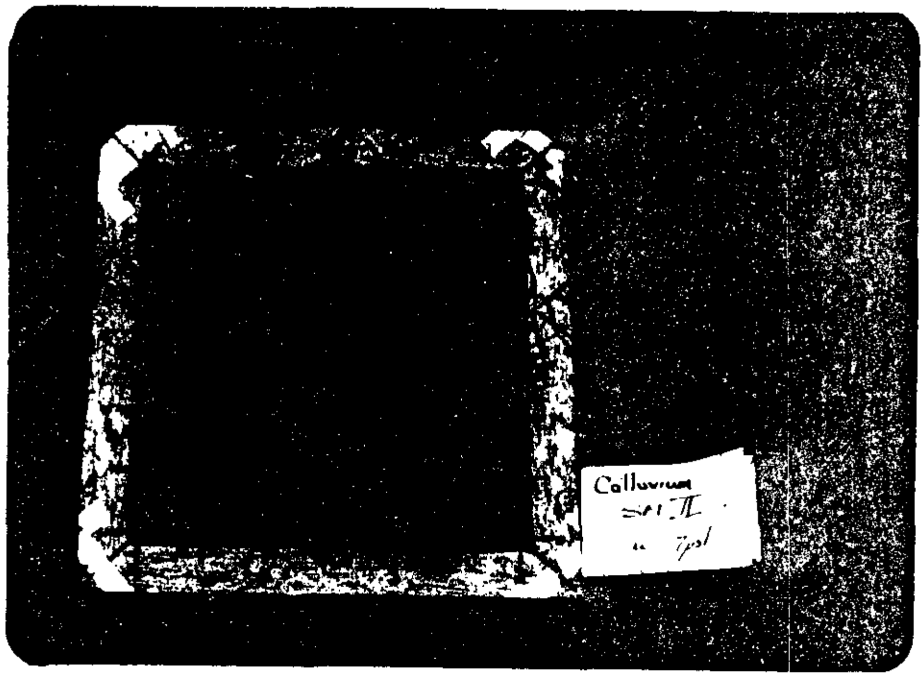
RANDOM SAMPLE SET NUMBER ASSIGNMENTS

Soil Type and Treatment	Seed Mix 1	Seed Mix 2	Seed Mix 3
Sandstone:			
Without topsoil	1	3	5
With topsoil	2	4	6
Coal Waste:			
Without topsoil	3	2	1
With topsoil	4	5	6
Carbonaceous Shale:			
Without topsoil	5	4	2
With topsoil	6	3	1
Baked Clay:			
Without topsoil	6	4	2
With topsoil	5	3	1
Colluvium:			
Without topsoil	4	5	6
With topsoil	3	2	1
Bentonitic Clay:			
Without topsoil	2	4	6
With topsoil	1	3	5
Glacial Gravels:			
Without topsoil	2	3	4
With topsoil	1	6	5
Fly Ash:			
Without topsoil	3	4	-
With topsoil	2	3	-

wearing plastic gloves clipped each 0.1 m^2 quadrat using acid washed (10% HNO_3) stainless steel scissors. Each seeded species was bagged separately in labelled, bleached white paper bags to minimize contamination by trace elements. The sampling was performed during late July and early August 1978 when plants were relatively dry. Only the aerial portion of each plant was collected. Weed species (invaders) were identified and counted and collectively placed in one bag per population. Typical sampling quadrats are shown in photographs 3 and 4.



Photograph 3 -
Sampling Quadrat - Bentonitic Clay



Photograph 4 -
Sample Quadrat - Colluvium

During the sampling, the total number of each plant species, average plant heights and percent ground cover were recorded for each quadrat. These data is presented in the 46 tables in Appendix 1.

The bagged samples were sent to B.C. Hydro Research and Development laboratory in Vancouver for drying and weighing. The samples were generally left in the paper bags and dried in a forced-air circulation oven at 100° C for 24 hours. Selected samples for trace element analyses were dried at 45° C for 72 hours to minimize loss of volatile elements.

2.1.4 Results of Vegetation Sampling

Details of plant counts and biomass produced for each of the eight test plots is presented in Appendix 1 and Appendix 2. These data are summarized in Tables 2-6 to 2-9.

ranked last in germination success of grasses on both topsoil and non-topsoil. The Rubens variety indicates much better results than common Canada bluegrass but is still lower than originally predicted by Acres[6]. Perhaps the success of this species will increase after the first year.

Flower Development - The colluvium, baked clay and glacial gravel plots had a lower percentage of plants than reached maturity compared to some of the other plots, however, these soils had a much higher germination success. On the soils the panicles were larger and better developed whereas the panicles on those plants which grew on the other soils were rudimentary in structure.

Overall, the Rubens species appeared healthy on the better soils exhibiting a dark green color on leaves and stems and often the basal leaves were dead or had brownish tips.

Drylander Alfalfa: This legume was not found to be as prolific as originally had been expected to occur based on laboratory studies[6]. The best results were produced on the fly ash plot with topsoil. Plants never attained heights of more than 8.7 cm (fly ash with topsoil) and therefore biomass production is small. Carbonaceous soils produced extremely poor results. Highest germination success was obtained on colluvium without topsoil.

Flower/Fruit Development - None of the plants observed had any indication of flower development.

Leaf/Plant Description - Generally the condition of the plants varied from plot to plot but overall the plants were erect (no lodging) and quite often leaf chlorosis and necrosis was evident. On the whole the plants seemed to be stunted and indicated rudimentary development. The undersides of leaves were commonly found to be purplish in color. When chlorosis was evident it was more prominent on lower leaves than upper, and occurred on the periphery of the leaves.

Drylander alfalfa was found to be the second most successfull legume (sainfoin was best) when considering germination success (both on NT and T). In terms of biomass it was the lowest producer of all legumes.

<u>Sainfoin</u>: The best results were obtained on the fly ash plot, with topsoil, yielding plants of the highest total biomass, as well as biomass per plant and highest average plant height. Baked clay, colluvium and glacial gravels also produced good results both with and without topsoil. Coal waste and carbonaceous shale produced poorest results.

The best germination results were obtained on baked clay (24.9%), however the plants did not attain high biomass. Perhaps the texture of the soil was the limiting factor, as it has been suggested that since the baked clay was a fairly coarse texture, and a low organic matter content that the ability of this material to hold plant-available water is less than optimum.

Other factors which might inhibit the growth of the sainfoin are those involved with the nitrogen-fixing bacterial nodules on the roots of the plant. These microorganisms require elements essential for their well-being that are otherwise not essential to the plant itself. i.e. it has been postulated that these bacterial organisms require certain concentrations of cobalt in order to fix nitrogen - which is not otherwise known to be an essential elements in plant. In addition the molybdenum requirement of legumes is much higher when they are fixing atmospheric nitrogen than when utilizing nitrate or ammonia. These two elements were found to be present in higher concentrations in the legumes than in the grasses at Aleece Lake.

Sainfoin had the best germination success of all the legumes on both topsoil and non-topsoil, and also produced the highest amount of biomass.

Flower Development - was poor on sainfoin overall. Fly ash with topsoil resulted in highest percentage of mature plants ($\simeq$ 10%), but the rest of the plots had generally 5% of plants in a mature state. Even on colluvium with topsoil all the plants were immature.

Plant Descriptions - On the colluvium, baked clay and glacial gravels plots the plants appeared to be healthy, exhibiting variable shades of green leaves (light to dark), while on the other soils, leaf tip chlorosis was apparent and often the plant appeared to be dried out. Minor chew on leaves was evidenced also.

Sweet Clover: This legume appears to have poor vigor after its first year growth on all soils. Germination success was very low overall. The better soils produced the best results on non-topsoils, while fly ash with topsoil had highest biomass/plant even though the germination success was not the highest. Zero growth was obtained on fly ash without topsoil.

Flower Development - Absent.

Plant Description - Plants on the better soils appeared healthier than those on the carbonaceous and other soils.

Damage by insects was apparent on many plants but was not extensive. Generally the plants were clean and exhibited very few spots or signs of chlorosis. Since sweet clover is a biennial it is expected to perform better after the second years growth.

Double Cut Red Clover: This legume exhibited poor success and poor vigor overall. Among the legumes it ranked last in terms of germination success and was not a high biomass producer among legume species. Performance of this species was best on the topsoil and non-topsoil halves of the colluvium, baked clay and glacial gravels plots. Moderate results were obtained on the gritstone and bentonitic clay plots with poor results on the carbonaceous shale and coal waste plots.

The best results were obtained on baked clay with topsoil.

Flower Development - The only occurrence of reproductive organs was indicated on the three better soils. Flower development was noted expecially on the perimeter of these plots, where very large red clover plants were present. Within the plots, approsimately 5% indicated flower development.

Plant Descriptions - The red clover generally exhibited stunted growth but relatively healthy appearing plants, leaves were uniformily green, had few chew marks, and the plants were erect.

Seed Mix Species Compatibility

Species selected for the field revegetation program were considered to be potentially adaptable to the severe climate at Hat Creek. Species considered compatible in terms of rooting competition and life cycles were selected for each of the three seed mixes as the competition for the limited moisture supply and nutrients can be a major factor in vegetation establishment. Legumes, as well as grasses, were included in the seed mixes.

The results of a species compatibility assessment after the first year's growth are discussed in the following and suggestions made for improvements in seed mix selection.

Seed Mix 1

Seed mix 1 consisted of the following four species: crested wheatgrass, drylander alfalfa, canada bluegrass and fall ryegrass.

The selection of fall ryegrass was based on its expected high return of organic matter to the soil after the first year, since it is an annual species. The growth data at Aleece Lake indicate that fall rye is a particularly vigorous species, exhibiting excellent emergence success and productivity on all the soils tested. It may have caused an inhibition in the emergence and productivity of the other species in the seed mix, in particular with drylander alfalfa. Although longer term effects are not yet known, the present data indicate that a lower application rate of fall rye may be advantageous to the first year development of other less vigorous species.

It was expected that the fall ryegrass, an annual species, would die out after the first year by which time the longer-lived species would be sufficiently established to take their place. Crested wheatgrass and canada bluegrass are both long-lived species selected for this seed mix. These are expected to show greater success in the second year.

Canada bluegrass exhibited extremely poor germination success and first year biomass production on all soil types. This may be attributed to low seed viability in addition to poor seedling vigor against the fall ryegrass.

Crested wheatgrass exhibited much better performance than canada bluegrass but the emergence rate was less than some of the other seed species. It is suspected that this species also would show greater success in the absence of the fall ryegrass.

Legumes are commonly used in association with grasses on soils of low nitrogen content. The effect of this combination is to increase the root biomass of the grasses and increase the nitrogen concentration in the soil. Drylander alfalfa exhibited low emergence and productivity in comparison with other grasses and legumes in the other seed mixes. It is suspected that the presence of fall ryegrass attributed to its poor success. In areas where the competition with fall ryegrass was reduced, as at the sloped plots, drylander alfalfa showed dramatic improvements in growth. This legume is expected to show increased performance over longer periods since it is a long-lived species.

Seed mix 1 exhibited the highest values of biomass per m^2 compared to the other seed mixes on both topsoil and non-topsoil treated plots. However this can be attributed to the fall ryegrass which accounted for most of the biomass produced. In fact, seed mix 1 had the lowest average number of plants per m^2 on both non-topsoil and topsoil.

In summary, the performance of seed mix 1 might be improved by reducing the percentage of fall ryegrass seeds, eliminating the canada bluegrass and substituting another legume or perhaps another perennial grass.

Seed Mix II

Seed mix II consisted of the following species: russian wild ryegrass, slender wheatgrass, sainfoin and sweet clover.

Russian wild ryegrass and slender wheatgrass were selected for this seed mix because of their diversity in characteristics, such as rooting systems, life cycles and ability to withstand adverse climate conditions.

Russian wild rye exhibited excellent emergence on most soil types, although the plant size is relatively small. This is, however, a result of slow seedling development of russian wild rye which is characteristically slower than for most other grasses. Russian wild rye plants are known to resist invasion by weeds and other grass; this may have had some effect on the emergence of the slender wheatgrass.

The slender wheatgrass was expected to establish quickly. Whilst this species did not exhibit emergence success as great as the russian wild rye, it showed higher productivity. Basically it seems that these two grasses are able to compete successfully for nutrients, water and space without adversely affecting one another's performance.

These grasses can be expected to show greater success in poor soils in the presence of legumes. Two legumes were selected for this seed mix, sainfoin and sweet clover. The sweet clover was included since it typically establishes quickly. Sainfoin indicated the best emergence and productivity of all the legumes tested, possibly due to its larger seed size. Sweet clover emergence was slightly lower than the other legumes, but productivity was good. The sweet clover and sainfoin generally showed similar growth on topsoil and non-topsoil treated plots. On many of the plots the legumes appeared to do much better around the periphery of the plots, where there may have been reduced competition from grasses.

Overall, seed mix II showed the highest number of plants growing per m^2 on nearly all the soils tested on both topsoil and non-topsoil plots. Furthermore, weed species were less abundant on the non-topsoil treated plots of seed mix II than on the non-topsoil plots of seed mix I and III. This may be a reflection of the ability of the species in seed mix II to resist invasion by weeds.

Seed Mix III

Seed mix III consisted of the following species: smooth bromegrass, streambank wheatgrass, canada bluegrass (Rubens) and double cut red clover.

All of the species in this seed mix are long-lived species. Streambank wheatgrass and smooth bromegrass were selected because they are sod grasses which establish quickly. Canada bluegrass is also long-lived and in addition has creeping rhizome roots. Double cut red clover is a long-lived perennial legume.

The first year data indicate that compatibility between the species is relatively good. Streambank wheatgrass and smooth bromegrass both exhibited good emergence success when compared with the other grass species tested at Aleece Lake. These grasses help stabilize the soil through the combined effects of their roots. Smooth bromegrass has creeping rooted rhizomes and produces a good yield of root biomass, while streambank wheatgrass develops a dense, low-growing sod which gives good protection to the soil and also helps to keep out weeds.

Generally it is presumed that these grasses will increase their root production if they are planted in association with a legume. In this seed mix, double cut red clover was selected. This legume showed very poor emergence on most soil types, but generally had an overall emergence similar to the drylander alfalfa.

It was observed that the red clover grew better around the periphery of the plots. This increased peripheral growth was also noted with sweet clover and sainfoin. The exact reasons for the relative success on the edges of the plots are unclear, however, the most likely explanation is reduced competition by grasses.

Canada bluegrass (rubens) exhibited better emergence and production than the common variety of canada bluegrass, but its growth was poor relative to other grass species tested at Aleece Lake. It seems probable that the poor success of this species is related to low seed viability and poor seedling vigor.

Seed mix III produced similar biomass per m^2 results as seed mix II, but indicated slightly lower emergence success. This effect may be attributed to the poor germination success of canada bluegrass. The performance of seed mix III might be improved by substituting another legume or grass species for the canada bluegrass.

TABLE 2-10

AVERAGE NUMBERS AND BIOMASS OF INVADERS AT ALEECE LAKE TEST PLOTS

	With Topsoil				Without Topsoil			
	Average Number of Invaders/m^2	% of Total Plants	Average Invader Biomass g/m^2	% of Total Biomass	Average Number of Invaders/m^2	% of Total Plants	Average Invader Biomass g/m^2	% of Total Biomass
Carbonaceous Shale	14	4	6	13	0	0	0	0
Coal Waste	12	3	5	11	2	1	0.4	6
Bentonitic Clay	14	3	12	16	3	1	0.6	2
Gritstone	41	10	17	19	4	1	3	9
Colluvium	6	1	16	7	3	< 1	8	3
Baked Clay	10	2	9	6	2	< 1	1	<1
Glacial Gravel	9	3	11	9	3	< 1	3	2
Fly Ash	70	36	69	36	19	21	5	6

Invader Species

Weeds were encountered in all of the areas sampled. The number of weeds per M^2 and the weed biomass as a percentage of total plot plants and biomass is shown in Table 2-10. The majority of the weeds are located on the topsoil half of the plots presumably transported there as seeds in the topsoil. In terms of total biomass produced the invader species do not represent a major obstacle to the growth of agronomics on the non-topsoil treated plots. On the topsoil portion of the plots however, weeds comprise a greater proportion of the biomass; on the fly ash this amounts to more than half of the total biomass and it is likely that some competition from the weeds occurred in this case.

The success of the weed species on the topsoil treated half of the plots, as measured by plants/m^2, shows a dependence on seed mix. Table 2-11 shows that there is no substantial difference in the abundance of weeds on the untreated soils, however on the topsoil it is evident that plots seeded with seed mix I are least susceptible to weed invasion. This effect can be attributed to the presence of the fall ryegrass which acts as a deterrent to the invasion of weed species.

TABLE 2-11

ABUNDANCE OF INVADER SPECIES BY SEED MIX

Seed Mix	Average Number of Weeds/M^2	
	Non-Topsoil	Topsoil
I	2.8	9.3
II	2.4	17.3
III	4.0	19.0

The abundance and type of invaders on the topsoil treated and untreated soil plots are shown in Tables 2-12 and 2-13. The four most abundant weeds made up over 75% of the total found on the non-topsoil portions of the plots and over 60% on the topsoil treated portions. Invader species on the topsoil treated portions indicate slightly more species diversity, 21 species as compared to 15 on the untreated soils, but basically show the same distribution.

Shrub species were present but not abundant on the Aleece Lake plots, comprising only 5% of the total invaders. Generally it is more difficult for shrub species to become established on reclaimation sites due to poor seedling vigor and the inability of seedlings to compete successfully against the more aggressive grasses.

Generally the invader species were more advanced, in terms of plant maturity than the agronomics; the weeds were at the flowering or seeding stage while the agronomics were still in vegetative growth.

The characteristics of the major invader species are given below:

Flixweed

- is an annual or biennial plant with an erect stem. Plants were most frequently developed to the point of maturity (flowers or pods), and ranged in height from 3.0 cm on the carbonaceous shale plot to 80.0 cm on the colluvium plot. Often the plants were devoid of leaves.

Prostrate Knotweed

- is an annual, which grows in a creeping or semi-erect fashion. This species indicated excellent growth on all plots, and usually displayed flower development.

TABLE 2-12

OCCURRENCE OF INVADER SPECIES ON
NON-TOPSOIL PORTIONS OF PLOTS

Species	Number Plants/M^2	Percent of Total
1. Flixweed	27	30
2. Prostrate Knotweed	23	26
3. Downy Brome	12	13
4. Bluebur	6	7
5. Compositae	4	4
6. Sagebrush	3	3
7. Pepperweed	2	2
8. Chenopodialgae	2	2
9. Shepherd's Purse	2	2
10. Wild Oats	1	1
11. Foxtail Barley	1	1
12. Fringed Sage	1	1
13. Lamb's Quarters	1	1
14. Curciferae	1	1
15. Slimleaf Goosefoot	1	1
16. Unknowns	4	4
Total	90	

TABLE 2-13

OCCURRENCE OF INVADER SPECIES ON TOPSOIL PORTIONS OF PLOTS

Species	Number Plants/M^2	Percent of Total
1. Flixweed	116	26
2. Prostrate Knotweed	79	18
3. Downy Brome	44	10
4. Bluebur	40	9
5. Lamb's Quarters	26	6
6. Shepherds Purse	24	5
* 7. Stickweed	16	4
* 8. Povertyweed	16	4
9. Common Sagebrush	13	3
10. Compositae	11	3
11. Chenopodiaceae	7	2
12. Pepperweed	4	1
* 13. Graminae	3	1
14. Slimleaf Goosefoot	3	1
* 15. Falseflax	2	-
* 16. Leguminosae	1	-
17. Foxtail Barley	1	-
18. Fringed Sagebrush	1	-
19. Cruciferae	1	-
* 20. Brown-Eyed-Susan	1	-
* 21. Wild Forget-Me-Not	1	-
22. Unknowns	29	7
Total	439	

Plants ranged in length from about 3.0 cm to about 40 cm and averaged 20-25 cm. Leaves were green most often and some evidence of chewing was noted in various areas.

<u>Downy Brome</u>

- is an annual grass, similar to form to smooth brome-grass. On many plots this species indicated much lodging. The plants were almost always with an in-florescent development and averaged 25-30 cm. Heights of up to 50 cm were noted on the baked clay.

<u>Bluebur</u>

- is an annual or winter annual species. In many instances the plants were devoid of leaves but indicated seed development. Average heights of the bluebur are in the range of 15-25 cm, but heights of up to 240 cm were noted on some plots.

These species are the most abundant at Aleece Lake. They are characteristically found in the native environment on soils of poor quality.

2.2 SLOPED TEST PLOT AREAS

2.2.1 Introduction

In the present mining plan a major waste disposal area it to be located at Houth Meadows. During 1977 sloped revegetation test areas were constructed at Houth Meadows to provide a large scale area where the effects of embankment slope and other variables on revegetation success could be studied.

At Houth Meadows three sloped test plots with slopes of 22^{o}, 26^{o} and 30^{o} were constructed using recent gravels from Trench B.

Photograph 5 -
Houth Meadows Slope Test Plots

A 5cm layer of topsoil from Trench B was applied to half of each sloped plot. A level area at the base of the sloped plots was also included in the revegetation tests. The plots face east-south-east the same direction that the major embankment of the proposed waste disposal area would face.

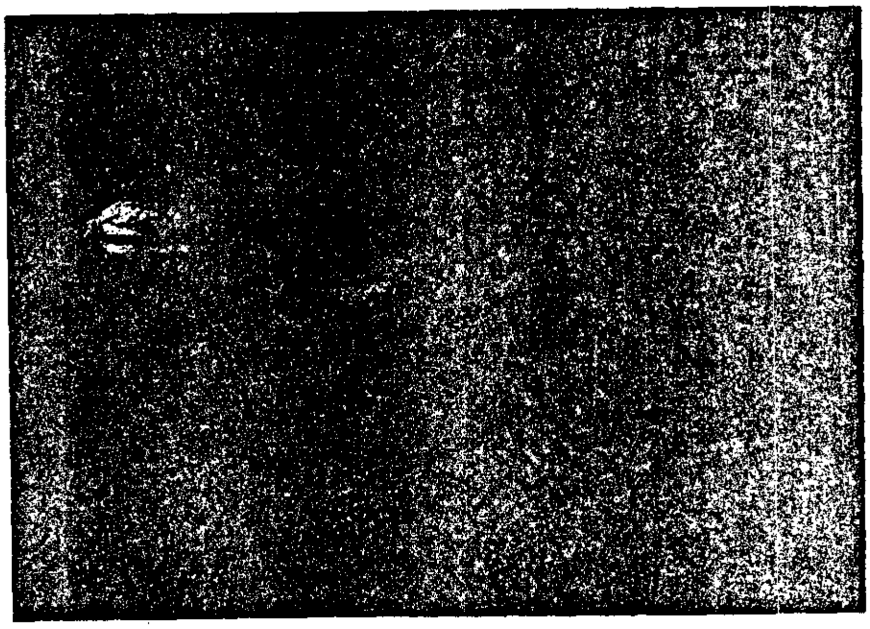
The second major waste disposal area selected in the mining plan is in the vicinity of Medicine Creek to the east of Houth Meadows. In 1977 a sloped revegetation test area was also constructed near Medicine Creek.

Photograph 6 -
Medicine Creek Slope Test Plots

This test area was similar to that at Houth Meadows except that the slopes face west rather than east-south-east. Three test plots with slopes of 22°, 26° and 30° were constructed of in situ glacial till. No topsoil was added.

These test plots were fertilized and seeded in September 1977. The sloped plots and most of the level area were hydro-seeded. A small section of the level area at Houth Meadows was harrowed and hand planted.

The second major waste disposal area selected in the mining plan is in the vicinity of Medicine Creek to the east of Houth Meadows. In 1977 a sloped revegetation test area was also constructed near Medicine Creek.



Photograph 6 -
Medicine Creek Slope Test Plots

This test area was similar to that at Houth Meadows except that the slopes face west rather than east-south-east. Three test plots with slopes of 22°, 26° and 30° were constructed of <u>in situ</u> glacial till. No topsoil was added.

These test plots were fertilized and seeded in September 1977. The sloped plots and most of the level area were hydro-seeded. A small section of the level area at Houth Meadows was harrowed and hand planted.

Photograph 7 -
Houth Meadows Slope Test Plots
Harrow and Hydro-seeded portions
of level areas.

Seed mix #1, one of the three seed mixes used at the Aleece Lake test plots, was used for all of the seeding.

A complete description of the design and construction of the sloped test plots is presented in the report to B.C. Hydro by Acres entitled "Environmental Studies, Bulk Sample Program".

2.2.2 Soil Nutrient Analyses

Soil samples were collected at Houth Meadows and Medicine Creek sloped test plots on 26 April 1978 in a similar manner as used at Aleece Lake. A composite sample of soil was made by combining samples taken from the midslope position of each slope at about the centre of the plot. At Houth Meadows, composite samples were collected from both the topsoil treated

The success of the revegetation trials is discussed in the light of the soils characteristics of the various waste materials. The effect of topsoil and the performance of the twelve vegetation species tested is discussed separately.

Soils as Growth Media

Based on their chemical and physical properties (Table 2-1) the eight waste materials may conveniently be grouped into four categories: carbonaceous, sodic, alkaline and fly ash materials. Results of biomass and plants produced per unit area are given in Tables 2-6 and 2-9.

Carbonaceous Materials

Both the coaly waste and carbonaceous shale exhibited low pH and a moderately high soluble boron concentration. Their dark colour would be expected to cause high surface temperature and surface drying. In addition, the shale is somewhat water repellent and moisture does not easily penetrate the surface.

In terms of biomass produced and seedling emergence neither material proved to be successful growth medium (Tables 2-6 and 2-8). The chemical chatacteristics of the materials appear to be less deterrent to plant growth than do their physical properties , particularly their dark colour and the hydrophobic mature of the shale. The poor plant emergence on these materials may be attributed to unsuitably low soil moisture conditions during the period of potential germination. Average biomass production per plant was low compared with that in other soils. Plants rarely progressed beyond the seedling stage.

The addition of topsoil increased markedly the emergence success and total biomass production. Biomass per plant increased sharply for the coal waste but remained essentially unchanged on the shale. This is discussed further, see The Effects of Topsoil.

TABLE 2-6

NUMBER OF PLANTS PRODUCED ON ALEECE LAKE PLOTS

Plot	Average Number of Plants Per m^2							
	Seed Mix 1		Seed Mix 2		Seed Mix 3		Average	
	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil
Carbonaceous Shale	30	380	0	400	20	360	17	380
Coal Waste	120	240	110	490	210	270	147	333
Bentonitic Clay	140	230	400	530	270	330	270	363
Gritstone	190	390	430	510	260	240	293	380
Colluvium	310	240	600	450	650	520	520	403
Baked Clay	170	230	520	480	360	520	350	410
Glacial Gravels	300	270	490	490	390	190	393	317
Fly Ash	310	140	370	500	–	–	340	320
Average	200	270	370	480	310	350		

TABLE 2-7

EMERGENCE SUCCESS RATIO - AVERAGE NUMBER OF PLANTS PRODUCED AS A PERCENT OF SEED SOWN

PLANT	CARBONACEOUS SHALE		COAL WASTE		BENTONITIC CLAY		GRIT STONE		COLLUVIUM		BAKED CLAY		GLACIAL GRAVELS		FLY ASH		AVERAGE	
	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T
GRASSES																		
Crested Wheat Grass	3	36	11	21	12	20	18	37	26	21	12	18	24	24	29	11	17	24
Canada Blue Grass	0	0	0	0	0	0	0	0.5	1	0	0	0	1	0	0	0	0	0
Fall Rye Grass	4	45	23	42	15	24	26	38	36	38	58	42	53	36	39	14	32	35
Russian Wild Rye Grass	0	30	8	27	34	39	33	40	43	30	33	35	38	35	40	34	29	34
Slender Wheat Grass	0	16	9	49	14	16	22	17	33	21	27	9	21	22	5	21	16	21
Smooth Brome Grass	0	23	9	22	16	27	16	22	62	45	34	48	40	15	-	-	25	29
Streambank Wheat Grass	2	30	20	21	25	22	24	16	41	35	19	32	18	12	-	-	21	24
Canada Blue Grass (Reubens)	0	2	0	1	0	3	0	3	1	4	8	5	6	4	-	-	2	3
LEGUMES																		
Drylander Alfalfa	0	4	0	4	4	7	2	7	9	5	2	6	8	5	3	5	4	5
Sainfoin	0	13	1	12	10	21	12	16	16	20	20	25	14	16	2	21	9	18
Sweet Clover	0	2	<1	2	2	4	1	5	4	3	7	3	5	6	0	4	2	4
Red Clover	0	1	0	1	0	4	0	1	9	6	6	8	9	3	-	-	3	3

NT - No Topsoil
T - With Topsoil

TABLE 2-8

TOTAL BIOMASS PRODUCED ON ALEECE LAKE PLOTS

Plot	Biomass Produced In G/M^2 *						Average	
	Seed Mix 1		Seed Mix 2		Seed Mix 3			
	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil
Sandstone	56 (57)	152 (157)	21 (22)	33 (57)	16 (24)	32 (55)	31	72
Coal Waste	6 (6)	71 (72)	3 (4)	17 (20)	6 (6)	29 (39)	5	39
Carbonaceous Shale	5 (5)	81 (82)	0 (0)	22 (36)	0 (0)	23 (28)	1.7	42
Baked Clay	320 (320)	322 (322)	104 (104)	74 (85)	88 (91)	52 (68)	171	149
Colluvium	506 (517)	486 (491)	139 (141)	125 (145)	171 (182)	127 (152)	272	246
Bentonitic Clay	41 (41)	120 (124)	20 (21)	35 (45)	11 (11)	41 (53)	24	65
Glacial Gravels	260 (260)	236 (237)	62 (63)	62 (69)	67 (74)	32 ((58)	130	110
Fly Ash	142 (151)	144 (196)	4 (4)	103 (189)	-	-	73	124
Average	167	202	44	59	51	48		

* Figure in parenthesis includes invader species.

TABLE 2-9

AVERAGE SIZE OF PLANTS PRODUCED IN GRAMS/PLANT

Plant	Carbonaceous Shale		Coal Waste		Bentonitic Clay		Gritstone		Colluvium		Baked Clay		Glacial Gravels		Fly Ash		Average	
	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T	NT	T
GRASSES																		
Crested Wheat Grass	0.02	0.02	0.01	0.04	0.05	0.13	0.03	0.07	0.24	0.20	0.11	0.12	0.08	0.12	0.13	0.18	0.084	0.110
Canada Blue Grass	0	0.01	0	0	0	0.02	0	0.11	0.02	0	0	0	0.03	0.07	0	0	0.006	0.026
Fall Rye Grass	1.17	1.82	0.27	1.67	2.73	4.64	2.25	3.77	14.1	15.2	5.90	8.12	5.12	6.67	3.10	9.08	4.33	6.37
Russian Wild Rye Grass	0	0.01	0.02	0.02	0.02	0.04	0.02	0.04	0.12	0.13	0.11	0.08	0.08	0.07	0.01	0.13	0.048	0.065
Slender Wheat Grass	0	0.21	0.04	0.12	0.18	0.22	0.11	0.16	0.66	0.90	0.52	0.84	0.34	0.35	0.02	0.44	0.233	0.405
Smooth Brome Grass	0	0.09	0.03	0.21	0.04	0.14	0.04	0.14	0.20	0.19	0.22	0.20	0.18	0.18	-	-	0.101	0.114
Streambank Wheat Grass	0	0.06	0.03	0.06	0.04	0.13	0.07	0.14	0.35	0.31	0.30	0.22	0.22	0.19	-	-	0.144	0.160
Canada Blue Grass (Reubens)	0	0.03	0	0.07	0	0.07	0	0.04	0.03	0.08	0.27	0.11	0.04	0.05	-	-	0.049	0.064
LEGUMES																		
Drylander Alfalfa	0	0.03	0	0.01	0.02	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.01	0.01	0.02	0.06	0.011	0.025
Sainfoin	0	0.08	0.03	0.05	0.05	0.06	0.07	0.08	0.09	0.13	0.16	0.13	0.11	0.11	0.02	0.23	0.066	0.109
Sweet Clover	0	0.02	0.01	0.02	0.07	0.03	0.05	0.04	0.10	0.18	0.13	0.13	0.07	0.08	0	0.29	0.054	0.099
Red Clover	0	0.03	0	0.02	0.04	0.06	0.02	0.05	0.03	0.08	0.07	0.15	0.09	0.04	-	-	0.036	0.061

NT - No Topsoil
T - With Topsoil

In general terms plants appeared stunted and suffered from chlorosis. Most of the grasses showed only limited spike development while the legumes were devoid of any signs of maturity.

Sodic Materials

The materials in this category, bentonitic clay and gritstone, exhibited high concentrations of sodium, Field observations indicated that the soil structure was poor under extreme conditions of moisture, that is, gel-like and swollen when saturated, and severely shrunken and cracked when dry.

Results (Tables 2-6 and 2-8) indicated that those soils were moderately successful in terms of seedling emergence but biomass production was relatively low. This may be due to the high concentration of sodium which contributed to poor soil structure and nutrient imbalances.

The effect of topsoil was to increase substantially the emergence success and to double the individual plant size. These aspects are discussed further, see The Effects of Topsoil.

Plants on the beontonitic clay and gritstone were stunted and generally exhibited leaf tip chlorosis. Grasses showed up to 20% inflorescence except for fall rye which exhibited a greater, almost 100%, degree of maturity. None of the legumes showed flower development.

Alkaline Materials

These materials, colluvium, baked clay and glacial gravels, exhibited moderately good soil characteristics. There did not appear to be any potentially adverse constituents to inhibit plant growth although, as with most other materials tested, they were low in nitrogen. Physically they were relatively coarse. Their water holding capacity would therefore be low and thus they were expected to be droughty during periods of low rainfall.

Biomass production and seedling emergence confirmed the good soil characteristics of these materials as growth media (Tables 2-8 and 2-6). Although quantitative data showed less overall vegetative growth on baked clay and glacial gravel as compared to the colluvium plot, qualitatively they appeared similar; growth in all three cases was most abundant. Plants appeared healthy with little sign of chlorosis.

The effect of topsoil on these materials was inconsistent. The glacial gravels and colluvium exhibited similar results in that overall emergence success and biomass production decreased with topsoil. The baked clay did not show a consistent trend; whilst a greater emergence success yielded more plants/m^2 with topsoil they were smaller in size resulting in a decrease in overall biomass production. This aspect is discussed further, see The Effects of Topsoil.

Fly Ash

The fly ash is discussed separately because it is anthropogenic. It exhibits a high pH and a high soluble boron concentration which might be sufficient to be detrimental to plant growth. This material was a uniform silty loam which maked it susceptible to wind erosion in the absence of a vegetation cover.

The plant emergence data suggests that the fly ash provided a good environment for seed germination. However, total biomass production was low and individual plants were stunted (Tables 2-6 and 2-8). It is suggested that metabolic interference due to boron may have occurred. Plants appeared dried out and exhibited chlorotic conditions.

The topsoil treatment had a positive effect on average plant size. Biomass production was approximately doubled yet the number of plants that emerged was approximately the same.

The Effects Of Topsoil

Half of each soil material test plot at Aleece Lake was covered with a 5 cm capping of topsoil. The seeds were sown at equal rates on both topsoil and non-topsoil portions. Three different seed mixes were tested on each soil material, except on the smaller fly ash plot where only two seed mixes were applied. Results of emergence success and biomass production are shown in Tables 2-6 and 2-9 and Tables 2-7 and 2-8 for the three seed mixes and twelve individual species respectively.

Considering first the effect of topsoil on plant emergence: on the least successful materials, the carbonaceous soils, the presence of topsoil dramatically increased the number of plants per m^2. A smaller but nevertheless substantial increase also occurred with the gritstone and bentonitic clay materials, whereas there was a marked decrease in overall emergence success on the colluvium and glacial gravels. The baked clay and fly ash showed variable responses among the seed mixes with the former showing a net increase and the latter a slight overall decrease.

Emergence on the topsoiled portions of the plots showed an average value of 363 plants/m^2 over all materials with a range of values from 317 to 410 plants/m^2. This consistency would be expected for vegetation germinating in the same medium. The microenvironment presented to the seeds was clearly improved in the topsoil as compared with the carbonaceous materials, bentonitic clay and gritstone where such adverse factors as soil pH, soil structure as it affects the movement of gases and moisture, and salinity existed.

Surprisingly, the glacial gravel and colluvium provided a more suitable microenvironment than the topsoil.

The practice of stripping and stockpiling topsoil or other suitable surface material during initial mining for subsequent surfacing of waste materials is being widely recommended as a method of improving the success of revegetation programs. These results indicate that the separate stripping and stockpiling of only topsoil horizons at Hat Creek need to be evaluated further. It may be beneficial to include other suitable subsurface materials such as gravels and colluvium if soil for future surfacing of dumps is to be retained.

Biomass results and emergence data showed similar trends (Tables 2-6 and 2-8). However, although major improvements were noted on the coal waste, carbonaceous shale, bentonitic clay and gritstone, the yields were substantially less than those obtained on other materials at Aleece Lake.

The reasons for these effects cannot be defined precisely with data presently available. Nevertheless it seems clear that the plant seedling, as its root system penetrated the thin topsoil layer, encountered the poorer material where further root development was inhibited. Thus the continued uptake of nutrients and consequently, plant growth, was retarded. The net result was that plants were stunted with a higher incidence of chlorosis than those grown on the better materials. It did not appear that acute toxic conditions, e.g. due to boron, existed, since vegetation continued to develop on the topsoil-treated side throughout the first year of growth.

The effect of topsoil on individual species performance shows essentially the same trends as those outlined for the three seed mixes. Complete data is given in Appendix 2.

Individual Vegetation Species

Twelve plant species were tested at Aleece Lake; eight grasses and four legumes. These species were originally selected on the basis of their suitability for use on the soil materials available and their adaption to the climate of the Hat Creek Valley. Individual species were examined, counted and their biomass production determined. Summaries of the data are reported on Tables 2-7 and 2-9. Results are discussed for each species and collectively for the three seed mixes.

Crested Wheatgrass: Overall, colluvium soil produced the greatest biomass/plant and greatest average height. Gritstone with topsoil had highest germination success (36.9%) and carbonaceous shale without topsoil had poorest germination (3.2%).

Spike Development - Varied from one soil type to the next. No development on non-topsoil coal waste or on bentonitic clay without topsoil. 20-25% inflorescence development on glacial gravels with topsoil. Generally, the topsoil had best spike development. Spike length varied from 2.5 cm carbonaceous shale to 4.0 cm on the glacial gravels.

Leaf Description - On all plots it was found that the basal leaves were brown and/or dead. Generally the upper leaves were green, except at tips which were brownish or purple. Lodging of plants was not apparent on any plots. Plants were clean; free of visible dust and dirt.

Canada Bluegrass: This grass species had the poorest germination success of all the species studied, on both topsoil and non-topsoil. Poor results were obtained on all soils, and three soils; baked clay, fly ash and coal waste produced zero growth. Of the non-topsoil materials only glacial gravels and colluvium produced any growth. Colluvium produced best results on non-topsoil but when topsoil was added produced zero growth. Germination success was highest on non-topsoil glacial gravels (0.6%). Biomass production was exceedingly low.

Flower Development - No panicle development was evidenced on either topsoil or non-topsoil plots.

Plant Description - Overall the plants had rudimentary development generally the leaves were green and exhibited an interveinal purplish color, especially toward the leaf tips. Plants generally were clean.

Fall Ryegrass: This grass was the most successfull of all the species tested, producing the highest germination success on both topsoil and non-topsoil plots. Overall, fall rye performed best on topsoils, although on the baked clay, glacial gravels and fly ash, a higher emergence success was obtained on the non-topsoil side. A greater biomass/plant production on the topsoil portions of these same soils was obtained. Colluvium (NT and T) produced best results overall, while the carbonaceous soils produced poorest growth.

Spike Development - Fall rye reached maturity (spike development) on all plots, and generally 90 to 100% of the plants had spikes. The spikes ranged in length and stage of development depending on the soil type - i.e. poorer soil types such as carbonaceous shale resulted in small spikes (8.0 cm) while the preferred soils such as baked clay had the largest spikes (12.0 cm). On some plots, e.g. bentonitic clay, the spikes had already released seeds while on other plots the seeds were retained on 100% of plants.

Plant Description - All plants examined were found to have a light greenish-blue to grey-white powder on the stems and leaves. This 'powder' was found to rub off with the finger. A common feature of all plants observed was dead and/or brown, dry basal leaves. Upper leaves were generally more healthy (green color) but invariable exhibited brownish-yellow tips and edges.

Lodging was another feature common to fall rye, but varied between plots. No lodging was evidenced on the non-topsoil baked clay. Up to 20% lodging was observed on coal waste with topsoil.

Although lodging was common on all plots it was noted that the root systems were still intact with the soil, allowing growth to continue. Deficiencies of certain nutrients such as potassium are known to cause lodging of plants due to a weakening of stacks and by easily infected root organs. Note, though, that 5% lodging is a normal level in fall ryegrass crops.

Russian Wild Ryegrass: This grass was the second best species tested at Aleece Lake, producing the second highest germination success on both non-topsoil and topsoil materials. Russian wild rye appears to have a slight preference on the topsoiled areas overall. Non-topsoil colluvium produced the best results out of all soils tested, while carbaonaceous soils (NT and T) exhibited poorest growth, (only non-topsoil carbonaceous shale resulted in zero growth). Gritstone and bentonitic clay exhibited moderate growth results on both non-topsoil and topsoil.

Flower Development - No plants on any soil type produced flowers, or buds, however it is noted that this species is particularly slower to establish compared with similar type grasses.

Plant Descriptions - Generally the plants exhibited green leaves with yellow-brown tips, often with white spots but clean. The plant appeared to be dried out on most of the plots.

Slender Wheatgrass: The highest biomass and greatest number of plants occurred on colluvium with topsoil. The greatest germination success occurred on coal waste with topsoil (48.7%), however, this soil type also produced the lowest biomass results (total G/M^2 and G/plant). The high germination success of the slender wheatgrass on the coal waste is probably an effect of topsoil and having the proper conditions available for germination - however, the plants were not able to maintain growth once the end of the seedling stage was reached due to poor vigor suggesting that the initial growth (germination - seedling) was promoted by nutrients within the seed itself and by the early initial stages of the roots within the topsoil. Once the roots had penetrated the topsoil into the coal waste material growth was inhibited.

Flower Development - On the better soils, baked clay, colluvium and glacial gravels, the percentage of plants that had spike development was highest on both topsoil and non-topsoil (75 to 100% of plants mature). On the poorer plots, where germination success was low, the percentage of plants with spike development is low (0 to 25%). Slender wheatgrass improved best on the fly ash plot, where the non-topsoil had no plants with spikes, to the topsoil side which resulted in 80% of the plants with spikes.

Plant Descriptions - The plants characteristically indicated brownish-yellow leaf tips on all plots. Generally the plants were clean to slightly dirty and exhibited white spots on the blades on many plots.

Smooth Bromegrass: Overall, this long-lived sod grass ranked third among the grasses in terms of germination success. On the non-topsoils only carbonaceous shale was found to inhibit growth. The non-topsoil bentonitic clay and sandstone plots produced moderate success, while the non-topsoil colluvium, baked clay and glacial gravels plots produced excellent results. Colluvium soil resulted in 62.1% germination success. The same trend is found in biomass produced. On the topsoils, baked clay was found to produce the best results.

Flower Development - The percentage of plants that reached the reproductive stage ranged from 0 to 10% on the different soils. Pancile development (dark red-green or brownish-green panicles) occurred must successfully on the colluvium, baked clay and glacial gravels plots while the coal waste and carbonaceous shale produced the poorest development.

Plant Descriptions - The plants appeared to have stunted growth on the carbonaceous soils (generally rudimentary development), and seemed to be slightly dried out. On the better soils the plants were much healthier and more well developed, although quite often the basal leaves were brownish, partially chewed on and occassionally exhibited white spots along the ribs on some blades.

Streambank Wheatgrass: This grass is also a long-lived sod grass. The seeds are large and have good seedling vigor which makes them easy to establish. Streambank wheatgrass ranked fourth among the grasses in terms of germination success. *This grass has strong rhizomes that enable the grass to* spread rapidly to form a good ground cover thus giving good soil protection and helps to keep out weeds through competition. This grass will have poor success if the site is wet, due to crowding out by other grasses.

At Aleece Lake plots streambank wheatgrass performed best on colluvium, both on the topsoil and non-topsoil, but performed slightly better on non-topsoil. Overall performance was similar to the smooth bromegrass.

Spike Development - Best results occurred on the better soils, - eg. 10 to 30% of plants have reproductive organs, glacial gravels produced best results on topsoil and non-topsoil. The bentonitic clay and gritstone plots had moderate to poor spike development while the carbonaceous soils had very poor results.

Apparently it is normal for streambank wheatgrass to produce few seeds and therefore does not spread quickly to new sites by seeding.

Plant Description - Stunted growth and rudimentary development are characteristic results of poorer soils. For example, on the bentonitic clay, without topsoil, many of the plants are only 3 to 4 cm in height and never progressed from the seedling stage. On the three better soils the plants were erect and not as dried out as on the other plots. A bluish-green dust (or powder) was noted on the stems and leaves of the plants on the alkaline soils, in addition the younger parts of the plants was found to be healthiest (greener), often the basal leaves were dead and the upper leaves had brown tips.

Canada Bluegrass (Reubens): On the non-topsoil materials this grass exhibited exceedingly poor vigor - only colluvium and baked clay established bluegrass growth, and even this growth was very poor. Germination success was low (6.2 to 7.5%) on topsoil materials Canada bluegrass performed slightly better -- i.e. germination occurred on all soils, however, colluvium topsoil resulted in dramatic reductions in germinations success and biomass/plant. Overall both bluegrass species and the non-topsoil treated portions of each slope. The parent material was a composite sample obtained from the harrowed and hydroseeded areas.

The sampling, handling and testing procedures used were identical to those used at Aleece Lake and described in Section 2.1 of this report.

The results of the soils analyses are shown in Table 2-14. No fertilizer additions were made during 1978.

2.2.3 Vegetation Sampling and Handling Methods

The upper and lower sections of each sloped plot were sampled along transect lines as shown in Figure 2-2. The line for the upper portion of each slope was located one quarter of the distance down from the top of the slope. Similarly the line of the lower portion of each slope was located one quarter of the distance up from the bottom of the slope. The quadrat sampling line (as used at Aleece Lake) was used for sampling five 0.1 m^2 quadrate, arbitrarily selected as Quadrats 1, 5, 10, 15 and 20 or where reasonable, considering a number of factors such as disturbance by sampler or actual plot dimensions.

The level area at Houth Meadows of a harrowed, hand-seeded area and a hydro-seeded area. One transect line was run into each area. The transect lines both started at the same point, a marker located in the middle of the south boundary between the plots. The transect lines extended about 16 m into each plot with sampling quadrats located every 1.5 m starting at 0.8 m.

The sample collection and handling procedures were the same as used at Aleece Lake and described in Section 2.1 of this report.

TABLE 2-14

NUTRIENT ANALYSES OF SOIL MATERIALS* ON SLOPED PLOTS

Sample	Soil Texture	Organic Matter %	pH	Salts mmhos/cm	Available Plant Nutrients kg/ha					S ppm	B ppm	Na ppm
					NO_3-N	P	K	Ca	Mg			
Houth Meadows												
Topsoil	3	3.6	8.3	0.34	10	100	531	>11,200	>1,120	2.9	0.46	30
Recent Gravels	2	2.5	7.7	0.74	37	127	277	9,192	1,073	>30	<0.20	40
Parent Material	5	1.1	8.8	0.32	4	6	250	10,211	>1,120	2.3	0.38	20
Medicine Creek												
Till	4	1.6	8.4	0.44	29	113	618	>11,200	> 112	5.3	0.53	20

* Samples were collected 26 April 1978

2.2.4 Results of Vegetation Sampling

The total biomass produced on the sloped plots is summarized in Tables 2-15 to 2-18. Average plant counts and biomass production data for the sloped test plots is given in appendices 1 and 2.

There is no apparent relationship between plot slope and the amount of biomass grown on the individual test plots. However, the average values show the greatest quantity of biomass was produced on the 30° slope and the least on the 22° slope. The upper area of the slope plots generally produced less biomass than the lower levels. This may be due to uneven distribution of the seed as the slopes were hydro-seeded from below. Observations during the harvest indicated that the mulch distribution was patchy near the top of the sloped plots.

The number of plants followed similar trends as the biomass production. There were more plants produced on the lower parts of the sloped plots. The success ratio, the number of plants produced divided by the calculated number of seeds sown expressed as a percentage, was significantly higher for the lower portions of the sloped plots as shown in Table 10. The average number of plants produced was greatest on the 30° plot and least on the 22° plot.

The level area at the foot of the sloped plots was mainly hydro-seeded with a small section, about 10% of the area, harrowed and hand-seeded. The hydro-seeded area produced a very poor crop. The fall rye, the dominant species where seed mix 1 was planted, produced almost no growth on the hydro-seeded level area. The drylander alfalfa however produced a good crop which was reasonably uniform over most of the level area. The reasons for the failure of fall rye and relative success of the alfalfa are not clear. The most logical explanation would be improper seeding or possibly the larger rye seeds were not thoroughly mixed with the mulch.

The addition of topsoil to the sloped plots resulted in a substantial decrease in the number of plants produced and germination success. The effects on biomass production were inconsistent, the upper slopes had an increase while the biomass produced on the lower sloped decreased when topsoil was applied.

The characteristics of the recent gravels at Houth Meadows resemble closely those of the glacial gravels at Aleece Lake, as shown in Table 2-14 and 2-1. However the plant growth produced was not similar. The glacial gravels showed higher success ratio, for all species except fall rye, and higher biomass per plant. The legume in seed mix 1, drylander alfalfa, did better at Houth Meadows, probably due to the reduced competition from the fall rye grass which produced fewer and small plants at Houth Meadows than at Aleece Lake.

The results at Medicine Creek and Houth Meadows are very similar. The lower portion of the three slopes produced more vegetation; more plants grew on the 30° slopes than on the 22° and 26° slopes at both locations, and similar numbers of plants were produced, except for the lower portions of the 22° and 26° slopes at Medicine Creek which produced a low number of plants.

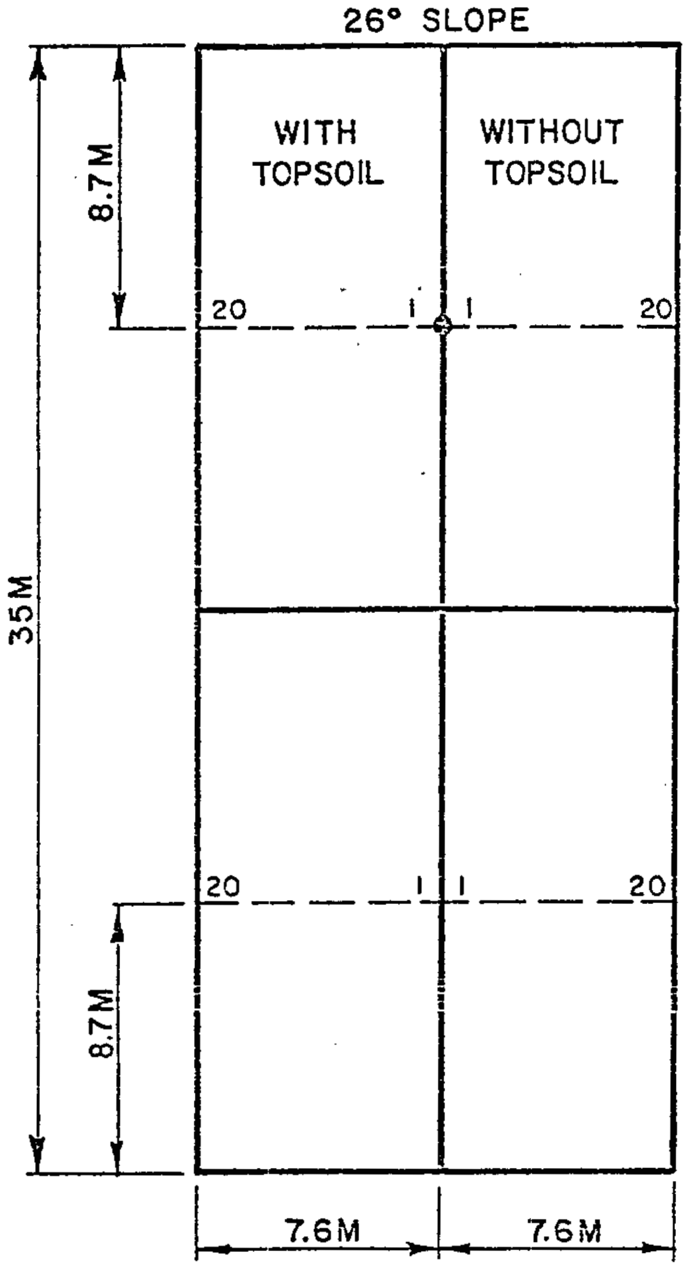
Examination of these slopes at both Medicine Creek and Houth Meadows indicated that waterborne erosion was minimal in the first year. See field notes on page 2-51.

These results show that the revegetation of dump faces comprised of either colluvium/till or gravel with an overall height of 15 m and with slopes up to 30° could be achieved in the first year after seeding. This conclusion if verified in the long term would result in reduced embankment material requirements at Hat Creek and therefore substantial cost savings.

EROSION ASSESSMENT AT
MEDICINE CREEK AND MOUTH MEADOWS
FIELD NOTES

Location	Date	Vegetative Cover	Mulch Cover	Erosion Characteristics	Comments
Medicine Creek					
22° Upper Slope	July 27	Good - excellent	undisturbed	none present	Vegetation appears to grow well in micro depressions i.e. tractor tracks and foot prints. Less disturbance to slope from footprints relative to steeper slopes.
22° Lower Slope	July 27	Good - excellent	undisturbed	none present	as above
26° Upper Slope	July 27	Good - appears to be distribution problems related to hydro-seeding	undisturbed	none present*	*except minor areas where footprints cause very minor local disturbances of approximately 2'x 1' dimensions (see photo 98-13-16). Plants appear to catch even in disturbed areas. Water may have cleared "faces" of soil aggregates.
26° Lower Slope	July 27	Good - excellent	undisturbed	non present*	* as above
30° Upper Slope	July 27	Good - excellent	generally undisturbed	none present	Subject to slightly greater disturbance from traffic than the lesser slopes. This characteristic could lead to further complications if cattle were allowed to cross this type of slope on a regular basis as water would tend to concentrate on such paths. Mulch is disturbed at footprint scars.
30° Lower Slope	July 27	Good - excellent	generally undisturbed	none present	as above
Mouth Meadows					
22° Upper Slope with topsoil	August 9	Poor - moderate appears to be problems with hydro-seeding application distribution	undisturbed** relatively thin	none present**	**Possibly sheet erosion - more likely poor distribution of mulch, gravelly pavement, only large rocks without mulch.
22° Upper Slope without topsoil	August 9	Poor - moderate appears to be problems with hydro-seeding application distribution	undisturbed*** relatively thin	none present***	*** possibly sheet erosion - more likely poor distribution of mulch.
22° Lower Slope with topsoil	August 9	Good - excellent	undisturbed	none present	
22° Lower Slope without topsoil	August 9	Good - excellent	undisturbed	none present	Generally gravelly, only large rocks without mulch.
26° Upper Slope with topsoil	August 9	Moderate - good	patchy though undisturbed	none present	
26° Upper Slope without topsoil	August 9	Poor - distribution problem	patchy though undisturbed	none present	
26° Lower Slope with topsoil	August 9	Moderate - good	undisturbed	none present	
26° Lower Slope without topsoil	August 9	Good	undisturbed	none present	
30° Upper Slope with topsoil	August 9	Moderate - good	undisturbed	one channel from top of slope*	*It appears that a puddle formed above the slope and drained part way down the face of the slope, depositing a thin layer of topsoil approximately 120 cm wide a short distance down the slope.
30° Upper Slope without topsoil	August 9	Moderate - good	undisturbed	none present	Material tends to slide under pressure of foot causing local disturbance downhill, this applies to all populations on the 30° slope.
30° Lower Slope with topsoil	August 9	Moderate - poor	patchy	none present	
30° Lower Slope without topsoil	August 9	Moderate	undisturbed	none present	

No weeds were found on the non-topsoil portions of the test slopes or on the seeded level areas at the foot of the Houth Meadows sloped. Eleven species of weeds were found on the topsoil portion at Houth Meadows sloped plots. On average 42 invaders per m^2 were found on the Houth Meadows plots compared to 9 per m^2 on the gravel plot at Aleece Lake. This increased invader population may have contributed to the lower number of plant per m^2. Two weeds (Stinkweed 41.5%, Flixweed 36.4%) make up 78% of the total number of weeds found. No Prostrate Knotweed are found at Houth Meadows. The abundance of Stinkweed and the occurance of Falseplax and American Dragonhead along with the absense of Prostrate Knotweed indicates a different topsoil than that used at Aleece Lake. The topsoil spread at Houth Meadows was taken from Trench B while the topsoil at Aleece Lake came from near Trench A.



LEGEND

—— Population boundaries

---- Transect line

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

TYPICAL SLOPED PLOTS TRANSECT & SAMPLING POINT LOCATIONS

DATE FEB 1979	FIG. 2-2	R
DWN CY	DWG No.	

REPORT No.

A

TABLE 2-15

TOTAL BIOMASS PRODUCED - G/M^2
HOUTH MEADOWS

Plot	Upper Slope		Lower Slope		Average
	No Topsoil	Topsoil	No Topsoil	Topsoil	
22°	83	54	245	249	158
(Incl. Invaders)	-*	102	-	307	
26°	65	161	327	202	189
(Incl. Invaders)	-	182	-	218	
30°	208	442	306	144	275
(Incl. Invaders)	-	497	-	159	
Averages	119	219	293	198	
	-	260	-	228	

* - indicates zero invaders

TABLE 2-16

AVERAGE PLANT GROWTH DATA
HOUTH MEADOWS

Plot	No. Of Plants Per M^2 And % Success				Average
	Upper Slope		Lower Slope		
	No Topsoil	Topsoil	No Topsoil	Topsoil	
22°	100	28	223	174	131
	7.8%	5.5%	23%	17%	13%
26°	94	106	214	130	136
	7%	8.8%	18%	16%	13%
30°	168	138	212	200	180
	14%	15%	17%	14%	15%
Average	121	91	216	168	
	9.6%	9.8%	19%	16%	

TABLE 2-17

AVERAGE PLANT GROWTH DATA
MEDICINE CREEK

Plot	Upper Slope		Lower Slope		Average Number Of Plants-/M^2
	Number Of Plants-/M^2	Success Ratio-%	Number Of Plants-/M^2	Success Ratio-%	
22°	138	13	60	5.3	99
26°	76	6.8	100	11	88
30°	176	13	186	14	181
Average	130	11	115	10	

TABLE 2-18

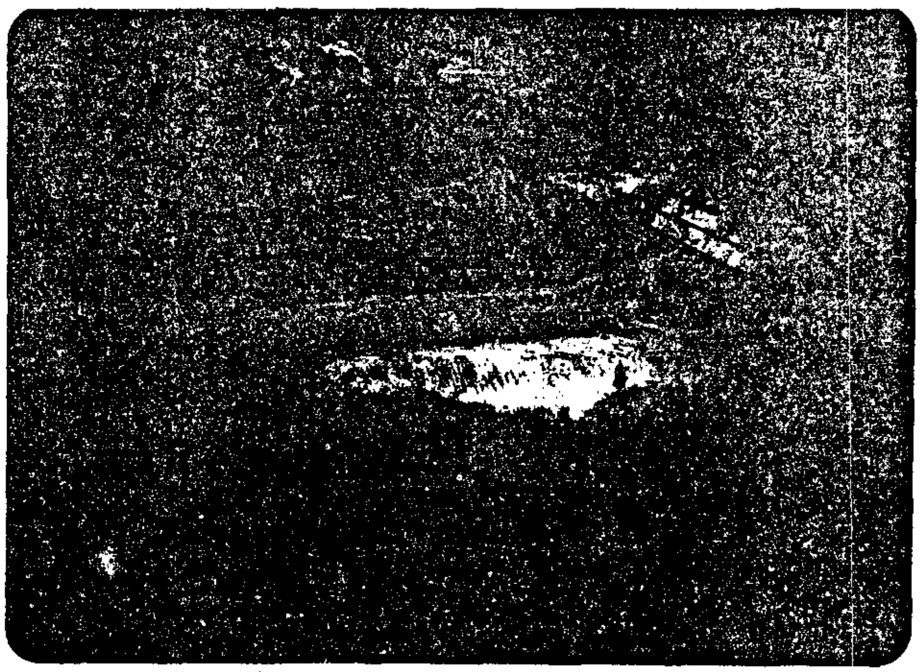
GROWTH ON LEVEL AREAS
HOUTH MEADOWS

Plot	Average Number Of Plants Per M^2	Total Success Ratio - %	Total Biomass G/M^2
Harrowed, Hand-Seeded	240	22	204
Hydro-Seeded	89	5.5	21

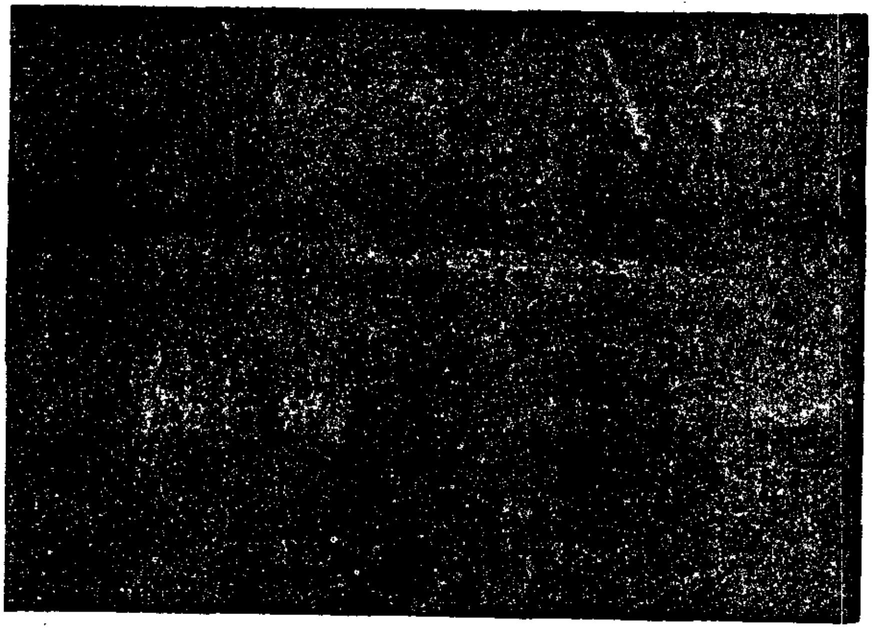
2.3 WASTE PILES AT TRENCH 'A' AND TRENCH 'B'

2.3.1 Introduction

During the Bulk Sample Program in 1977, waste materials were disposed of in dumps close to the trenches. At Trench 'A', the largest excavation, overburden materials were dumped to form three benches at elevations 3120', 3140' and 3160' as shown in photograph 8. These were reclaimed by contouring and hydro-seeding and hand-seeding in September 1977. At Trench 'B', three overburden piles were made; topsoil, recent gravels and subsoil, which resembles topsoil except for a lower organic matter content. The gravel pile is shown in photograph 9. These waste piles were reclaimed by shaping and seeding using both hydro-seeding and hand-seeding methods in September 1977. Seed mix 1 was used at both locations.



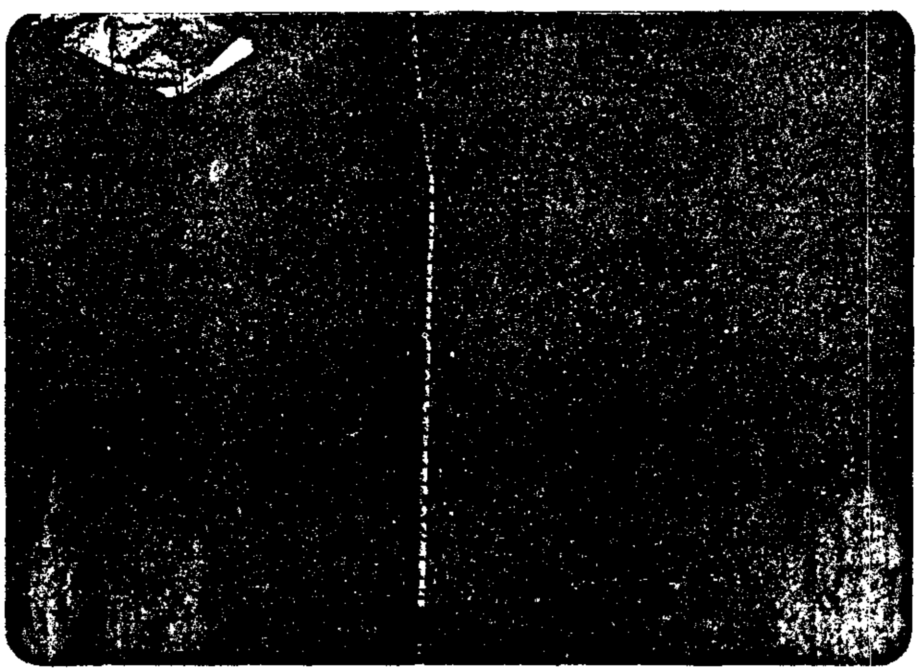
Photograph 8 -
Trench A Waste Dumps



Photograph 9 -
Trench B - Gravel Waste Pile

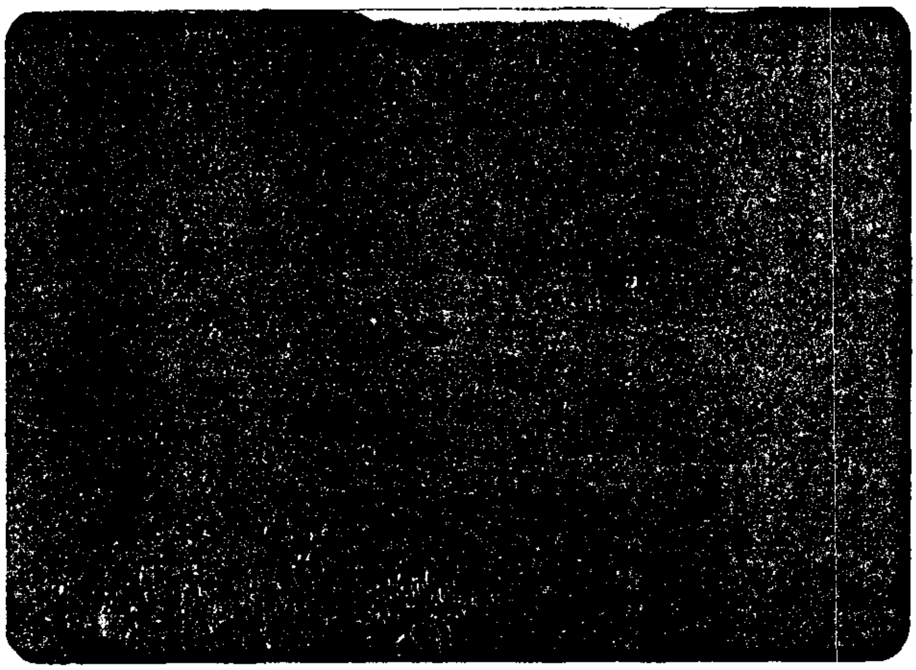
2.3.2 Vegetation Sampling

Six populations were sampled at Trench A: two on a level area and four on sloped areas. Because of the sparseness of vegetation 1.0 m^2 quadrats were used for sampling as shown in photograph 10.



Photograph 10 -
Trench A - 1 m^2 Sampling Quadrat

The level area, the top of the sandstone bench at elevation 3120', contained a harrowed hand-seeded area and an area that was hydro-seeded. These areas are shown in photograph 11. Two thirty metre transect lines were run in northwest and southwest directions from a common point at the southeastern corner of the harrowed area. Five quadrats per population were sampled. These were spaced along the transect lines at 3 m, 9 m, 15 m, 21 m and 27 m. Four populations consisting of two slopes, 30° and about 20°, on the 3120' sandstone plot face and two slopes, 35° and 26°, on the 3140' baked clay plot face, were sampled. Fifteen metre transect lines were run across the slopes at about the middle of the slope. Three 1.0 m^2 quadrats were sampled at 1.5 m, 7 m and 13 m along the transect lines.



Photograph 11 -
Trench A - 3120' Dump -
Dotted line encloses harrowseeded area.

At Trench 'B' five populations were sampled; three on the recent gravel waste pile, one on the topsoil pile and one on the subsoil pile. A 0.1 m^2 quadrat was used. Vegetation was counted at all five populations but only the vegetation harvested from the topsoil pile was retained for biomass determinations. The three populations sampled on the recent gravel waste pile included hydro-seeded and hand seeded level areas and a hydro-seeded sloped area. All of the five populations were sampled at ten locations along a 15 m transect line at 1.5 m spacing.

The sample collection and handling procedures used at Trench 'A' and Trench 'B' were the same as those used at Aleece Lake and described in Section 2.1 of this report.

2.3.3 Results of Vegetation Sampling

Average plant count and success ratios for Trench A and Trench B and biomass production data for Trench B are summarized in Table 2-19. Complete results are presented in Appendix 2.

The average number of plants produced on all of the 3120', sandstone areas at Trench A were similar. The 3140', baked clay, areas produced considerably fewer plants. The 3160', carbonaceous shale area produced negligible vegetation and was not sampled. There was no difference in the number of plants produced between the 20° and 30° slopes. The harrowed, hand-seeded area produced more plants than the similar hydro-seeded area. The test plots of the three similar materials at Aleece Lake produced considerable greater number of plants than produced at Trench A. The number of weeds found at Trench A was negligible. Two weed plants were found on the 3120 dump.

Trench A Waste Dumps

A comparison between the number and size of plants produced at the 3120' sandstone area at Trench A and the Aleece Lake sandstone plot is shown in Table 2-20.

TABLE 2-19

VEGETATION PRODUCED AT TRENCH A AND TRENCH B PLOTS

Plot	Average Number of Plants /M^2	Total Success Ratio-%	Total Biomass G/M^2
TRENCH "A"			
3120', level area, hydro-seeded	60	17	
3120', level area, hand-seeded	111	33	
3120', sloped area, 20°	99	21	
3120', sloped area, 30°	100	21	
3140', sloped area, 35°	34	13	
3140', sloped area, 26°	53	20	
TRENCH "B"			
Gravel, level area, hydro-seeded	70	15	
Gravel, level area, hand-seeded	395	118	
Gravel, sloped area, 5°	126	40	
Topsoil	50	15	15
Topsoil including invaders	137		174
Subsoil	129	28	

TABLE 2-20

COMPARISON OF PLANT GROWTH AT TRENCH A AND ALEECE LAKE

Species	Number of Plants Per M^2			Average Plant Heights - cm		
	3120' Bench		Aleece Lake Sandstone Plot	3120' Bench		Aleece Lake Sandstone Plot
	Harrow	Hydro		Harrow	Hydro	
Crested Wheatgrass	83.4	49.0	151	6.9	13.1	10.9
Drylander Alfalfa	7.8	10.4	12	1.4	2.0	2.9
Canada Bluegrass	0	0.4	0	0	6.0	0
Fall Ryegrass	19.4	8.0	23	32.6	38.6	54.1

Vegetation success on the 3120' sandstone bench is considerably poorer than that on the sandstone plot at Aleece Lake. This effect may be attributed to physical disturbance of the area; part of the dump surface was used as an access road to drill site which resulted in excessive surface compaction and poor overall revegetation success. Invader species were not present on the 3120' sandstone bench.

It is interesting to note that the sloped sandstone areas produced plants of a considerably larger size than those of the level areas (see Table 2-21). This difference in plant size is likely due to the nature of the slope surface. In resloping the dump faces caterpillar tractor tracks remained and ridges clearly enhanced plant growth. This is accomplished presumably by improving the microclimate for seed germination and by increased moisture retention.

It is noteworthy that, while the germination success of crested wheatgrass on the sandstone slopes was not particularly good in comparison with the results obtained on the Aleece Lake sandstone plot, the size of the plants produced on the slopes was substantially greater than that recorded for any of the soils tested at Aleece Lake. This again supports the conclusion that the ridges on the sandstone slopes are particularly good locations for plant development.

TABLE 2-21

PLANT SIZE ON LEVEL AND SLOPED 3120' SANDSTONE AREAS

Species	Average Plant Heights - cm			
	3120' Level Area		Sloped Areas	
	Harrowed Area	Hydro Area	22° Slope	30° Slope
Crested Wheatgrass	6.9	13.1	35.2	30.3
Drylander Alfalfa	1.4	2.0	6.1	4.6
Canada Bluegrass	0.0	6.0	11.0	15.0
Fall Ryegrass	32.6	38.6	66.6	69.3

The revegetation results from the sloped 3140' baked clay dumps are summarized in Table 2-22. The overall performance of seed mix mix 1 was slightly better on the 26° slope than on the 35° slope. This is likely not an effect of slope angle, but reflects inconsistency in seed mix application rates.

TABLE 2-22

COMPARISON OF TRENCH A AND ALEECE LAKE PLANT GROWTH

Species	Average Plant Heights - cm			Number of Plants Per M^2		
	3140 Waste Dump		Aleece Lake	3140 Waste Dump		Aleece Lake
	26° Slope	35° Slope	Baked Clay	26° Slope	35° Slope	Baked Clay
Crested Wheatgrass	19.6	17.6	17.3	27.0	21.7	104
Drylander Alfalfa	7.8	4.1	5.3	13.0	3.7	13
Canada Bluegrass	0	0	0	0	0	0
Fall Ryegrass	44.6	38.9	92.5	13.3	8.3	52

The crested wheatgrass and fall ryegrass exhibited a lower percentage of mature plants on the 26° slope; for example the 26° slope indicates 25% of fall rye with flower development while the 34° slope shows 90 to 100% fall rye at maturity. Similar results were obtained for crested wheatgrass. There is no apparent explanation as to why this occurred.

Vegetation success in terms of plants per M^2 on the 3140' baked clay waste dump is substantially poorer than on the baked clay plot at Aleece Lake. However in other areas when the number of plants was reduced, the size of the plants increased. This was not the case here. Baked clay was one of the more successful growth media tested at Aleece Lake. Plant heights are generally similar except for the fall ryegrass which shows plants of greater height on the baked clay plot at Aleece Lake. The reasons for the apparent poor success on the baked clay slope at Trench A are unclear but it is speculated that this may be due to a lower hydroseed application rate. Contrary to expections, the vegetation success on the 3140 baked clay slopes is appreciably poorer in comparison with the 3120 sandstone slopes; and this also lends support to the conclusion that the baked clay slopes may have received a lower hydroseeding application rate.

The 3140 dump surface was also hydro-seeded but was not sampled because of poor overall revegetation success. Use of the dump as a road access to a drill site resulted in excessive surface compaction.

The 3160' carbonaceous shale dump produced little vegetation growth. Growth that did occur did so in small depressions where moisture could collect. Vegetation success on the dump face was considerably greater than on the surface, however this may be due to a greater hydroseed application rate. Part of the dump face was recontoured from the natural dump angle of 34° to 26° to test vegetation at different slopes. No difference in the vegetation success between the two slopes was visually apparent.

Trench B Waste Dumps

A comparison between the number and size of plants produced on the recent gravel waste pile at Trench B and the glacial gravel plot at Aleece Lake is presented in Table 2-23. Growth was considerably more successful on the harrowed, hand-seeded section of the gravel pile due possibly to higher seed application rates and in part by the manner of seeding; the fact that harrowing provides a larger number of preferred germination sites, particularly on gravelly materials

On the harrowed hand-seeded portion of the recent gravel pile the fall rye showed excellent growth, in terms of the number of plants per M^2 and the plants were of comparible size to those in the hydroseeded areas. In contrast the crested wheatgrass and drylander alfalfa were more successful in terms of emergence success but were quite small in comparison to other areas. It is suspected that when the fall ryegrass is very prolific it has the effect of inhibiting the growth of neighbouring vegetation. This seems particularly apparent with the drylander alfalfa. These results somewhat parallel those obtained at Aleece Lake plots where seed mix 1 was used.

TABLE 2-23

COMPARISON OF PLANT GROWTH AT TRENCH B AND ALEECE LAKE

Species	Number of Plants Per M^2				Average Plant Heights - cm			
	Recent Gravels			Aleece Lake Glacial Gravels	Recent Gravels			Aleece Lake Glacial Gravels
	Hydro-Seeded		Harrow-Seeded Area		Hydro-Seeded		Harrow-Seeded Area	
	Sloping	Level			Sloping	Level		
Crested Wheatgrass	87	58	253	209	14.3	15.7	10.3	14.4
Drylander Alfalfa	15	6	73	43	14.5	18.3	5.3	4.2
Canada Bluegrass	0	0	2	4	0	0	6.0	4.5
Fall Ryegrass	24	6	67	47	54.3	44.2	54.9	90.6

Invader species had little effect, if any, on the vegetation at the Trench 'B', recent gravel pile.

TABLE 2-24

PLANT GROWTH ON TRENCH B SUBSOIL AND TOPSOIL PILES

Species	Number of Plants Per M^2		Average Plant Heights - cm	
	Subsoil Pile	Topsoil Pile	Subsoil Pile	Topsoil Pile
Crested Wheatgrass	104	38	38.4	22.9
Drylander Alfalfa	11	3	14.2	5.0
Canada Bluegrass	2	0	11.5	-
Fall Ryegrass	12	9	97.1	76.4
Invader Species	10	87	-	-

The number and size of plants produced on the subsoil and topsoil piles is shown in Table 2-24. The revegetation potential of the subsoil pile appears substantially better than that of the topsoil pile. The reason for the lower success on the topsoil pile is presumably competition with weeds, which make up over 60% of the plants and 90% of the biomass growing on the topsoil pile. Weeds were less abundant on the subsoil. The number of fall ryegrass plants produced on the subsoil pile was low compared to the other areas at Trench A and B and Aleece Lake. However all four species produced very large plants on the subsoil pile. This may have been due to the fact that the fall ryegrass was not as dominant. The reasons for the low number of fall rye plants is not known.

No other area examined at Hat Creek produced an abundance of weeds comparable to that of the Trench 'B' topsoil pile. It is suspected that the weed species were present in the topsoil. Nine species of invaders dominated the topsoil pile as shown in Table 2-25.

TABLE 2-25

INVADER SPECIES ON TOPSOIL PILE AT TRENCH B

Species	Number of Plants Per M^2	Average Plant Height - cm
Blueburr	40	30
American Dragonhead	21	16
Povertyweed	15	30
Stinkweed	12	50
Flixweed	7	75
Falseflax	3	75
Lambs Quarters	2	10
Chenopodiaieae	1	7
Prostrate Knotweed	1	11

The invaders accounted for 68 percent of the total aerial biomass and seemed to have caused a general decrease in average height, number of plants, and success ratio for all four agronomic species. The dominant weeds were Blueburr, 39.1% of a total number of weeds, American Dragonhead, 19.5%, Poverty Weed, 13.8%, and Stinkweed, 11.5%. Invader species are present, but not abundant on the subsoil pile and absent at the other revegetated areas near Trench B.

Of the invader species present on the Trench 'B' topsoil pile, only one, Stinkweed (*Thalspi arvense*) is known to be noxious. Apparently the seeds produced by this species contains an oil substance which can cause gastric distress in livestock upon ingestion of grain.

2.4 SEEDING PROGRAM IN 1978

2.4.1 Introduction

Waste disposal piles at Bulk Sample Program Trenches A and B were seeded during September 1977. Inspection of these areas in the summer of 1978 revealed that while revegetation was generally successful there were notable exceptions. In addition the waste piles at Trench C and the overburden storage areas were not seeded in 1977. To correct these deficiencies a seeding program was undertaken in September 1978. Seeding had to be carried out before quantitative results of the growth assessment studies at Aleece Lake were known. Nevertheless it was possible to devise a suitable seeding program based on the qualitative visual inspection of the areas. The following presents a summary of these inspections and details of the 1978 seeding program.

2.4.2 Visual Growth Assessments of Areas Seeded in September 1977

The Hat Creek area receives only 317 mm of precipitation annually, about half of which falls in the form of snow. Examination of the waste piles seeded September 1977 showed evidence that the lack of moisture seemed to be major limiting factor in vegetation success. Whenever moisture collected in depressions on waste dumps, growth was enhanced. Thus, a small section of the Trench A 3160 dump and one of the Trench C dumps were subjected to surface treatment in improve water retention before seeding in September 1978.

Trench A - 3160 Dump

The dump surface was almost entirely devoid of vegetation both on the hydroseeded and harrowseeded areas. Growth that did occur did so in small depressions where moisture had collected. This growth appeared very satisfactory.

The surface material on this dump is exclusively carbonaceous shale. The nature of this shale is such that it does not 'wet', so that any water that does collect penetrates only a very short distance (5-10 mm) below which the material remains powder dry. This occurs even when free standing water is present on the surface. Hence, water stress, and not the low pH of the soil (4.5) appears to have contributed to the poor vegetation success on the dump surface.

Vegetation success was considerably greater on the dump face than on the surface possibly due to the greater hydroseed application on the faces. No difference in vegetation success was evident between the part of the dump face left at the natural dump angle of 34° and that part recontoured at a 26° angle to test revegetation at different slopes.

It was concluded that a major effort will be necessary to encourage successful revegetation on the dump surface whereas the dump face needs no further attention at this time.

- 3140 Dump

Both the dump surface and face were hydroseeded in September 1977. The dump surface showed successful early growth in most areas, but use of the dump as a drill site access road resulted in excessive surface compaction and poor overall revegetation success. The surface material on this dump is baked clay, one of the more successful growth media tested at Aleece Lake.

The dump face showed inconsistent success, however, it was evident upon close examination during September 1978 that there was a high concentration of juvenile plants, which should develop further during the spring of 1979. No difference in vegetation success was apparent between the dump faces recontoured to a slope of 26° and the slopes left at the natural dump angle of 34°.

It was concluded that the dump surface which was used as a road required breaking up and reseeding, while the dump face was considered satisfactory.

- 3120 Dump

The surface material on this dump is baked clay on the western portion and claystone/gritstone on the eastern portion, including the dump face.

As with the 3140 dump, part of the baked clay surface was used as a drill site access road, consequently vegetation could not become established. On the claystone material vegetation success was mixed with some large areas of poor success. It appears that when the clayey material wets then dries a hard surface crust is formed which inhibits plant development. Moisture stress was apparent since in the small depressions where water could collect growth was enhanced. Also the claystone material is quite saline.

On the dump face, slopes of 20°, 30° and the natural dump angle of 38° were seeded in September 1977. Good success was achieved on the 20° and 30° slopes particularly in ruts left by the bulldozer. This again suggests that lack of moisture may be a major limitation to successful revegetation at Hat Creek. On the 38° slope only limited revegetation success was achieved, possibly due in part to the non-compacted surface and the tendancy of the clayey material to "flow" somewhat down the steep slope when wet, and form a hard surface crust when dried. No major difference was evident between hydroseeded and harrowseeded areas. It was concluded that the dump surface which had been used as a road and two smaller areas required reseeding. Although revegetation on the steepest dump face slope was unsatisfactory, it was decided to leave it unattended for a further year.

<u>Coaly Waste Pile</u>

This dump is made up of carbonaceous material which, although giving the appearance of coal is of such low quality as to be unusable. The dump surface material was harrowseeded and the dump faces hydroseeded in September 1977. The surface material on the dump face was similar to the carbonaceous shale on the 3160 dump, very fine and dusty, and vegetation success was not good. Examination of the slopes showed that germination and growth most often occurred in small level areas such as those made by footprints. It is presumed that these areas provide a small catchment for moisture thereby improving the local microclimate for seed germination.

On the harrowseeded dump surface the material is more typical of coal. Vegetation germinated well in the spring and early growth was encouraging. However, the dark colour of the material caused excess heating during the summer months resulting in very dry surface conditions. Nevertheless the vegetation survived as evidenced by renewed growth in early September following rain.

Although success on the dump faces was not good it was decided to give the vegetation a further season to develop. The dump surface was considered satisfactory.

Topsoil and Waste Storage Areas

These areas were originally cleared and grubbed prior to laying down topsoil and waste material for later use at Aleece Lake. Two piles, one colluvium and one carbonaceous shale, remained in the waste storage area. This area had not been seeded in 1977 however, invasion of native species and regeneration of vegetation remaining after clearing had occurred to a limited extent. Leveling of the piles will be required before seeding.

Trench B - Major Dump

This dump contained the alluvial gravels extracted from above the coal in Trench B. The dump was hydroseeded in September 1977 except for a small area, 50' x 100', which was harrowseeded. Early spring growth on the harrowseeded portion seemed particularly good, much thicker than on the hydroseeded areas. It is suspected that this is due in part to a lower seeding rate on the hydroseeded part and in part to the manner of seeding. Harrowseeding provides a large number of attractive germination sites particularly on gravelly material.

Late summer examination showed an interesting difference between the two areas. On the harrowseeded portion the fall rye was very dense while the crested wheat and alfalfa seedings were healthy but still quite small. On the more sparcely populated (in terms of fall rye) hydroseeded area, the alfalfa was very well established, being on occassion over 18 cm tall. These results parallel those obtained on the Aleece Lake plots where seed mix I was used. It would seem logical to conclude that the rye grass, when prolific, inhibits development of less vigorous species by out-competing them for the available moisture or light. Since fall rye is an annual and should therefore largely die out, it will be interesting to follow the development of the fall rye "protected" vegetation in the harrowseeded area. It may be that the growth of alfalfa could later surpass that on the other areas where the rye grass was less dense.

Subsoil Dump

This material has the same texture as the topsoil but it has a lower organic matter content. Vegetation success was excellant though as with other areas where fall rye was very dense, development of alfalfa and crested wheatgrass was slow. In addition to the agronomic species hydroseeded, a wide range of weeds were also present. These species were probably transported into the pile during excavation.

Topsoil Pile

The topsoil pile was hydroseeded in September 1977 but almost all the growth consisted of weed species transported during excavation. Growth was quite dense indicating that this material is well suited for plant growth.

Since vegetation growth was satisfactory on all three Trench B dumps no further attention appeared necessary.

Trench C

Three waste dumps exist at Trench C, which is an excavation into bentonitic clay material west of Trench A. These areas were not seeded during 1977 and consequently no vegetation was present on them. It was decided, based on the Aleece Lake plots, that topsoil treatment and different seed species should be tried here.

2.4.3 Seed Selection

The purpose of the 1978 seeding program was to revegetate the waste dumps not seeded in 1977 and those areas which were seeded but where growth was unsatisfactory. These waste dumps comprised of the following materials: carbonaceous shale, baked clay, sandstone and bentonitic clay.

Based on the results from the Aleece Lake test plots, soil salinity in the sandstone and bentonitic clay materials appeared to be a serious growth inhibitor. In addition, the acidity of the coaly materials may have contributed to the lack of success on these materials. Thus a further search for acid and saline tolerant species was made and several new species selected for testing.

As a result of the inter-species competition noted previously, seed was sown individually as well as in mixes comprised of compatible species to assess the effects competition might have on vegetation growth.

Seed Species

The following species were selected for the seeding program. The first seven were selected from the 12 original species seeded in 1977 while the last four are new species.

Crested Wheat Grass (CWG) (Nordan) - While emergence rates were not as great as with some other species, the presence of fall rye, which is a particularly vigorous species, may have caused a reduction in emergence or productivity by out-competing CWG for the available mositure, light and/or nutrients. CWG did well on the acidic carbonaceous materials relative to other species.

<u>Slender Wheatgrass</u> - This species showed good emergence and productivity on untreated bentonitic clay and sandstone.

<u>Smooth Bromegrass (Manchar)</u> - Average emergence was achieved with this species on both the carbonaceous and saline materials. If emergence success could be sustained it could act as a good minor species in a mix.

<u>Streambank Wheatgrass (Sodar)</u> - This species appears to be a particularly good species for reclamation at Hat Creek. It showed good emergence on both carbonaceous and saline materials. Generally it is short and provides good ground cover.

<u>Alfalfa (Drylander)</u> - Emergence and productivity were quite low when compared with the grass species but, as with the crested wheatgrass, it may have suffered from competition with fall rye. In areas where competition was absent the size of plants was dramatically larger.

<u>Sainfoin (Melrose)</u> - Showed clearly the best emergence of all the legumes tested and good productivity. In comparison with other legumes, the seed of this species was quite large which may have contributed to its success.

<u>Double Cut Red Clover</u> - Showed poor emergence on the carbonaceous and saline materials. However, it was decided to try it again since the overall emergence was similar to alfalfa.

<u>Hard Fescue (Durar)</u> - This is a drought and cold tolerant, long-lived bunch grass which, although slow to develop, was selected for use on carbonaceous shale because of its reported acid tolerance.

<u>Tall Fescue (Altar)</u> - This species is not as drought tolerant as hard fescue but develops rapidly.

Tall Wheatgrass (Alkar) - Although not particularly drought tolerant and slow to establish, this species is well adapted to saline and alkaline soils making it potentially useful on the sandstone and bentonitic clay materials.

Birdsfoot Trefoil (Leo) - This legume is tolerant to a wide range of soil reaction (pH) and was selected primarily for its acid tolerance. It is adapted to a wide variety of fertility and moisture; however, it is not known whether it is sufficiently drought tolerant for use at Hat Creek.

Of the original species the following were not used in the 1978 revegetation work on the trench dump area:

Canada Blue Grass (both varieties) - Both Canada blue grasses were rejected because of very poor emergence and growth. The present test areas will be monitored to see if these grasses develop later.

Fall Rye - This species was the most successful of all those tested. It is a tall growing annual which would be expected to die off after the first year, apart from any natural seeding which might occur. The reasons for using it included its rapid development which was expected to protect the other seeds and seedlings from wind erosion and the fact that it was an annual and therefore in dying would return organic matter to the soil, a most desirable consequence considering the lack of organic matter in the materials being revegetated. However, it would appear that an appreciable degree of competition takes place between the fall rye and other species seeded with it, which inhibits the development of the latter. Whilst still considered an excellent first year species for revegetation it was decided to omit it from the 1978 program and to continue monitoring those areas seeded with Seedmix I to assess any natural reseeding of fall rye and the further development of the other species seeded with it.

Russian Wild Rye - This species proved to be an excellent performer for all soil types but the more acid carbonaceous materials. The emergence success rate was high on untreated soils although the individual plant size was small. It was decided to omit the species from the 1978 program simply to accommodate other species in the testing program.

Sweet Clover - This showed slightly lower emergence success and higher productivity than the other legumes sown in 1977. Although not rejected as a potential revegetation species, it is presently less favoured than either sainfoin or alfalfa.

2.4.4 Selection of Seed Mixes and Fertilizer

Three seed mixes were devised depending on soil material. Two legumes and three grasses were selected for each mix with equal numbers of seed for each species. As in 1977 the seeding rate was 2150 seeds/m^2. In addition to using seed mixtures, seeds were sown individually in 3 m wide strips at a rate of 2150 seeds/m^2. Details of seed mixes are shown in Tables 2-25, 2-26 and 2-27.

Fertilizer requirements were based on 1977 analyses and additions were made as necessary during the September 1978 seeding.

2.4.5 Surface Preparations and Seedings Methods

All areas were harrowseeded, that is, seed was spread using either a hand-held or tractor-mounted broadcaster and then the area was harrowed. 50 hp rubber-tired tractors were used to seed, fertilize and to drag harrows. A spring-tooth harrow was used to break up compacted areas at the trench A and C dumps and a 48 cm single blade plow was used to create furrows. A diamond-drag harrow was used before seeding to scarify the surface,then after seeding and fertilizing to bury the seed.

TABLE 2-25

SEED MIX IV

Grass or Legume (Variety)	Characteristics	Seeds/kg. X1000	Mix Seed %	Mix Weight %	Mix kg/ha
Smooth Bromegrass (Manchar)	1. cold tolerant, moderately drought tolerant 2. long-lived sod grass 3. establishes easily 4. creep rooted rhizomonous	275	20	10	16
Crested Wheatgrass (Nordan) (Fairway)	1. very drought and cold tolerant 2. long-lived bunchgrass 3. easy to establish 4. extensive root system	385 440	20	7	11
Slender Wheatgrass	1. cold and drought tolerant 2. short lived bunchgrass 3. establishes quickly 4. grows in fairly poor soil	353	20	8	12
Sainfoin (Melrose)	1. cold and drought tolerant 2. perennial forage legume 3. easy to establish 4. deep branched tap root 5. begins spring growth prior to alfalfa	40	20	69	108
Alfalfa (Drylander)	1. very drought and cold tolerant 2. long lived 3. capable of fixing nitrogen 4. creeping rooted 5. not recommended on soil of pH <6	469	20	6	9

Total weight of seed per hectare 156 kg (139 lb/acre)

TABLE 2-26

SEED MIX V

Grass or Legume (Variety)	Characteristics	Seeds/kg X1000	Mix		
			Seed %	Weight %	kg/ha
Crested Wheatgrass (Nordan) (Fairway)	1. very drought and cold tolerant 2. long-lived bunchgrass 3. easy to establish 4. extensive root system	385 440	20	8	11
Hard Fescue (Durar)	1. drought and cold tolerant 2. long-lived bunchgrass 3. slow to establish 4. deep rooted 5. acid tolerant	1245	20	3	3
Tall Fescue (Alta)	1. rapid developing long-lived bunchgrass 2. produces good ground cover 3. not particularly drought tolerant 4. extensive root system	400	20	8	11
Sainfoin (Melrose)	1. cold and drought tolerant 2. perennial forage legume 3. easy to establish 4. deep branched tap root 5. begins spring growth prior to alfalfa	40	20	78	109
Birdsfoot Trefoil (Cascade)	1. perennial forage legume 2. tolerant to wide range of soil reaction 3. adapted to wide variety of fertility and moisture	1036	20	3	4

Total weight of seed per hectare 138 kg (123 lb/acre)

TABLE 2-27

SEED MIX VI

Grass or Legume (Variety)	Characteristics	Seeds/kg	Mix		
		X1000	Seed %	Weight %	kg/ha
Streambank Wheatgrass (Sodar)	1. drought tolerant 2. long-lived sod 3. established quickly	375	20	18	11
Slender Wheatgrass	1. cold and drought tolerant 2. short lived bunchgrass 3. establishes quickly 4. grows in fairly poor soil	353	20	20	12
Tall Wheatgrass (Altar)	1. cold tolerant 2. slow to establish 3. long-lived bunchgrass 4. adapted to very saline and alkaline soils. 5. not particularly drought tolerant	174	20	41	25
Birdsfoot Trefoil (Cascade)	1. perennial forage legume 2. tolerant to wide range of soil reaction 3. adapted to wide range of fertility and moisture	1036	20	7	4
Alfalfa (Drylander)	1. very drought and cold tolerant 2. long-lived 3. capable of fixing nitrogen 4. creeping rooted 5. not recommended on soil of pH <6	496	20	14	9

Total weight of seed per hectare 61 kg (148 lb/acre)

Trench A - 3160 Dump

Three different surface preparations were used on this dump. Half the surface was covered with about 15 cm of topsoil from the Trench A stockpile. Of the remaining half of the dump, one third was left as it was, i.e. merely as dumped, and essentially smooth. The remaining portion was furrowed perpendicular to the dump fall line using a 45 cm single blade plough (Photo 12). Here the intent was to create a moisture retaining surface in the hope of reducing the apparent moisture stress on this dump. For seeding purposes the furrowed area was divided in half.

Two different seed mixes were used. In addition seeds were sown independently in rows 3 m wide. The seeding pattern used is shown on Figure 2-3.

Fertilizer additions and seed quantities are given in Table 2 - 28.

Seed and fertilizer were spread using a hand-held broadcaster (photo 13). The entire area was then chain harrowed in a lengthwise direction; this direction was particularly selected for the furrowed area in the hope of constructing small moisture collecting basins (Photographs 14 and 15).

- 3140 Dump

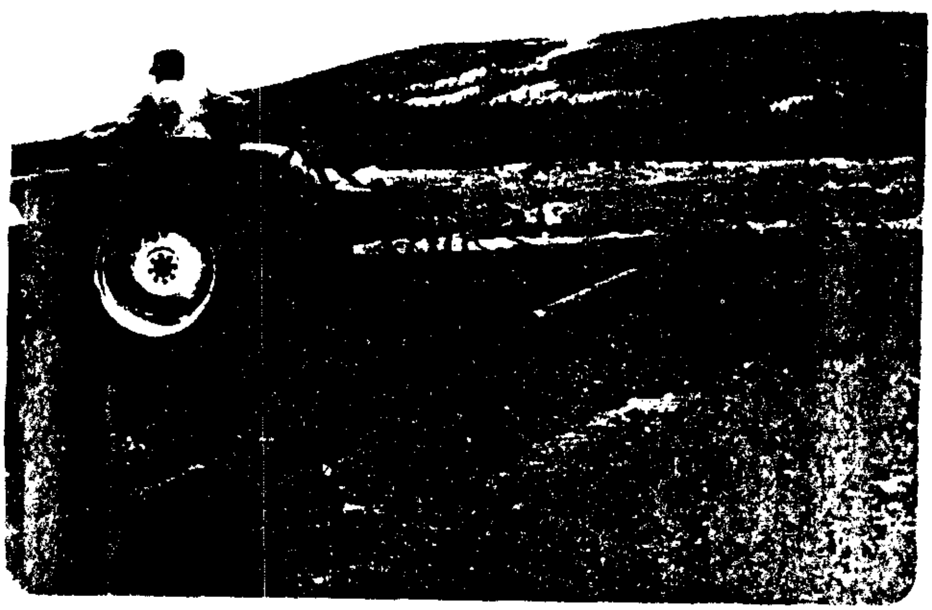
The dump surface had been compacted by vehicular traffic and some of the baked clay had been quarried for use on other areas at Hat Creek. The quarry was smoothed using a D6 bulldozer and the road compaction broken with a heavily weighted spring-tooth harrow (Photo 16). Seed mix IV and fertilizer were applied using a tractor-mounted broadcaster (Photo 17) and the area was harrowed (Photo 18). Details of seed and fertilizer applications are given in Table 2 - 28.

- 3120 Dump

Road compaction was broken using the weighted spring-tooth harrow. In addition, two other small areas to be seeded were harrowed since weathering

Photograph 12 - 3160 Dump - surface preparation - furrowing perpendicular to dump fall line

Photograph 13 - 3160 Dump - spreading seed and fertilizer using hand-held broadcaster



Photograph 14 - 3160 Dump - chain harrowing across furrows

Photograph 15 - 3160 Dump - moisture collecting basins

TABLE 2-28

DETAILS OF SEED AND FERTILIZER USED IN 1978
SEEDING PROGRAM

TRENCH A

3160 Dump

Seeding Pattern

		Topsoil		No Topsoil	Furrows	
	A					
	B					
Individual	C					
Plot	D					
	E					
	F					
		Balance	Balance	Balance	Balance	Balance
		1	2	3	4	5

Strip	Area (ha)	Seed	Kg
1 A	0.012	Smooth Brome	0.91
B		Sainfoin	6.35
C		Crested Wheatgrass	0.68
D		Alfalfa	0.45
E		Slender Wheatgrass	0.73
Balance	0.049	Seedmix IV	7.71
2 A	0.012	Hard Fescue	0.23
B		Double Cut Red Clover	0.45
C		Tall Wheatgrass	1.45
D		Birdsfoot Trefoil	0.23
E		Streambank	0.68
F		Tall Fescue	0.64
Balance 2 + 3 + 4	0.097	Seedmix V	14.5
3 A	0.006	Crested Wheatgrass	0.36
B		Sainfoin	3.27
C		Hard Fescue	0.11
D		Birdsfoot Trefoil	0.11
E		Streambank	0.36
F		Tall Fescue	0.73
Balance included (under 2 above)			

(Continued..)

Table 2-28 (continued)

Strip	Area (ha)	Seed	Kg
4 A	0.006	Crested Wheatgrass	0.36
B		Sainfoin	3.27
C		Hard Fescue	0.11
D		Birdsfoot Trefoil	0.11
E		Streambank	0.36
F		Tall Fescue	0.73
Balance (included under 2 above)			
5 A	0.006	Smooth Brome	0.45
B		Double Cut Red Clover	0.23
C		Slender Wheatgrass	0.36
D		Alfalfa	0.23
E		Tall Wheatgrass	0.73
Balance	0.020	Seedmix IV	3.18

Fertilizer*	11 - 48 - 0	224 Kg/ha
	16 - 20 - 0	56 Kg/ha
	0 - 0 - 60	112 Kg/ha

3140 Dump

Area	0.19 ha	
Seedmix IV	30 Kg	
Fertilizer*	11 - 48 - 0	168 Kg/ha
	16 - 20 - 0	56 Kg/ha

3120 Dump

Strip H	Area (ha)	Seed Applied	Kg
1	0.105	Seedmix VI	6.35
2	0.029	Seedmix VI	1.81
3	0.015	Seedmix VI	0.91

Fertilizer*	11 - 48 - 0	168 Kg/ha
	16 - 20 - 0	56 Kg/ha

* Fertilizer additions were made based on soil analyses carried out in 1977.

Topsoil and Material Storage Area

Area	0.44 ha	
Seedmix IV	24.5 Kg	
Fertilizer*	11 - 48 - 0	280 Kg/ha
	0 - 0 - 60	112 Kg/ha

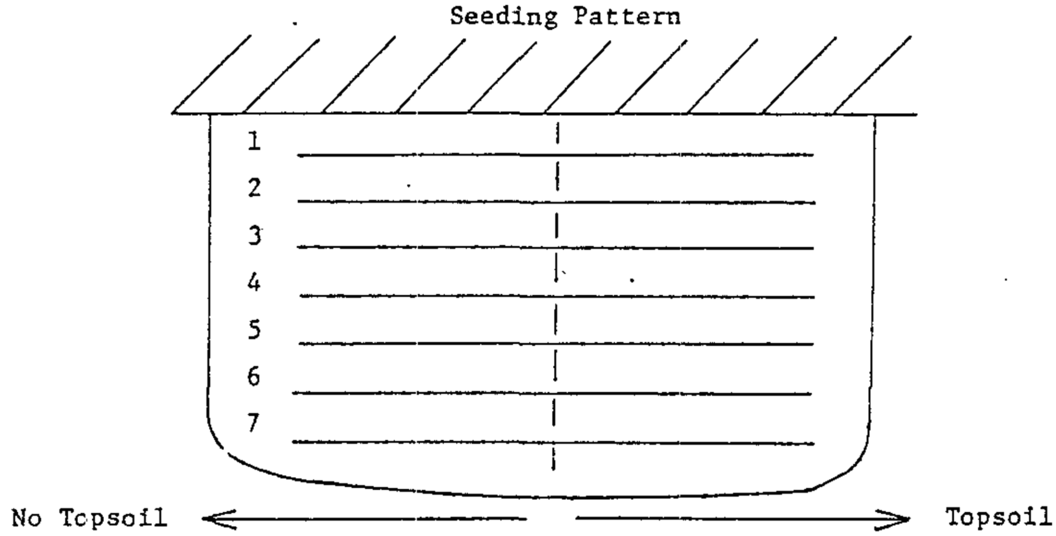
Miscellaneous Areas

Area	.061 ha	
Seedmix IV	9.5 Kg	
Fertilizer*	11 - 48 - 0	224 Kg/ha

TRENCH C

Dump 3

Seeding Pattern

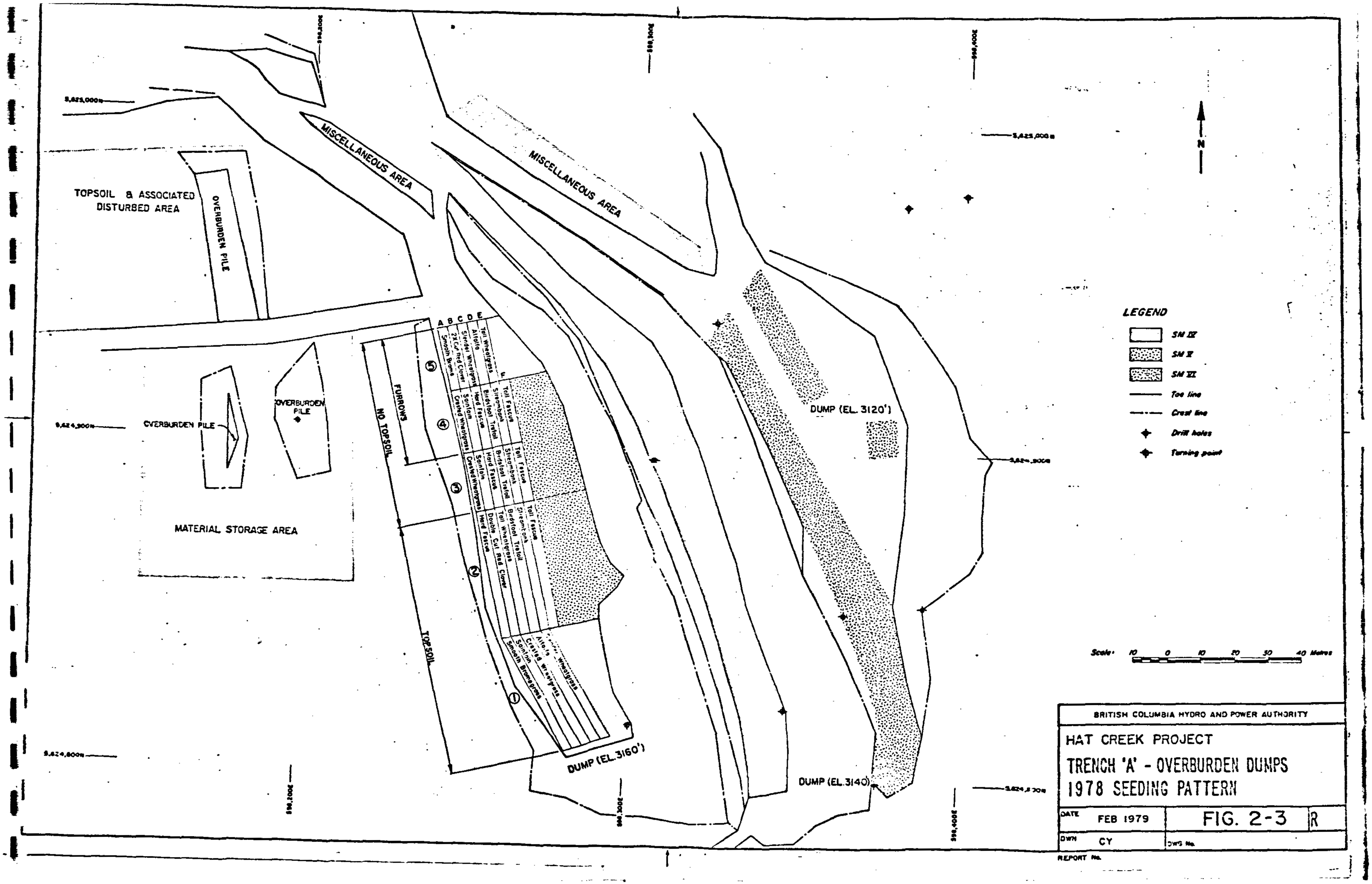


Strip	Area	Seed	Kg
1	0.006	Sainfoin	3.04
2		Alfalfa	0.23
3		Tall Wheatgrass	0.68
4		Streambank	0.32
5		Birdsfoot Trefoil	0.12
6		Slender Wheatgrass	0.34
7		Vacant	

Balance

Dump 1, 2, Scraped area and Balance of Dump 3

Area	1.70 ha	
Seedmix VI	114 Kg	
Fertilizer*	11 - 48 - 0	224 Kg/ha
(all areas)	16 - 20 - 0	56 Kg/ha



TOPSOIL & ASSOCIATED DISTURBED AREA
OVERBURDEN PILE
MISCELLANEOUS AREA
MISCELLANEOUS AREA
OVERBURDEN PILE
OVERBURDEN PILE
MATERIAL STORAGE AREA
NO TOPSOIL
FURROWS
TOPSOIL
A B C D E
Toll Wheatgrass
Alfalfa
Slender Wheatgrass
2X Cut Red Clover
Smooth Brome
Tall Fescue
Streambank
Birdsfoot Trefoil
Hard Fescue
Sainfoin
Crested Wheatgrass
Tall Fescue
Streambank
Birdsfoot Trefoil
Hard Fescue
Sainfoin
Crested Wheatgrass
Tall Fescue
Streambank
Birdsfoot Trefoil
Tall Wheatgrass
Double Cut Red Clover
Hard Fescue
Wheatgrass
Alfalfa
Crested Wheatgrass
Sainfoin
Smooth Bromegrass
1
2
3
4
5
DUMP (EL. 3160')
DUMP (EL. 3120')
DUMP (EL. 3140')
N
LEGEND
SM IV
SM V
SM VI
Toe line
Crest line
Drill holes
Turning point
Scale: 10 0 10 20 30 40 Metres
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
TRENCH 'A' - OVERBURDEN DUMPS
1978 SEEDING PATTERN
DATE FEB 1979
FIG. 2-3
R
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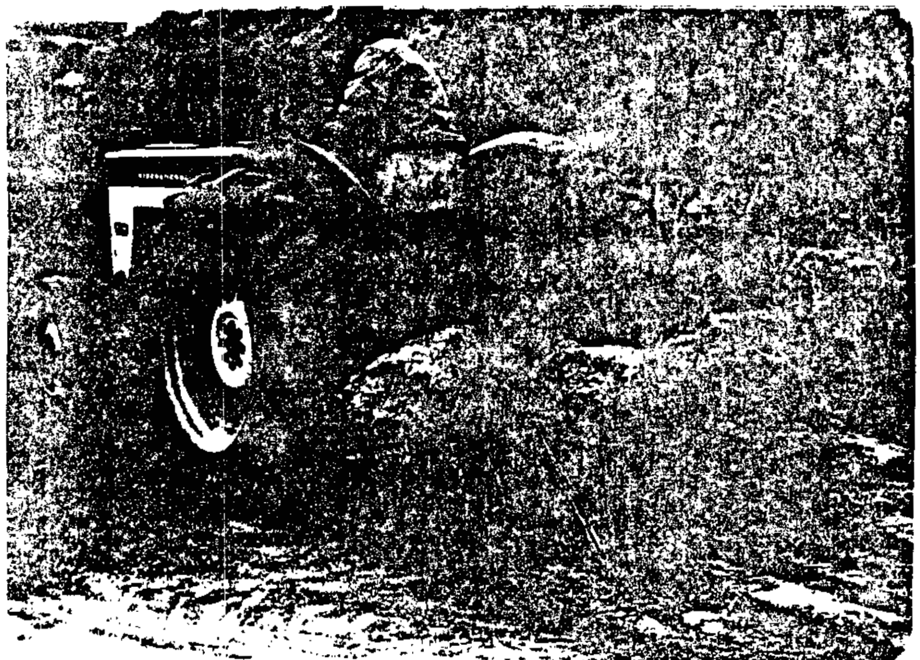
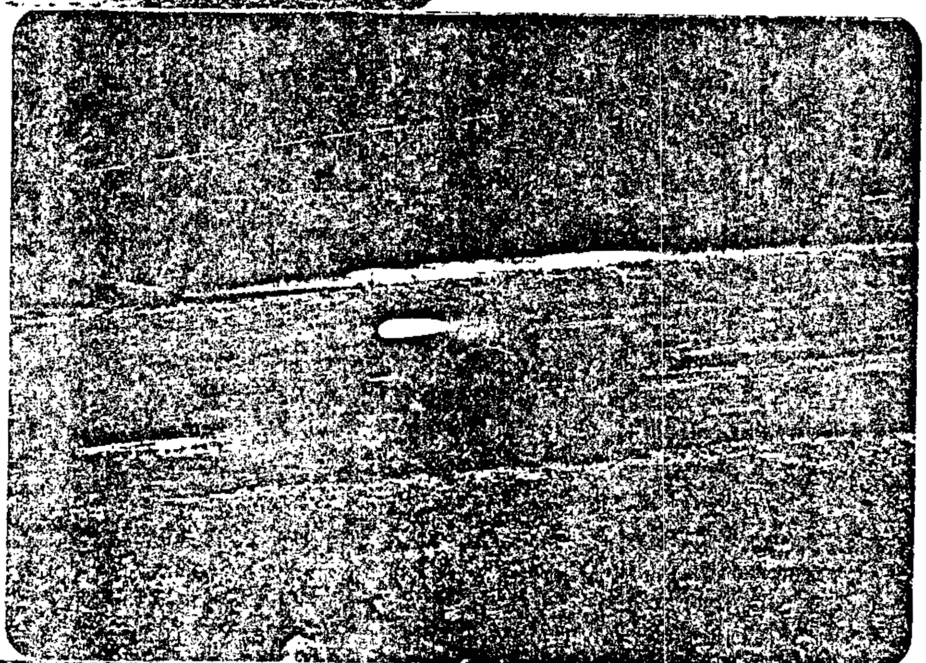
DWG No.
REPORT No.



Photograph 16 - 3140 Dump - breaking road compaction with weighted spring-tooth harrow

Photograph 17 - 3140 Dump - application of seed and fertilizer using a tractor-mounted broadcaster



Photograph 18 - 3140 Dump - harrowing area after seeding and fertilization of the clayey material had resulted in the formation of a hard surface crust. Seed Mix VI and fertilizer were applied using both hand-held and tractor-mounted broadcasters as appropriate and the area chain harrowed. The areas treated are shown in Figure 2-3 and details of seed and fertilizer given in Table 2-28.

Trench A - Topsoil and Waste Storage Area

The remaining small storage piles of carbonaceous shale and colluvium were spread and the topsoil quarry smoothed out. The area was chain harrowed, seeded and fertilized using a tractor-mounted broadcaster and then harrowed again. The area seeded is shown in Figure 2-3 and details of seed and fertilizer addition rates are given in Table 2-28.

- Miscellaneous Areas

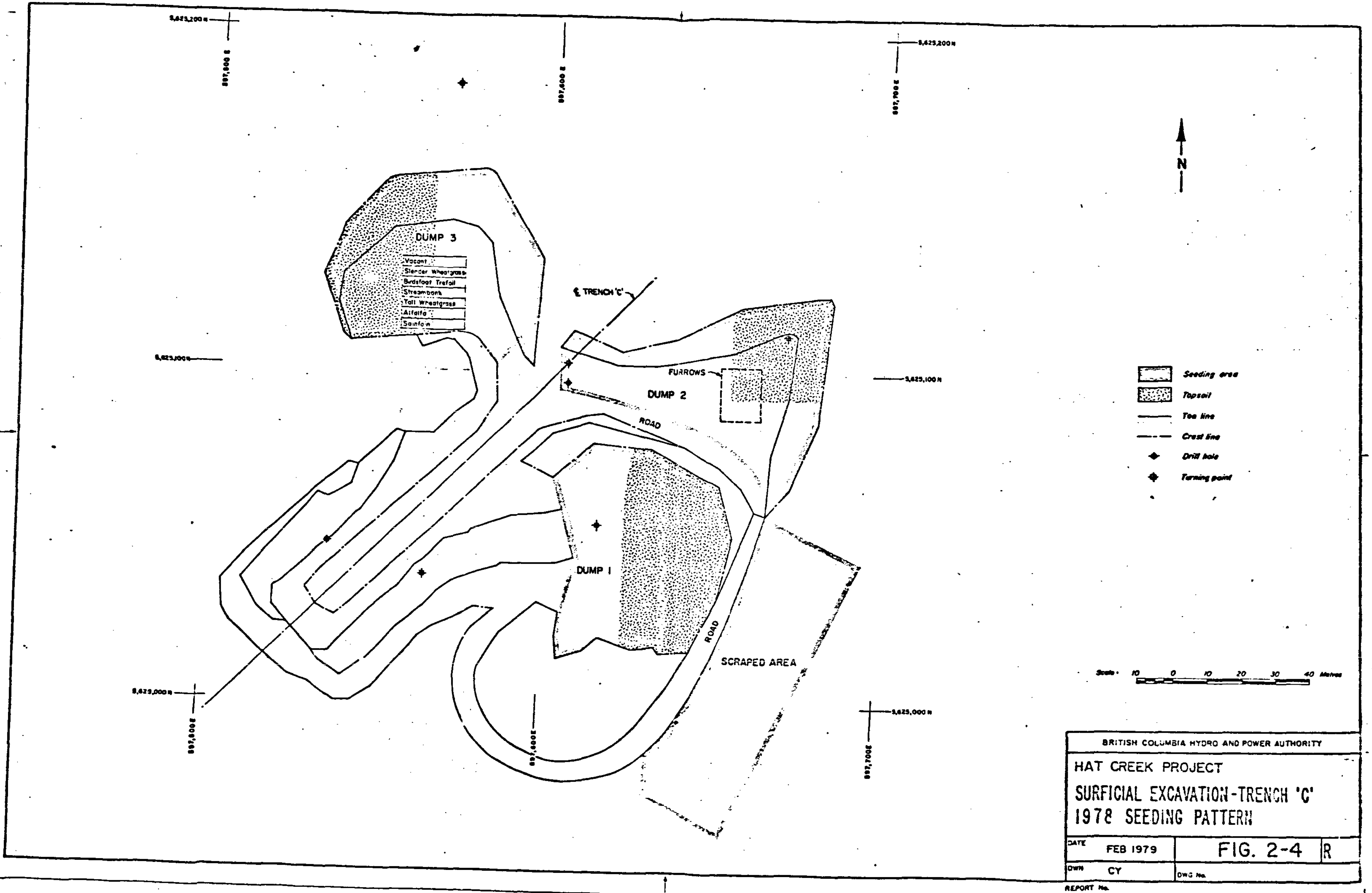
Two small areas adjacent to roads around Trench A were seeded using Seed Mix IV as shown in Figure 2-3. Following seeding and fertilizing, the areas were harrowed where possible.

Trench B

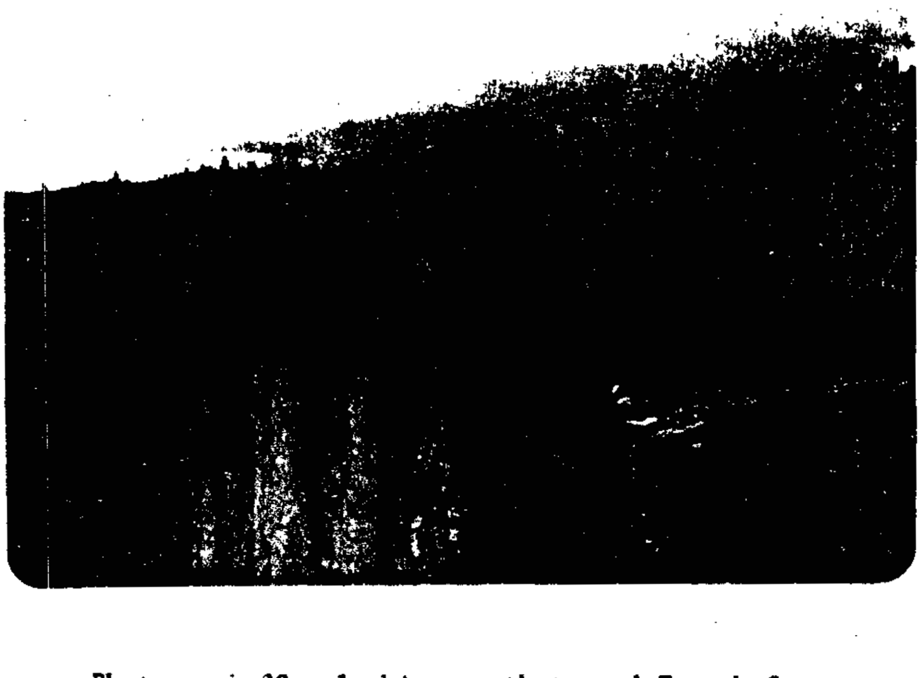
No seeding or fertilizing was carried out during 1978. Maintenance fertilizing may be carried out in 1979.

Trench C

There are three dumps at Trench C arbitrarily denoted 1, 2 and 3 as shown in Figure 2-4. Topsoil 10 to 15 cm thick was applied to approximately half the area of the dumps including both surface and slope faces (Photographs 19 & 20). Slopes of dump faces were left at the natural dump angle of 38°. Seeds were sown in individual 3 m rows on both raw waste and topsoiled waste material on Dump 3(Figure 2-4). Otherwise Seed Mix VI was used as shown in Table 2-28. In places where weathering of the surface material and vehicular


N
DUMP 3
Vacant
Slender Wheatgrass
Birdsfoot Trefoil
Streambank
Tall Wheatgrass
Alfalfa
Sainfoin
℄ TRENCH 'C'
FURROWS
DUMP 2
ROAD
DUMP 1
ROAD
SCRAPED AREA
5,625,200 N
5,625,100 N
5,625,000 N
Seeding area
Topsoil
Toe line
Crest line
Drill hole
Turning point
Scale: 10 0 10 20 30 40 Metres
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
SURFICIAL EXCAVATION-TRENCH 'C'
1978 SEEDING PATTERN
DATE FEB 1979
FIG. 2-4 R
DWN CY
DWG No.
REPORT No.

Photograph 19 - looking west toward Trench C
and dumps



Photograph 20 - looking south toward Trench C
dump faces

traffic had caused excessive compaction it was necessary to rip the surface with a bulldozer; otherwise the spring-tooth harrow was used.

On dump 2 surface treatment to create small water collection basins was carried out in a manner similar to that used at Trench A. An attempt was made to pull a diamond-drag harrow across the dump face. However, this proved unsuccessful and consequently seed was left as it fell on the dump faces, although in walking around the faces during seeding, a measure of burying did occur.

An early cut that had been made into the hill immediately adjacent and southeast of Trench C was seeded using Seed Mix VI, fertilized and then harrowed.

2.5 DRILL SITES

Introduction

Revegetation of drill sites and access roads was continued during 1978. All drill sites from 1978 and previous years were reclaimed in 1978. Some roads are still in use for piezometric measurements and general access and have not yet been reclaimed. The following describes the drill site reclamation carried out during 1978.

Reclamation Program in 1978

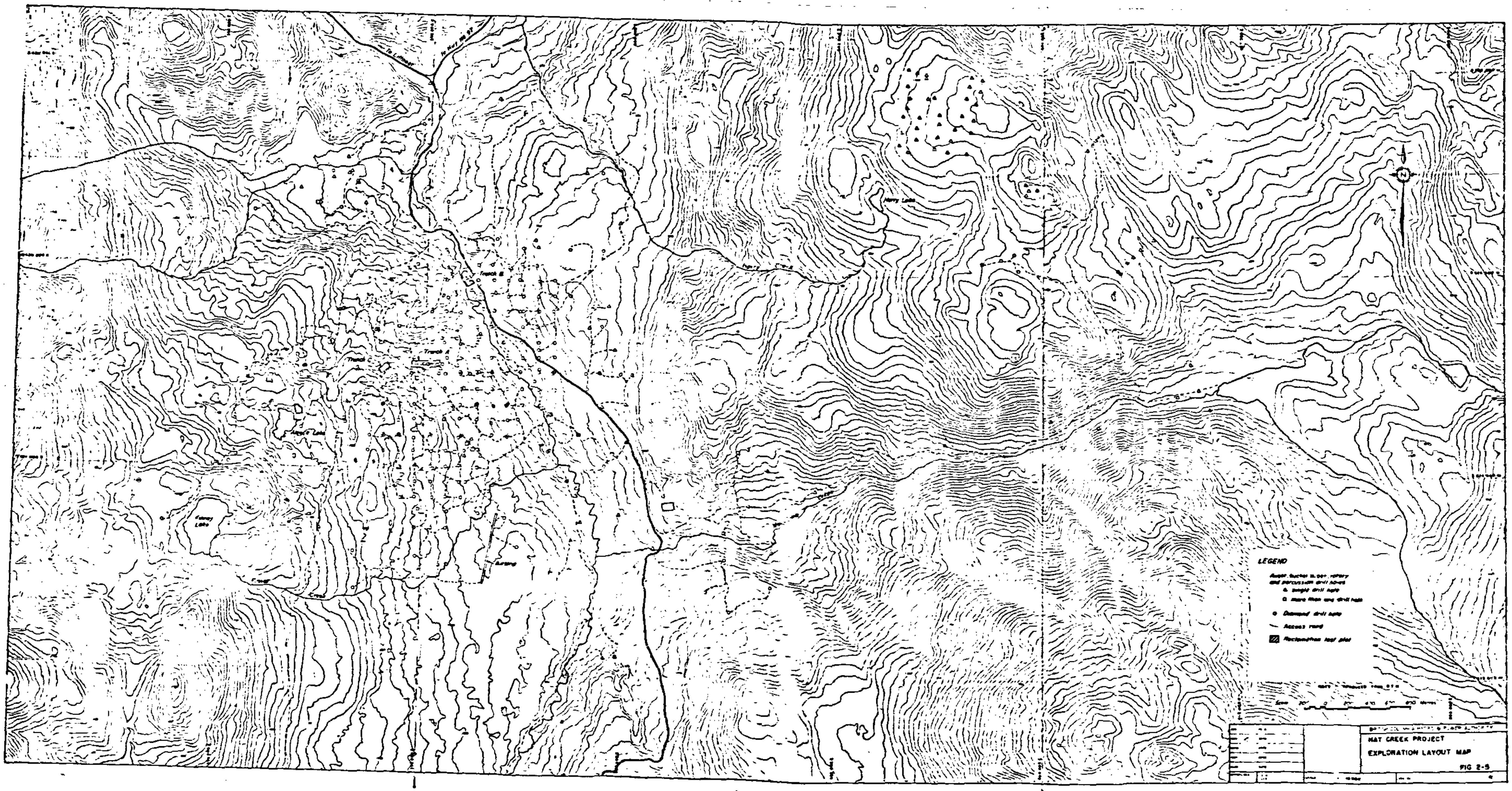
During 1978 74 exploratory holes were drilled which had a total drilled length of over 15,000 m. These disturbed 6.7 hectares of land. Access roads to these sites disturbed another 2.3 hectares. The drill sites and roadways are shown on Figure 2-5.

All of the drill sites from 1978 and from previous years were seeded, fertilized and harrowed in 1978. In total about 29 hectares of drill sites and 4.5 hectares of roads (equivalent to about 7.5 km) were reclaimed. The drill sites were seeded, fertilized then drag-harrowed to bury the seed. Access roads were draf-harrowed before and after seeding and fertilization.

The following seed mixes were used on the drill site and access road areas:

Seed Mix I

	Rate of Seeding kg/ha
Crested Wheatgrass (Nordan)	22.4
Alfalfa (Drlyander)	11.2
Fall Rye	22.4
Canada Bluegrass	1.1
	57.0


LEGEND
Access road
HAT CREEK PROJECT
EXPLORATION LAYOUT MAP
FIG 2-5

Approximately 37% of the area was seeded with this seed mix.

Seed Mix II

	Rate of Seeding kg/ha
Streambank Wheatgrass	11.2
Crested Wheatgrass (Nordan)	16.8
Smooth Bromegrass (Manchar)	15.7
Alfalfa (Drylander or Vernal)	13.4
	57.0

This mix with alfalfa drylander was applied to approximately 43% of the seeded area, and with alfalfa vernal to approximately 20% of the seeded area.

Fertilizer was applied as follows:

N	P_2O_5	K_2O	Application Rate
11	48	0	280 kg/ha
0	0	62	112 kg/ha

These fertilizer application rates were based on soils analyses done in 1977.

2.6 TRACE ELEMENT TESTING

2.6.1 Introduction

The Aleece Lake experimental program was designed to evaluate, on a large scale, the revegetation potential of various waste materials from the proposed coal mine and thermal power plant. Many of these waste materials contain concentrations of trace elements different from that found in surface soils. The manner in which these trace elements could be released to the environment through leaching and uptake by plants is presently not well understood. As part of the experimental revegetation program, therefore, total and leachable trace element levels in the various waste materials and the levels of trace elements in plants grown on these waste materials were determined.

Twenty-three elements were studied including some macronutrient elements as well as trace elements, which were defined as elements present in concentrations of less than 1000 ppm. The selection of these elements was based upon many factors including: potential environmental effects; levels known to be present in similar wastes; ability of plants to concentrate certain elements; mobility in the environment and toxicity to plants and animals.

The methods of testing and results of these trace element analyses are presented and discussed in this section.

2.6.2 Total Trace Elements in Soil Materials

Soil samples were collected on 25 and 26 April 1978 from the eight test plots at Aleece Lake and from the sloped test plots at Houth Meadows and Medicine Creek. The sample collection and handling procedures are described in Section 2-1 of this report. Thirteen wet and thirteen air-dried samples were analysed for trace elements by Chemex Labs Ltd., North Vancouver. The wet samples were analysed as received for Hg only; the dried samples for all 23 elements. The air-dried samples were oven-dried overnight at 55 to 60° C in aluminum trays, screened on 10 mesh screen and the minus 10 mesh fraction was pulverized in a tungsten-carbide mill to a fine powder. Subsamples were acid digested and analysed to determine total element concentrations. All analyses were done in duplicate and one sample was divided and submitted as a duplicate blind to assess the accuracy of the analyses.

Analytical methods used for the soils analyses are as follows:

(i) Cu, Mo, Pb, An, Cd, Ni, Fe, Mo: Samples were wet-ashed with a combination of nitric and perchloric acids and each metal was determined by direct atomic absorption. Background corrections were applied to Dc, Ni and Pb determinations.

(ii) As, Se: An aliquot of the above solution was reduced and both elements were analyzed as their hydrides via hot vapour flameless atomic absorption.

(iii) Hg: Samples were digested with nitric and sulphuric acids, potassium permanganate and potassium persulfate. Mercury was reduced and analyzed via cold vapour U.V. absorption.

(iv) Sr, Cr, Co, Be, V, K, Sr Mg, Th, U: Samples were dry-ashed at 550° C, digested with nitric perchloric and hydrofluoric acids and analyzed by direct atomic absorption.

(v) F: Samples were ashed at 550° C using NaOH as an ashing aid. The ash was fused with sodium carbonate, leached with water, buffered and analyzed for fluoride with a specific ion electrode.

(vi) Boron: Samples were ashed overnight at 550° C and the ash was dissolved in hydrochloric and nitric acids. Pyrex glassware (borosilicate glacc) was not used. Samples were ashed and leached in polyethylene containers. The resulting solutions were analyzed by Cantest Ltd., Vancouver, using an inductively-coupled plasma torch.

The results of the soils analyses are presented in Table 2-29. Each value reported is the average of two duplicate analyses. Average results of analyses of local soils done by ERT[5] as part of a trace element study are shown in Table 2-29. These values are the mean result from 25 surface soil samples collected in October 1976, January 1977 and May 1977 from five sampling locations in the Hat Creek region. Average results from 15 soil samples collected at the same five sampling locations in October 1978 are also reported in Table 2-29.

Except for the fly ash plot at Aleece Lake, all trace element data are within the range of values normally found in natural soils[6]. The levels of arsenic, boron and copper were higher in the fly ash while the fluorine level was much lower.

All of these soils analyses were done in duplicate. Most of the duplicate analyses agreed well, only about 10 percent of the more than 300 pairs of analyses differed by more than 10 percent. The results for the divided sample, which was analysed as two unrelated samples, show an average difference of 9.2 percent for the 23 element analysed. Six results differed by more than 20 percent, mainly when the results were close to the detection limits of the tests.

Mercury levels were determined on both air/oven-dried samples and on undried, as-collected samples. The mercury concentration measured in the undried samples averaged 26 percent higher than the concentration measured in those samples dried overnight at 60° C.

2.6.3 Extractable Trace Elements in Soils

Many different analytical procedures are commonly used to obtain estimates of the quantities of various soil constituents that may be available to plants. Most of these methods have been developed for agricultural purposes and have not been correlated with actual plant uptake, except for important nutrient materials. To obtain an estimate of trace elements that could potentially be available to plants, soil extractions were carried out

TABLE 2-29 - SOILS ANALYSES* - TOTAL TRACE ELEMENTS

Element (PPM)	Gritstone	Coal Waste	Carbonaceous Shale	Baked Clay	Colluvium	Bentonitic Clay	Glacial Gravels	Fly Ash	Medicine Creek Till	Topsoil from Trench B	Recent Gravels from Trench B	Houth Meadows Parent Material	Local Soils ERT	Local Soils Oct. 1978
As	6	5	8	9	10	9	6	16	6	6	4	5	58	4.2
Be	2.0	1.5	2.0	2.5	2.0	2.0	2.0	2.0	1.5	1.8	1.5	1.0	0.4	1.0
B	8.8	17	12	13	11	24	15	178	<20	<20	<20	<20	8.9	9.3
Cd	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	5.7	1.1
Cr	133	105	110	135	125	123	140	128	155	155	157	120	117	108
Co	18	11	16	14	15	16	14	10	14	15	12	7	12.9	11
Cu	46	55	69	61	39	40	44	530	41	38	29	23	37	30
F	200	133	198	123	203	265	160	20	218	213	173	260	307	228
Fe %	2.33	1.60	2.50	3.10	2.63	2.65	3.03	2.30	2.65	2.90	2.63	1.45	>0.1	2.8
K %	0.95	0.38	0.51	0.50	1.02	1.23	0.82	0.61	1.12	1.12	1.00	0.51	>0.1	-
Pb	6	6	6	3	4	7	3	2	1.5	3	1.5	1.3	<4	7
Mg %	0.55	0.13	0.20	0.50	0.78	0.68	1.26	0.48	1.40	1.25	1.33	1.11	>0.1	7
Mn	330	140	200	453	533	313	668	288	675	780	643	393	>945	-
Hg ppb dried	95	80	115	45	90	170	65	50	50	50	40	58	113	76
Hg ppb wet	94	130	157	52	108	254	81	64	65	66	47	49	-	-
Mo	2	4	3	3	2	2	2	5.5	2.5	1.5	1.5	3	2.87	<1
Ni	51	45	55	60	45	52	59	53	61	53	50	24	45.5	-
Se	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.2	<1
Na %	1.75	0.27	0.20	0.70	1.70	1.93	1.30	0.62	1.45	1.80	2.00	0.93	>0.1	-
Sr	205	80	110	300	275	255	205	250	220	295	290	390	378	201
Th	20	10	20	10	20	30	10	10	10	10	10	10	<5.4	-
U	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<3.60	<0.5
V	145	150	190	245	135	130	160	270	130	140	135	90	147	121
Zn	82	57	57	51	75	68	75	40	71	81	59	53	125	131

* Analyses by Chemex Labs Ltd., samples collected April 1978.

using 0.1 N hydrochloric acid. These tests were done with a liquid to soil ratio of 10 to 1, by shaking for 30 minutes at room temperature. No references correlating 0.1 N hydrochloric acid extracted trace elements to actual uptake by plants were found. However, the B.C. Department of Agriculture and others[7] indicate that this test provides a useful indication of the long term availability of a wide range of trace elements; conditions in the immediate vicinity of plant roots are mildly acidic.

The soils samples used for the extraction tests were those from the Aleece Lake plots which were collected 25 and 26 April 1978 and had been analysed for total trace elements. Each sample had been dried overnight at 60° C, screened and the minus 10 mesh fraction was pulverized in a tungsten-carbide mill to a fine powder and sealed in a plastic bag. Some of the samples were subdivided and sent to two different laboratories for similar analyses.

The analytical methods used at the two laboratories were not exactly the same. The methods used by Beak Consultants Limited were given as follows:

1. The following elements were run directly by atomic absorption spectrophotometry:

Cadmium	Chromium	Cobalt
Copper	Iron	Potassium
Manganese	Magnesium	Nickel
Sodium	Lead	Strotium
Zinc		

2. Arsenic was run using a hydride generator.

3. Beryllium was run using a plasma emission spectrometer.

4. Boron was run by evaporating the acidified sample in the presence of curcumin. When the sample contains boron, a red-colored product, rosocyanine, is formed. The rosocyanine is taken up in 95% ethanol and the color is measured spectrophotometrically at 540 nm.

5. Fluoride was measured using a specific ion meter.

6. Mercury was run by first oxidizing the sample with sulfuric acid and potassium permanganate. When this is followed by reduction with acidic stannous sulfate - hydroxylamine sulfate, any mercury is aerated from the solution as a vapor which is carried over in the airstream to a quartz cuvette and measured using an atomic absorption spectrophotometer.

7. Molybdenum was run using an atomic absorption spectrophotometer equipped with a graphite furnace.

8. Selenium was run by first oxidizing the sample to convert any selenium compounds to selenate by acid permanganate. The selenate is then reduced to selenite. Addition of diaminobenzidine reagent forms the piazselenol complex which is extracted into toluene. The color is measured spectrophotometrically at 420 nm.

9. Vanadium was run using a combination of plasma emission, direct atomic absorption, and graphite furnace techniques, depending upon the level present.

10. Uranium was run fluorometrically.

The analytical methods used by Chemex Labs Ltd. were given as follows:

(i) The following elements were determined by direct atomic absorption: Be, Cd, Cr, Co, Cu, Fe, K, Mn, Mg, Mo, Ni, Ma, Pb, Sr, V, Zn. Those corrected for background absorption were Cd, Co, Ni, Pb.

(ii) As and Se were analyzed as their hydrides via hot vapour flameless atomic absorption.

(iii) B was determined using an inductively-coupled plasma torch.

(iv) F was determined using a specific ion electrode.

(v) Hg was determined using cold vapour U.V. absorption.

(vi) Th was determined colorimetrically as its arsenazo III complex.

(vii) U was determined fluorimetrically as its fluoride complex.

The results of the 0.1 N hydrochloric acid extraction of the Aleece Lake soil materials are given in Table 2-30 along with the total trace element concentrations. In addition to the Aleece Lake soil materials a sample of fly ash collected at Battle River during the test burn was also analysed. This sample had been kept in a closed container since the tests in mid 1977. In Table 2-30, the analyses done by Beak are labelled '1' and those done by Chemex are labelled '2'. All of the analyses done by Chemex were done in duplicate and the number reported is the average of the two results. Two samples, the colluvium and glacial gravels, were submitted to Beak as blind duplicates to enable assessment of the precision of the test results.

The fly ash and coal waste materials showed higher concentrations of some acid extractable elements than the other soil materials. These included As, B, Cu and Mo. The gritstone material also had higher levels of extractable elements than the other materials.

Other extractions have been done on the same soil material samples. The B.C. Department of Agriculture tests given in Table 2-1 report ammonium acetate extractions for magnesium, potassium and sodium and hot water extraction for boron. Acres[7] report results for multiple water extractions on fly ash and coal waste materials which are similar to the Aleece Lake materials.

The amount of boron extracted with the hot water was similar to that extracted with 0.1 N hydrochloric acid for all of the soil materials except the fly ash where the acid extracted ten times the quantity of boron. The quantities of magnesium and sodium extracted were similar in the ammonium acetate and hydrochloric acid extractions except for the fly ash. The amounts of potassium extracted by the acid were less than for the acetate except in the fly ash where the acid extracted larger quantities.

The multiple water extractions reported by Acres[8] were alkaline and thus differed substantially from the acid extractions. In general, greater quantities of B, Fe, Mg, Sr, V were extracted by the acid; the water extractions extracted greater amounts of F and Zn.

The results obtained by Beak on the blind duplicate samples show that the precision of the test procedures was excellent. Only three of the 46 pairs of analyses differed by more than 10%. Ninety-two analyses were done on similar samples by Beak and Chemex. These results also agree extremely well considering the variation reflects the non-homogeneity of the soil materials, the variation in extraction procedures and conditions and the differences in analytical methods. Nine of the 92 pairs of results differed by 50% or more. All of the fluoride analyses done by Chemex showed higher results than those of Beak. Other elements that showed large differences were iron, molybdenum, uranium and zinc.

2.6.4 Trace Elements in Test Plot Vegetation

Vegetation samples for trace element analyses were collected at Aleece Lake test plots in July and August. Each sample was a composite of vegetation of a single species collected from 18 quadrats on each soil type. The sample collection and handling procedures are described in Section 2.1 of this report. The samples selected for trace element analyses were dried at 40° C for approximately 72 hours, milled to minus 20 mesh and placed in plastic bags for analyses. Analytical methods were the same as those employed for the trace element analyses of soils. These methods were described in the total trace elements in soils' section of this report.

Vegetation samples from the colluvium, glacial gravels and fly ash test plots at Aleece Lake were analysed for 17 trace elements. Vegetation was harvested and analysed from both topsoiled and nontopsoiled halves of the colluvium plot, and from only the nontopsoiled halves of the glacial gravel and fly ash plots. Results are given in Tables 2-31 through 2-35.

On the colluvium and glacial gravel plots the concentrations of trace elements in vegetation were very similar and were all within the range normally found in natural environments[5]. The trace element testing done by ERT[6] and in

October 1978 by B.C. Hydro (detailed in Section 5.0 of this report) show similar levels in native vegetation growing in the Hat Creek region. Generally levels in legumes were higher than those in the grasses. Some elements such as arsenic, tin and selenium were below their detection limits in both grasses and legumes. Topsoil appeared to have no major effect on trace element concentrations as shown by the results from the colluvium plot. Comparison of levels in vegetation with the total concentrations in soils shows that only Boron and Molybdenum concentrated in the vegetation to greater levels than in the soils, Table 2-36. Zinc and Cadmium showed concentration in the vegetation of about one half of that in the soil.

As may be expected the ratio of trace element concentrations in vegetation to that extractable in the soils is larger than that involving the total soil concentration. Of particular note are the ratios for Boron, Copper, iron, mercury, molybdenum and zinc. (Table 2-36).

Trace element concentractions in vegetation grown on the fly ash plot were different from the colluvium and glacial gravel plots. The levels of arsenic boron, copper, molybdenum and selenium were greater than in the vegetation grown on the other plots and greater than found in natural vegetation growing in the Hat Creek area; the level of manganese was considerably lower. The trace element concentrations found in the vegetation grown on the fly ash plot closely follow the levels found in the total and extraction analyses of the material. The levels of trace elements found in the vegetation may have been increased by dust and dirt on the plants. The fly ash material is very fine and it was impossible not to disturb the material and create dust during sampling. Also, it was very dusty due to winds the day the fly ash vegetation was sampled.

Because of the small sample size, no trace element analyses were done on vegetation growing on the acid soil materials, coal waste and carbonaceous shale. These tests will be done when sufficient vegetation develops.

TABLE 2-30 - SOILS ANALYSES* - TOTAL AND 0.1 N HCL EXTRACTIONS

Element	Gritstone		Coal Waste		Carbonaceous Shale		Baked Clay		Bentonitic Clay	
(MG/KG)	Extract	Total	Extract	Total	Extract	Total	Extract	Total	Extract	Total
As	0.82	6	0.60	5	0.29	8	0.25	9	0.14	9
Be	0.35	2.0	0.51	1.5	0.59	2.0	0.22	2.5	0.52	2.0
B	<1.0	8.8	4.5	17	1.7	12	1.1	13	<1.0	24
Cd	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2	<0.5	<0.2
Cr	1.5	133	1	105	1	110	3.0	135	< 1	123
Co	8.6	18	4.0	11	3.0	16	2.6	14	3.4	16
Cu	16	46	3.0	55	0.8	69	2.7	61	8.0	40
F	2.0	200	0.80	133	0.5	198	<0.5	123	3.25	265
Fe	2400	23300	680	16000	96	25000	28	31000	480	26500
K	420	9500	170	3800	180	5100	490	5000	530	12300
Pb	2.0	6	< 1	6	< 1	6	< 1	3	2.1	7
Mg	2600	5500	1000	1300	1300	2000	1200	5000	1400	6800
Mn	51	330	64	140	72	200	140	453	92	313
Hg	<0.0025	0.095	<0.0025	0.105	<0.0025	0.136	<0.0025	0.049	<0.0025	0.212
Mo	0.07	2	0.07	4	0.07	3	0.06	3	0.07	2
Ni	19	51	10	45	12	55	3.0	60	4.9	52
Se	<0.03	< 1	0.03	< 1	0.03	< 1	<0.03	< 1	<0.03	< 1
Na	1100	17500	86	2700	130	2000	240	7000	2100	19300
Sr	28	205	21	80	40	110	46	300	40	255
Th	-	20	-	10	-	20	-	10		30
U	-	<0.5	-	<0.5	-	<0.5	-	<0.5		<0.5
V	0.98	145	16	150	3.2	190	2.1	245	5.0	130
Zn	17	82	11	57	8.1	57	3.3	51	11	68

* Extractions and analyses by Beak Consultants Limited

Total analyses by Chemex Labs Ltd.

TABLE 2-30 (Cont'd)

Element (MG/KG)	Colluvium				Glacial Gravels				Fly Ash			Battle River Fly Ash		
	Extractions			Total	Extractions			Total	Extractions		Total	Extractions		Total
	1*	1	2		1	1	2		1	2		1	2	
As	<0.10	<0.10	<1	10	<0.10	<0.10	<1	6	6.4	6.5	16	13	16	
Be	<0.03	<0.03	0.1	2.0	<0.03	<0.03	<0.1	2.0	0.26	0.3	3.3	0.10	0.25	
B	1.1	1.1	1.1	11	<1.0	<1.0	0.65	15	120	93	178	64	51	75
Cd	<0.5	<0.5	0.1	<0.2	<0.5	<0.5	<0.1	<0.2	<0.5	<0.1	<0.2	<0.5	<0.1	
Cr	<1	<1	1	125	<1	<1	1	140	2.5	3	128	1.5	1	
Co	2.4	2.0	2.8	15	<1	<1	0.5	14	<1	0.75	10	<1	0.5	
Cu	<0.5	<0.5	<1	39	<0.5	<0.5	<1	44	180	148	530	170	140	
F	2.6	1.1	4.0	203	2.9	2.6	5.9	160	0.70	4.2	20	2.5	8.6	
Fe	6.7	6.8	50	26300	1.5	2.7	<5	30300	860	900	23000	870	875	
K	270	270	410	10200	160	160	270	8200	180	225	6100	100	140	
Pb	<1	<1	<1	4	<1	<1	<1	3	<1	1	2	<1	1.5	
Mg	2200	2100	2040	7800	900	890	875	12600	670	625	4800	990	940	
Mn	130	130	150	533	100	98	120	668	39	42	288	15	17	
Hg	<0.0025	<0.0025	<0.005	0.100	<0.0025	<0.0025	<0.005	0.073	<0.0025	<0.005	0.057	<0.0025	<0.005	
Mo	0.05	0.05	<1	2	0.06	0.06	<1	2	0.88	<1	5.5	5.1	<1	
Ni	3.0	2.7	3.5	45	1.8	1.8	1.5	59	2.8	3	53	2.6	2.5	
Se	<0.03	<0.03	<0.5	<1	<0.03	<0.03	<0.5	<1	<0.03	<0.5	<1	<0.03	<0.5	
Na	200	200	208	17000	57	61	75	13000	200	215	6200	150	165	
Sr	52	51	26	275	58	59	31	205	55	55	250	20	26	
Th	–	0.17	<10	20	–	–	<10	10	0.1	<10	10	0.12	<10	
U	–	0.10	1.8	<0.5	–	–	<0.5	<0.5	0.29	<0.5	<0.5	0.32	<0.5	
V	<0.10	<0.10	2	135	0.18	0.19	<2	160	18	20	270	23	25	
Zn	1.1	1.0	2.3	75	<0.5	<0.5	1	75	0.90	7.5	40	5.5	5	

* 1. Analyses by Beak Consultants Limited.
2. Average of duplicate analyses by Chemex Labs Ltd.

TABLE 2-31 - VEGETATION TRACE ELEMENT CONCENTRATIONS - COLLUVIUM PLOT - SEED MIX #1

Element	Crested Wheatgrass		Drylander Alfalfa		Fall Ryegrass		Invader Species		Colluvium			
									Extractions			
(MG/KG)	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	1*	1	2	Total
As	<1	<1	<1	<1	<1	<1	<1	<1	<0.10	<0.10	<1	10
Be	0.01	0.01			0.01	0.01	0.04	0.03	<0.03	<0.03	0.1	2.0
B						6.0			1.1	1.1	1.1	11
Cd	0.1	<0.1	0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.5	<0.5	0.1	<0.2
Co	0.08	<0.04			<0.04	<0.04	0.04	0.24	2.4	2.0	2.8	15
Cu	4.5	4.5	6	5	6	4.5	7.5	6	<0.5	<0.5	<1	39
F	<10	<10			<10	<10	<10	<10	2.6	1.1	4.0	203
Fe	135	105	200	3200	60	63	400	295	6.7	6.8	50	26300
Pb	1	1	1	<1	1	1	1	1	<1	<1	<1	4
Mn	52	52	59	110	32	32	69	47	130	130	150	533
Hg	0.01	0.01	0.01	0.03	0.02	0.01	0.01	0.01	<0.0025	<0.0025	<0.005	0.100
Mo	1	<1	4	4	2.5	2.5	<1	1.5	0.05	0.05	<1	2
Ni	<1	<1	2	1	<1	<1	1.5	1	3.0	2.7	3.5	45
Se	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.03	<0.03	<0.5	<1
Sn	<1	<1			<1	<1	<1	<1				
V	1.0	0.5			0.3	0.6	3.2	2.0	<0.10	<0.10	2	135
Zn	32	36	37	36	40	31	47	47	1.1	1.0	2.3	75

TABLE 2-32 - VEGETATION TRACE ELEMENT CONCENTRATIONS - COLLUVIUM PLOT - SEED MIX #2

Element	Russian Wild Ryegrass		Slender Wheatgrass		Sainfoin		Sweet Clover		Invader Species		Colluvium			
											Extractions			
(MG/KG)	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	1*	1	2	Total
As	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.10	<0.10	<1	10
Be	0.02	0.02	<0.01	0.01	0.04	0.04			0.03		<0.03	<0.03	0.1	2.0
B			11.3								1.1	1.1	1.1	11
Cd	0.1	0.1	0.1	<0.1	0.2	<0.1	0.3	0.2	0.2	0.2	<0.5	<0.5	0.1	<0.2
Co	0.12	0.10	0.04	0.08	0.30	0.44			0.24		2.4	2.0	2.8	15
Cu	7	7.5	6.5	5	8	8.5	9	9	9	8	<0.5	<0.5	<1	39
F	<10	<10	<10	<10	<10	<10	<10		<10	<10	2.6	1.1	4.0	203
Fe	270	175	95	110	430	525	310	410	335	350	6.7	6.8	50	26300
Pb	<1	1	1.5	<1	<1	<1	1	1	<1	1	<1	<1	<1	4
Mn	92	75	86	84	145	155	88	58	80	70	130	130	150	533
Hg	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.02	0.03	0.02	<0.0025	<0.0025	<0.005	0.100
Mo	1.5	1	1	<1	4	5	11	6	1	1	0.05	0.05	<1	2
Ni	<1	<1	<1	1	2	2.5	2	3	2	1	3.0	2.7	3.5	45
Se	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.03	<0.03	<0.5	<1
Sn	<1	<1	<1	<1	<1	<1			<1	<1				
V	1.7	1.2	0.4	0.3	2.7	3.4			1.8		<0.10	<0.10	2	135
Zn	34	33	40	33	54	50	33	29	82	37	1.1	1.0	2.3	75

TABLE 2-33 - VEGETATION TRACE ELEMENT CONCENTRATIONS - COLLUVIUM PLOT - SEED MIX #3

Element	Smooth Bromegrass		Streambank Wheatgrass		Canada Bluegrass (Rubens)		Red Clover		Invader Species		Colluvium			
											Extractions			
(mg/KG)	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	Topsoil	No Topsoil	1*	1	2	Total
As	<1	<1	<1	<1	<1	Insufficent	<1	<1	<1	<1	<0.10	<0.10	<1	10
Be	0.015	0.01	0.01	0.015					0.025	0.02	<0.03	<0.03	0.1	2.0
B			31.5			Sample					1.1	1.1	1.1	1.1
Cd	<0.1	0.15	<0.1	0.2	<0.1		<0.1	0.1	0.15	0.3	<0.5	<0.5	0.1	<0.2
Co	0.04	0.08	<0.04	0.06					0.32	0.22	2.4	2.0	2.8	15
Cu	5	4.5	4	4.5	3		8	11	6.5	6.5	<0.5	<0.5	<1	39
F	<10	<10	<10	<10			<10		<10	<10	2.6	1.1	4.0	203
Fe	235	115	108	125	80		500	1100	500	300	6.7	6.8	50	26300
Pb	<1	<1	<1	1	<1		<1	1	<1	1.5	<1	<1	<1	4
Mn	150	101	71	70	49		79	101	75	44	130	130	150	533
Hg	0.03	0.03	0.02	0.02	0.01		0.01	0.04	0.02	0.02	<0.0025	<0.0025	<0.005	0.100
Mo	2.5	1	<1	1	2		6	16	4	1.5	0.05	0.05	<1	2
Ni	<1	<1	<1	<1	2		3	6	1	2	3.0	2.7	3.5	45
Se	<0.2	<0.2	<0.2	<0.2	<0.2		<0.2	<0.2	<0.2	<0.2	<0.03	<0.03	<0.5	<1
Sn	<1	<1	<1	<1			<1		<1	<1				
V	1.7	0.7	0.6	0.9					0.3	2.6	<0.10	<0.10	2	135
Zn	21	24	25	32	20		27	52	35	35	1.1	1.0	2.3	75

TABLE 2-34 - VEGETATION TRACE ELEMENT CONCENTRATIONS - GLACIAL GRAVELS - NO TOPSOIL

Element (MG/KG)	Seed Mix #1			Seed Mix #2					Seed Mix #3					Glacial Gravels			
														Extractions			
	Crested Wheatgrass	Drylander Alfalfa	Fall Ryegrass	Russian Wild Ryegrass	Slender Wheatgrass	Sainfoin	Sweet Clover	Invader Species	Smooth Bromegrass	Streambank Wheatgrass	Canada Blue Grass (Rubens)	Red Clover	Invader Species	1	1	2	Total
As	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.10	<0.10	<1	6
Be	0.01		0.01	0.02	0.01	0.05			0.01	0.01		0.08	0.04	<0.03	<0.03	<0.1	2.0
B										28				<1.0	<1.0	0.65	15
Cd	0.2	0.1	<0.1	<0.1	0.15	0.1	0.2	0.1	0.1	0.1	0.1	<0.1	0.5	<0.5	<0.5	<0.1	<0.2
Co	<0.04		<0.04	0.14	0.06	0.56			0.18	0.14		0.72	0.40	<1	<1	0.5	14
Cu	3	6	2	5	4	6.5	15	4	6	4.5	4	13	6.5	<0.5	<0.5	<1	44
F	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	2.9	2.6	5.9	160
Fe	125	260	58	265	170	470	600	100	455	255	120	755	530	1.5	2.7	<5	30300
Pb	<1	2	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	3
Mn	75	96	40	125	125	250	150	42	240	145	73	150	60	100	98	120	668
Hg	0.02		0.01	0.03	0.02	0.03	0.05		0.04	0.05		0.06	0.04	<0.0025	<0.0025	<0.005	0.073
Mo	2	8	1.5	3	1.5	5	7	1	3	2	3	9	3	0.06	0.06	<1	2
Ni	<1	3	<1	1	1	2	6	1	1	<1	4	6	1	1.8	1.8	1.5	59
Se	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.03	<0.03	<0.5	<1
Sn	<1		<1	<1	<1	<1			<1	<1		<1	<1				
V	1.3		0.6	2.0	1.0	3.8			2.2	2.1		6.0	3.4	0.18	0.19	<2	160
Zn	12	24	9.5	12	14	35	37	19	13	16	10	30	30	<0.5	<0.5	1	75

TABLE 2-35 - VEGETATION TRACE ELEMENT CONCENTRATIONS - FLYASH PLOT - NO TOPSOIL

Element (MG/KG)	Seed Mix #1		Seed Mix #2		Fly Ash	
	Crested Wheatgrass	Drylander Alfalfa	Russian Wild Ryegrass	Slender Wheatgrass	Extract	Total
As	1	3	3	2	6.5	16
Be	0.02				0.28	3.3
B	488				107	178
Cd	<0.1	<0.2	0.1	<0.2	<0.5	<0.2
Co	0.24				0.8	10
Cu	8.5	16	38	30	164	530
F	<10		15		2.5	20
Fe	145	240	820	420	880	23000
Pb	<1	<2	<1	2	≤1	2
Mn	19	25	26	15	40	288
Hg	0.02		0.06		<0.005	0.057
Mo	9	22	19	16	0.88	5.5
Ni	<1	3	2	5	2.9	53
Se	0.35	0.2	1.4	0.4	<0.5	0.32
Sn	<1		<1			
V	3.0				19	270
Zn	17	30	12	20	4.2	40

3.0 WATER QUALITY MONITORING

3.1 INTRODUCTION

During 1977 water quality monitoring was started to provide background data and to monitor possible effects of the Bulk Sample Program on regional surface water and groundwater quality. This monitoring program was continued during 1978 to obtain additional water quality information.

It has been calculated that the temperature of Hat Creek could be significantly increased by the mining and powerplant development. Daily temperature data were collected to establish background water temperatures, particularly maximum water temperatures in Hat Creek.

During the Bulk Sample Program two waste materials, low grade coal and coal waste, were piled on specially prepared areas near Trench A to enable collection of leachates from the piles. Collection and analyses of these leachates was continued during 1978.

3.2 SURFACE WATER

In 1978, surface waters were sampled at two stations in Hat Creek, about 0.5 km above and below Trench B; at MacLaren Creek near McLean Lake; at Medicine Creek about 3 km upstream of its confluence with Hat Creek; and at Pavilion Lake.

The water samples were collected by Acres Consulting Services Ltd. and sent to Beak Consultants Limited, Vancouver for analyses. Some duplicate samples were also sent to the B.C. Hydro Research Laboratory, Vancouver, for analyses. Samples were preserved and filtered as required in the field and shipped in plastic bottles in coolers. A complete description of the sampling, preservation and analytical methods is given in the reports entitled Hat Creek Project, Detailed Environmental Studies, Water Resources Subgroup, prepared for B.C. Hydro by Beak Consultants Limited, May 1978.

The results of the surface water quality monitoring program are presented in Tables 3-1 to 3-5. The results are consistent with

TABLE 3-1

Parameter Dissolved Total CATIONS (Mg/l) / Date	26/4/77 Diss.	11/5/77 Diss.	24/5/77 Diss.	8/6/77 Diss.	22/6/77 Diss.	5/7/77 Diss.	20/7/77 Diss.	4/8/77 Diss.	14/9/77 Diss.	HAT CREEK STATION No. 1 19 / 10 / 77 Diss.	19 / 10 / 77 Total	29 / 11 / 77 Diss.	29 / 11 / 77 Total	1 / 5 / 78 Diss.	1 / 5 / 78 Total	7 / 6 / 78 Diss.	7 / 6 / 78 Total	B.C.Hydro Lab. 7 / 6 / 78 Diss.	B.C.Hydro Lab. 7 / 6 / 78 Total	23 / 8 / 78 Diss.	23 / 8 / 78 Total
Aluminum (Al)	*	*	*	*	*	*	*	*	*	<0.1	0.060	0.077	0.080	0.030	7.8	0.051	7.2	0.04	15.8	0.008	0.13
Arsenic (As)	*	*	*	*	*	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.05		<0.005	<0.005
Cadmium (Cd)																					
Calcium (Ca)	42	59	60	37	57	60	60	56	58	64	64	60		45	52	24	29	24.5	32.8	65	65
Chromium (Cr)	*	*	*	*	*	*	*	*	*	<0.010	<0.010	<0.010	<0.010	<0.010	0.020	<0.010	<0.010	<0.01	0.09	<0.010	<0.010
Copper (Cu)	*	*	*	*	*	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	0.033	<0.005	0.024	0.016	0.024	<0.005	<0.005
Iron (Fe)	0.018	0.019		0.029	0.022	0.020	0.014	0.014	0.030	0.023	0.065	0.031	0.074	0.057	12	0.076	8.6	0.083	15.2	0.022	0.17
Lead (Pb)																					
Lithium (Li)	0.010	0.005	0.004	0.003	0.004	0.004	0.005	0.004	0.002	0.004	0.004	0.005	0.005	0.004	0.006	0.001	0.004	0.001	0.006	0.004	0.004
Magnesium (Mg)	13	21	21	12	15	22	19	17	19	18	18	6		19	21	6.0	7.5	8.1	11.3	21	21
Mercury (Hg)(µg/l)	*	*	*	*		*	*	0.25	*	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.32			0.3	0.35
Molybdenum (Mo)																					
Nickel (Ni)														0.014	0.054	<0.010	0.018	0.012	0.028		
Potassium (K)																		1.2	2.08		
Selenium (Se)	*	*	0.005	*	0.003	*	*	*	*	<0.003		<0.003		<0.003	<0.003	<0.003	<0.003			<0.003	<0.003
Sodium (Na)	14	24	25	15	21	20	22	23	22	21	22	23		17	18	7.4	7.4	7.0	9.48	26	28
Strontium (Sr)	0.24	0.30	0.30	0.13	0.18	0.31	0.24	0.25	0.29	0.24	0.24	0.25	0.28	0.26	0.27	0.095	0.14			0.32	0.37
Vanadium (V)	*	0.002	0.011	*	*	0.001	0.001	0.006	0.006	0.003	0.003	<0.003	<0.003	<0.003	0.019	0.002	0.021	<0.002	<0.002	0.003	0.003
Zinc (Zn)	0.008	0.005	*	0.010	*	*	0.024	0.036	0.006	<0.005	0.007	0.019	<0.005	0.007	0.055	0.012	0.031	0.049	0.061	0.006	0.006
Manganese (Mn)										0.011	0.012	0.010	0.012					0.01	0.36		
Silica (Si as SiO_2)																		11.9	200.9		
Titanium (Ti)																		<0.1	1.25		
Barium (Ba)																		0.13	0.14		

* Denotes <MDC

Table 3-1 (continued)

Date / (Mg/l) Parameter Dissolved Total ANIONS, ORGANIC, CALCULATED VALUES	HAT CREEK STATION No. 1																		B.C. Hydro Lab.			
	26/4/77	11/5/77	24/5/77	8/6/77	22/6/77	5/7/77	20/7/77	4/8/77	14/9/77	19 / 10 / 77		29 / 11 / 77		1 / 5 / 78		7 / 6 / 78		7 / 6 / 78		23 / 8 / 78	
										Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total
Boron (B)	*	0.2	*	*	0.1	*	*	*	*	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	0.053		<0.10	<0.10
Chloride (Cl)	0.78	1.2	1.0	0.63	0.88	0.99	1.0	1.3	1.2		0.78		0.92		1.3		0.30		0.32		1.4
Fluoride (F)	0.088	0.120	0.107	0.090	0.107	0.112	0.118	0.118	0.101		0.059		0.059		0.121		0.071				0.12
Sulfate (SO_4)	41	56	65	34	44	68	52	45	41		51		47		50		23		9.3		70
Total-Kjeldahl-Nitrogen (N)																					
Nitrate-Nitrogen (NO_3 - N)																					
Nitrite-Nitrogen (NO_2 - N)																					
Total-Orthophosphate-Phosphorus (P)																					
Dissolved-Total-PO_4-Phosphorus (P)	Diss. 0.010	Diss. 0.056	Diss. 0.054	Diss. 0.051	Diss. 0.083	Diss. 0.049	Diss. 0.032	Diss. 0.045	Diss. 0.049	0.026		0.024		0.041		0.029		<0.05		0.027	
COD																					
TOC	15	10	17	19	24	34	26	17	6		5		14		33		10				6
Phenol																					
Total Hardness($CaCO_3$)	158	234	236	142	204	240	228	210	223		234		216		191		84.5		88.0		249
Total Alkalinity($CaCO_3$)	149	220	230	149	198	236	243	250	234		235		220		197		87		80		240
BOD_5																					
D.O.																					
% Saturation																					

* Denotes <MDC

Table 3-1 (continued)

Parameter \ Date Dissolved Total PHYSICAL DATA (Mg/l)	HAT CREEK STATION No. 1 26/4/77	11/5/77	24/5/77	8/6/77	22/6/77	5/7/77	20/7/77	4/8/77	14/9/77	19/10/77	29/11/77	1/5/78	7/6/78	BCH Lab. 7/6/78	23/8/78						
pH (units)	7.9	8.5	8.4	8.3	8.4	8.4	8.5	8.6	8.4	8.3	8.2	8.4	8.0	8.1	8.3						
Specific Conductance (μmhos/cm @ 25° C)	370	490	520	350	440	547	520	520	508	506	485	436	190	170	557						
True Color (Pt-Co Units)																					
Turbidity (NTU)															1.8						
Temperature (°C)																					
Total residue	323	362	383	288	313	383	351	353	359	327	320	567	354	224	385						
Filtrable residue	253	360	367	253	306	378	349	353	346	324	316	286	138	158	381						
Non-filtrable residue	70	2	16	35	7	5	2	<1	13	3	4	281	216	65.5	4						
Fixed total residue																					
Fixed filtrable residue																					
Fixed non-filtrable residue																					

TABLE 3-2

Date of Sampling / (mg/L) Parameter Dissolved (D), Total (T)	26/4/77	11/5/77	24/5/77	8/6/77	22/6/77	5/7/77	20/7/77	3/8/77	14/9/77	19/10/77		29/11/77		1/5/78		7/6/78		23/8/78	
	HAT CREEK STATION NO. 3																		
										Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total
Aluminum (Al)	*	*	*	*	*	*	0.015	0.25	*	<0.010	0.032	<0.010	0.020	0.039	4.3	0.067	8.9	0.008	0.27
Arsenic (As)	*	*	*	*	*	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (Cd)																			
Calcium (Ca)	45	60	59	39	57	61	60	57	57	65	65	60		47	49	24	31	65	65
Chromium (Cr)	*	*	*	*	*	*	*	*	*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)	*	*	*	*	*	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	0.017	<0.005	0.032	<0.005	<0.005
Iron (Fe)	0.012	0.032	0.032	0.021	0.028	0.018	0.010	0.010	0.026	0.025	0.064	0.030	0.056	0.064	6.0	0.074	11	0.023	0.29
Lead (Pb)																			
Lithium (Li)	0.011	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.003	0.004	0.004	0.004	0.004	0.003	0.004	0.001	0.004	0.004	0.004
Magnesium (Mg)	15	20	21	12	15	21	19	17	18	18	18	15		19	20	6.0	8.5	20	20
Mercury (Hg)(ug/l)	*	*	*	*	*	*	*	*	*	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.35	0.37
Molybdenum (Mo)																			
Nickel (Ni)														0.015	0.033	0.010	0.023		
Potassium (K)																			
Selenium (Se)	0.004	0.004	*	*	0.003	*	*	*	0.005	<0.003		<0.003		<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Sodium (Na)	14	24	25	14	19	20	21	23	22	21	21	23		18	20	6.2	6.2	26	27
Strontium (Sr)	0.26	0.29	0.31	0.20	0.18	0.34	0.24	0.26	0.30	0.24	0.24	0.23	0.28	0.26	0.28	0.10	0.16	0.36	0.37
Vanadium (V)	*	0.001	*	*	*	0.003	*	0.004	*	0.006	0.006	<0.003	<0.003	<0.003	0.012	0.002	0.027	0.003	0.003
Zinc (Zn)	*	0.008	0.011	0.005	0.021	*	0.084	0.010	0.007	0.010	0.010	0.022	0.010	0.008	0.029	0.008	0.071	0.007	0.010
Manganese (Mn)										<0.005	0.007	<0.010	0.010						

* Denotes <MDC

Table 3-2 (continued)

HAT CREEK STATION NO. 3

Parameter (mg/L) Diss. (D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES / Date of Sampling	26/4/77	11/5/77	24/5/77	8/6/77	22/6/77	5/7/77	20/7/77	3/8/77	14/9/77	19/10/77		29/11/77		1/5/78		7/6/78		23/8/78			
										Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total		
Boron (B)	*	*	*	*	*	*	*	*	*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10		
Chloride (Cl)	0.95	1.3	1.3	0.70	0.85	0.94	0.85	1.1	0.88		0.82		0.92		1.4		0.42		1.5		
Fluoride (F)	0.088	0.107	0.113	0.082	0.117	0.108	0.120	0.122	0.091		0.086		0.079		0.123		0.078		0.12		
Sulfate (SO_4)	35	56	64	34	42	66	50	41	41		52		45		50		23		67		
Total-Kjeldahl-Nitrogen (N)																					
Nitrate-Nitrogen (NO_3-N)																					
Nitrite-Nitrogen (NO_2-N)																					
Total-Orthophosphate-Phosphorus (P)																					
Dissolved-Total PO_4 Phosphorus (P)	0.030	0.045	0.062	0.052	0.078	0.055	0.038	0.048	0.042	0.029		0.029		0.006		0.024		0.025			
COD																					
TOC	19	6	16	20	32	28	28	12	.5		12		16		22		12		2		
Phenol																					
Total Hardness($CaCO_3$)	174	232	234	147	204	239	228	212	216		236		212		226		84.6		245		
Total Alkalinity($CaCO_3$)	158	219	230	153	196	237	247	248	229		237		223		227		91		239		
BOD_5																					
D.O.																					
% Saturation																					
* Denotes <MDC																					

Table 3-2 (continued)

Parameter / Date of Sampling — PHYSICAL DATA (mg/L)	26/4/77	11/5/77	24/5/77	8/6/77	22/6/77	5/7/77	20/7/77	3/8/77	14/9/77	19/10/77	29/11/77	1/5/78	7/6/78	23/8/78							
	HAT CREEK STATION NO. 3																				
pH (units)	7.9	8.5	8.4	8.3	8.4	8.6	8.5	8.6	8.4	8.4	8.2	8.4	7.9	8.3							
Specific Conductance (µmhos/cm @ 25° C)	380	410	530	360	446	540	530	520	498	516	497	444	200	552							
True Color (Pt-Co Units)																					
Turbidity (NTU)														2.8							
Temperature (°C)																					
Total residue	336	355	385	270	308	378	352	362	337	329	331	412	447	383							
Filtrable residue	258	350	367	236	300	371	349	360	328	329	328	296	152	376							
Non-filtrable residue	78	5	18	34	8	7	3	2	9	<1	3	116	295	7							
Fixed total residue																					
Fixed filtrable residue																					
Fixed non-filtrable residue																					

TABLE 3-3

(mg/L) Parameter Dissolved (D), Total (T) CATIONS / Date of Sampling	21/5/77	27/7/77	6/8/77	11/9/77	18/10/77	27/4/78	6/6/78	6/6/78	21/8/78
	MEDICINE CREEK							BCH Lab	
	D	D	D	D	D	D	D	D	D
Aluminum (Al)	<0.010								
Arsenic (As)	<0.005								
Cadmium (Cd)	<0.005								
Calcium (Ca)	61	57	61	58	60	31	29	28.5	60
Chromium (Cr)	<0.010								
Copper (Cu)	<0.005								
Iron (Fe)	0.021								
Lead (Pb)	<0.010								
Lithium (Li)	0.003								
Magnesium (Mg)	29	20	21	24	23	19	10	12.5	23
Mercury (Hg)(µg/l)	0.5								
Molybdenum (Mo)	<0.020								
Nickel (Ni)									
Potassium (K)		2.5	2.2	2.3	1.6	2.2	0.81	0.7	1.5
Selenium (Se)	<0.003								
Sodium (Na)	14	12	12	11	9.0	11	2.5	2.5	13
Strontium (Sr)	0.44								
Vanadium (V)	<0.005								
Zinc (Zn)	0.009								
Silica (SiO_2) Dissolved Total		0.5	2.0	5.2	10.7	12.1	10.9		12.95
Silica Dissolved Molybdate Reactive						11.9	10.8		12.0

Table 3-3 (continued)

Date of Sampling (mg/L) Parameter Diss (D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES	MEDICINE CREEK							BCH Lab	
	21/5/77 D	27/7/77 D	6/8/77 D	13/9/77 D	18/10/77 D	27/4/78 D	7/6/78 D	7/6/78 D	21/8/78 D
Boron (B)	<0.1								
Chloride (Cl)	0.50	0.35	0.20	0.26	0.16	0.80	0.24	0.35	0.44
Fluoride (F)	0.122								
Sulfate (SO_4)	40	20	18	15	16	18	13	6.3	23
Total-Kjeldahl-Nitrogen (N)	0.26								
Nitrate-Nitrogen (NO_3 -N)	0.04								
Nitrite-Nitrogen (NO_2 -N)	<0.0010								
Total-Orthophosphate-Phosphorus (P)	0.010								
Dissolved-Total PO_4 Phosphorus (P)									
COD	10								
TOC	27					22	20		5
Phenol	<0.002								
Total Hardness($CaCO_3$)	272					156	114	118	245
Total Alkalinity($CaCO_3$)	188	255	263	262	256	169	111	110	260
BOD_5									
D.O.									
% Saturation									
Phenolphthalein Alkalinity ($CaCO_3$)		5.9	4.9	7.3	4.8				

Table 3-3 (continued)

Parameter / Date of Sampling PHYSICAL DATA (mg/L)	21/5/77	27/7/77	6/8/77	MEDICINE CREEK 13/9/77	18/10/77	27/4/78	7/7/78	BCH Lab 7/7/78	21/8/78
pH (units)	6.4	8.5	8.5	8.5	8.5	7.8	7.9	8.0	8.2
Specific Conductance (umhos/cm @ 25° C)	550	470	500	482	473	338	220	200	500
True Color (Pt Co Units)	10								
Turbidity (NTU)	0.30					18	32		1.1
Temperature (°C)	7								
Total residue	361							212	
Filtrable residue	359	304	322	318	297	218	158	164	337
Non-filtrable residue	2					109	72	48.1	<1
Fixed total residue	261								
Fixed filtrable residue	260								
Fixed non-filtrable residue	1								
Settleable Matter (by weight) mg/l.						79	44	103.1	

TABLE 3-4

Parameter (mg/L) Diss. (D), Total (T) / Date of Sampling	MacLAREN CREEK 27/7/77 D	6/8/77 D	13/9/77 D	18/10/77 D	27/4/78 D	6/6/78 D	21/8/78 D
CATIONS							
Aluminum (Al)							
Arsenic (As)							
Cadmium (Cd)							
Calcium (Ca)	52	56		60	43	56	50
Chromium (Cr)							
Copper (Cu)							
Iron (Fe)							
Lead (Pb)							
Lithium (Li)							
Magnesium (Mg)	17	19		22	30	25	17
Mercury (Hg) (µg/l)							
Molybdenum (Mo)							
Nickel (Ni)							
Potassium (K)	1.8	2.4		1.3			
Selenium (Se)							
Sodium (Na)	4.4	5.6		4.1			
Strontium (Sr)							
Vanadium (V)							
Zinc (Zn)							
Silica Dissolved Total	1.8	1.4		12.5			

Table 3-4 (continued)

(mg/L) Parameter Diss. (D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES \ Date of Sampling	MacLAREN CREEK						
	27/7/77 D	6/8/77 D	13/9/77 D	18/10/77 D	27/4/78 D	6/6/78 D	21/8/78 D
Boron (B)							
Chloride (Cl)	<0.1	30.0		0.20	1.5	0.88	<0.10
Fluoride (F)							
Sulfate (SO_4)	9.6	11		15	22	12	13
Total-Kjeldahl-Nitrogen (N)							
Nitrate-Nitrogen (NO_3 -N)							
Nitrite-Nitrogen (NO_2 -N)							
Total-Orthophosphate-Phosphorus (P)							
Dissolved Total PO_4 Phosphorus (P)							
COD							
TOC							
Phenol							
Total Hardness ($CaCO_3$)							
Total Alkalinity ($CaCO_3$)	220	240		250	249	260	191
BOD							
D.O.							
% Saturation							
Phenolphthalein Alkalinity ($CaCO_3$)	0	0		0.0			

Table 3-4 (continued)

Parameter / Date of Sampling			MacLAREN CREEK																		
PHYSICAL DATA (mg/L)	27/7/77	6/8/77	13/9/77	18/10/7	23/4/7	6/6/78	21/8/78														
pH (units)	8.3	8.2		8.3	8.3	8.3	8.4														
Specific Conductance (µmhos/cm @ 25° C)	400	450		466	453	490	360														
True Color (Pt-Co Units)																					
Turbidity (NTU)																					
Temperature (°C)																					
Total residue																					
Filtrable residue	257	284		285	190	333	242														
Non-filtrable residue					392	2	<1														
Fixed total residue																					
Fixed filtrable residue																					
Fixed non-filtrable residue																					

TABLE 3-5

PAVILION LAKE

Date of Sampling (mg/l) Parameter Dissolved (D), Total (T) - CATIONS	27/7/77	6/8/77	13/9/77	18/10/77	29/11/77	27/4/78
Aluminum (Al)						
Arsenic (As)						
Cadmium (Cd)						
Calcium (Ca)	37	37	40	39	42	38
Chromium (Cr)						
Copper (Cu)						
Iron (Fe)						
Lead (Pb)						
Lithium (Li)						
Magnesium (Mg)	16	16	18	18	17	18
Mercury (Hg)(ug/l)						
Molybdenum (Mo)						
Nickel (Ni)						
Potassium (K)	4.1	4.4	3.5	2.9	3.0	
Selenium (Se)						
Sodium (Na)	6.2	7.7	6.7	7.0	7.0	
Strontium (Sr)						
Vanadium (V)						
Zinc (Zn)						
Silica Dissolved Total	1.6	1.1	6.5	13.3	15.0	

Table 3-5 (continued)

Parameter (mg/L) Diss. (D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES / Date of Sampling	PAVILION LAKE 27/7/77	6/8/77	13/9/77	8/10/77	29/11/77	27/4/78
Boron (B)						
Chloride (Cl)	0.53	0.50	0.40	0.46	0.71	0.60
Fluoride (F)						
Sulfate (SO_4)	52	53	50	53	52	58
Total Kjeldahl-Nitrogen (N)						
Nitrate-Nitrogen (NO_3 -N)						
Nitrite-Nitrogen (NO_2 -N)						
Total-Orthophosphate-Phosphorus (P)						
Dissolved-Total PO_4 Phosphorus (P)						
COD						
TOC						
Phenol						
Total Hardness($CaCO_3$)						
Total Alkalinity($CaCO_3$)	141	139	138	139	143	142
BOD_5						
D.O.						
% Saturation						
Phenolphthalein Alkalinity ($CaCO_3$)	2.0	3.0	4.9	2.0	<1	

Table 3-5 (continued)

Parameter / Date of Sampling	PAVILION LAKE					
PHYSICAL DATA (mg/L)	27/7/77	6/8/77	13/9/77	18/10/77	29/11/77	27/4/78
pH (units)	8.5	8.5	8.5	8.5	8.3	8.3
Specific Conductance (µmhos/cm @ 25° C)	360	360	359	363	370	363
True Color (Pt-Co Units)						
Turbidity (NTU)						
Temperature (°C)						
Total residue						
Filtrable residue	239	241	238	234	250	240
Non-filtrable residue						4
Fixed total residue						
Fixed filtrable residue						
Fixed non-filtrable residue						

1977 data. The samples from 7 June 1978 were collected during the spring freshet and the results are different reflecting the higher flowrate. The freshet in 1978 was greater than in 1977 and flooding occurred near the B.C. Hydro camp. During the freshet the levels of dissolved solids, hardness and alkalinity decreased about 100% and the suspended solids concentration increased from less than 10 mg/l to over 200 mg/l. These differences reflect the greater contribution from surface runoff compared with groundwater infiltration to Hat Creek during this period. Field notes prepared at the time of sampling are given on page 3 - 18.

3.3 HAT CREEK TEMPERATURE MONITORING

During the period 20 August to 5 October 1978 the water temperatures in Hat Creek and Bonaparte River were monitored at five locations. Three temperature monitoring locations were in Hat Creek; at its confluence with Anderson Creek, at the junction with Highway No. 12 near the site offices and at the confluence with the Bonaparte River. Two stations were located in the Bonaparte River, above and below its confluence with Hat Creek.

Maximum-minimum thermometers were installed at all five locations. Peabody "J" thermograph recorders were installed at positions (1), (2), (3) and (4). Due to flooding, readings from the thermograph at position (3) were discontinued after 25 August, 1978.

The maximum and minimum temperatures recorded by the thermograph at Anderson Creek and the differential temperatures at locations (2), (3) and (4) are tabulated on Table 3-6. These recordings indicate that during the summer months the temperature of Hat Creek increases at an average rate of approximately one degree centigrade for every 10 kilometres of its course downstream. On the section between Anderson Creek and Highway #12 Junction there is virtually no temperature change during the night period when the minimum temperatures occur. The maximum temperatures invariably occur at 4:00 p.m. and minimum temperatures at 6:00 a.m.

Table 3-8 tabulates the readings obtained from the maximum-minimum thermometers at positions (1), (2), (3), (4) and (5).

TABLE

WATER SAMPLES COLLECTED FOR ANALYSIS
FIELD NOTES

Station	Post-Winter	Freshet	Mid-Summer (low flow)
Surface Waters			
Creek Station #1	May 1, 1978 - very turbid, high flow, slow filtering	June 7, 1978 - turbid, close to peak flow	August 23, 1978 - moderate flow, clear
Creek Station #3	May 1, 1978 - very turbid, high flow, slow filtering	June 6, 1978 - turbid, close to peak flow	August 23, 1978 - moderate flow, clear
MacLaren Creek	April 27, 1978 - snow melt makes access very poor, high flow, muddy	June 6, 1978 - water clear, moderate to low flow	August 21, 1978 - moderately low flow, clear
Medicine Creek	April 27, 1978 - high flow, muddy	June 6, 1978 - high sediment load, flowing quickly	August 21, 1978 - algae in creek, low flow, clear
Pavilion Lake	Level of lake up from summer of 1977, sampled April 27, 1978	-	-
Ground Water			
Groundwater Well #2	Well sampler broken	June 8, 1978 - relatively clear	August 22, 1978 - clear, water table high
Groundwater Well #3	Well sampler broken	June 8, 1978 - very poor to filter, clay clogging filters	August 22, 1978 - muddy, clay clogging filters
Trench B	May 1, 1978 - clear	June 8, 1978 - clear	August 22, 1978 - algae blooming, water clear
Leachate			
Coal Waste Pile	Maximum flow rate of leachate - yellowish liquid. 28 April 1978	June 9, 1978 - very reduced flow rate though adequate for complete sample, yellowish	Very slow flow, 3 1/51.5 hours. Inadequate sample for complete analysis, yellow. 23 August 1978
Low Grade Coal	April 28, 1978 - maximum rate of leachate, clear liquid	June 9, 1978 - insufficient sample available for complete analysis, clear	No leachate suitable

The temperatures of Hat Creek at the Bonaparte (T_3), the Bonaparte above Hat Creek (T_5), and the differential temperature between T_5 and the Bonaparte temperature below Hat Creek (T_4) are tabulated on Table 3-9. This table was prepared to indicate any moderating effect Hat Creek might have on the Bonaparte River. In view of the small temperature differential between Hat Creek and Bonaparte and the large flow of the Bonaparte River, compared to Hat Creek, it is unlikely that the temperature of the Bonaparte could be affected significantly by the inflow from Hat Creek.

The maximum temperature recorded in Hat Creek was 16.5°C during a low flow period in late August. During September there were a number of rainy and cloudy days. The river maximum temperature decreased from an average of about 15°C in early September to about 10°C near the end of the month. The flow in Hat Creek was at a minimum in August averaging 7.90 cfs and averaged 26.3 cfs and 14.3 cfs in July and September respectively. River water temperature was found to be more a function of weather than flowrate as shown in Figure 3-1.

TABLE 3-6

STREAM TEMPERATURE MONITORING

MONITORS - PEABODY "J" THERMOGRAPHS

Instrument # Location	65063 Anderson Creek T_1		65374 Junction T_2		65075 at Bonaparte T_3		65034 Bonaparte Below Hat Creek T4	
Date	Temperature °C		Differential Temperature		Differential Temperature		Differential Temperature	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Aug. 20	11.0	9.0	1.0	0.5	2.5	2.0	4.0	3.0
21	11.5	8.0	1.5	-0.5	2.5	1.5	3.5	3.0
22	11.0	8.5	0	0	2.0	2.0	3.0	3.0
23	11.5	8.5	0.5	0	3.0	2.0	3.5	3.5
24	11.5	9.5	0	0	2.5	2.0	3.0	3.5
25	11.0	8.5	0.5	-0.5		2.0	3.5	3.0
26	11.0	8.5	0.5	0			4.5	3.0
27	11.5	9.0	1.5	0.5			3.5	3.0
28	10.5	9.0	1.5	0			4.0	3.5
29	12.0	9.0	1.0	-0.5			4.0	3.0
30	12.0	10.0	0.5	0			3.5	3.0
31	12.0	10.5	0	-0.5			3.5	3.0
Sep. 1	10.5	9.0	0	0			3.5	3.5
2	11.0	9.5	1.0	-0.5			4.5	2.5
3	10.0	9.5	-0.5	-0.5			2.5	2.5
4	10.5	9.0	0	0			3.0	2.5
5	9.5	9.0	0	0			3.0	2.5
6	10.0	8.5	0.5	0			2.5	3.0
7	9.5	7.5	0.5	-0.5			3.0	2.5
8	10.0	8.0	0.5	0			3.5	3.0
9	9.5	8.5	-0.5	0.5			3.5	3.0
10	9.5	8.5	-0.5	0			2.5	2.5
11	9.5	6.5	0.5	0			2.5	2.0
12	9.5	6.5	1.5	0			3.0	2.5
13	9.0	7.0	1.5	0			2.5	2.5
14	9.0	7.0	1.0	0			2.0	2.0
15	8.5	7.5	1.0	0			1.5	2.0
16	7.5	5.5	0.5	0.5			2.5	2.0
17	7.0	5.5	1.0	1.0			3.0	2.5
18	8.0	6.5	2.5	0			2.5	1.5
19	7.5	5.0	1.0	0			2.0	2.0
20	8.5	7.0	0.5	0			1.5	2.0
21	8.0	7.0	0.5	0			2.0	1.0
22	7.0	5.5	0.5	0			2.5	2.0
23	6.5	4.0	1.0	0.5			2.5	2.0
24	8.5	6.0	2.0	0.5			3.0	2.0
25	8.0	6.5	0	0			2.5	2.5
26	9.0	6.5	0	-1.0			2.0	2.0
27	9.0	8.0	0.5	-1.0			2.0	1.5
28	8.5	6.5	0	-0.5			2.0	2.0
29	8.5	7.0	0	-0.5			2.0	1.5
30	9.0	7.0					2.0	2.0
Oct. 1	8.5	7.5					2.0	1.5
2	7.5	5.5					1.0	2.0
3	8.5	7.0					1.5	1.0
4	7.0	5.0					1.5	1.5
5	7.0	5.0					1.5	1.0
AVERAGE	11.3	7.5	0.6	-0.1	2.5	2.0	2.7	2.4

TABLE 3-7

CALIBRATION OF PEABODY "J" THERMOGRAPHS

	18 August 1978	6 October 1978		
# 65034	18.3 °C	19.9 °C	#4	Bonaparte River Below Hat Creek.
# 65063	18.6 °C	20.0 °C	#1	Hat Creek at Anderson Creek.
# 65075	18.5 °C	-	#3	Hat Creek at Bonaparte River.
# 65374	18.3 °C	19.6 °C	#2	Hat Creek Junction Highway #12.
Air Temperature	?	19.6 °C		

Installed	19	August 1978
Removed	6	October 1978

#65075 broke open 8 September 1978 during high water flow.

TABLE 3-8

STREAM TEMPERATURE MONITORING

MONITORS - MAX.-MIN. THERMOMETERS

Location		Anderson Creek T_1		Junction T_2		At Bonaparte T_3		Bonaparte Above Hat Creek T_5		Bonaparte Below Hat Creek T_4	
Date		Temperature °C		Temperature °C		Temperature °C		Temperature °C		Temperature °C	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Aug.	20	24.0	8.5	10.0	9.0	15.5	10.5	14.5	13.0	14.0	12.5
	21	16.5	7.5	12.0	5.0	14.0	11.0	16.5	11.5	15.5	11.0
	22	17.5	8.0	11.0	8.0	14.5	10.5	16.5	11.5	16.0	11.5
	23	16.5	8.0	8.0	8.0	13.5	12.0	14.5	12.5	14.5	12.0
	24	17.0	9.0	13.0	11.0	15.0	12.0	16.5	12.5	16.0	12.5
	25	17.0	8.0	12.5	11.5	15.0	11.5	15.5	12.0	15.0	12.0
	26	17.0	8.0	12.5	11.0	14.5	11.0	15.5	11.5	14.5	12.0
	27	17.0	8.0	13.0	9.0	15.0	11.0	17.0	12.0	16.0	12.0
	28	17.5	8.0	14.0	9.5	15.0	11.5	16.5	12.5	15.5	12.5
	29	17.0	8.0	-	-	15.5	11.5	16.0	12.5	15.0	12.5
	30	18.5	9.0	14.0	9.0	16.5	12.0	17.0	13.5	16.0	13.5
	31	18.0	10.0	13.0	11.0	16.5	12.5	16.5	14.0	16.0	13.5
Sep.	1	18.5	11.5	13.0	11.0	15.5	11.5	16.0	13.0	15.5	12.5
	2	16.0	11.5	11.0	8.5	14.0	11.0	15.5	12.0	14.5	12.0
	3	17.0	8.5	12.5	9.5	15.0	11.5	14.5	12.0	15.5	12.0
	4	16.0	8.5**	11.0	9.0	13.0	11.5	13.5	12.0	13.5	12.0
	5	16.0	11.5**	12.0	9.5	13.0	11.5	14.5	12.0	12.5	11.5
	6	14.5	8.5	10.5	8.5	12.5	11.0	13.0	12.0	12.5	11.4
	7	16.0	6.5	11.0	7.0	13.0	9.0	13.5	11.0	13.0	10.5
	8	16.0	7.0	10.5	8.5	12.0	9.0	13.5	10.5	12.0	11.5
	9	15.5	8.0	-	-	13.0	11.0	14.5	12.0	13.0	11.5
	10	-	-	-	-	12.0	12.0	13.5	12.0	12.0	11.5
	11	15.0	6.0	11.5	6.0	12.5	8.0	12.5	9.5	12.0	9.0
	12	14.5	6.0	11.0	6.5	11.5	8.5	13.0	10.0	13.0	10.0
	13	15.0	6.0	11.5	6.5	12.5	8.5	14.0	10.5	13.5	9.5
	14	14.0	6.5	10.5	6.0	11.5	8.5	12.5	9.0	(9.5) ?	9.5
	15	14.5	7.0	10.5	6.5	11.5	9.0	12.0	10.0	11.5	10.0
	16	14.5	5.0	10.0	5.0	10.0	7.0	11.5	8.5	10.0	8.0
	17	13.0	5.0	8.5	5.0	9.5	6.5	11.5	8.5	10.0	8.5
	18	8.0	4.5	7.5	6.0	9.0	7.5	11.5	8.5	10.0	8.5
	19	13.5	4.5	10.0	4.5	10.0	5.5	12.0	7.5	10.0	7.0
	20	13.5	5.0	9.0	4.5	10.0	5.5	11.0	7.5	10.0	9.5
	21	14.0	6.0	8.5	6.5	10.0	8.5	11.0	9.0	10.0	8.5
	22	13.5	4.5	8.5	5.5	10.0	7.0	11.5	9.0	9.5	8.0
	23	12.5	3.0	7.5	4.0	9.0	5.0	10.5	7.5	9.0	6.5
	24	12.5	4.0	7.5	3.5	8.5	5.0	12.0	6.5	9.0	8.5
	25	14.0	6.0	10.0	6.0	11.5	8.0	12.5	9.0	11.5	9.0
	26	13.5	5.5	9.0	5.5	10.0	7.5	12.0	9.0	10.0	8.5
	27	-	-	-	-	-	-	-	-	-	-
	28	15.0	6.0	10.0	6.0	11.0	8.0	13.0	9.5	12.5	9.0
	29	14.0	6.5	13.0	6.0	10.0	7.5	11.5	9.0	10.0	8.5
	30	13.5	6.5	9.0	6.5	10.5	8.0	11.5	10.5	10.5	10.5
Oct.	1	14.5	6.5	9.0	6.5	12.0	9.0	12.5	10.0	9.5	9.5
	2	14.5	5.0	8.5	5.5	10.0	6.5	12.0	8.0	8.0	7.0
	3	13.0	5.5	7.0	5.5	11.0	7.0	10.0	7.5	8.5	7.5
	4	13.5	4.0	9.0	4.0	9.5	5.0	13.5	7.5	7.0	6.5
	5	13.0	3.5	8.0	4.0	7.5	5.5	9.0	6.0	9.0	6.5
	6	12.0	3.5	8.0	3.5	7.0	5.0	9.5	6.0	8.0	6.0

** Water Rose 3" - 4", muddy.

TABLE 3-9

BONAPARTE STREAM TEMPERATURE MONITORING MONITORS - MAX.-MIN. THERMOMETERS

Location	Hat Creek At Bonaparte T_3		Bonaparte Above Hat Creek T_5		Differential Temperature Bonaparte Above Hat Creek/ Bonaparte Below Hat Creek T_5-T_4	
Date	Temperature °C		Temperature °C		Temperature °C	
	Max.	Min.	Max.	Min.	Max.	Min.
Aug. 20	15.5	10.5	14.5	13.0	0.5	0.5
21	14.0	11.0	16.5	11.5	1.0	0.5
22	14.5	10.5	16.5	11.5	0.5	0.0
23	13.5	12.0	14.5	12.5	0.0	0.5
24	15.0	12.0	16.5	12.5	0.5	0.0
25	15.0	11.5	15.5	12.0	0.5	0.0
26	14.5	11.0	15.5	11.5	1.0	-0.5
27	15.0	11.0	17.0	12.0	1.0	0.0
28	15.0	11.5	16.5	12.5	1.0	0.0
29	15.5	11.5	16.0	12.5	1.0	0.0
30	16.5	12.0	17.0	13.5	1.0	0.0
31	16.5	12.5	16.5	14.0	0.5	0.5
Sep. 1	15.5	11.5	16.0	13.0	0.5	0.5
2	14.0	11.0	15.5	12.0	1.0	0.0
3	15.0	11.5	14.5	12.0	-1.0	0.0
4	13.0	11.5	13.5	12.0	0.0	0.0
5	13.0	11.5	14.5	12.0	2.0	0.5
6	12.5	11.0	13.0	12.0	0.5	0.5
7	13.0	9.0	13.5	11.0	0.5	0.5
8	12.0	9.0	13.5	10.5	1.5	-1.0
9	13.0	11.0	14.5	12.0	1.5	0.5
10	12.0	12.0	13.5	12.0	1.5	0.5
11	12.5	8.0	12.5	9.5	0.5	0.5
12	11.5	8.5	13.0	10.0	0.0	0.0
13	12.5	8.5	14.0	10.5	0.5	1.0
14	11.5	8.5	12.5	9.0	-	-0.5
15	11.5	9.0	12.0	10.0	0.5	0.0
16	10.0	7.0	11.5	8.5	1.5	0.5
17	9.5	6.5	11.5	8.5	1.5	0.0
18	9.0	7.5	11.5	8.5	1.5	0.0
19	10.0	5.5	12.0	7.5	2.0	0.5
20	10.0	5.5	11.0	7.5	1.0	-2.0
21	10.0	8.5	11.0	9.0	1.0	0.5
22	10.0	7.0	11.5	9.0	2.0	1.0
23	9.0	5.0	10.5	7.5	1.5	1.0
24	8.5	5.0	12.0	6.5	3.0	-2.0
25	11.5	8.0	12.5	9.0	1.0	0.0
26	10.0	7.5	12.0	9.0	2.0	0.5
27	-	-	-	-	-	-
28	11.0	8.0	13.0	9.5	0.5	0.5
29	10.0	7.5	11.5	9.0	1.5	0.5
30	10.5	8.0	11.5	10.5	1.0	0.0
Oct. 1	12.0	9.0	12.5	10.0	3.0	0.5
2	10.0	6.5	12.0	8.0	4.0	1.0
3	11.0	7.0	10.0	7.5	1.5	1.0
4	9.5	5.0	13.5	7.5	-	1.0
5	7.5	5.5	9.0	6.0	0.0	0.5
6	7.0	5.0	9.5	6.0	1.5	0.0
Average	11.9	9.0	13.36	10.23	1.09	[illegible]

TABLE 3-10

CALIBRATION OF MAX. - MIN. THERMOMETERS

6 OCTOBER 1978

Thermometer Water T°	Hat Creek at Anderson #1 Min./Max.	Hat Creek at Junction #2 Min./Max.	Hat Creek at Bonaparte #3 Min./Max.	Bonaparte Below Hat Creek #4 Min./Max.	Bonaparte Above Hat Creek #5 Min./Max.
18.7	18.0/24.0	17.5/17.5	18.0/18.0	18.5/17.0	18.0/18.0
38.5	38.5/44.2	37.5/37.5	37.5/37.5	38.5/38.5	37.5/38.0
15.5	15.0/21.5	15.0/15.0	15.0/15.0	15.0/15.0	15.0/15.0
21.5	21.5/27.5	21.0/21.0	22.0/21.5	21.5/21.0	22.0/22.0
20.5	21.0/27.5	20.5/20.5	21.0/21.0	21.0/21.5	21.5/21.5
Correction Factor	0/-6	0/0	0/0	0/0	0/0

3.4 GROUNDWATER

During 1978 samples of groundwater were collected at Trench B and from wells #2 and #3 near Trench B. The groundwater samples were collected by Acres at the same time as the surface water samples and sent to Beak for analyses. Similar sampling, preservation and analytical procedures were employed for the groundwater as for the surface water testing.

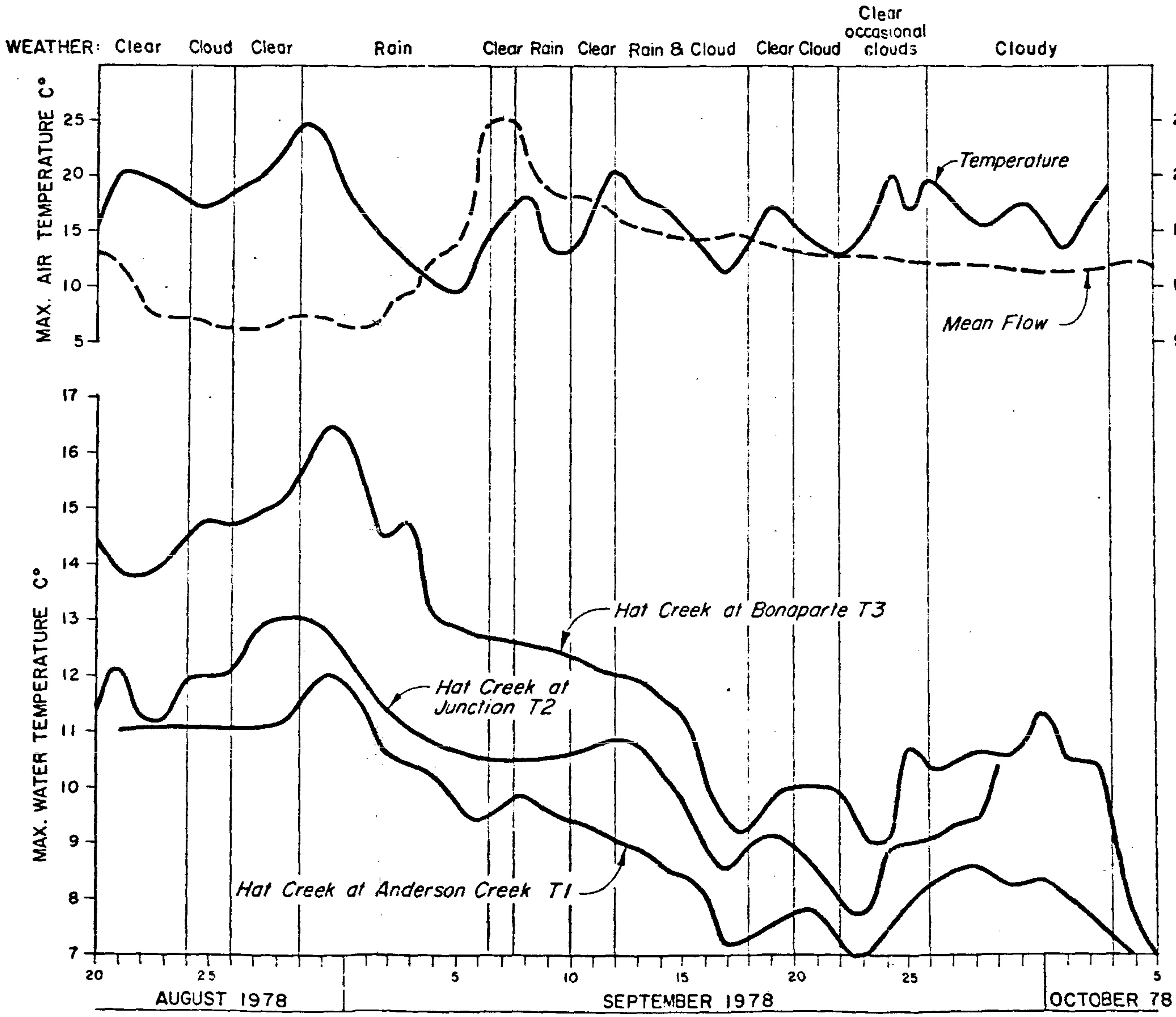
The results of the groundwater monitoring program are shown in Tables 3-11 to 3-13. The groundwater quality in 1978 showed no signigicant variation from the 1977 results.

3.5 WASTE COAL LEACHATES

Leachate from the low grade coal and coal waste piles at Trench A were collected during 1978 when possible from the specially prepared piles. During the Bulk Sample Program in 1977, two areas were prepared to enable collection of leachates. Two large areas were smoothed and sloped, at about 10% to form a slight V shape. The area was covered with heavy plastic sheeting and a perforated pipe was layed on top of the plastic along the bottom of the V. This pipe was sloped at about 8% such that water percolating through the pile would collect and run out the pipe into a collection bucket. The area of the coal waste pile was about 1050 m^2. The low grade coal pile had an area of about 280 m^2. The coal waste pile measured 15 m high by 30 m wide by 35 m long and the low grade coal pile measured 3 m high by 12 m wide by 25 m long.

Leachate samples were collected on a daily basis from both waste piles during September, October and November 1978. These were tested on site for pH and conductivity and total daily leachate volume was measured. Samples collected in April, June and August were sent with the surface and groundwater samples for detailed chemical and physical analyses.

FIG. 3-1 HAT CREEK PROJECT: STREAM TEMPERATURE MONITORING



The results of the field collection and testing program are presented in Tables 3-14, 3-15 and 3-16. The leachate flow from the piles was intermittant, dependent mainly upon rainfall. This is shown in Figure 3-2. The volume of leachate from the smaller low grade coal pile responded more rapidly to the level of precipitation. The leachate from the coal waste pile was always yellow in colour while the leachate from the low grade coal pile was normally colorless.

The results of the coal waste and low grade coal leachate detailed analyses are shown in Tables 3-17 and 3-18. The single sample from the low grade coal pile contained a generally lower quantity of contaminants than the coal waste leachate sample collected on the same day.

The leachate from both the coal waste and low grade coal piles were considerably different from the water leaching laboratory tests done on similar samples by Acres[8]. The results of the water leaching tests are also presented in Tables 3-17 and 3-18. The field collected samples contained substantially lower concentrations of most trace elements. In many cases iron, arsenic, mercury, copper and selenium concentrations for example were two orders of magnitude lower than those found in the laboratory studies. Only calcium, magnesium and filtrable solids were higher in the field samples. The final pH in the laboratory extractions was near neutral or slightly alkaline while the field piles produced a leachate that was always acidic. The pH measured daily in the field ranged from 3.4 to 4.1 from the low grade coal pile and 3.1 to 4.1 from the coaly waste pile. The leachate conductivity ranged from 3100 to 6500 umhos/cm from both piles.

TABLE 3-11

GROUNDWATER WELL NO. 2

Date of Sampling / Parameter (mg/L) Disolved (D), Total (T) - CATIONS	7/6/77	21/6/77	6/7/77	20/7/77	20/10/77 Diss.	20/10/77 Total	30/11/77 Diss.	30/11/77 Total	8/6/78 Diss.	8/6/78 Total	22/8/78 Diss.	22/8/78 Total
Aluminum (Al)	*	*	0.010	0.030	<0.010	0.08	0.010	0.40	0.013	0.28	0.009	0.30
Arsenic (As)	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (Cd)												
Calcium (Ca)	64	75	65	66	79	79	59		57	57	59	59
Chromium (Cr)	*	*	*	*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)	*	*	*	*	<0.005	<0.005	<0.005	<0.005	0.012	0.019	<0.005	0.006
Iron (Fe)	0.034	0.024	0.035	0.13	0.026	0.44	0.011	0.42	0.015	0.28	0.015	0.31
Lead (Pb)												
Lithium (Li)	0.003	0.004	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.003	0.003
Magnesium (Mg)	15	15	16	16	17	17	13		14	14	14	15
Mercury (Hg)(ug/l)	*	*	*	*	<0.25	<0.25	<0.25	<0.25	0.27	0.32	0.37	0.37
Molybdenum (Mo)												
Nickel (Ni)									<0.010	<0.010		
Potassium (K)												
Selenium (Se)	0.006	0.005	*	0.004	0.004		0.003		<0.003	<0.003	<0.003	<0.003
Sodium (Na)	18	18	18	18	18	19	20		16	17	33	33
Strontium (Sr)	0.20	0.21	0.28	0.23	0.24	0.24	0.19	0.21	0.31	0.32	0.24	0.27
Vanadium (V)	*	*	*	0.001	0.003	0.003	<0.003	0.003	0.002	0.004	0.006	0.006
Zinc (Zn)	*	0.014	0.008	0.041	<0.005	0.011	0.032	0.007	0.005	0.010	0.011	0.029
Manganese (Mn)					0.085	0.092	0.012	0.026				

* Denotes <MDC

Table 3-11 (continued)

Date of sampling (mg/L) Parameters Dis (D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES	7/6/77	21/6/77	6/7/77	20/7/77	20/10/77		30/11/77		8/6/78		22/8/78		GROUNDWATER WELL NO. 2
					Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total	
Boron (B)	*	*	*	*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10	<0.10	
Chloride (Cl)	1.7	1.4	1.3	1.3		1.0		0.88		1.4		1.4	
Fluoride (F)	0.104	0.128	0.135	0.146		0.140		0.107		0.14		0.18	
Sulfate (SO_4)	38	45	54	48		120		61		57		41	
Total-Kjeldahl-Nitrogen (N)													
Nitrate-Nitrogen (NO_3 -N)													
Nitrite-Nitrogen (NO_2 -N)													
Total-Orthophosphate-Phosphorus (P)													
Dissolved-Total PO_4 Phosphorus (P)	0.032	0.033	0.043	0.009	0.12		0.015		0.017		0.020		
COD													
TOC	27	32	24	50		12		22		10		<2	
Phenol													
Total Hardness($CaCO_3$)	222	249	228	231		267		201		200		205	
Total Alkalinity($CaCO_3$)	229	232	231	241		200		179		208		232	
BOD_5													
D.O.													
% Saturation													
* Denotes <MDC													

Table 3-11 (continued)

GROUNDWATER WELL NO. 2

Parameter / Date of Sampling	7/6/77	21/6/77	6/7/77	20/6/77	20/10/77	30/11/77	8/6/78	22/8/78
PHYSICAL DATA (mg/L)								
pH (units)	7.6	7.4	7.4	7.6	7.4	7.7	7.6	
Specific Conductance (μmhos/cm @ 25° C)	510	520	531	540	582	460	470	514
True Color (Pt Co Units)								
Turbidity (NTU)							1.8	2.5
Temperature (°C)								
Total residue	354	370	409	387	404	318	317	358
Filtrable residue	330	346	340	349	389	304	310	350
Non-filtrable residue	24	24	69	38	15	14	7	8
Fixed total residue								
Fixed filtrable residue								
Fixed non-filtrable residue								
* Denotes <MDC								

TABLE 3-12

Parameter (mg/L) Dissolved (D), Total (T) – CATIONS \ Date of Sampling	GROUNDWATER WELL No. 3										
	7/6/77	21/6/77	6/7/77	20/7/77	4/8/77	30 / 11 / 77		8 / 6 / 78		22 / 8 / 78	
						D	T	D	T	D	T
Aluminum (Al)	*	*	*	0.057	*	0.17	1.1	0.32	16	0.027	40
Arsenic (As)	*	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (Cd)											
Calcium (Ca)	260	260	230	250	230	310		290	290	300	320
Chromium (Cr)	*	*	*	*	*	<0.010	<0.010	<0.010	0.023	<0.010	<0.010
Copper (Cu)	0.007	*	*	*	*	0.006	0.014	0.024	0.087	0.020	0.095
Iron (Fe)	0.060	0.081	0.23	0.25	0.19	0.039	2.6	0.19	11	0.025	23
Lead (Pb)											
Lithium (Li)	0.064	0.063	0.067	0.007	0.055	0.060	0.060	0.12	0.11	0.15	0.15
Magnesium (Mg)	81	83	85	88	65	97		110	110	100	120
Mercury (Hg) (μg/l)	*	*	*	*	0.63	<0.25	<0.25	0.45	0.57	0.36	0.59
Molybdenum (Mo)											
Nickel (Ni)								0.010	0.034		
Potassium (K)											
Selenium (Se)	*	*	*	*	*	<0.003		0.006	<0.003	<0.003	<0.003
Sodium (Na)	360	380	400	440	340	460		450	460	580	580
Strontium (Sr)	0.72	0.70	2.1	0.99	1.8	1.1	1.1	1.5	0.98	1.9	1.9
Vanadium (V)	*	*	0.008	*	0.003	0.005	0.006	0.004	0.029	<0.01	0.070
Zinc (Zn)	0.024	0.016	0.012	0.13†	0.10	0.18	0.018	0.031	0.063	0.017	0.088
Manganese (Mn)						0.40	0.40				

* Denotes NDC

† Contamination Suspected

Table 3-12 (continued)

(mg/L) Parameter Diss. (D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES \ Date of Sampling	7/6/77	21/6/77	6/7/77	20/7/77	4/8/77	30 / 11 / 77 D	30 / 11 / 77 T	8 / 6 / 78 D	8 / 6 / 78 T	22 / 8 / 78 D	22 / 8 / 78 T
	GROUNDWATER WELL No. 3										
Boron (B)	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.66	0.87	0.69	0.81
Chloride (Cl)	7.4	7.5	7.3	7.4	7.7		7.8		20		11
Fluoride (F)	0.105	0.134	0.134	0.133	0.135		0.127		0.12		0.11
Sulfate (SO_4)	1400	1300	1360	1280	1300		3800		1500		1800
Total-Kjeldahl-Nitrogen (N)											
Nitrate-Nitrogen (NO_3 -N)											
Nitrite-Nitrogen (NO_2 -N)											
Total-Orthophosphate-Phosphorus (P)											
Dissolved-Total PO_4 Phosphorus (P)	0.038	0.035	0.046	0.034	0.048	0.024		0.018		0.013	
COD											
TOC	97	102	101	80	61		28		70		95
Phenol											
Total Hardness($CaCO_3$)	983	991	924	987	842		1173		1180		1161
Total Alkalinity($CaCO_3$)	464	506	538	572	586		458		562		646
BOD_5											
D.O.											
% Saturation											

Table 3-12 (continued)

Date of Sampling / Parameter	GROUNDWATER WELL No. 3																				
PHYSICAL DATA (mg/L)	7/6/77	21/6/77	6/7/77	20/7/77	4/8/77	30/11/77	8/6/78	22/8/78													
pH (units)	7.8	7.3	7.2	7.3	7.3	7.8	7.8	7.3													
Specific Conductance (µmhos/cm @ 25° C)	3000	3000	2970	3030	3030	3380	3600	3815													
True Color (Pt-Co Units)																					
Turbidity (NTU)								560													
Temperature (°C)																					
Total residue	2871	2877	2845	2851	2846	3246	3770	3364													
Filtrable residue	2710	2730	2700	2690	2740	3050	3280	3185													
Non-filtrable residue	161	147	132	161	106	196	490	179													
Fixed total residue																					
Fixed filtrable residue																					
Fixed non-filtrable residue																					

TABLE 3-13

Parameter (mg/l) Dissolved (D), Total (T) Cations \ Date of Sampling	21/6/77	6/7/77	19/7/77	4/8/77	14/9/77	TRENCH B - GROUNDWATER 20 / 10 / 77		30 / 11 / 77		1 / 5 / 78		8 / 6 / 78		B.C.Hydro Lab. 8 / 6 / 78		22 / 8 / 78	
						D	T	D	T	D	T	D	T	D	T	D	T
Aluminum (Al)	*	*	0.025	*	*	0.014	0.020	<0.010	0.035	0.020	0.080	0.013	0.048	<0.02	<0.02	0.010	0.038
Arsenic (As)	*	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.05		<0.005	<0.005
Cadmium (Cd)																	
Calcium (Ca)	71	56	60	59	67	67	67	61		61	63	60	62	67	70	49	49
Chromium (Cr)	*	*	*	*	*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.01	<0.01	<0.010	<0.010
Copper (Cu)	*	*	*	*	*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	0.004	<0.005	<0.005
Iron (Fe)	0.009	0.012	0.022	*	0.014	0.016	0.024	<0.010	0.022	0.024	<0.068	0.023	0.049	0.11	0.17	0.008	0.032
Lead (Pb)																	
Lithium (Li)	0.004	0.004	0.005	0.004	0.004	0.005	0.005	0.005	0.005	0.003	0.001	0.003	0.003	0.002	0.003	0.003	0.003
Magnesium (Mg)						17	17	16		18	18	18	18	24.5	24.5	13	13
Mercury (Hg) (μg/l)			*	0.20	*	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.27	0.28			0.35	0.45
Molybdenum (Mo)																	
Nickel (Ni)										0.014	0.016	<0.010	<0.010	0.008	0.008		
Potassium (K)														2.5	2.5		
Selenium (Se)	0.003	*	0.003	*	0.004	<0.003		<0.003		<0.003	<0.003	<0.003	<0.003			<0.003	<0.003
Sodium (Na)	21	19	20	26	26	25	25	25		22	23	22	24	24.5	24.5	21	22
Strontium (Sr)	0.23	0.26	0.24	0.25	0.32	0.23	0.23	0.24	0.28	0.25	0.25	0.40	0.44			0.23	0.24
Vanadium (V)	*	*	0.002	0.003	*	0.003	0.003	<0.003	0.004	<0.003	<0.003	0.003	0.003	<0.002	<0.002	0.005	0.005
Zinc (Zn)	0.012	*	0.009	0.047	0.007	0.016	0.016	0.021	0.011	0.013	0.062	0.012	0.015	0.061	0.034	0.005	0.005
Manganese (Mn)						<0.005	0.007	<0.010	<0.010					0.004	0.006		
Si (SiO_2)														16.6	16.6		
Barium														0.17	0.17		
Titanium														<0.1	<0.1		
* Denotes nil.																	

Table 3-13 (continued)

(mg/L) Date of Sampling / Parameter Diss. (D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES	TRENCH 8 - GROUNDWATER													B.C. Hydro Lab.			
	21/6/77	6/7/77	19/7/77	4/8/77	14/9/77	20 / 10 / 77		30 / 11 / 77		1 / 5 / 78		8 / 6 / 78		8 / 6 / 78		22 / 8 / 78	
						D	T	D	T	D	T	D	T	D	T	D	T
Boron (B)	*	*	*	*	*	<0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.054		<0.10	<0.10
Chloride (Cl)	1.4	1.1	1.3	1.3	1.1		1.0		1.2		3.1		2.4		2.55		1.1
Fluoride (F)	0.142	0.099	0.102	0.143	0.112		0.135		0.108		0.114		0.11				0.12
Sulfate (SO_4)	44	56	48	46	58		56		51		74		82		6.3		44
Total-Kjeldahl-Nitrogen (N)																	
Nitrate-Nitrogen (NO_3-N)																	
Nitrite-Nitrogen (NO_2-N)																	
Total-Orthophosphate-Phosphorus (P)																	
Dissolved-Total PO_4 Phosphorus (P)	0.032	0.024	0.026	0.026	0.025	0.098		0.095		0.006		<0.003		<0.05		<0.003	
COD																	
TOC	31	83	95	11	4		12		11		22		< 2				13
Phenol																	
Total Hardness ($CaCO_3$)	243	206	220	213	246		237		218		226		224		256		176
Total Alkalinity ($CaCO_3$)	222	218	229	236	257		245		228		227		241		228		198
BOD_5																	
D.O.																	
% Saturation																	
* Denotes <MDC																	

Table 3-13 (continued)

Parameter / PHYSICAL DATA (mg/L) — Date of Sampling	TRENCH B - GROUNDWATER 21/6/77	6/7/77	19/7/77	4/8/77	14/9/77	20/10/77	30/11 1977	1/5/78	8/6/78	BCH Lab 8/6/78	22/8/78										
pH (units)	8.0	7.9	7.8	8.0	8.0	8.0	7.8	8.3	8.2	8.2	8.2										
Specific Conductance (µmhos/cm @ 25° C)	510	499	530	540	603	542	516	547	560	490	432										
True Color (Pt-Co Units)																					
Turbidity (NTU)											0.75										
Temperature (°C)																					
Total residue	387		38846	361	380	347	349	314	376	370	285										
Filtrable residue	339	340	346	357	376	345	348	310	375	370	285										
Non filtrable residue	48		31500	4	4	2	1	4	1	<0.5	<1										
Fixed total residue																					
Fixed filtrable residue																					
Fixed non-filtrable residue																					
Settleable Matter										47.5											

TABLE 3-14

LEACHATE FROM COAL WASTE AND LOW GRADE COAL PILES

DATE	RAIN	COAL WASTE			LOW GRADE COAL
Sept. 1978	mm	Volume ml	PH	Cond umhos	Volume ml
1					
2					
3	7.8	0			0
4	3.4				
5	15.8	2800			0
6	1.6	8700			7500
7	0	3400			4100
8	0	1770			1270
9	0	1880			1395
10	1.8	2435			1475
11	0	1530			1380
12	0.4	1500			920
13	0	1700			900
14	0	1500			850
15	1.2	1500			700
16	3.6	1500			550
17	1.6	1500			400
18	0	1450			300
19	0	1550			150
20	0	1550			100
21	0	1500			50
22	0	1400	4.1	5000	0
23	0	1450	3.8	5900	0
24	0	1300	3.8	5750	0
25	0	1340	3.8	5700	0
26	0	1180	3.8	5700	0
27		2550	4.0	6000	0
28					0
29	0.4	1050	3.9	5100	0
30		1380	3.8	5900	0

TABLE 3-15

LEACHATE FROM COAL WASTE AND LOW GRADE COAL PILES

DATE	RAIN	COAL WASTE			LOW GRADE COAL		
Oct. 1978	mm	Volume ml	PH	Cond. umhos	Volume ml	PH	Cond. umhos
1	0	1150	4.0	5900	0		
2	0	1010	3.9	5000	0		
3	0	1140	3.8	5500	0		
4	0	1030	3.7	5200	0		
5	0	900	3.7	5000	0		
6	0	1010	3.9	5100	0		
7	0	900	3.9	4950	0		
8	0	960	3.9	5200	0		
9	0	940	3.9	5000	0		
10	1.0	840	3.7	3680	0		
11	0	780	3.8	4900	0		
12	0	790	3.9	4700	0		
13	0	520	3.7	4500	0		
14	0	580	3.7	6500	0		
15	0	730	3.6	5000	0		
16	0	740	3.6	5500	0		
17	2.0	700	3.6	5000	0		
18	0	520	3.5	5000	0		
19	0	1270	3.5	4900	0		
20	7.25				0		
21	0	480	3.6	4400	0		
22	0	590	3.7	5100	0		
23	3.25	550	3.7	4600	0		
24	5.5	580	3.7	4550	140	4.0	4200
25	0	240	3.2	7800	0		
26	0	760	3.0	3680	240	3.4	4300
27	0	670	3.3	4080	170	3.7	3050
28	0	360	3.4	4100	Frozen		
29	Snow	615	3.4	4000	Frozen		
30	0	210	3.1	6050	Frozen		
31	0	280	3.6	4300	Frozen		

TABLE 3-16

LEACHATE FROM COAL WASTE AND LOW GRADE COAL PILES

DATE	RAIN	COAL WASTE			LOW GRADE COAL		
Nov. 1978	mm	Volume ml	PH	Cond. umhos	Volume ml	PH	Cond. umhos
1	0	460	3.4	4390	0		
2	0	340	3.3	4100	0		
3	0	300	3.4	5100	0		
4	0	320	3.5	4650	0		
5	0	30			0		
6	0	30			0		
7	0.8	950	3.5	3000	0		
8	0	290	3.8	4730	3200	4.1	4080
9	Frozen	0			0		
10	"	0			0		
11	"	0			0		
12	"	0			0		
13	"	0			0		
14	"	0			0		
15	"	0			0		
16	"	0			0		
17	"	0			0		
18	"	0			0		
19	"	0			0		
20	"	0			0		
21	"	0			0		
22	"	0			0		
23	"	0			0		
24	"	0			0		
25	"	0			0		
26	"	0			0		
27	"	0			0		
28	"	0			0		
29	"	0			0		
30	"	0			0		

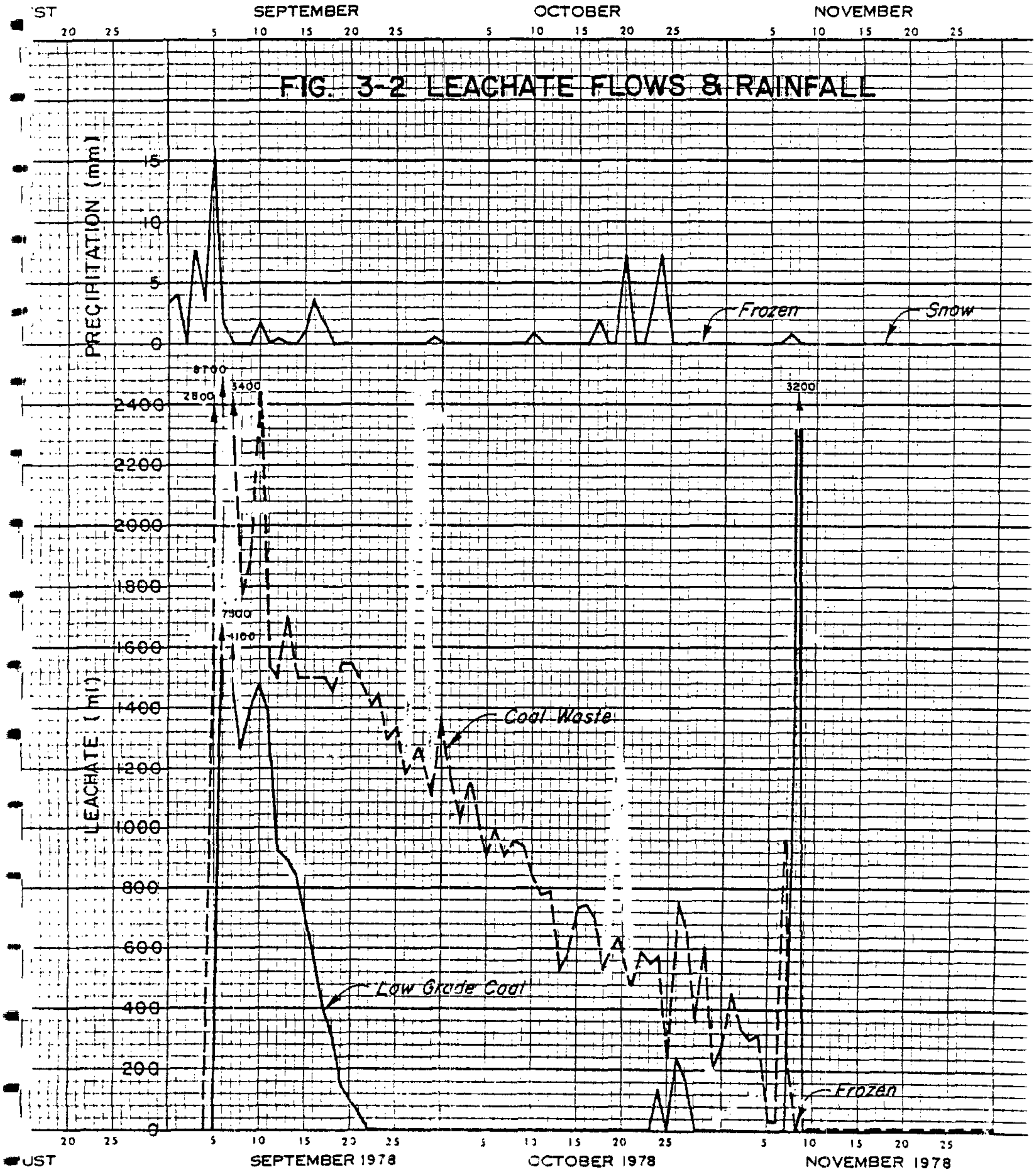


FIG. 3-2 LEACHATE FLOWS & RAINFALL

TABLE 3-17

(mg/L) Parameter Dissolved (D), Total (T) - CATIONS / Date of Sampling	28/4/78	9/6/78 Diss.	9/6/78 Total	23/8/78 Diss.	23/8/78 Total	COAL WASTE LEACHATE: Water Extract. of coal waste.
Aluminum (Al)	2.9	3.4	3.3	9.7		25
Arsenic (As)	<0.005	<0.005	<0.005	<0.005		0.8
Cadmium (Cd)						<0.08
Calcium (Ca)	760	720	720	800		-200
Chromium (Cr)	<0.010	<0.010	<0.010	<0.010		<1
Copper (Cu)	0.034	0.034	0.034	0.044		6.0
Iron (Fe)	0.30	0.13	0.37	0.38		76
Lead (Pb)						<3
Lithium (Li)	0.17	0.19	0.13	0.24		0.6
Magnesium (Mg)	580	570	570	550		180
Mercury (Hg)(ug/l)	<0.25	<0.25	<0.25			6
Molybdenum (Mo)						
Nickel (Ni)	0.10	0.052	0.053			
Potassium (K)	30			20		
Selenium (Se)	<0.003	<0.003	<0.003	<0.003		0.9
Sodium (Na)	240	190	190	190		1280
Strontium (Sr)	1.8	3.5	1.5	3.6		<4
Vanadium (V)	0.042	0.033	0.018	<0.04		0.3
Zinc (Zn)	0.057	0.089	0.089	0.13		15.0

Table 3-17 (continued)

(mg/L) Parameter Diss.(D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES \ Date of Sampling	28/4/78	9/6/78		23/8/78		COAL WASTE LEACHATE		
		Diss.	Total	Diss.	Total	Water Extraction of coaly waste.		
Boron (B)	0.2	0.2	0.23	0.44		1.0		
Chloride (Cl)	15		15		11	380		
Fluoride (F)			0.097		0.096	1.5		
Sulfate (SO_4)	3800		4300		2900	~700		
Total-Kjeldahl-Nitrogen (N)								
Nitrate-Nitrogen (NO_3 -N)								
Nitrite-Nitrogen (NO_2 -N)								
Total-Orthophosphate-Phosphorus (P)								
Dissolved-Total PO_4 Phosphorus (P)			<0.003	0.010				
COD								
TOC			395		430			
Phenol								
Total Hardness ($CaCO_3$)	4290		4140		4261			
Total Alkalinity ($CaCO_3$)	56		23		<0.5	3120		
BOD_5								
D.O.								
% Saturation								

Table 3-17 (continued)

Parameter / Date of Sampling PHYSICAL DATA (mg/L)	28/4/78	9/6/78 Diss.	9/6/78 Total	23/8/78	COAL WASTE LEACHATE Water Extraction of coaly waste.			
pH (units)	5.6		5.2	4.3	7.85			
Specific Conductance (μmhos/cm @ 25^{o} C)	7100		7500	7080				
True Color (Pt-Co Units)								
Turbidity (NTU)			32	4.0				
Temperature (^{o}C)								
Total residue			9231	8097				
Filtrable residue	8190		8960	8058	5320			
Non-filtrable residue	22		271	39	1650			
Fixed total residue								
Fixed filtrable residue								
Fixed non-filtrable residue								

TABLE 3-18

(mg/L) Parameter Dissolved (D), Total (T) - CATIONS / Date of Sampling	28/4/78	Water Extraction of low grade coal.		LOW GRADE COAL LEACHATE					
Aluminum (Al)	0.70	10							
Arsenic (As)	<0.005	0.6							
Cadmium (Cd)		<0.08							
Calcium (Ca)	430	80							
Chromium (Cr)	<0.010	1.0							
Copper (Cu)	0.007	7.0							
Iron (Fe)	0.010	40							
Lead (Pb)		<3							
Lithium (Li)	0.36	0.3							
Magnesium (Mg)	420	80							
Mercury (Hg)(ug/l)	<0.25	4							
Molybdenum (Mo)									
Nickel (Ni)	0.16								
Potassium (K)	36								
Selenium (Se)	<0.003	0.6							
Sodium (Na)	150	980							
Strontium (Sr)	1.2	<4							
Vanadium (V)	0.006	0.2							
Zinc (Zn)	0.18	8.4							

Table 3-18 (continued)

(mg/L) Parameter Diss.(D), Total (T) ANIONS, ORGANIC, CALCULATED VALUES / Date of Sampling	28/4/78	Water Extraction of low grade coal.	LOW GRADE COAL LEACHATE						
Boron (B)	0.7	1.0							
Chloride (Cl)	0.88	220							
Fluoride (F)									
Sulfate (SO_4)	3800								
Total-Kjeldahl-Nitrogen (N)									
Nitrate-Nitrogen (NO_3 -N)									
Nitrite-Nitrogen (NO_2 -N)									
Total-Orthophosphate-Phosphorus (P)									
Dissolved-Total PO_4 Phosphorus (P)									
COD									
TOC									
Phenol									
Total Hardness($CaCO_3$)	2800								
Total Alkalinity($CaCO_3$)	<0.5	2940							
BOD_5									
D.O.									
% Saturation									

TAble 3-18 (continued)

Date of Sampling / Parameter / PHYSICAL DATA (mg/L)	28/4/78	Water Extraction of low grade coal.	LOW GRADE COAL LEACHATE						
pH (units)	4.6	7.1							
Specific Conductance (µmhos/cm @ 25° C)	4630								
True Color (Pt-Co Units)									
Turbidity (NTU)									
Temperature (°C)									
Total residue									
Filtrable residue	5400	2940							
Non-filtrable residue	3	2010							
Fixed total residue									
Fixed filtrable residue									
Fixed non-filtrable residue									

4.0 AIR QUALITY MONITORING

4.1 SUSPENDED PARTICULATES

A network of six high-volume air samplers was established in 1977 to monitor ambient air suspended particulate levels in the Hat Creek region. Suspended particulate monitoring was continued during 1978 at five of the six monitoring stations to provide additional background information.

The locations of the monitoring stations are as follows: Station Number 1 is located along Highway 12, about 10 km from the mine site. Station Number 2 is located at the junction of the Hat Creek Road and Highway 12, near the project office. Station Number 3 was located on top of the pump house at the Hydro camp trailer. This station was abandoned in 1978 as it was installed for use during the Bulk Sample Program which was completed. Station Number 4 is located in Upper Hat Creek at the Milner Ranch. The weather trailer about 3 km from the mine site is the location of Station Number 5. Station Number 6 is located in Cache Creek.

The results of the 1978 suspended particulate monitoring program are presented in Tables 4-1 and 4-2. Annual geometric means for 1978 included data from an entire year whereas only data for the months April to December was included in the 1977 mean. Nevertheless the results for the two years are not markedly different except for station 2. Only on one occasion did a specific value exceed the PCB 24 hour average objective of 150 $\mu g/m^3$ namely 169 $\mu g/m^3$ at site 6 in the Cache Creek District office yard. The PCB annual geometric mean of 60 $\mu g/m^3$ was met at all the sites.

TABLE 4-1

HAT CREEK PROJECT ENVIRONMENTAL PROGRAM

AMBIENT AIR QUALITY MONITORING

24-Hour Suspended Particulate Concentrations (Hi-Volume Sampler) In $\mu g/m^3$

1978		STATION 1	2	3	4	5	6
Jan.	2	4	4		2	4	*
	8	5	*		6	14	18
	14	17	16		7	27	40
	20	9	7		3	7	*
	26	8	3		<2	4	25
Feb.	1	10	10		5	11	*
	7	5	3		<2	5	16
	13	30	14		12	20	*
	19	8	7		3	7	41
	25	8	9		3	6	169
Mar.	3	13	11		6	11	126
	9	*	3		<2	10	100
	15	7	6		2	*	*
	21	5	13		3	6	68
	27	4	6		3	7	40
Apr.	2	5	9		9	*	25
	8	8	17		8	8	58
	14	4	7		6	*	35
	20	3	5		2	*	31
	26	10	25		10	12	96
May	2	7	9		8	7	*
	8	7	10		12	9	44
	14	4	6		6	3	27
	20	16	21		31	19	97
	26	6	10		7	12	37
June	1	14	26		71	29	*
	7	20	39		58	72	67
	13	6	11		11	*	32
	19	12	26		16	*	*
	25	14	14		13	22	55

1978		STATION 1	2	3	4	5	6
July	1	13	19		17	20	32
	7	19	29		21	20	58
	13	12	18		11	19	60
	19	14	33		14	15	*
	25	18	59		*	19	77
	31	11	28		*	9	43
August	6	9	23		*	8	*
	12	5	7		*	38	27
	18	7	11		5	5	*
	24	6	*		*	7	9
	30	9	32		14	8	52
Sept.	5	5	9		3	3	14
	11	6	9		<2	6	50
	17	4	6		4	4	*
	23	7	39		*	7	65
	29	12	16		*	14	98
Oct.	5	14	46		*	15	85
	11	4	7		49	7	27
	17	13	16		14	11	71
	23	5	7		7	5	30
	29	*	7		5	5	35
Nov.	4	*	*		7	4	*
	10	12	20		11	4	*
	16	24	27		27	10	*
	22	23	23		12	<2	*
	28	5	5		2	<2	20
Dec.	4	*	6		4	<2	47
	10	9	8		6	*	25
	16	4	3		2	*	22
	22	5	4		2	*	13
	28	11	9		3	*	21

* = No Data

	1	2	3	4	5	6
Total Number of Operating Days	61	61	-	61	61	61
Number of Valid Operations	57	58	-	53	51	45
Maximum 24-Hour Concentration	30	59	-	71	72	169
Geometric Mean Concentration	84	11.4	-	6.6	8.6	40.7

TABLE 4-2

AMBIENT AIR QUALITY MONITORING

Summary of 1977 and 1978 24-Hour Suspended Particulate Concentrations (Hi-Volume Sampler)

Station No. and Year		No. of Valid Observations (% of Total)	Number of Observations in Range (Data in ug/m^3)											Geometric Mean µg/m^3
			0-20	21-40	41-60	61-80	81-100	101-120	121-140	141-160	>150	161-200	>200	
1	1977	38 (73)	33	5										9.2
	1978	57 (93)	55	3										8.4
2	1977	36 (67)	19	6	7	3			1					21.0
	1978	58 (95)	43	13	2									11.4
3	1977	23 (50)	14	7	2									17.2
	1978				Discontinued									
4	1977	33 (79)	28	5										9.6
	1978	53 (87)	47	3	2	1								6.6
5	1977	22 (96)	21	1										7.6
	1978	51 (84)	46	4		1								8.6
6	1977	35 (70)	5	14	8	4	3	1						37.3
	1978	45 (74)	6	17	10	5	5		1			1		40.7

Station 1 - Highway 12
Station 2 - Valley Junction
Station 3 - B. C. Hydro Camp
Station 4 - Milner Ranch
Station 5 - Weather Trailer
Station 6 - B. C. Hydro District Office, Cache Creek

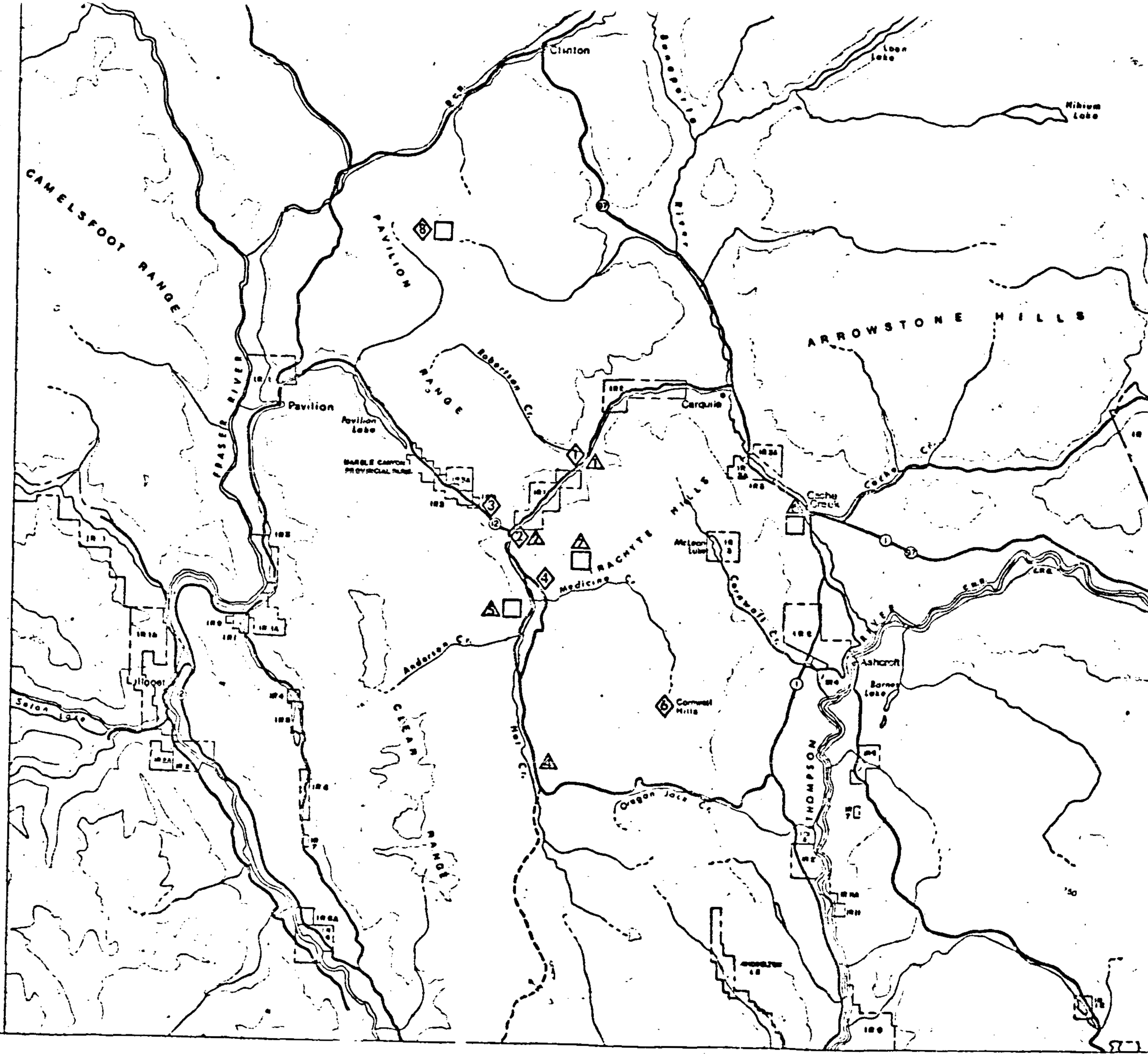
4.2 WEATHER STATIONS

In 1974 eight weather stations were established in the Hat Creek area to continuously monitor, wind run, wind direction, temperature and humidity. The locations of these eight stations are shown in Figure 4-1. The stations coordinates and elevations are given in Table 4-3.

During 1978 data collection was continued. This data is being reduced and put into computer storage by the Environmental Services Section, Operations Group.

4.3 AMBIENT AIR CHARACTERISTICS

In 1977 a program was initiated to measure physical and chemical characteristics of the ambient air in the vicinity of Hat Creek. Four monitoring locations were established: the valley station is located at weather station No. 5, shown in Figure 4-1; the mobile station is located in Cache Creek in the Hydro yard; the mountain station is located atop Pavillion Mountain at weather station No. 8; and the plant station is located at weather station No. 7, shown in Figure 4-1. A 100 m tower is located at the plant station and some variable are measured both at ground level or 10 m and at 100 m. The variables monitored at each of these four locations are shown in Table 4-4. The results of this detailed monitoring are reported to B.C. Hydro monthly by Western Research and Development who are conducting this monitoring program.



SCALE - 1:250,000

CONTOUR INTERVAL - 250 METRES

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT

METEOROLOGICAL & AIR QUALITY MONITORING STATIONS

LEGEND

◇ *Meteorological stations*

△ *High volume sampler stations*

□ *Air quality monitoring stations*

FIG. 4-1

TABLE 4-3

COORDINATES AND ELEVATIONS OF HAT CREEK WEATHER STATIONS

Station No.	North	West	Elevations (Metres)
1	50° 50' 10"	121° 32' 30"	768.1
2	50° 47' 45"	121° 36' 15"	838.2
3	50° 48' 38"	121° 37' 50"	853.4
4	50° 45' 45"	121° 35' 15"	960.1
5	50° 45' 20"	121° 36' 40"	1005.8
6	50° 41' 45"	121° 27' 15"	2026.9
7	50° 46' 45"	121° 31' 55"	1408.2
8	50° 58' 38"	121° 41' 50"	2087.9

TABLE 4-4

AMBIENT AIR CHARACTERISTICS MONITORING STATIONS

VARIABLE	MONITORING STATION				
	VALLEY	MOBILE	MOUNTAIN	$PLANT_{10}$	$PLANT_{100}$
Wind Speed & Direction	X	X	X	X	X
Sulphur Dioxide	X	X			
Ozone	X	X			
Oxides of Nitrogen	X	X			
Nitrogen Dioxide	X	X			
Carbon Monoxide		X			
Precipitation	X	X	X	X	
Temperature	X	X	X	X	X
Dew Point Temperature	X	X		X	X
Total Visibility	X				
Atmospheric Haze	X	X			
Solar Radiation	X				
Barometric Pressure				X	

5.0 ENVIRONMENTAL TRACE ELEMENT STUDIES

5.1 INTRODUCTION

In October 1976 a study was conducted to determine trace element concentrations naturally present in the terrestial and aquatic environments in the vicinity of Hat Creek. Seven materials were analysed including: water, sediments and fish at two locations in Hat Creek and at two locations in the Bonaparte River; and soils, shrubs, grasses, lichen and small mammals at five terrestial sites. This study was conducted for B.C. Hydro by Environmental Research and Technology, Inc. (ERT) Santa Barbara, California. In the October 1976 survey three samples of each material were collected from the sampling sites. In January and May 1977 single samples of each material were collected from the sampling sites.

The results of the 1976 and 1977 studies are reported by ERT in the report entitled "Air Quality and Climate Effects of the Proposed Hat Creek Project, Appendix F, The Influence of the Project on Trace Elements in the Ecosystem", document P-507-F-F, July 1978[5]. Most of the analyses showed normal levels of trace elements in the Hat Creek receptors tested. However, the concentrations of some elements, particularly fluorine and tin, were found to be considerably greater than the levels normally present in natural environments. The ERT report contained no explanation of these exceptional results but did recommend that additional studies be conducted to provide additional data to enable the design of a valid trace element monitoring program.

In October 1978, further trace element studies were conducted to provide additional data and to verify the earlier data. Acres Consulting Services Limited were retained by B. C. Hydro to collect samples from the five terrestial sampling sites established by ERT. Samples of soils, shrubs, grasses and lichen were collected. The aquatic sites were not sampled because the terrestial sites showed the greatest variations and considerable data has been developed on surface water quality in Hat Creek and the Bonaparte River. Small mammals were not sampled because of the difficulty in obtaining samples. The samples were prepared and analysed by Chemex Labs Ltd., North Vancouver.

A description of the October 1978 sampling program, the analytical results and comparisons to the ERT data are presented in this section of the report.

5.2 SAMPLING SITES

The five terrestrial sampling sites established and described by ERT[5] are as follows:

Site Number	Name	Elevation (feet)	Slope (degrees)	Aspect
1	Pavilion Mountain	6,853	20 to 25	SE
2	Lower Hat Creek	2,460	10	W
3	Arrowstone Creek	4,920	20	WSW
4	Cornwall Mountain	6,678	10	NW
5	Ashcroft	4,510	10 to 20	W

The exact locations of these sites were not specified by ERT, however, approximate locations were indicated on a 1:250,000 map. During this study it was not possible to identify any of the original 100 m^2 sites, therefore new sites, which closely approximate the above conditions, were selected. These sites were marked with a metal stake which had yellow tape or a yellow flag on it. The sampling sites, which are indicated in Figure 5-1, can be reached as follows:

Site #1 - Pavilion Mountain

Follow Highway 12 west from Highway 97 until just past Pavilion Lake. Turn right at Milkranch Creek onto a dirt road that goes through an Indian reserve. This road is maintained by B.C. Telephone Company for the microwave station. Follow this road for about 15 kilometres to the microwave station. Just past the station, follow the southeast fork in the road to the end, approximately 800 metres. These roads are not indicated on the government topographical maps but are shown on the map included in this report. Photo 1 was taken from the Pavilion Mountain site looking north.

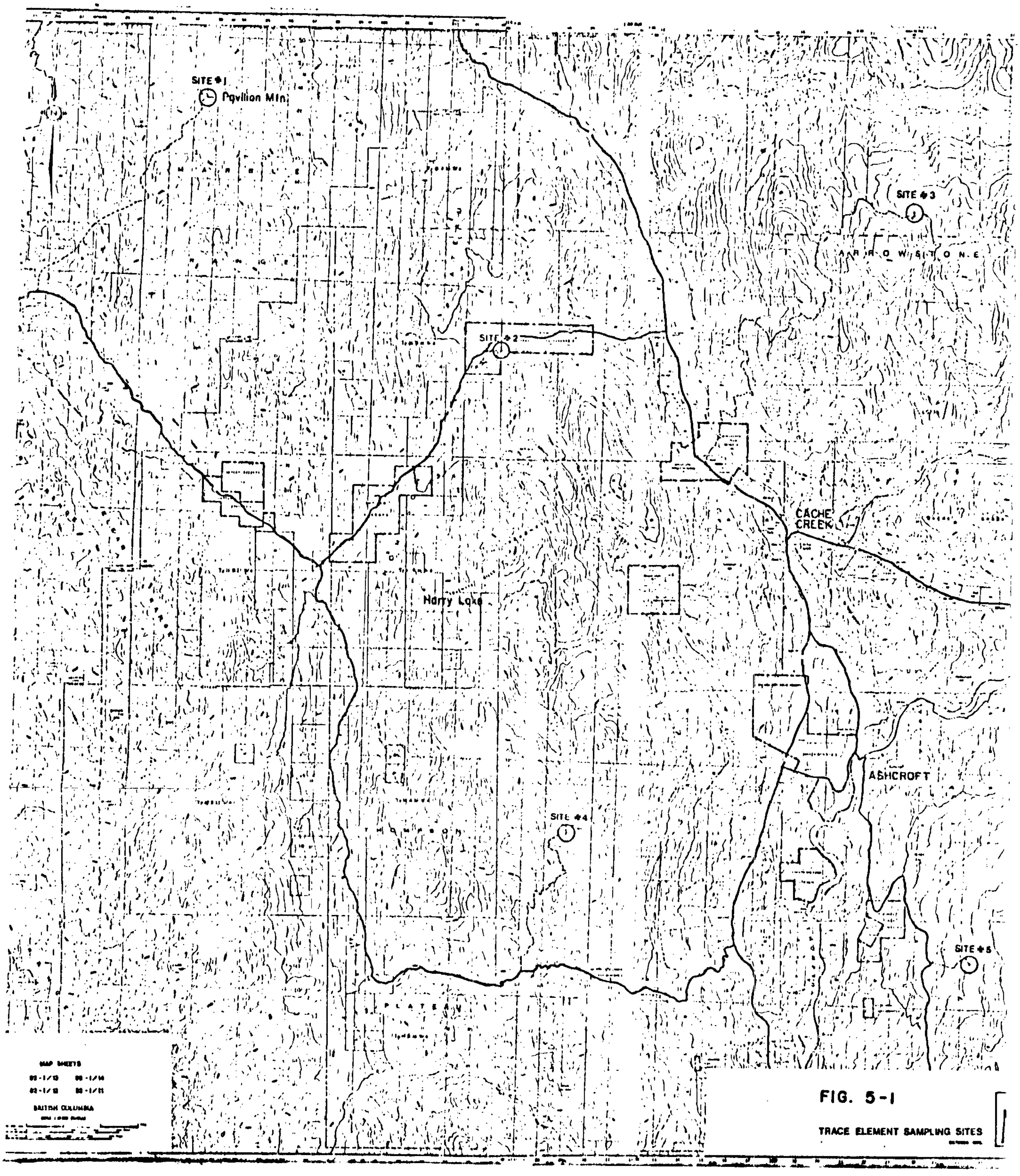


FIG. 5-1

TRACE ELEMENT SAMPLING SITES

Site #2 - Lower Hat Creek

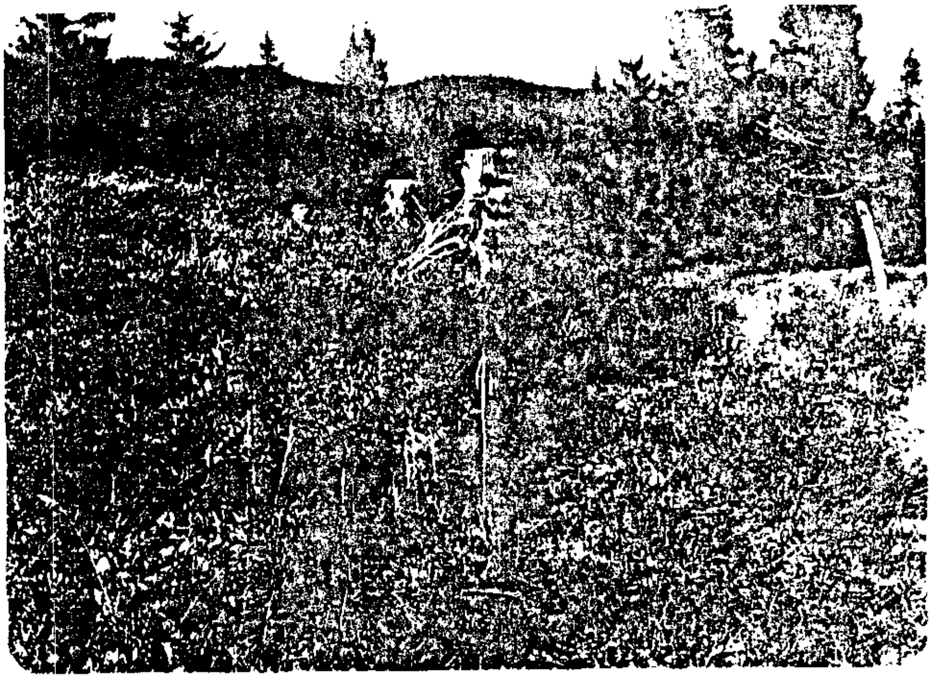
Take Highway 12 west from Highway 97 to the Bonaparte Indian Reserve #2. About 2 kilometres by road from the west end of the Indian reserve there are two buildings along the highway. Park here and walk in a southerly direction until an elevation of approximately 2,460 feet is attained. This site has a slope of $>15^{\circ}$ and faces west. This site is near the center of Photo 2.

Site #3 - Arrowstone Creek

Follow Highway 97 north from Cache Creek to Bonaparte Indian Reserve #3A. Turn right (northwest) onto a gravel road about halfway through the reserve. Follow this road (which is indicated as a "cart track" on the government topographical map) past the transformer station to a very sharp curve in the road at a road elevation of 4,850 feet. There is also a forest service marker on a tree on the east side of the road at this point. From this point on the road the site is about 200 metres to the northwest. The center stake at this site is shown in Photo 3.

Site #4 - Cornwall Mountain

This location can be reached from the Hat Creek site or from Highway 1 just south of Ashcroft. The road is gravel and well maintained as there is a forest lookout station at the top. The sample site is about 50 to 75 metres southwest of the lookout. This site which faces northwest is shown in Photos 4 & 5.



Site #5 - Ashcroft

Follow paved road south from Ashcroft about 12 kilometres. At this point there is a gravel pit on the northeast side of the road and a sharp bend in the road. A gravel road to the west is located at this bend in the paved road. Follow this gravel road about 2 kilometres to an elevation of 4,150 feet. Walking from this point the site is about 200 metres to the southeast.

5.3 SAMPLE COLLECTION

Samples were collected from Site #1 on October 17, 1978, from Site #2 on October 18, from Sites #3 and #4 on October 19 and from Site #5 on October 20. The weather during sampling was warm and sunny except on October 20 when it was colder and rainy.

Three samples of each material (grass, willow, lichen and soil) were collected at each site. The three sampling locations at each site were chosen in a random manner by using a random numbers chart to determine direction from a central point. Initially, random distances from the central point were to be utilized; however, due to the low abundance of the lichen and willow specimens, this method could not be employed. All samples were collected along a random direction in degrees from magnetic north ($\pm 5^{\circ}$) until sufficient quantities were accumulated. The distance from the central points ranged from 1 to 30 metres depending on sample availability.

Central points are marked with metal stakes with a yellow tape. At three site (Pavilion Mountain, Cornwall Mountain and Arrowstone Creek), fluorescent purple stakes were driven into the ground in order to assist in location of the random directions. These spikes are located within 4 to 6 metres of the central stake and are not indicators of random distances.

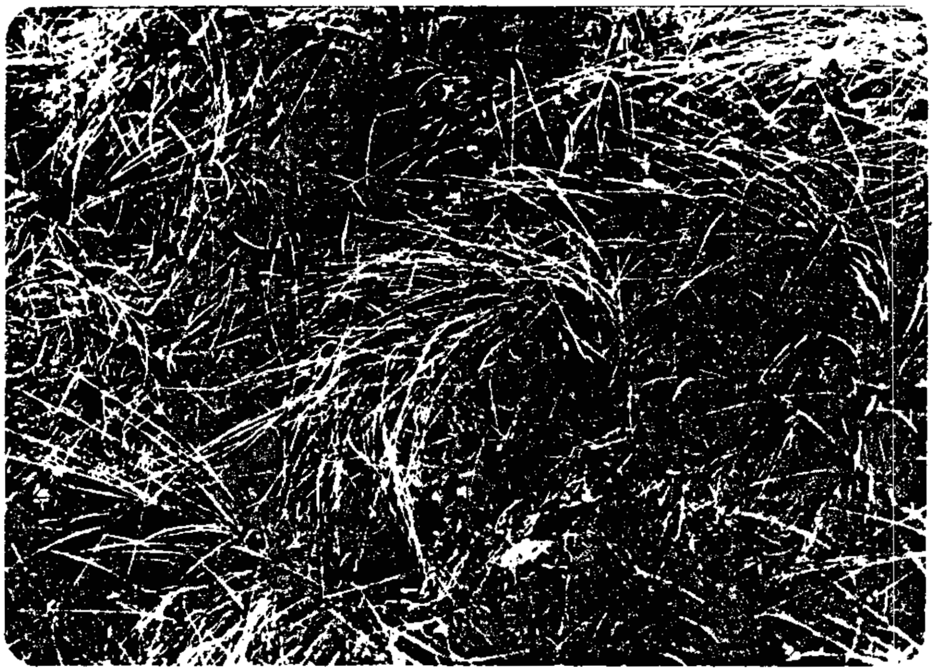
The sampler, wearing plastic gloves and using acid-washed (10% HNO_3) stainless steel scissors, clipped the vegetative samples. Grass was cut 3 to 5 cm above the soil; willow was sampled by cutting ends of branches less than 30 cm in length. Lichens were picked from trees.

As much as possible (up to 200 gm) of each sample was collected. However, it was not possible in some areas to collect the specified 200 gm due to time and/or a low abundance of the specimen. Samples were placed directly into labelled white paper bags then double bagged and sent to Vancouver to be analyzed.

Soil samples were collected from the top 5 cm using an acid-washed stainless steel knife and plastic trowel. A minimum of 200 gm of each soil sample was collected. Soil samples were placed into labelled, heavy plastic bags and sent to B. C. Hydro, Vancouver, B. C. A typical soil sample collection site is shown in Photo 6.

Different species of shrub willow were noted in the five sites. No attempt was made to identify and segregate the species. The samples collected probably included more than one species. Willow plants at the Arrowstone Creek, Cornwall Mountain and Ashcroft sites are shown in Photos 7, 8 and 9 respectively.

At the higher elevation sites it was not possible to be absolutely certain of the identification of the Bluebunch Wheatgrass. At this time of year the grasses are brown and in most cases are lodging. The inflorenscence has deteriorated markedly and only at the Lower Hat Creek location (Site 42) was positive identification made. Grass samples from the other sites may be a composite of grass species. A typical grass sample collection site is shown in Photo 10.



Lichen samples were collected from trees as shown in Photo 11.

5.4 ANALYTICAL PROCEDURES

In the laboratory the grass, shrub, lichen and soil samples were dried at 45°C, weighed and milled to minus 20 mesh. The sample preparations and analyses were carried out by Chemex Labs Ltd., North Vancouver, as follows:

(i) Cu, Mo, Pb, Zn, Cd, Fe: Samples were wet-ashed with a combination of nitric and perchloric acids and each metal was determined by direct atomic absorption using Varian AA5 or AA6 spectrophotometers. Pb, Ni and Cd were corrected by background absorption.

(ii) As, Se: An aliquot of the above solution was reduced and both elements were analyzed as their hydrides via hot vapour flameless atomic absorption using a Varian AA6 spectrophotometer.

(iii) Hg: Samples were digested with nitric and sulphuric acids, potassium permanganate and potassium persulfate. Mercury was reduced and analyzed via cold vapour U.V. absorption using a Jarrell Ash spectrophotometer.

(iv) Sr, Cr, Co, Be, V: Samples were dry-ashed at 550°C, digested with nitric perchloric and hydrofluoric acids and analyzed by direct atomic absorption.

(v) F: Samples were ashed at 550°C using NaOH as an ashing aid. The ash was fused with sodium carbonate, leached with water, buffered and analyzed for fluoride with a specific ion electrode.

(vi) Sn: Samples were ashed at 550°C fused with ammonium iodide, leached, extracted and analyzed by atomic absorption.

(vii) Boron: Samples were ashed overnight at 550°C and the ash was dissolved in hydrochloric and nitric acids. The use of normal Pyrex glass ware (borosilicate glass) was avoided. Samples were ashed to porcelain and leached in polyethylene containers. The resulting solutions were analyzed (by Cantest Ltd.) using an inductively-coupled plasma torch.

(viii) Sulphate: Samples were digested with aqua regia, diluted and filtered. The resulting clear solution was treated with barium chloride and appropriate reagents to yield a barium sulphate precipitate which was measured turbidimetrically.

(ix) Uranium: Duplicate analyses were performed in most cases except when sufficient sample was not available. The duplicate analyses included separate weighing and digestion/fusion in all cases.

5.5 ANALYTICAL RESULTS AND DISCUSSION

The results of the trace element analyses are shown in Tables 5-1 to 5-4. At each of the five sites, three samples of each material were collected. These results are presented as numbers 1, 2 and 3 in the tables. Each number reported is, in most cases, the average of duplicate analyses. Number 4 is the average of three samples collected in October 1976 and analysed by ERT[5]. One sample of each of the four materials collected was subdivided and submitted as three separate samples for analyses to evaluate the accuracy of the analytical procedures. These blind triplicate analyses are reported in the tables as three number 1's.

The concentrations of most trace elements in the grass samples collected in October 1978 are similar to the levels found by ERT in samples collected in October 1976. However, the levels of some elements differ significantly. The largest difference was in the level of tin. The concentrations reported by ERT[5] ranged from 10.3 to 161 mg/kg, while all analyses indicated less than 1 mg/kg in the grass samples collected in October 1978. Other elements which showed differences in concentrations between the October 1976 survey and the October 1978 surveys were boron, copper, fluorine and molybdenum. Except for boron, all of these elements were found at higher concentrations in the 1976 ERT survey.

The results of the shrub analyses were similar to those for the grass. Again the concentration of tin found by ERT in October 1976 were exceptionally high exceeding the levels found in 1978 by as much as 800 times. The concentrations of chromium, cobalt, copper, fluorine, molybdenum and zinc were also significantly high in 1976 than in 1978.

The lichen samples also showed exceptionally high levels of tin in the 1976 ERT survey. Much lower levels of tin were found in 1978. Boron and mercury were lower in the 1976 survey than in 1978, while copper, fluorine and molybdenum were higher.

The results of the soils analyses also indicate much greater tin levels in the ERT data for 1976 than in 1978. Beryllium concentrations were generally lower in the 1976 survey and molybdenum and selenium were higher than in 1978.

The levels of tin found in the four plant and soil materials in October 1978 are within the normal range found in natural environments. The 1976 values are 10 to 1000 times higher than values normally found. Contamination of the 1976 samples seems the most likely explanation for the exceptionally high concentrations of tin. Chemex (personal communication) indicated that they had found tin contamination, probably from drying ovens, to be a problem when doing mass spectrometry but they did not determine the exact source of the tin contamination.

In addition to tin, the levels of copper, fluoride and molybdenum in all four materials tested were consistently lower in the 1978 survey than in the 1976 survey. The 1976 samples were analysed by spark source mass spectrometry (SSMS). ERT[5] report quality control checks using U. S. National Bureau of Standards (NBS) fly ash standards, to verify the spark source mass spectrometry methods. No vegetation or animal standards were analysed. Of the four elements, tin, copper, fluoride and molybdenum, only copper was part of the fly ash standard. The standard had a certified copper concentration of 28 ±5 mg/kg. The result reported for the SSMS method was 130 mg/kg, a factor of 5 higher than the actual level. The concentrations of several other elements measured in the NBS standard by the SSMS method differed significantly from the certified values. In most cases, the concentration determined by the SSMS method was higher than the certified value, rather than lower. Thus the higher levels of certain trace elements in the 1976 ERT survey could be due to the higher than actual results of the SSMS analytical procedure. In subsequent surveys in January and May 1977, ERT abandoned the SSMS methods in favour of the more accurate method, atomic absorption spectrophotometry, the method used by Chemex for the Oct. 1978 survey.

Overall, concentrations of all of the trace elements measured in the October 1978 survey are within the range of values normally found in natural environments.

TABLE 5-1

HAT CREEK TRACE ELEMENT ANALYSES - GRASSES

Element	Pavilion Mountain				Cornwall Mountain				Arrowstone Creek				Lower Hat Creek						Ashcroft			
(MG/KG)	1*	2	3	4	1	2	3	4	1	2	3	4	1	1	1	2	3	4	1	2	3	4
As	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.23	<0.5	<0.5	<0.5	0.40	<0.5	<0.5	<0.5	<0.5	<0.5	<1.83	<0.5	<0.5	<0.5	0.33
Be	0.02	0.02	0.025	<0.17	0.025	-	0.05	<0.17	0.025	0.02	0.02	<0.20	0.02	0.02	0.02	0.045	0.01	<0.23	0.03	0.02	0.03	<0.20
B	7.0	7.1	8.3	2.67	18.8	23.6	23.8	5.0	4.2	6.4	4.6	2.33	15.8	13.6	11.4	18.9	6.5	3.0	16.3	16.3	16.7	2.33
Cd	<0.1	<0.1	<0.1	<0.27	0.95	0.45	1.15	<0.30	<0.1	<0.1	<0.1	<0.30	0.1	<0.1	<0.1	<0.1	<0.1	<0.33	<0.1	<0.1	<0.1	<0.37
Cr	2.5	2.2	1.6	3.67	4.9	-	8.0	<1.10	3.8	1.7	1.8	3.67	5.5	3.1	2.2	4.8	3.2	8.33	1.6	1.4	1.4	6.67
Co	<0.04	<0.08	<0.04	<0.23	0.10	-	0.40	<0.20	0.08	<0.04	<0.04	<0.27	<0.08	<0.08	0.08	0.32	0.04	<0.53	<0.04	<0.04	<0.04	<0.30
Cu	3	3	2	5.33	3.5	3	4	4.67	3	3	3	6.33	3	2	2	3	2	13.67	3	2	2	6.67
F	<10	<10	<10	29	<10	<10	<10	14	<10	<10	<10	22	<10	<10	<10	<10	<10	24	<10	<10	<10	13.33
Fe	115	60	63	102	153	138	765	152	83	53	50	230	158	135	130	500	120	208	58	48	48	210
Pb	1	<1	<1	<4.0	<1	2	<1	<4.0	<1	<1	<1	<4.0	2	<1	<1	1	<1	<21.7	<1	<1	<1	<4.0
Hg	0.17	0.08	0.08	0.19	0.14	0.16	0.11	0.12	0.11	0.09	0.08	0.18	0.08	0.06	0.07	0.06	0.08	0.12	0.05	0.07	0.08	0.08
Mo	<1	<1	<1	5.0	<1	<1	<1	4.0	<1	<1	3	6.33	<1	<1	<1	<1	<1	11.0	2	2.5	2	4.33
Se	<0.2	<0.2	<0.2	<2.23	<0.2	<0.2	<0.2	<0.93	<0.2	<0.2	<0.2	<3.33	<0.2	<0.2	<0.2	<0.2	<0.2	<2.3	<0.2	<0.2	<0.2	<6.67
Sr	18	10	22	19.0	6.6	-	8.2	13.3	50	32	36	19.0	52	51	84	118	34	45.7	28	31	31	27.3
Sn	<1	<1	<1	10.3	<1	<1	<1	23.7	<1	<1	<1	31.0	<1	<1	<1	<1	<1	131	<1	<1	<1	161
U	<0.1	<0.1	<0.1	<0.87	<0.1	<0.1	<0.1	<0.83	<0.1	<0.1	<0.1	<1.30	<0.1	<0.1	<0.1	<0.1	<0.1	<1.33	<0.1	<0.1	<0.1	<1.67
V	0.4	0.6	0.4	0.43	0.6	-	0.4	0.80	0.6	0.8	0.8	<0.27	0.8	0.4	0.8	4.4	0.4	1.60	0.6	0.8	0.4	0.67
Zn	48	34	30	20.7	87	100	125	35.7	23	17	23	14.0	22	18	18	29	14	23.3	14	17	20	16.7

* 1, 2, 3 are triplicate samples collected at each site in October 1978.
4 is average of triplicate samples collected at same site in October 1976.

TABLE 5-2

HAT CREEK TRACE ELEMENT ANALYSES - LICHENS

Element	Pavilion Mountain				Cornwall Mountain				Arrowstone Creek				Lower Hat Creek						Ashcroft			
(MG/KG)	1 *	2	3	4	1	2	3	4	1	2	3	4	1	1	1	2	3	4	1	2	3	4
As	0.5	0.5	0.75	0.63	1.0	0.5	0.5	0.93	0.5	0.75	0.5	1.20	0.5	0.5	0.5	0.5	0.5	1.57	1.0	0.5	1.25	0.73
Be	0.035	0.03	0.03	<0.2	0.045	0.05	0.045	<0.2	0.05	0.045	0.04	<0.2	0.07	0.045	0.055	0.045	0.04	<0.23	0.035	0.045	0.04	<0.2
B	7.4	5.1	5.0	1.57	3.4	3.9	3.4	1.83	6.7	5.2	4.6	2.57	14.1	9.4	11.9	8.3	20.4	1.80	4.5	5.0	3.7	2.27
Cd	0.1	<0.1	<0.1	<0.33	0.25	0.25	0.25	<0.30	<0.1	<0.1	<0.1	<0.33	<0.1	<0.1	0.1	<0.1	<0.1	<0.40	<0.1	<0.1	0.1	<0.33
Cr	2.15	1.75	1.85	5.67	2.8	2.05	2.25	5.0	2.15	1.5	2.1	11.33	6.65	4.65	4.5	3.75	3.1	9.67	2.9	2.8	2.2	7.0
Co	0.34	0.30	0.36	<1.20	0.42	0.36	0.34	2.0	0.34	0.32	0.36	0.93	0.72	0.46	0.50	0.46	0.34	1.83	0.36	0.38	0.28	<1.57
Cu	5	3	4	12.0	4	1	2	16.33	7	6	8	8.67	9	7.5	8	5.5	6	9.67	28	26	14	32.33
F	<10	<10	<10	16.0	<10	<10	<10	46.67	<10	<10	<10	49.0	<10	<10	<10	<10	<10	157.0	<10	<10	<10	52.0
Fe	398	430	598	573	885	625	598	387	450	385	460	593	1125	820	880	653	465	570	565	470	268	443
Pb	19.5	15	19	29.33	27	16.5	22	14.67	15	13.5	13.5	17.67	24	24	25	17.5	18.5	53.33	24.5	21	13.5	36.67
Hg	1.02	1.45	1.58	0.58	1.43	2.18	1.45	0.56	1.53	1.68	1.10	0.48	0.65	0.90	0.90	0.33	0.58	0.25	1.38	1.15	0.53	0.47
Mo	<1	<1	<1	4.7	<1	<1	<1	8.0	<1	<1	<1	4.3	<1	<1	<1	<1	<1	5.7	<1	<1	<1	4.3
Se	<0.2	<0.2	<0.2	<1.07	<0.2	<0.2	<0.2	<0.67	<0.2	<0.2	<0.2	<1.17	<0.2	<0.2	<0.2	<0.2	<0.2	<1.47	<0.2	<0.2	<0.2	<1.10
Sr	11.5	4.8	5.2	14.3	5.4	8.0	4.6	19.0	14.5	14	10	46.0	8.8	9.0	9.0	9.4	9.8	29.0	8.4	8.6	8.8	23.7
Sn	<1	<1	<1	>381	<1	<1	<1	305	<1	<1	<1	>354	<1	<1	<1	<1	<1	51	<1	<1	<1	239
U	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<0.1	<0.97	<0.1	<0.1	<0.1	<0.1	<0.1	<1.33	<0.1	<0.1	<0.1	<1.67
V	1.6	1.6	2.2	2.33	3.2	2.2	2.4	3.0	2.4	2.0	2.4	3.67	6.8	4.6	4.8	3.6	2.6	6.0	3.2	3.2	1.8	2.33
Zn	32	31	28	25.3	36	56	31	57.7	32	35	40	55.3	28	24	32	33	26	31.0	25	26	21	67.0
SO_4	2150	1800	2350		2550	2400	2200		1900	1900	2000		2000	2100	2450	1950	2200		2750	2500	2200	

* 1, 2, 3 are triplicate samples collected at each site in October 1978.
4 is average of triplicate samples collected at same site in October 1976.

TABLE 5-3

HAT CREEK TRACE ELEMENT ANALYSES - SHRUBS

Element	Pavilion Mountain				Cornwall Mountain						Arrowstone Creek				Lower Hat Creek				Ashcroft			
(MG/KG)	1 *	2	3	4	1	1	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
As	<0.5	<0.5	<0.5	<0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.6	<0.5	<0.5	<0.5	<0.37	<0.5	<0.5	<0.5	<0.97	<0.5	<0.5	<0.5	<0.47
Be	0.03	0.03	0.025	<0.13	0.025	0.02	0.03	0.025	0.035	<0.17	0.01	0.015	0.015	<0.17	0.02	0.025	0.03	<0.10	0.02	0.02	0.03	<0.10
B	18.2	13.3	10.2	10.67	16.0	15.1	15.9	17.0	12.8	16.67	17.3	12.1	14.8	46.67	14.6	18.7	23.0	11.67	23.4	18.6	22.8	111.0
Cd	1.45	2.05	1.85	<0.87	4.2	4.75	4.55	3.35	4.35	<0.83	<0.1	<0.1	<0.1	<0.3	0.2	<0.1	<0.1	<0.33	<0.1	<0.1	0.85	<0.47
Cr	1.25	1.05	1.2	2.00	1.25	1.15	1.2	1.25	1.0	3.33	1.05	1.1	1.0	9.00	1.05	1.0	1.15	1.67	0.75	0.85	0.95	6.00
Co	0.24	0.18	0.20	0.43	0.20	0.18	0.16	0.40	0.44	0.93	<0.04	0.06	0.06	4.00	0.08	<0.04	0.06	3.93	<0.04	<0.04	<0.04	1.43
Cu	6	9	6	100	4	5	5	4	3	10.67	5	6	5	14.33	6.5	6	7	31.33	5.5	6.5	9	21.33
F	<10	<10	<10	263	<10	<10	<10	<10	<10	>707	<10	<10	<10	78	<10	<10	<10	111	<10	<10	<10	115
Fe	203	118	100	123	135	135	145	135	110	141	93	95	88	87	95	60	220	57	68	88	75	138
Pb	1	1.5	2.5	5.67	2	3	2	1	1	<3.00	3.5	2.5	3	<3.00	3.5	3	4	10.00	2.5	3.5	2.5	5.00
Hg	0.07	0.08	0.075	0.07	0.09	0.085	0.075	0.105	0.06	0.05	0.125	0.085	0.125	0.04	0.115	0.055	0.105	0.10	0.10	0.06	0.07	0.10
Mo	<1	<1	<1	5	<1	<1	<1	<1	<1	6.67	<1	<1	<1	<5	<1	<1	<1	4	<1	<1	<1	5
Se	<0.2	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	0.40	<0.2	<0.2	<0.2	<0.43	0.2	<0.2	<0.2	<0.30	<0.2	<0.2	<0.2	<0.43
Sr	26.5	34	33	26.33	13	13.5	12.5	13	14	44.33	21.5	22	21	87.0	95	87	132	102	15	13	36.5	273
Sn	<1	<1	<1	>345	<1	<1	<1	<1	<1	>399	<1	<1	<1	61.33	<1	<1	<1	>833	<1	<1	<1	25.33
U	<0.1	<0.1	<0.1	<0.7	<0.1	<0.1	<0.1	<0.1	<0.1	<0.63	<0.1	<0.1	<0.1	<0.93	<0.1	<0.1	<0.1	<0.6	<0.1	<0.1	<0.1	<0.77
V	0.6	0.4	0.8	0.27	0.8	0.6	0.6	0.4	0.6	0.37	0.4	0.8	0.8	0.43	0.4	0.8	0.8	<0.17	0.8	0.8	0.8	0.27
Zn	136	186	121	187	147	158	162	99	130	313	10	10	9	69	53	60	46	157	12	13	86	383

* 1, 2, 3 are triplicate samples collected at each site in October 1978.
4 is average of triplicate samples collected at same site in October 1976.

TABLE 5-4

HAT CREEK TRACE ELEMENT ANALYSES - SOILS

Element	Pavilion Mountain				Cornwall Mountain						Arrowstone Creek				Lower Hat Creek				Ashcroft			
(MG/KG)	1*	2	3	4	1	1	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
As	3.0	2.8	3.0	4.33	3.3	3.5	2.8	14.5	2.5	5.0	1.0	1.3	1.0	3.0	5.8	8.3	7.8	8.33	4.0	3.5	3.8	3.67
Be	0.9	1.1	1.15	0.53	0.40	0.45	0.40	1.25	1.3	<0.33	1.55	1.25	1.55	0.30	1.9	1.85	1.8	0.43	1.2	1.2	1.1	<0.43
B	14.0	10.2	10.1	6.33	9.0	8.6	8.6	10.4	6.3	11.7	4.6	6.8	6.1	3.0	16.1	18.1	16.3	15.0	8.3	7.3	15.2	8.67
Cd	0.5	0.55	0.35	<0.57	1.95	4.5	1.6	3.8	2.45	<1.13	0.1	0.15	0.1	<0.33	0.1	0.1	0.15	<0.43	0.1	0.45	1.05	<0.43
Cr	137	130	125	88.3	27	28	23	110	145	82.7	113	94	112	530	121	149	137	154	148	123	115	380
Co	21.5	15	9	13.3	2.5	6	3	8	5	10.7	6	7	12	21.3	18	18	14.5	12.0	10	10.5	9	7.3
Cu	35	22	28	40.3	18	18	16	30	14	34.3	20	16	14	37.7	58	59	50	58.3	26	26	30	65.0
F	158	208	220	217	60	68	75	275	148	222	200	173	183	43.7	325	273	470	>467	248	243	233	89.0
Fe %	3.68	3.10	3.53	>0.1	0.65	0.75	0.60	2.65	1.08	>0.1	2.15	1.78	2.00	>0.1	4.60	4.85	5.00	>0.1	2.63	2.45	2.35	>0.1
Pb	3.5	9	6.5	10.0	21.5	19	25	1015	170	11.3	8.5	6	5	4.0	9.5	9.5	8	7.7	3	4.5	4	5.7
Hg	0.085	0.14	0.14	0.16	0.115	0.060	0.045	0.095	0.07	0.09	0.06	0.065	0.04	0.07	0.055	0.055	0.065	0.07	0.065	0.050	0.080	0.04
Mo	<1	<1	1	3.0	<1	<1	<1	1	<1	5.0	<1	<1	<1	2.33	1	<1	1	3.0	<1	<1	<1	1.0
Se	<1	<1	<1	<2.97	<1	<1	<1	<1	<1	<1.27	<1	<1	<1	2.33	<1	<1	<1	2.0	<1	<1	<1	2.33
Sr	128	170	173	483	50	65	53	100	193	207	290	258	253	567	270	173	117	233	285	275	275	400
Sn	<1	<1	<1	>337	<1	<1	<1	<1	<1	5.33	<1	<1	<1	23.3	<1	<1	<1	24.3	<1	<1	<1	35.7
U	<0.5	<0.5	<0.5	<4.33	<0.5	<0.5	<0.5	<0.5	<0.5	<3.67	<0.5	<0.5	<0.5	<3.0	<0.5	<0.5	<0.5	4.33	<0.5	<0.5	<0.5	<2.67
V	148	140	155	387	30	30	30	105	55	194	98	85	98	377	195	185	173	278	120	120	103	253
Zn	111	138	148	116	122	132	120	200	107	220	62	81	85	226	148	146	139	92	100	159	210	82

* 1, 2, 3 are triplicate samples collected at each site in October 1978.
4 is average of triplicate samples collected at same site in October 1976.

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