BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

DETAILED ENVIRONMENTAL STUDIES

MINERALS AND PETROLEUM

May 1978

GENERATION PLANNING DEPARTMENT

SYSTEM ENGINEERING DIVISION

HAT CREEK PROJECT

DETAILED ENVIRONMENTAL STUDIES

MINERALS AND PETROLEUM

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SECTION 1.0 - SUMMARY AND CONCLUSIONS

The coal deposits of the Upper Hat Creek Valley lie in the Interior Plateau of British Columbia, 21.7 km (13.5 mi) west of Ashcroft. It has been proposed that these coal deposits be the source of fuel for a thermal plant in the Trachyte Hills 4.8 km (3 mi) east of the deposits.

The purpose of this investigation is to provide baseline data for other environmental studies, to determine the regional geology and extent of the coal resource, to provide an inventory of all rock, mineral and petroleum resources that could be affected by the Hat Creek Project and to note potential uses of these resources where applicable. The land area that would be alienated by the project is estimated at 4310 ha (10,650 acres). The greatest impact on geological resources would be in the Upper Hat Creek Valley and the Trachyte Hills, the locations of the proposed mine and powerplant.

The Upper Hat Creek Valley is composed of a graben or down-dropped fault block. The Tertiary strata in the centre of the valley are flanked by older, primarily volcanic and plutonic rocks on the west and by older limestone and volcanic rocks on the east. The No. 1 coal deposit is near the north end of the valley. The area from the No. 1 deposit southward for 22.5 km (14 mi) is believed to be underlain by coal. Within the valley both the No. 1 and No. 2 deposits have been drilled extensively. Additional exploration holes have been drilled throughout the valley.

The No. 1 deposit has been proposed as the source of coal for a 2000 MW thermal generating station with a planned life of 35 years. At the end of 35 years appreciable reserves would still remain in the

No. 1 deposit and in the remainder of the Upper Hat Creek Valley. These resources could be used to extend the life of the proposed plant, enlarge the thermal generating capacity, or for the alternate uses that have been proposed.

This report investigates the effect of the Hat Creek Project on resources of petroleum and natural gas, salts, aggregate, limestone, claystone, baked claystone, additional coal and by-product coaly waste, base metals, precious metals, semi-precious rocks and minerals and by-product trace elements. It was found that the only resources significantly affected would be: aggregate, limestone, claystone, baked claystone and by-product coaly waste. Of these resources aggregate and limestone are abundant in the area; the former should be stored in the waste dump to ensure that sufficient reserves are readily available to meet future needs; reserves of the latter could be quarried nearby, in areas not affected by the project. The claystone at Hat Creek is being examined for the properties of its montmorillonitic (bentonitic) and kaolinitic constituents. These minerals are occasionally separate, in discrete zones, thereby making extraction possible. The kaolinitic material could be used for making refractory materials, ceramic products or as a source of alumina; the bentonitic material may be useful in foundry sands, drilling mud or oil processing. Potential by-product coaly waste is being examined as a source of alumina and for the manufacture of grog, a component of bricks. Similarly, the baked claystone that overlies part of the coal deposit may be useful in grog or for road construction. These additional uses of the resources could enhance the project.

There are no known mineral or petroleum resources that would be adversely affected by the project which would not be mitigated by similar resources nearby. There is a possiblility that the excavation of claystone, burned claystone, and coaly waste may enhance the project.

SECTION 2.0 - INTRODUCTION

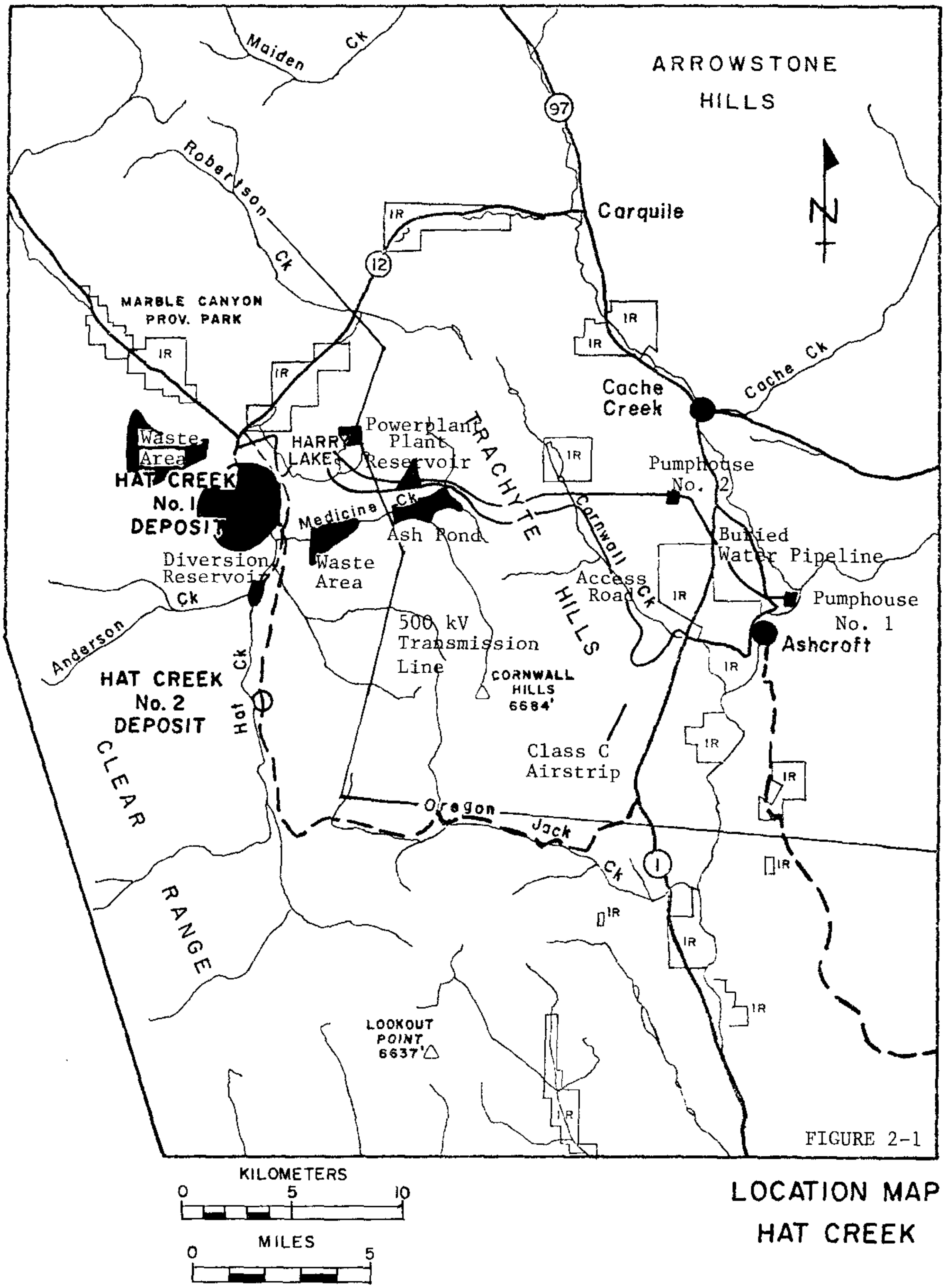
2.1 LOCATION

The Upper Hat Creek Valley is the site of the Hat Creek coal deposits. The valley lies midway between Ashcroft and Lillooet, 200 km (125 mi) northeast of Vancouver, British Columbia (Figure 2-1). The site is accessible by car or by small charter aircraft from nearby points or from Vancouver. All three major railways in British Columbia pass near the site. The nearest points are Ashcroft, 21.7 km (13.5 mi) to the east, on the Canadian National and Canadian Pacific Railways, and Pavilion, 19.3 km (12 mi) to the northwest, on the British Columbia Railway.

2.2 LAND

The subsurface rights to land necessary for the development of the Hat Creek coalfield are currently held by British Columbia Hydro and Power Authority under coal licence and Crown grant or have been withdrawn as Crown reserve. The Crown reserves were established under Orders-in-Council Nos. 1636, 1319 and 1666. B.C. Hydro currently holds 36 coal licences for a total of 8000 ha (19,760 acres) and one Crown grant of 259 ha (640 acres) in the Upper Hat Creek Valley (Figure 2-2). The reserves for coal, mineral and placer deposits, totalling approximately 51 700 ha (127,800 acres), cover the transportation and water supply corridors and the margins of the Upper Hat Creek Valley (Figure 2-3). These reserves could be reduced appreciably when plans are finalized and access routes for water, roads and transmission lines are confirmed.

The land alienated by the proposed openpit, a 305 m (1000 ft) buffer around the pit, two waste dumps, stockpiles of coal and topsoil,



LOCATION MAP
HAT CREEK

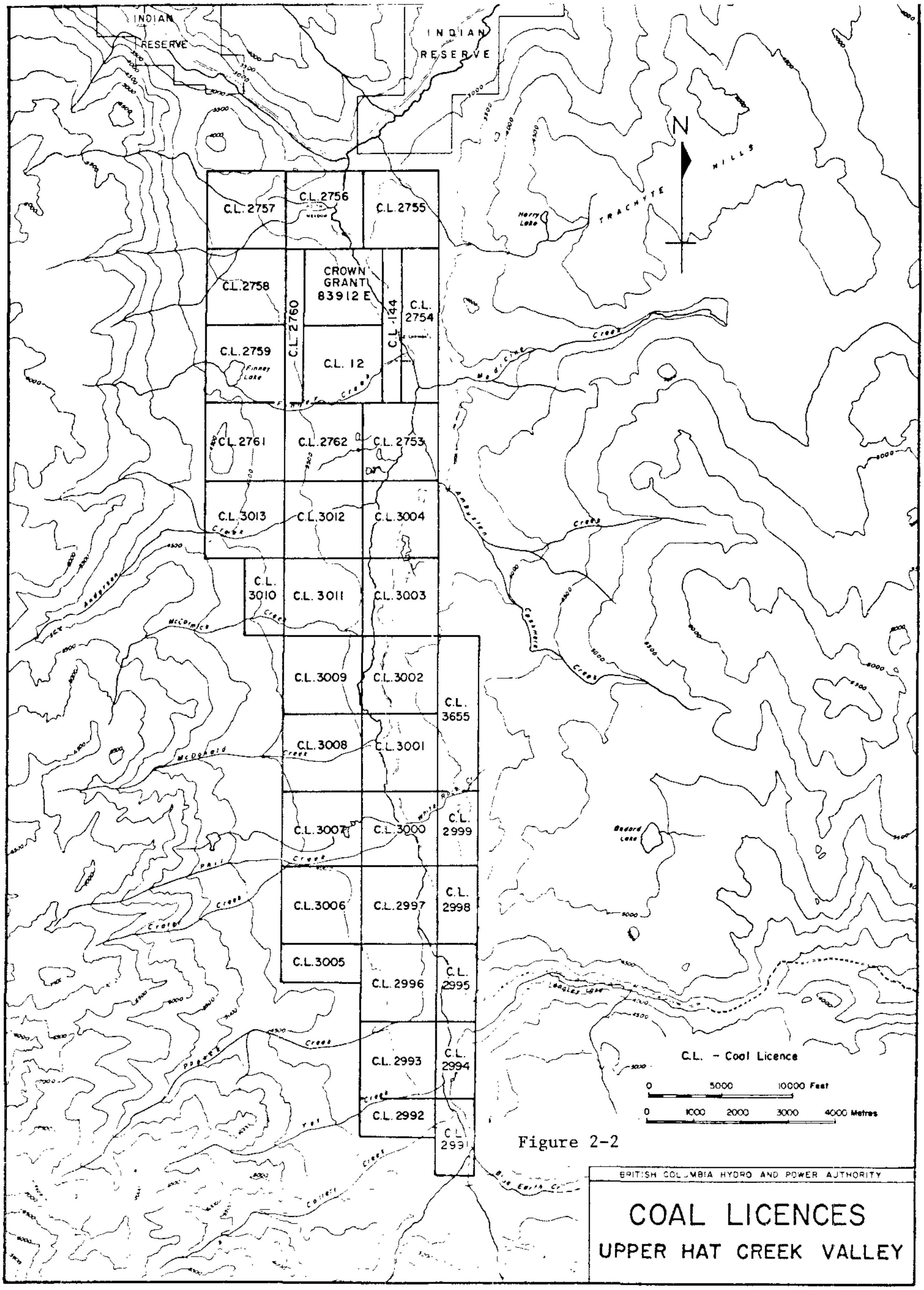
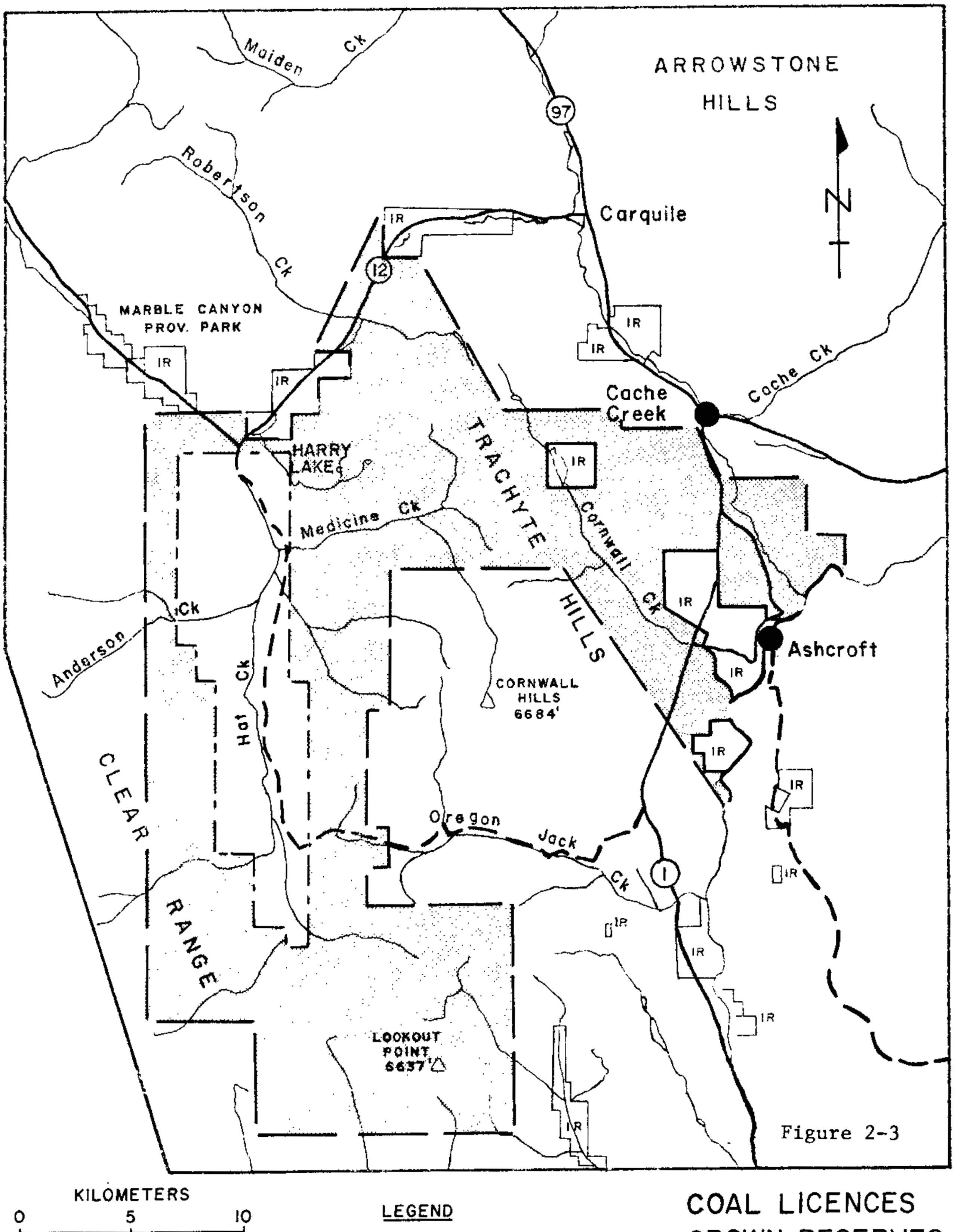

INDIAN RESERVE
INDIAN RESERVE
TRACHYTE HILLS
N
C.L. 2757
C.L. 2756
C.L. 2755
C.L. 2758
CROWN GRANT 83912 E
C.L. 2760
C.L. 144
C.L. 2754
C.L. 2759
C.L. 12
C.L. 2761
C.L. 2762
C.L. 2753
C.L. 3013
C.L. 3012
C.L. 3004
C.L. 3010
C.L. 3011
C.L. 3003
C.L. 3009
C.L. 3002
C.L. 3655
C.L. 3008
C.L. 3001
C.L. 3007
C.L. 3000
C.L. 2999
C.L. 3006
C.L. 2997
C.L. 2998
C.L. 3005
C.L. 2996
C.L. 2995
C.L. 2993
C.L. 2994
C.L. 2992
C.L. 2991
Harry Lake
Finney Lake
Finney Creek
Medicine Creek
Ambusten Creek
Cashmere Creek
Anderson Creek
McCormick Creek
McDonald Creek
White Rock Cr.
Phil Creek
Crater Creek
Bedard Lake
Blue Earth Cr.
Colleys Creek
C.L. - Coal Licence
0 5000 10000 Feet
0 1000 2000 3000 4000 Metres
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
COAL LICENCES
UPPER HAT CREEK VALLEY

Figure 2-2



LEGEND

COAL LICENCE BOUNDARY

CROWN RESERVE BOUNDARY

CROWN RESERVE

COAL LICENCES
CROWN RESERVES
HAT CREEK

2.2 LAND - (Cont'd)

a coal processing plant, reservoirs and diversion canals, internal conveyor systems and a conveyor system to the powerplant is estimated at 3380 ha (8360 acres).[61,46] The proposed powerplant road, airplane landing strip, water line, pumphouse, cooling water reservoir, fly ash dump and bottom ash dump could alienate 930 ha (2290 acres).[32] Therefore it is estimated that the land that could be alienated by the proposed Hat Creek Thermal Project is 4310 ha (10,650 acres). Several thousand hectares of this total would not be disturbed, but would lie within the boundaries of the operating part of the project.

2.3 HISTORY

The Hat Creek deposits are an old discovery; however, the large quantity of inherent clay and clay partings resulted in the failure of earlier attempts to market the coal. The history of coal mining at Hat Creek is summarized as follows:[19,41,23]

1877 - The Hat Creek coal occurrences were first reported by G.M. Dawson of the Geological Survey of Canada.

1925 - Three shallow shafts, two short adits, and seven drill holes were completed.

1933 to 1942 - There was limited production of coal.

1957, 1959 - The property was optioned by Western Power and Development Ltd., a subsidiary of B.C. Electric Co. Ltd.; 15 holes were drilled and a number of trenches excavated.

1974 to 1975 - Coal licences covering most of the Upper Hat Creek Valley were obtained by B.C. Hydro; 35 drill holes were completed in the No. 1 deposit and geological exploration of the remainder of the valley began.

2.3 HISTORY - (Cont'd)

1975 to 1976 - Exploration of the Upper Hat Creek Valley and specifically No. 2 deposit was completed. Mining feasibility studies were undertaken.

1976 to 1978 - Development drilling and geotechnical drilling in the No. 1 deposit were largely completed. Mining feasibility studies and conceptual design studies were completed and are being updated.

2.4 PURPOSE

The geological aspects of the environmental studies for the Hat Creek Thermal Project are described in this report. The terms of reference are listed in Appendix A. The purposes of these studies are as follows:

1. To provide baseline geological information for interpretation of hydrological, geotechnical, agricultural, waste disposal and trace element studies.

2. To provide a summary of the geology as it relates to the total coal resource and to extraction of the resource.

3. To provide an inventory of mineral, rock and petroleum resources and describe how their future exploitation would be affected by the Hat Creek Thermal Project.

4. To describe the potential uses of mine waste products and other mineral, rock and petroleum resources that may be affected by the project.

2.5 SCOPE

The minerals and petroleum evaluation describes the mineral, rock and petroleum resources in addition to the background geological information needed to assess them. Specifically this report examines and summarizes the following:

1. General geology, physiography and slope stability.

2. The reserves and resources of coal in the Upper Hat Creek Valley.

3. The potential for reserves of petroleum, natural gas, salts, aggregate, limestone, claystone, baked claystone, additional coal and coaly waste, base metals, precious metals, rock collecting localities and by-product trace elements.

4. The potential uses of mine by-products and other mineral, rock and petroleum resources that could be affected by the mine.

Unlike many of the impacts from the project, the mineral resource impacts are site specific. Because of this situation mineral resource potential has been examined only for areas within and immediately adjacent to the Crown reserves, coal licences and Crown grant. Therefore this study examines in detail only the resources in the Upper Hat Creek Valley and adjacent areas which could be affected by installations that in practice could not be moved readily.

SECTION 3.0 - METHODOLOGY

This aspect of the environmental study can be conveniently divided into geological and resource evaluation sections.

In the geological section the method of study consisted primarily of geological mapping of surficial deposits and rock outcrops in and adjacent to the Upper Hat Creek Valley. This information has been supplemented with considerable diamond (core), rotary, hammer, and auger drilling. Indirect methods of data collection have involved magnetometer surveys (both ground and airborne), a gravity survey, a very low frequency-electromagnetic (VLF-EM) survey and aerial photographic interpretation; additional geophysical methods were tested, but they provided little additional information. The regional and surficial geological maps are based on mapping by the Geological Survey of Canada.[23,56] Both of these reports by the Geological Survey of Canada have been updated with new information derived from this and other studies related to Hat Creek.[39,27]

The resource evaluation involves a variety of disciplines and a variety of study areas. As a result, literature surveys were undertaken and assumed prime importance in the case of petroleum and saline deposits. Tests were conducted on aggregate, limestone, claystone and by-product ash to determine their suitabilities for a number of uses. The potential for additional coal deposits was examined by literature review, geological mapping and geophysical reconnaissance. After a literature search, one area was established as being a favourable geological environment for base metal deposits. This area, west of Houth Meadows, was examined by geological mapping, supplemented by geochemical and geophysical surveys. Precious metal deposits have not been recorded in the Upper Hat Creek Valley; however, a fossil placer gold property north of the valley made it necessary to examine this site and analyze some drill core from below the Hat Creek coal deposit. A few minor rock and mineral collecting localities were discovered while conducting geological mapping; these were examined. No additional localities were found from the literature survey. The results of trace element studies on Hat Creek coal were examined to identify any intervals with high concentrations of any of 66 elements. These analyses were compared with results from other coalfields to determine if Hat Creek coal contained any anomalous concentrations. In addition the price and demand for various metals were examined where applicable.

SECTION 4.0 - GEOLOGY

4.1 PHYSIOGRAPHY AND SURFICIAL DEPOSITS

The Upper Hat Creek and Thompson River Valleys lie principally within the Thompson Plateau of British Columbia. The extreme western margin of the study area is in the physiographic region defined as the Fraser Plateau.

The surficial geology of the region is illustrated in Figure 4-1. The Thompson River, near Ashcroft, flows through a deeply incised river valley. Fluvial sand, gravel and silt form terraces which rise abruptly from river level at 275 m (900 ft) elevation, to the broad, commonly undulating part of the Thompson Valley above 450 m (1500 ft) elevation (Figure 4-2). The land slopes gently to moderately on the west to the base of the Cornwall and Trachyte Hills where there is an abrupt break in slope and the hills rise steeply to 2050 m (6700 ft). The gently sloping portion of the Thompson Valley is characterized by fluted ground moraine consisting of thick till or thin till over bedrock; the ground moraine is modified in part by esker, kame, and alluvial fan deposits consisting of sand and gravel. In the Thompson Valley, bedrock is commonly exposed on the steep flanks of hills which rise to 325 m (1100 ft) above the upper terrace. On the east side, the slopes rise abruptly from the terraces to the plateau at 1825 to 1975 m (6000 to 6500 ft) elevation. The terraces consist of fluvial sand and gravel and an upper layer of glacial till. Landslides are common along the banks of the Thompson River particularly where till overlies silt[57] (Figure 4-3). These banks become particularly unstable when the silt is saturated by snow melt or flood irrigation.

The Trachyte and Cornwall Hills, west of the Thompson River Valley, are covered by a gravelly veneer which thickens toward the north. Outcrops are generally scarce, but they are locally abundant.

HAT CREEK PROJECT DETAILED ENVIRONMENTAL STUDIES
LEGEND
TALUS, ROCK GLACIER, ROCKSLIDE, LANDSLIDE, EARTHFLOW, COLLUVIAL BLANKET, COLLUVIAL VENEER.
LACUSTRINE PLAIN.
ALLUVIAL FAN.
ALLUVIAL PLAIN, FLOODPLAIN, ALLUVIAL DEPOSITS.
DELTA, RIVER TERRACES, ALLUVIAL TERRACES.
ORGANIC TERRAIN.
OUTWASH PLAIN, KAME TERRACES.
KAMES, ESKER, KAME TERRACES AND ESKERS WITH MELTWATER CHANNELS.
GROUND MORAINE, TILL VENEER, TILL BLANKET.
DRIFT, DRIFT TERRACE, DRIFT VENEER, DRIFT BLANKET, TERRACE SCARPS AND RIVER BANKS, L-LOESS.
ROCK OUTCROP, STEEP BEDROCK, ROCK HUMMOCKS, CIRQUE COMPLEX.
FIGURE 4-1
(based on mapping by J.M. Ryder, 1976)
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
SURFICIAL GEOLOGY
LILLOOET
FRASER RIVER
THOMPSON RIVER
Seton R.
Gaycosh Prov. Park
Kwotlenemo Lake
Chilhil Lake
Cinquefoil Lake
Cinquefoil Creek
Phair Lake
Riley Creek
Fountain Creek
Anderson Creek
McDonald Creek
Pocock Creek
Ambusten Creek
Medicine Creek
Hat Creek
Harry Lake
McLean Lake
Cornwall Creek
Bonaparte River
Barnes Creek
Barnes Lake
Willard Lake
Separating Lake
Nesbit Lake
Bedard Lake
Langley Lake
Blue Earth Creek
Blue Earth Lake
Venables Lake
Oregon Jack Creek
Three Sisters Creek
Colley Creek
Rough Creek
Cold Stream Creek
Pukaist Creek

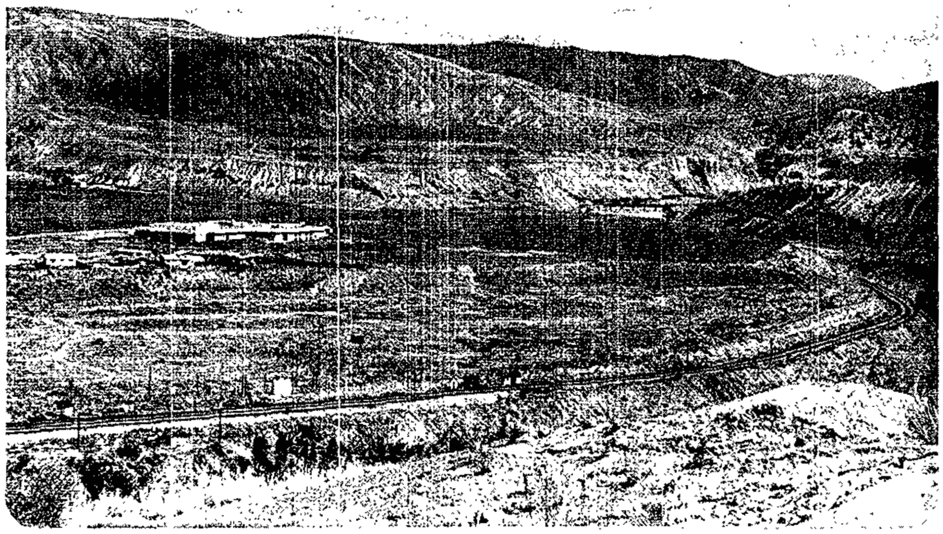


Figure 4-2 Fluvial terraces along the Thompson River with the proposed pumphouse site in the centre of the photo, left of the railway bridge.

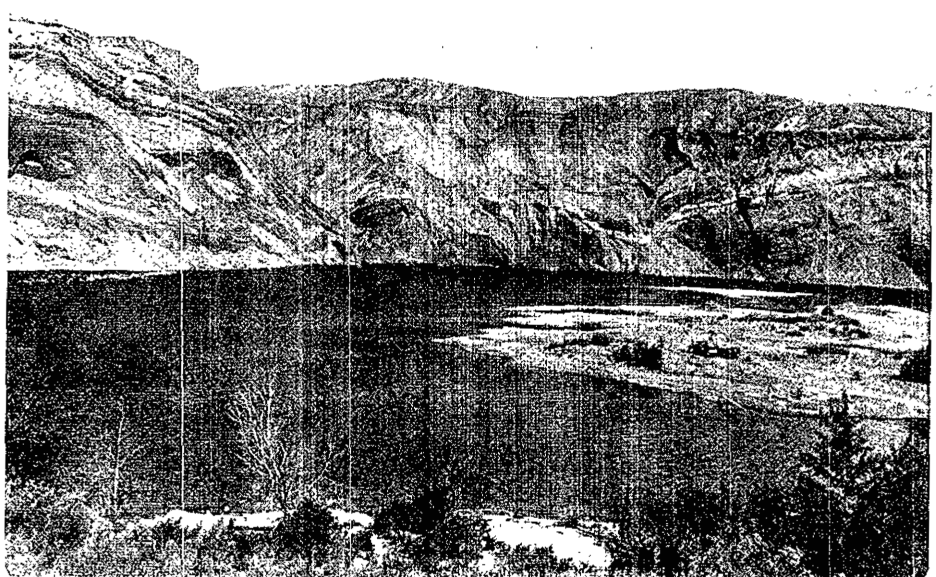


Figure 4-3 Slide area on the Thompson River upstream from the proposed pumphouse site.

4.1 PHYSIOGRAPHY AND SURFICIAL DEPOSITS - (Cont'd)

Bordering the Upper Hat Creek Valley the hills are covered with a veneer of glacial till and there are scattered outcrops.

The Upper Hat Creek Valley is near the centre of the map (Figure 4-1). The valley ranges from 825 to 1250 m (2700 to 4100 ft) in elevation. The valley is flanked by the Clear Range on the west which rises steeply to over 2300 m (7600 ft) and by the Trachyte and Cornwall Hills on the east (Figure 4-4). Surficial deposits in the valley consist of hummocky ground moraine, forming a thick blanket of till, but reduced to a thin veneer on hill tops and steep slopes (Figure 4-5). Locally bedrock is exposed through the veneer. On the east side of the valley, north of Medicine Creek and in the valleys of the larger tributary creeks, there are fluvial and glaciofluvial sands and gravels; some of these deposits are overlain by glacial till. The glacial history of the Upper Hat Creek Valley is complex. This complexity is particularly evident in exposures on the lower reaches of Harry Creek which drains from Harry Lake. In this area an alternation of coarse and fine till, each 2.4 m (8 ft) or more thick, overlies a thick sequence of glaciofluvial deposits consisting of sand and gravel. Loess more than 10 feet thick covers the bench on the east side of the Upper Hat Creek Valley south of Ambusten Creek.

Throughout the Cenozoic history of the Upper Hat Creek Valley, processes of mass wasting have been important. These can be divided into preglacial and postglacial features.

Preglacial lahars or volcanic mudflows at one time covered much of the Upper Hat Creek Valley. These deposits were eroded by glaciers leaving only a few remnants; some are exposed as hoodoos or pinnacles whereas others are covered by the till blanket. A preglacial landslide consisting of granitic, clastic material from boulder to sand size and derived from Mount Martley covers part of the Upper Hat Creek

Valley west of the No. 1 deposit. The slide is as much as 60 m (200 ft) thick. West of Bedard Lake there is a slide of volcanic debris over 60 m (200 ft) thick. These slides are currently stable and are not expected to cause severe problems in slope stability. Potential slip planes of clay or micaceous material in these slides tend to be discontinuous.

There are numerous additional postglacial slides and earthflows in the Upper Hat Creek Valley; all but one of these appears to be currently stable. West of the No. 1 deposit there are inactive slides covering an extensive area between Finney Lake and Houth Meadows. Part of this slide area is still active (Figure 4-6). The number of slide planes in the active slide has not been determined, but there is at least one at 27 m (90 ft) which is associated with bentonitic claystone.[27] The headwall of this slide is characterized by numerous ponds which could be drained and may help to stabilize the slide. The instability of the slide is an important factor in planning the mine. South of the No. 1 deposit there are numerous "sand boils" resembling quicksand as further evidence of the unstable nature of many of the surficial materials. An extensive flow slide 76 m (250 ft) thick, involving overburden and possibly some bedrock descended White Rock Creek and curved down the Hat Creek Valley (Figure 4-7).

There are numerous outcrops on the sides of the valley; however, there are few outcrops near the bottom. A talus slope has formed below volcanic outcrops east of the No. 1 deposit. In the southeast there are bluffs of limestone; limestone outcrops are also numerous along the northern limit of the Upper Hat Creek Valley. On the western margin of the valley outcrops of granitic and volcanic rocks are common.

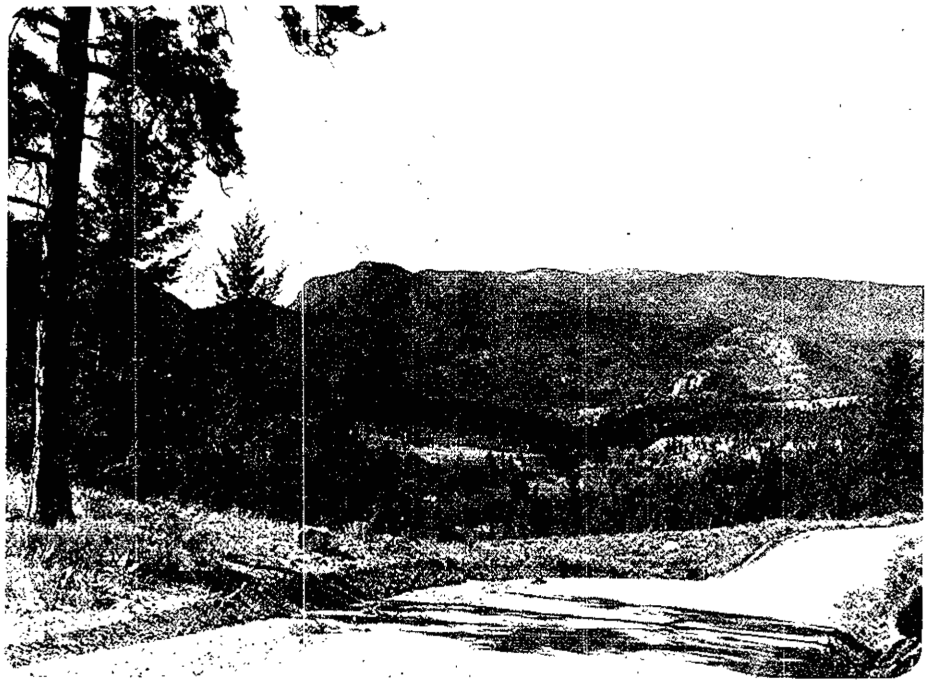


Figure 4-4 The site of the proposed No. 1 openpit is in the foreground with the Clear Range and Marble Canyon in the background.

Figure 4-5 Hummocky ground moraine in the foreground with outcrops of volcanic rocks in the centre of the photograph.

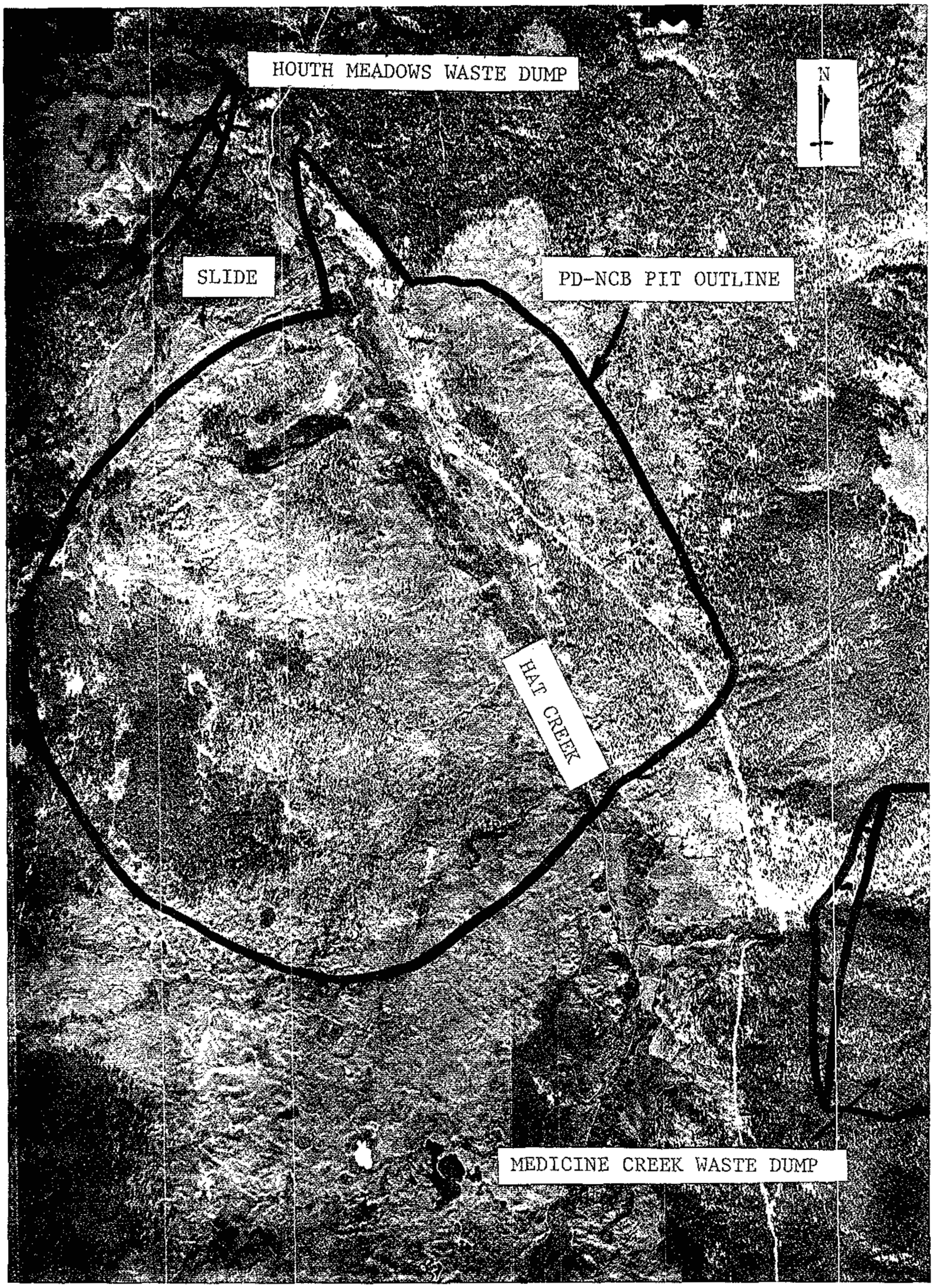


Figure 4-6 Area of the No. 1 Deposit with pit outlines and active slide.

Figure 4-7 Area of the No. 2 Deposit showing an inactive slide.

4.1 PHYSIOGRAPHY AND SURFICIAL DEPOSITS - (Cont'd)

The surficial materials in and around the Hat Creek Valley are very susceptible to gulleying. If the surface layer becomes broken, they also tend to form a fine dust which resists the rooting of plants in the dry climate.

4.2 BEDROCK GEOLOGY

(a) Introduction

There are few exposures of bedrock in the valleys within the mapped area; most of the outcrops are concentrated on steep hillsides or along deeply incised gulleys. As a result the geological evaluation has relied on diamond drilling, aerial photographic interpretation, and geophysics (gravity, ground magnetic, airborne magnetic, VLF-EM surveys and borehole geophysics) to supplement geological mapping.

(b) Stratigraphy

The bedrock consists of a wide variety of rock units as illustrated in Figure 4-8.[23] Paleozoic limestone and metavolcanic rocks of the Cache Creek group form the subcrop in the centre of the area. These rocks generally strike north-northwesterly; although dips are variable, they cluster around 60 degrees southwest. The Paleozoic rocks are locally intruded by peridotite and gabbro. Near Ashcroft, Jurassic sedimentary rocks lie unconformably on these older rocks. The limestone near Marble Canyon has been intruded by the Mount Martley stock, a biotite hornblende granodiorite, of Cretaceous age (Figures 4-8 and 4-9). A nonconformity separates the stock from the overlying Spences Bridge volcanic rocks which consist principally of andesite and dacite. Additional volcanic episodes occurred in the Cenozoic with resulting pyroclastic and flow rocks covering much of the area.

LEGEND

Tertiary

Cenozoic

Miocene

Vesicular basalt, olivine basalt, basalt, andesite

Eocene and/or Miocene

Kamloops Group
basalt, andesite, rhyolite; associated tuff and breccia; lahar

Sandstone, claystone, siltstone, conglomerate and coal (includes Coldwater and Finney Lake Beds plus Hat Creek Coal and Medicine Creek Formations)

Mesozoic

Cretaceous

Spences Bridge Group
andesite, dacite, basalt and rhyolite; tuff, breccia, agglomerate; conglomerate, sandstone, greywacke and arkose

Cretaceous or Jurassic

Granodiorite and quartz diorite

Jurassic

Shale, conglomerate, sandstone, breccia, tuff, siltstone and arenite

Triassic

Nicola Group
basalt, andesite flows, breccias and tuffs; argillite, greywacke and limestone

Triassic or Permian

Pavilion Group
argillite, phyllite, chert, limestone, tuff, greywacke, greenstone and schist

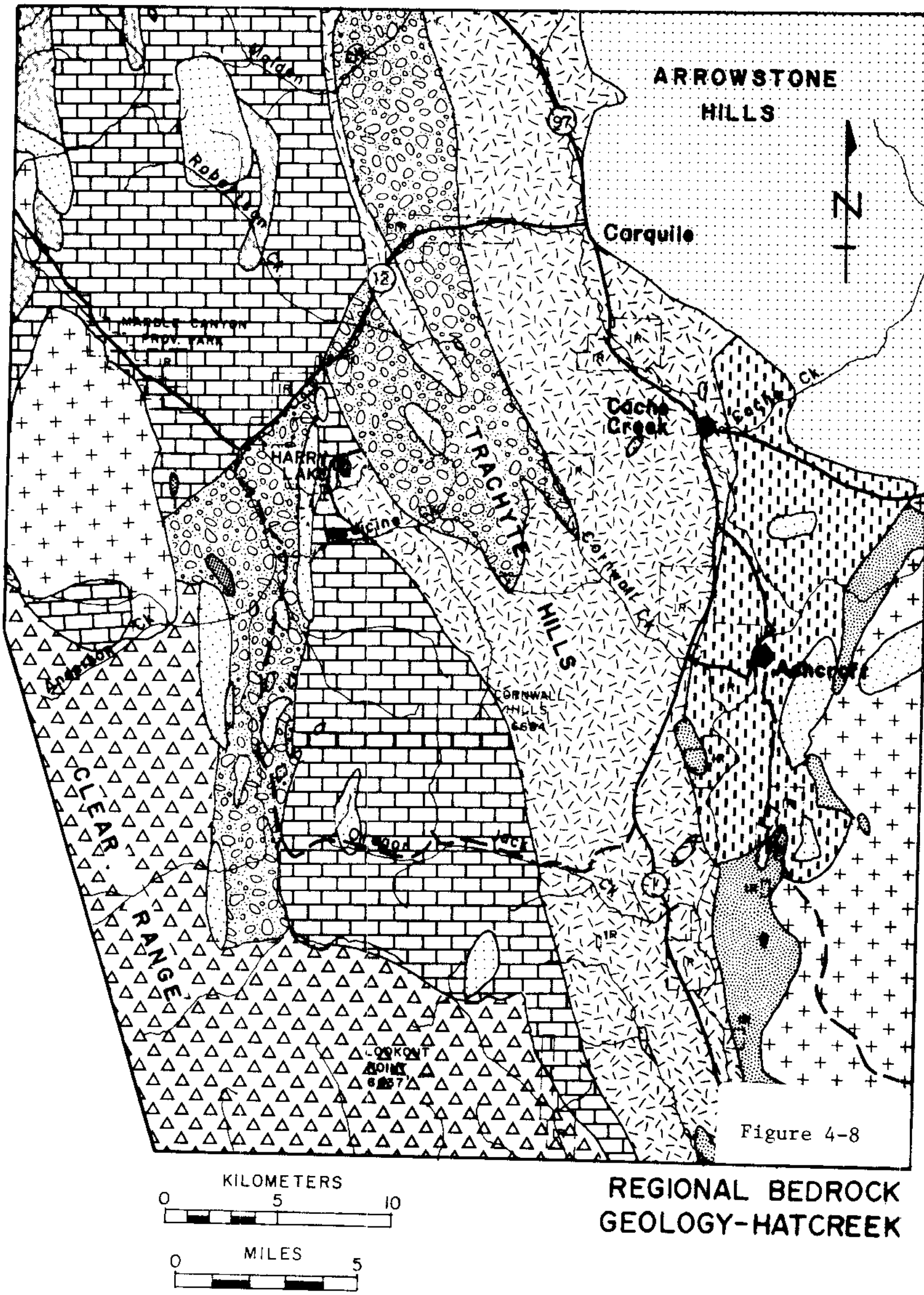
Paleozoic

Permian or Carboniferous

Cache Creek Group
greenstone, chert, argillite, greenschist, quartzite and limestone

Limestone

(based on mapping by Duffell and McTaggart, 1952)



REGIONAL BEDROCK GEOLOGY-HATCREEK

4.2 BEDROCK GEOLOGY - (Cont'd)

The oldest volcanic rocks of these episodes are of Eocene age; they are composed of basalt, dacite and rhyolite of the Kamloops group. The distribution of this unit is very erratic in the Upper Hat Creek Valley. It is exposed on the hills and on the western and eastern flanks of the valley. Sporadic occurrences were also noted in the area south of the Upper Hat Creek Valley. The attitude of bedding is variable throughout the unit. The contact between these lower Kamloops volcanic rocks and the overlying Coldwater beds is faulted wherever it has been found. The clastic sequence of the Kamloops group in the Hat Creek Valley has been divided into the Coldwater beds, the Hat Creek Coal formation, the Medicine Creek formation and the Finney Lake beds.[16] The Coldwater beds consist of sandstone, siltstone, claystone, conglomerate and minor coal which are moderately consolidated to almost unconsolidated. This unit is as much as 1370 m (4500 ft) thick east of the Upper Hat Creek Valley.[31] The Coldwater beds are overlain conformably by the Hat Creek Coal formation which ranges to 490 m (1600 ft) thick. The Hat Creek Coal formation consists mainly of coal with locally thick sections of siltstone, claystone, sandstone and conglomerate; thin partings of siltstone and claystone are common in the coal. It is not certain if there is a paraconformity, a hiatus or if the Medicine Creek formation lies conformably on the Hat Creek Coal formation. The Medicine Creek formation consists of poorly consolidated bentonitic, lacustrine claystone and siltstone. The Medicine Creek formation is overlain by the Finney Lake beds. This unit consists of sandstone and conglomerate at the base and volcanic rocks higher in sequence. The sandstones, for the most part, are well sorted except for scattered, rounded boulders of vesicular volcanic rocks similar to those in the lower part of the Kamloops group. The clastic sequence is overlain by lahar (volcanic mudstone) which is composed of angular to subrounded Kamloops volcanic rocks, lithified primarily by compaction of the sandy clay matrix. These beds are Upper Eocene or later in age and lie unconformably over the coal and claystone sequence; due to the presence of this unconformity it is not known if the beds are definitely part of the Kamloops group or if they are associated with Miocene volcanism. Locally these are small exposures of olivine basalt dykes and flows: these are probably related to extrusions of Miocene plateau basalts to the north.

(c) Coal Geology

Geological exploration in the Upper Hat Creek Valley has sought to determine the most economically and environmentally acceptable coal deposit. The No. 1 deposit was known for many years; however, exploration of the valley located the No. 2 deposit, a large additional reserve of coal.

The No. 1 deposit contains 410 million tonnes (450 million short tons) of thermal coal to 730 m (2400 ft) elevation and 825 million tonnes (910 million short tons) in the whole deposit.[44] Analyses of the heating value for in situ coal in the No. 1 deposit, to its total depth, average 17 477 kJ/kg (7513 Btu/lb); the ash content is 35.41 percent, volatiles 33.52 percent, fixed carbon 30.9 percent and sulphur 0.50 percent on a dry basis (Table 4-1). The equilibrium moisture content is approximately 25 percent.

The No. 1 deposit has been divided into a number of zones and subzones based on variations in the borehole geophysical logs[11] (Figures 4-10, 4-11 and 4-12). In the centre of the deposit the Hat Creek Coal formation consists of four zones designated A through D from the top downward. The A-zone consists of 180 m

TABLE 4-1

HAT CREEK COAL - MEAN PROXIMATE AND SULPHUR ANALYSES*

	Thickness**	Heating Value***	Ash	Volatiles	Fixed Carbon	Sulphur
No. 1 Deposit:						
All zones†	430 (1400)	17 477 (7 513)	35.41	33.52	30.97	0.50
A-zone	180 (600)	14 476 (6 240)	44.21	30.35	26.59	0.71
B-zone	75 (250)	17 463 (7 495)	35.10	32.87	31.84	0.80
C-zone	60-110 (200-350)	13 212 (5 670)	47.22	28.68	22.81	0.45
D-zone	60-110 (200-350)	20 817 (8 934)	25.83	37.13	37.71	0.33
No. 2 Deposit:						
All zones	460+ (1500+)	16 063 (6 906)	39.47	31.26	29.45	0.63

* All analyses are on a dry basis; carbonaceous intervals with above 75 percent ash have been defined as waste and have not been included in these analyses.

** Thicknesses are in meters with equivalent thicknesses in feet given in brackets.

*** Heating values are in kJ/kg with equivalent heating values in Btu/lb within the brackets; ash, volatiles, fixed carbon and sulphur are in percent.

† Analyses for all zones have been summarized over the whole deposit; analyses of individual zones have been summarized to the approximate bottom of one proposed pit, i.e. 650 m (2130 ft) elevation.[62] Analyses for No. 2 deposit are summarized to the base of the drilling.

HAT CREEK PROJECT
DETAILED
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STUDIES

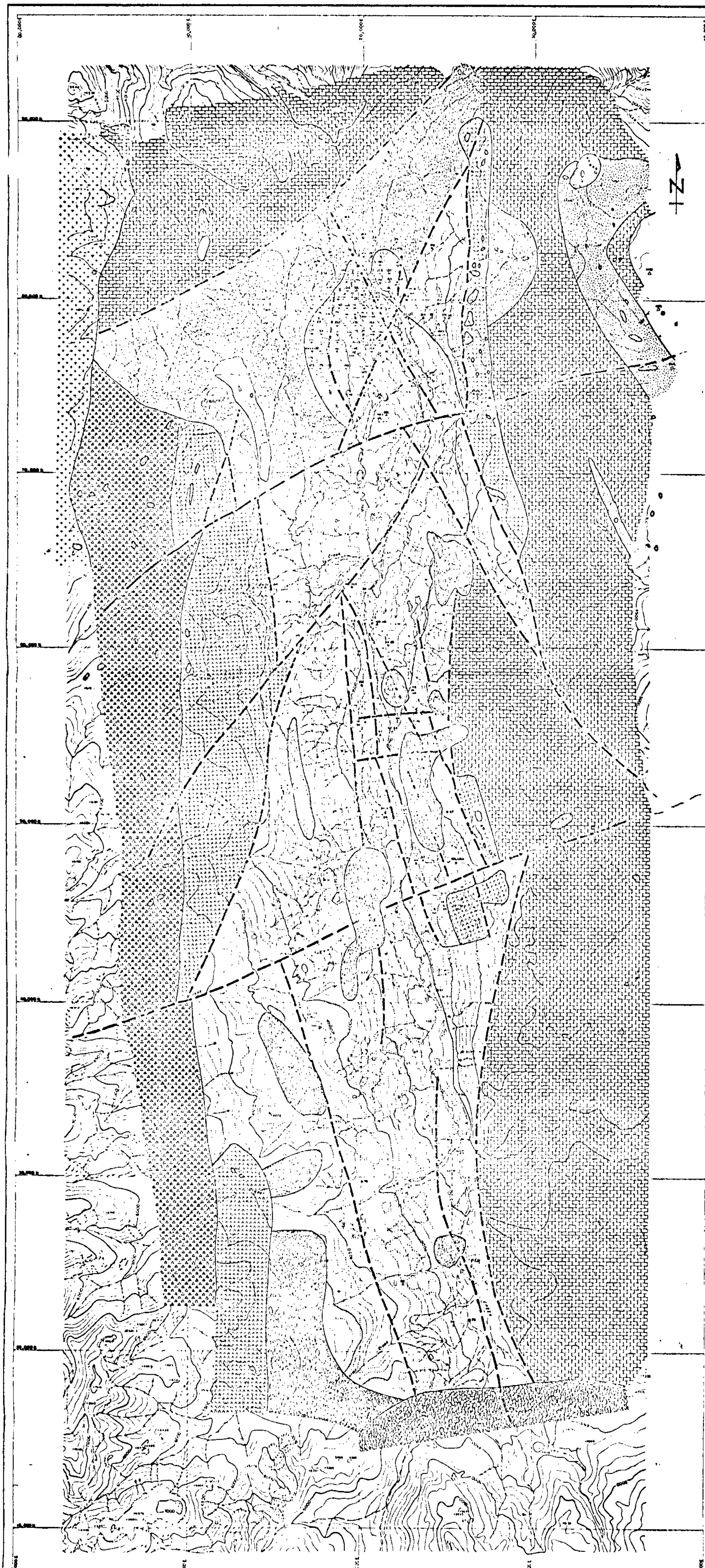


FIGURE 4-9

LEGEND

TERTIARY
MIOCENE

OLIVINE BASALT

MIOCENE OR EOCENE

LAHAR

EOCENE

KAMLOOPS GROUP: MEDICINE CREEK FORMATION:
SILTSTONE, CLAYSTONE

HAT CREEK COAL FORMATION:
COAL (NEAR SURFACE)

COLDWATER BEDS:
SANDSTONE, SILTSTONE, CONGLOMERATE,
MINOR SHALE AND CLAYSTONE

DACITE, VESICULAR BASALT
RHYOLITE, ANDESITE

CENOZOIC

CRETACEOUS AND LATER

UNDIFFERENTIATED VOLCANIC ROCKS

CRETACEOUS

SPENCES BRIDGE GROUP:
ANDESITE, RHYOLITE, BASALT, DACITE

MOUNT MARTLEY STOCK:
GRANODIORITE

MESOZOIC

PERMAIN AND EARLIER

CACHE CREEK GROUP: MARBLE CANYON
FORMATION, LIMESTONE

GREEN STONE

PALEOZOIC

OUTCROPS
CONTRACTS (APPROXIMATE)
FAULTS AND LINEAMENTS (TOPOGRAPHIC AND GEOPHYSICAL)
MAIN ROAD
SECONDARY ROAD
LAKE
CREEK

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

GEOLOGICAL MAP
HAT CREEK VALLEY

SCALE:

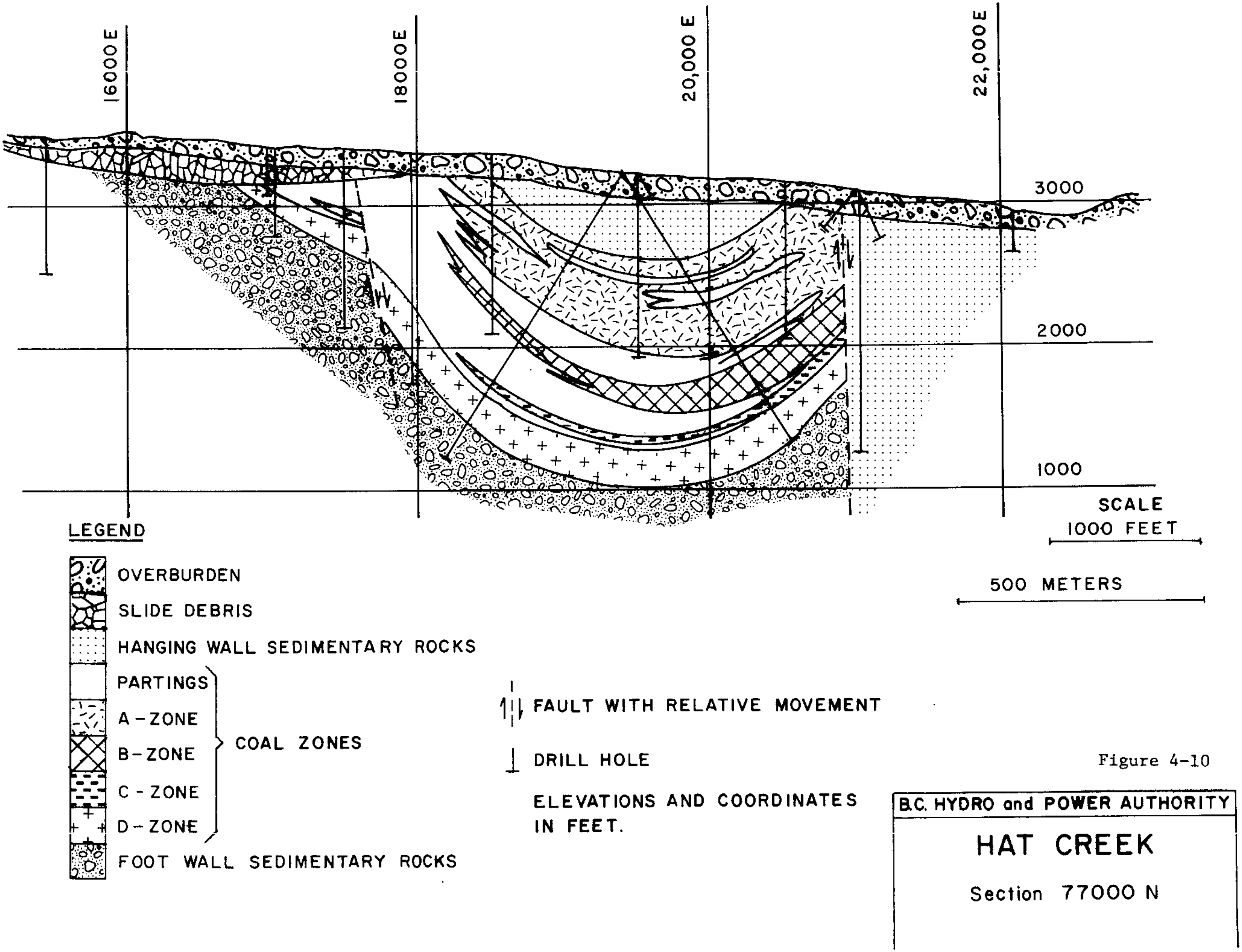
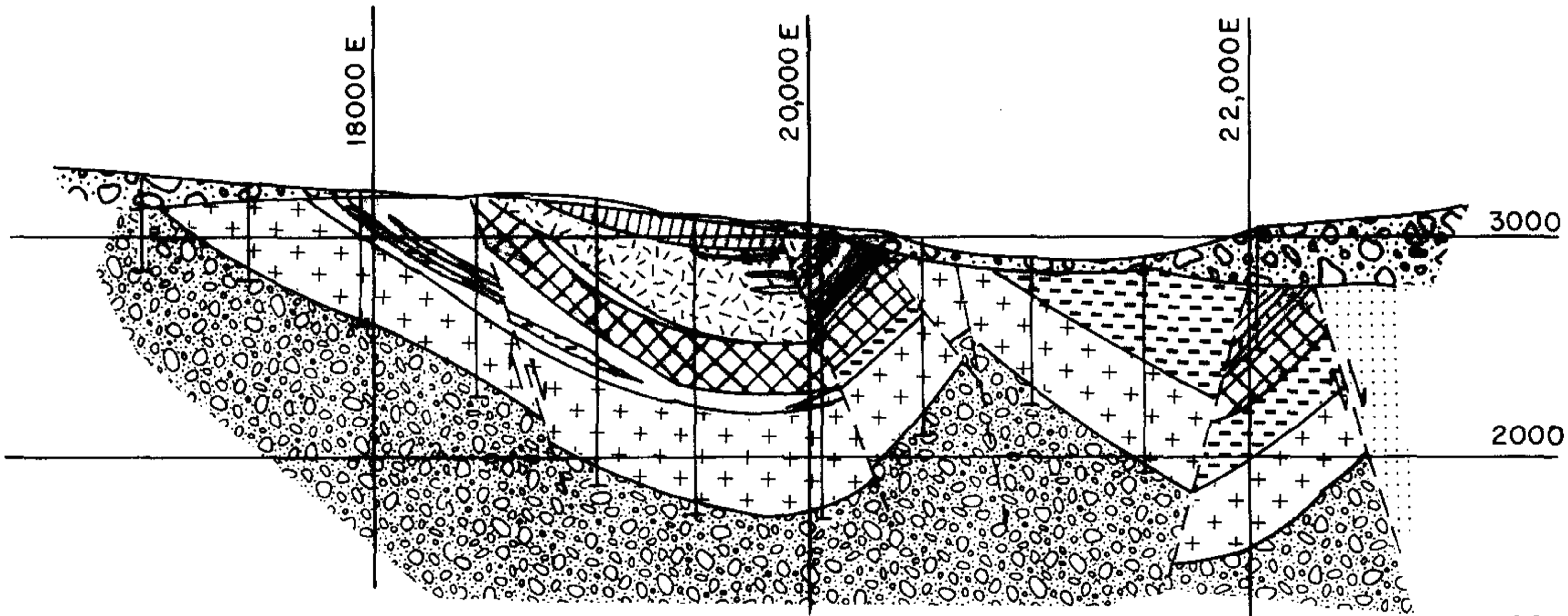

16000E
18000E
20,000 E
22,000E
3000
2000
1000
SCALE
1000 FEET
500 METERS
LEGEND
OVERBURDEN
SLIDE DEBRIS
HANGING WALL SEDIMENTARY ROCKS
PARTINGS
A-ZONE
B-ZONE
C-ZONE
D-ZONE
COAL ZONES
FOOT WALL SEDIMENTARY ROCKS
FAULT WITH RELATIVE MOVEMENT
DRILL HOLE
ELEVATIONS AND COORDINATES IN FEET.
B.C. HYDRO and POWER AUTHORITY
HAT CREEK
Section 77000 N

Figure 4-10



LEGEND

- OVERBURDEN
- BURN ZONE
- PARTINGS
- HANGING WALL SEDIMENTARY ROCKS
- A-ZONE } COAL ZONES
- B-ZONE } COAL ZONES
- C-ZONE } COAL ZONES
- D-ZONE } COAL ZONES
- FOOT WALL SEDIMENTARY ROCKS

FAULT WITH RELATIVE MOVEMENT

DRILL HOLE

ELEVATIONS AND COORDINATES IN FEET

SCALE

1000 FEET

500 METERS

Figure 4-11

B.C. HYDRO and POWER AUTHORITY

HAT CREEK

Section 79500N

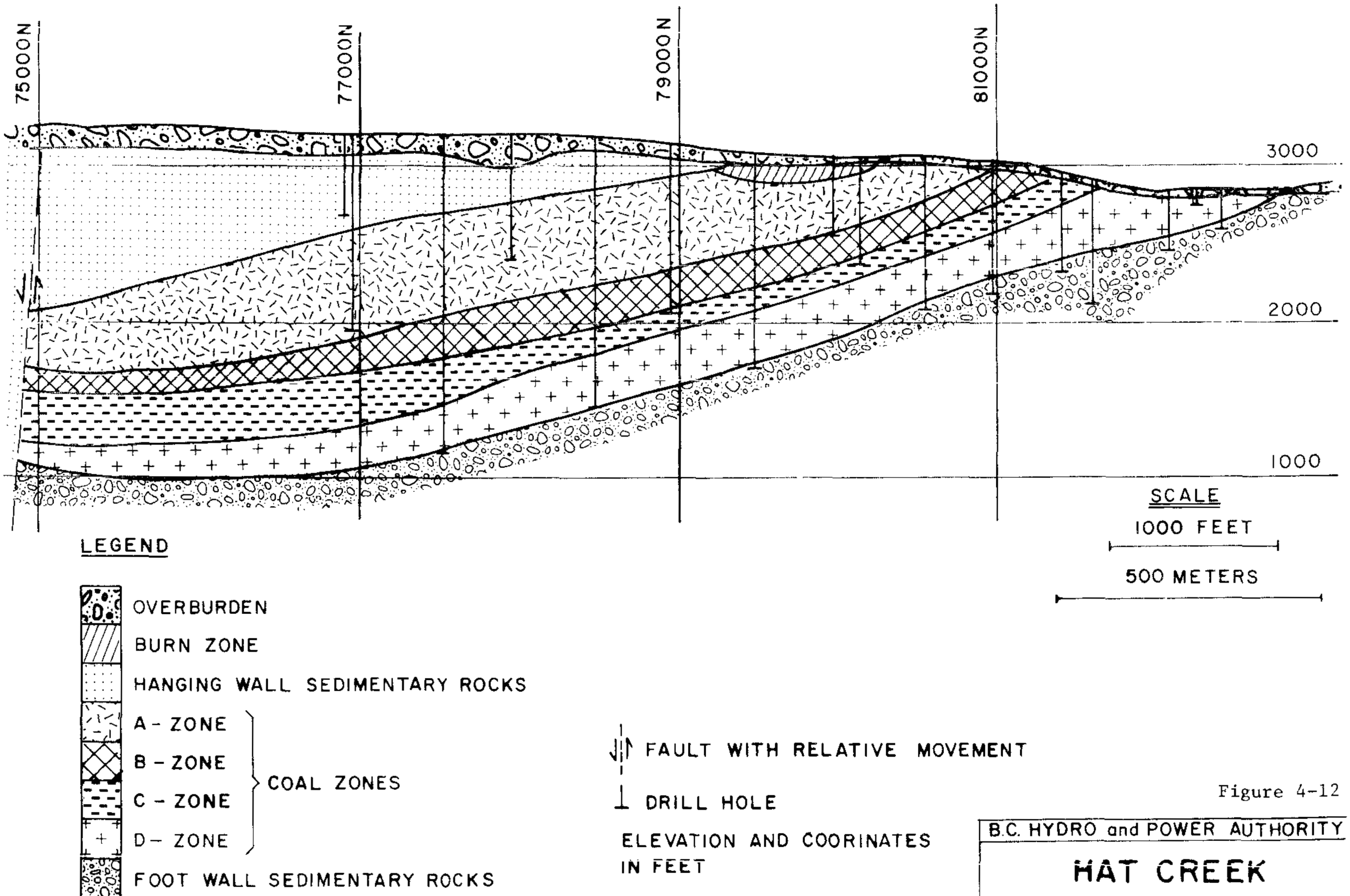


Figure 4-12

B.C. HYDRO and POWER AUTHORITY

HAT CREEK

Section 19500E

4.2 BEDROCK GEOLOGY - (Cont'd)

(600 ft) of interlayered clean coal, clayey coal and clastic rocks; the zone has a large number of partings and many seams with high inherent ash. The base of A-zone is predominantly waste and the zone as a whole consists of approximately 20 percent waste*. Analyses of the coal intervals of A-zone are summarized in Table 4-1. The B-zone is predominantly coal with few thick partings and moderate inherent ash content. The B-zone is approximately 75 m (250 ft) thick. Analyses of coal intervals in B-zone are summarized in Table 4-1. Approximately 10 percent of B-zone is waste. The C-zone is 60 to 100 m (200 to 350 ft) thick. The zone can be subdivided into an upper waste subzone and a lower coal subzone. The waste subzone becomes thicker to the west at the expense of the coal (Figure 4-10). The analyses of the coal intervals in C-zone are summarized in Table 4-1. Approximately 30 percent of C-zone is waste. The D-zone contains the highest grade of coal in the deposit and is the most persistent. The D-zone is from 60 to 110 m (200 to 350 ft) thick. The analyses of the coal intervals in D-zone are summarized in Table 4-1. Approximately 3 percent of D-zone is waste. In all zones the inherent ash and the frequency and thickness of partings increases toward the west (Figure 4-10).

The No. 2 deposit may contain as much as 3100 million tonnes (3400 million short tons) of in situ thermal coal to 610 m (2000 ft) elevation which is the limit of the current drilling (Figures 4-9 and 4-13).[45] Analyses of the coal indicate that the heating values average 16 063 kJ/kg (6906 Btu/lb) with an ash content of 39.47 percent, volatile content of 31.26 percent, fixed

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* Only parts of zones that could be defined have been used in determining the amount of waste in each zone. Therefore some thick waste intervals on the west side of the No. 1 deposit have not been considered.

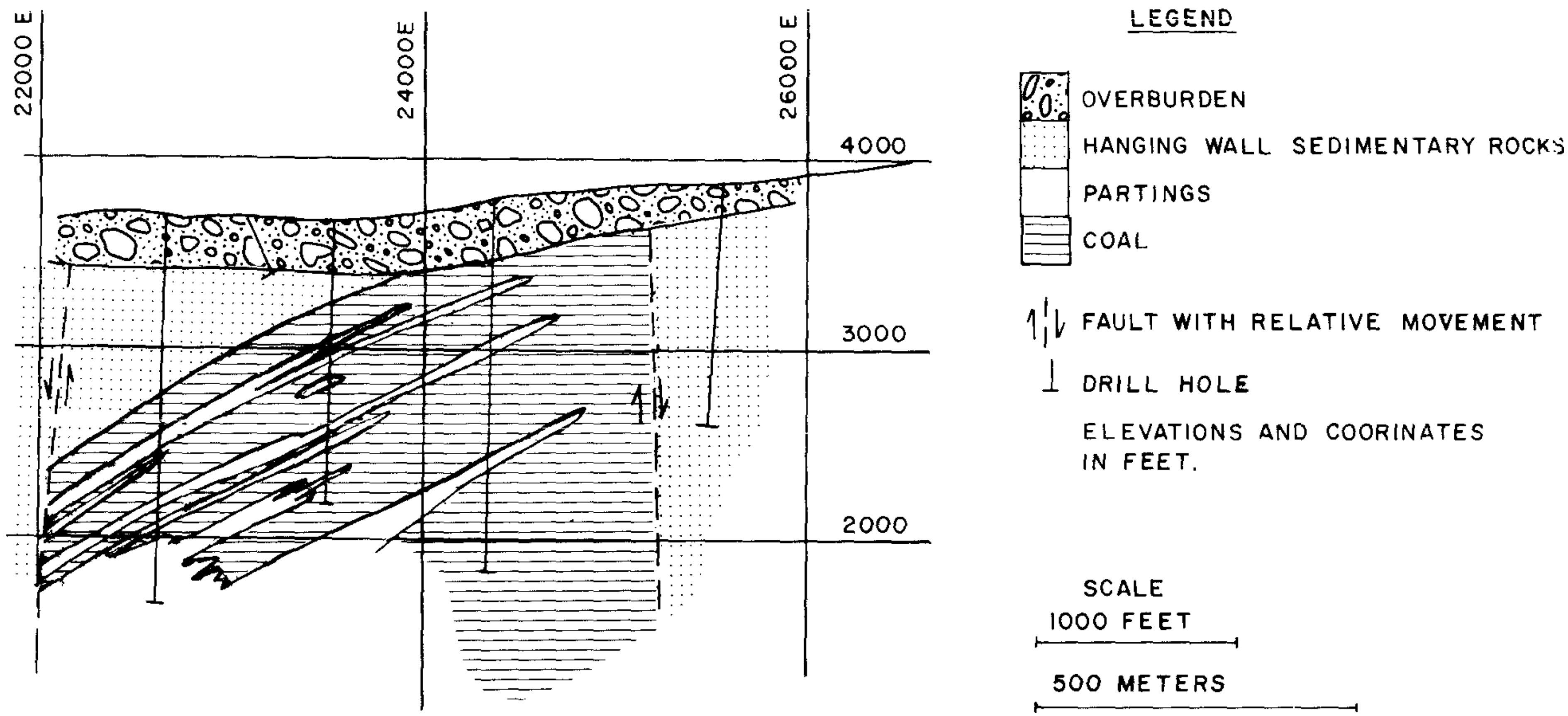


Figure 4-13

B.C. HYDRO and POWER AUTHORITY

HAT CREEK

Section 48000 N

carbon of 29.45 percent and 0.63 percent sulphur on a dry basis (Table 4-1). The equilibrium moisture content is similar to that in the No. 1 deposit.

(d) Structural Geology

Although the geological structures of the No. 1 and No. 2 deposits appear to differ, they are only different parts of the same overall structure of the coal basin. In the No. 1 deposit the geological structure consists of a syncline flanked on the east by a faulted anticline with an additional syncline farther east[38] (Figures 4-10 and 4-11). The locations of Figures 4-10 and 4-11 are illustrated in Figure 4-9. The No. 2 deposit is located on the eastern flank of the principal syncline (Figure 4-13). The geological structure plunges approximately 15 to 20 degrees south (Figure 4-12). The structure is complicated by strike-slip and normal faults. One of the latter faults has truncated the No. 1 deposit to the southeast; the displacement is at least 550 m (1800 ft).

(e) Seismicity

The proposed Hat Creek development is located in the Interior Plateau near the eastern margin of the Coast Range. The former physiographic region, in the area of Hat Creek, is classed as a Zone 1 seismic risk based on the Seismic Zoning Map of Canada (1967).[27] The latter region is classed as Zone 2 seismic risk. Between 1899 and 1974, 10 earthquakes of Modified Mercalli Intensity II or more have been felt at the site. The largest intensity was 0.02 g; this effect resulted from a 1946 earthquake of magnitude 7.3, with its epicenter in the Georgia Strait near Powell River.

4.2 BEDROCK GEOLOGY - (Cont'd)

None of the faults in the Hat Creek area are known to be active. The nearest fault where significant post-Pleistocene movement has been recorded is the Yalakom Fault zone, a branch of the Fraser fault system extending northwestward from Lillooet. A deep-seated displacement measuring 5.0 on the Richter scale was recorded near Relay Mountain in 1926. The main Fraser River fault system is considered to have been inactive since the Tertiary.

Based on the limited data available, the Dominion Observatory in Victoria has concluded that the maximum acceleration of an earthquake that would probably occur with a return period of 100 years is 0.017 g. It is concluded from this data that the Hat Creek area is subject to minor seismic risk.

SECTION 5.0 - RESOURCE EVALUATION

5.1 INTRODUCTION

This Section summarizes the evaluation of rock, mineral and petroleum resources of the Upper Hat Creek Valley and the Crown reserve associated with the Hat Creek Thermal Project. Only directly affected resources are examined because they are the only resources sterilized or enhanced by the project. In addition some by-products result from mining; these are examined as raw materials for other subsidiary industries. The purposes of the evaluation are to locate any natural resources and determine their potential for utilization with and without the presence of a mine and thermal plant at Hat Creek. The program involved appraisal of the following resources:

1. Petroleum and natural gas.
2. Saline deposits.
3. Aggregate deposits.
4. Limestone deposits.
5. Clay deposits.
6. Baked claystone deposits.
7. Additional coal deposits and by-product coaly waste.
8. Base metal deposits.
9. Precious metal deposits.
10. Rock and mineral collecting localities.
11. By-product trace elements.

To evaluate the geological resources of the Hat Creek region a suitable methodology had to be developed. This methodology is illustrated schematically in Figure 5-1. Eleven potential resources were initially identified based on specific evidence of geological potential or on the presence of a promising geological environment. Geological

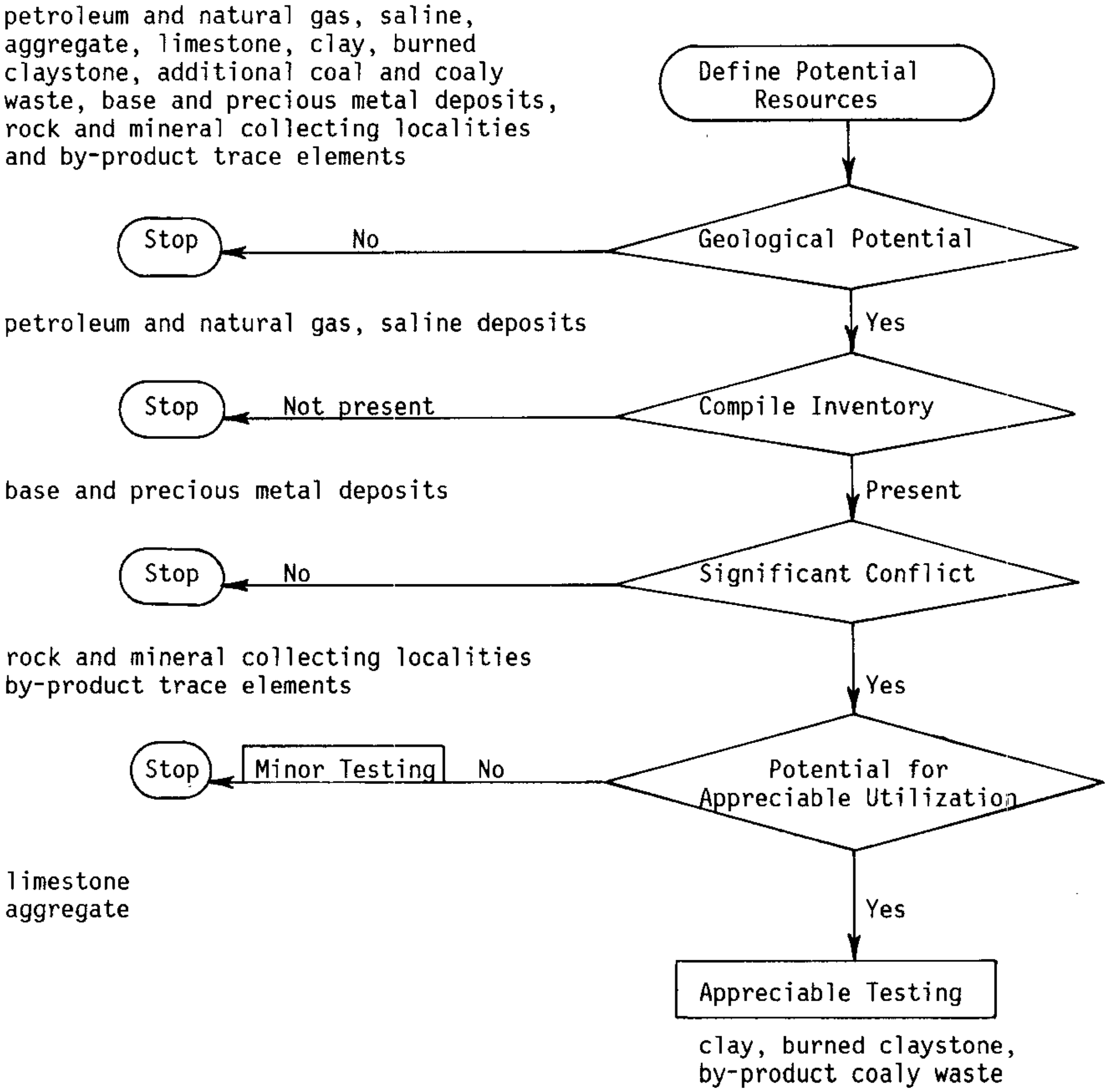


FIGURE 5-1

SCHEMATIC REPRESENTATION OF THE METHODOLOGY OF RESOURCE EVALUATION

5.1 INTRODUCTION - (Cont'd)

mapping indicated that there was no potential for saline deposits; mapping and drilling provided no evidence of petroleum or natural gas deposits. For the remaining potential resources the geological conditions were favourable and an inventory was collected. Based on this compilation it was concluded that there are no significant deposits of base metals or precious metals within the area of concern. If a resource was found the effect of the project on the resource was identified as significant or not significant. For by-product trace elements from the mine and for rock and mineral collecting localities the effects were regarded as not significant; therefore the resource is described only briefly. For the remaining resources the effects are significant. Therefore the properties and uses of the material were determined and the present situation, future situation without the project and future situation with the project are described. Other factors that influenced the degree to which a resource was examined included its scarcity in the area, economic value, and the location and ease with which a facility could be moved if it conflicted with potential utilization of the resource.

5.2 PETROLEUM AND NATURAL GAS

Some sedimentary rocks serve as source beds or reservoir rocks for petroleum. Intermontane sedimentary basins, such as the Hat Creek basin, occur throughout western North America and some of these contain petroleum resources. These relationships have necessitated a review of the Upper Hat Creek Valley as a potential source of petroleum and natural gas.

The methods employed in evaluating the potential for petroleum were a literature survey, observation of gases escaping from drill holes and logging of diamond drill cores.

5.2 PETROLEUM AND NATURAL GAS - (Cont'd)

Most petroleum and natural gas deposits are associated with marine or brackish water, lacustrine, sedimentary rocks. The Hat Creek sedimentary rocks are continental; there is no evidence that the water was brackish. One of the most famous lacustrine oil deposits occurs in the Green River formation of adjoining parts of Wyoming, Colorado and Utah.[24] These deposits are oil shales which have both brackish and fresh water phases; it is not clear which of these phases gave rise to the petroleum; therefore similar deposits could be postulated for the Upper Hat Creek Valley. However, in general, biological environments promoting the formation of coal do not favour the formation of petroleum.[34]

Petroleum deposits are associated with brown shales or sandstones. The brown colouration is due to an oil coating on the mineral grains; these rocks have a distinctive odor when struck with a hammer. The claystones and sandstones from the Upper Hat Creek Valley are grey (black if carbonaceous) and have no odor when struck indicating that petroleum is not present in the cores.

A gas has been seen bubbling from some drill holes once drilling has ceased. Although it has not been tested it is expected that at least some of the gas is methane. This escape stops soon after drilling has ceased. Such methane occurrences are common in coal sequences. No abnormal gas pressures have been encountered. These observations indicate that there is no appreciable natural gas in the areas drilled.

Investigation of areas outside the Upper Hat Creek Valley did not locate any favourable sites for petroleum exploration. The valley at the headwaters of Medicine Creek contains rocks similar to those underlying the coal sequence in the Hat Creek Valley. One drill hole penetrated a short distance into these rocks; no evidence of petroleum

5.2 PETROLEUM AND NATURAL GAS - (Cont'd)

was encountered. The petroleum potential between Medicine Creek, the proposed Thompson River pumping station and the powerplant is low because the area is underlain by Paleozoic metasedimentary and metavolcanic rocks which are unlikely reservoir or source rocks for petroleum or natural gas.

There has been considerable information collected on the potential for petroleum and natural gas deposits at Hat Creek as a result of coal exploration. No evidence of petroleum or natural gas deposits has been found.

5.3 SALINE DEPOSITS

Epsomite ($MgSO_4.7H_2O$), the natural form of Epsom salts, comprises the only significant saline deposits in the area. These deposits are designated Basque Nos. 1 to 4 and they are located in the Venables Valley, near the southern limit of the Crown reserve[23] (Figure 5-2). The deposits were last mined in 1942.[29] Because the deposits are outside the reserve they should not be affected by the proposed Hat Creek Development.

Initially a literature survey of the region was undertaken and the only saline deposits recorded are those listed above. As a result no further investigation is considered necessary.

5.4 AGGREGATE DEPOSITS

(a) Introduction

Aggregate is plentiful in British Columbia. Therefore to be useful it must be found in the area where it is required. Deposits in the Crown reserve are located in the eastern part of the No. 1 deposit and south of White Rock Creek in the Upper Hat

5.4 AGGREGATE DEPOSITS - (Cont'd)

Creek Valley, on the upper benches of the Thompson Valley and along the Thompson River. Other deposits are located near Pavilion Lake and on Bonaparte Indian Reserve No. 2. The deposits are located in alluvial, fluvial or glaciofluvial beds as illustrated in Figure 4-1.

The method and extent of the examination of aggregate was related to the proximity of the deposits to proposed fixed installations for the Hat Creek development. The deposits within the proposed openpit were mapped, analyzed and surveyed in the literature; information was also obtained from the Department of Highways. Information concerning the deposits on Boston Flats, south of Cache Creek, was obtained by literature research and by discussions with the Department of Highways. Because quarries are site specific and because of the large quantity of sand and gravel found in the Thompson Valley, no additional work was undertaken.

The analyses of the aggregate deposits were conducted by Thurber Consultants Ltd. using the procedures recommended by the American Society for Testing and Materials (ASTM) as designated in Table 5-1.[63]

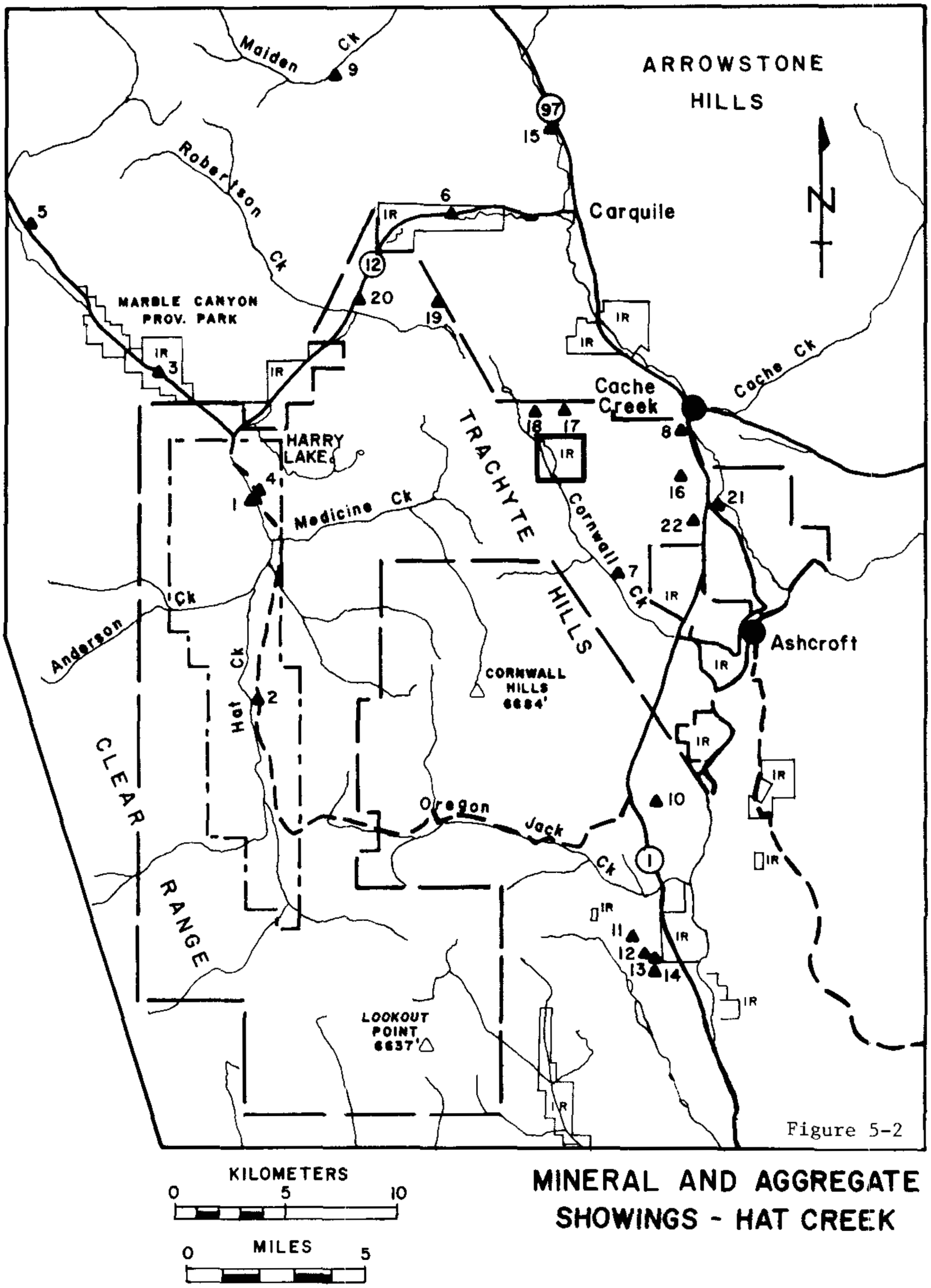
TABLE 5-1

ASTM TESTS FOR AGGREGATE

	Designation for ASTM Test
Grain Size Analysis	C136
Petrographic Examination	C295
Soundness Test	C 88
Abrasion Test	C131, C535
Unit Weight	C 29
Organic Impurities	C 40
Specific Gravity Absorption	C127, C128

LEGEND

Number	Name (product)
1.	Hat Creek No. 1 Deposit (coal)
2.	Hat Creek No. 2 Deposit (coal)
3.	Steel Brothers Canada Limited Quarry (limestone)
4.	Upper Hat Creek Quarry (gravel)
5.	Pavilion Lake Quarry (gravel)
6.	Lower Hat Creek Quarry (gravel)
7.	Cornwall (chromium)
8.	Cache Creek (chromium)
9.	AV (gold)
10.	Red Hill (copper, silver)
11.	Basque 1 (epsomite)
12.	Basque 2 (epsomite)
13.	Basque 3 (epsomite)
14.	Basque 4 (epsomite)
15.	Maggie Mine (copper, molybdenum, silver)
16.	Midas (chromium)
17.	McLean (unknown)
18.	Joe (unknown)
19.	Milk (unknown)
20.	R (unknown)
21.	Boston Flats No. 1 (gravel)
22.	Boston Flats No. 2 (sand)
——— ——	Boundary of coal reserve
——— - ——	Boundary of coal licence



MINERAL AND AGGREGATE SHOWINGS - HAT CREEK

5.4 AGGREGATE DEPOSITS - (Cont'd)

(b) *Inventory*

Five active aggregate quarries are located in the Hat Creek area. Quarries are located in the Upper Hat Creek Valley at the site of the No. 1 coal deposit, near Pavilion Lake, on Bonaparte Indian Reserve No. 2 and on Boston Flats (two deposits) as illustrated in Figure 5-2. The quarry at the site of the No. 1 coal deposit would be most seriously affected by a mine and powerplant at Hat Creek. At this site, bluffs of sand and gravel over 30 m (100 ft) high are developed along the east side of Upper Hat Creek and in the lower reaches of Harry Creek. Toward the east and south, the bench consists of more than 12 m (40 ft) of till overlying sand and gravel. Three horizons of till can be distinguished, one of which contains boulders as much as 1 m (3 ft) in diameter. Additional aggregate deposits of undetermined extent have been found south of White Rock Creek.

Four samples of aggregate were taken to serve as a guide in determining the size distribution and other engineering properties; they are not necessarily representative of the total deposit, but provide a general estimate of the characteristics of the aggregate. The samples were collected from the bench on the east side of the No. 1 deposit; two samples were collected from the gravel quarry (Figure 5-2), one was collected from a site near the Hat Creek bridge, north of the No. 1 deposit (Figure 4-9) and the fourth was collected from the banks of Harry Creek which flows from Harry Lake (Figure 4-9). The results of sieve analyses conducted at the Hat Creek Site on the raw samples are summarized in Table 5-2. These analyses were undertaken to determine which samples should be tested further.

Crushing would undoubtedly increase the finer sized fractions; however with screening and washing it is expected an

TABLE 5-2

SIEVE ANALYSIS OF HAT CREEK AGGREGATE

<table>
<tr><th rowspan="2">Sieve Sizes</th><th colspan="2">Hat Creek Bridge</th><th colspan="2">Harry Creek</th><th colspan="2">Upper Gravel Quarry</th><th colspan="2">Lower Gravel Quarry</th></tr>
<tr><th>Weight(g)</th><th>Percent</th><th>Weight(g)</th><th>Percent</th><th>Weight(g)</th><th>Percent</th><th>Weight(g)</th><th>Percent</th></tr>
<tr><td>+3/4"</td><td>403.9</td><td>9.4</td><td>719.8</td><td>12.4</td><td>1839.7</td><td>21.9</td><td>2451.4</td><td>31.2</td></tr>
<tr><td>3/4" x 3/8"</td><td>364.2</td><td>8.5</td><td>936.5</td><td>16.2</td><td>837.9</td><td>9.9</td><td>1630.0</td><td>20.7</td></tr>
<tr><td>3/8" x .265"</td><td>188.4</td><td>4.4</td><td>518.6</td><td>8.9</td><td>481.5</td><td>5.7</td><td>614.5</td><td>7.8</td></tr>
<tr><td>.265" x #6</td><td>429.7</td><td>10.0</td><td>1080.9</td><td>18.7</td><td>970.5</td><td>11.5</td><td>1083.7</td><td>13.8</td></tr>
<tr><td>#6 x #30</td><td>1429.7</td><td>33.2</td><td>2185.6</td><td>37.7</td><td>3420.5</td><td>40.6</td><td>1650.1</td><td>21.0</td></tr>
<tr><td>#30 x #60</td><td>900.6</td><td>21.0</td><td>237.4</td><td>4.1</td><td>743.3</td><td>8.8</td><td>309.6</td><td>3.9</td></tr>
<tr><td>#60 x #100</td><td rowspan="2">463.6</td><td rowspan="2">10.8</td><td rowspan="2">82.0</td><td rowspan="2">1.4</td><td>74.7</td><td>0.9</td><td>60.6</td><td>0.8</td></tr>
<tr><td>#100 x #200</td><td>33.8</td><td>0.4</td><td>34.8</td><td>0.4</td></tr>
<tr><td>-#200</td><td>118.1</td><td>2.7</td><td>34.9</td><td>0.6</td><td>23.6</td><td>0.3</td><td>35.2</td><td>0.4</td></tr>
<tr><td>Total</td><td>4298.2</td><td>100.0</td><td>5795.7</td><td>100.0</td><td>8425.5</td><td>100.0</td><td>7869.9</td><td>100.0</td></tr>
</table>

acceptably sized product could be obtained for road aggregate or building construction, although no data is available on crushing tests.

In addition to the sieve analyses other tests were conducted on two samples; one sample is from the Hat Creek gravel quarry and the other is from the Hat Creek bridge site. The sample from the quarry represents typical aggregate whereas the sample from the bridge represents the sandy materials from this site. The following tests and measurements were conducted on these materials: grain size analysis, petrographic examination, Los Angeles abrasion test, specific gravity and absorption, soundness, unit weight and organic impurities. A summary of the results is described in Tables 5-3a and 5-3b.

The petrographic analysis indicates that the aggregate samples consist of fragments of greenstone and quartzite with lesser granite, gneiss (more probably foliated granodiorite from Mount Martley), schist, claystone, limestone, hornfels, till and welded tuff. Fragments of claystone, till or welded tuff should not be permitted in the aggregate in significant quantities.

The samples are acceptable for coarse aggregate although some care must be taken to ensure that the specific gravity and absorption meet specifications. For fine aggregate the samples contain a high percentage of organic impurities. All other properties fall within the recommended limits for most uses.

(c) Present Situation

Of the five quarries in the Crown reserves and surrounding area the only quarries that may be directly affected by the project are the gravel quarry in the Upper Hat Creek Valley

TABLE 5-3a

TESTS FOR COARSE AGGREGATE

	Clay and Friable Particles(%)	Chert(%) (2.40 Sp. Gr.)	Clay and Chert(%)	200 mesh(%) (75 µm)	Coal(%)	L.A. Abrasion(%)	Soundness(%) ($MgSO_4$)	Specific Gravity	Absorption	Organic Impurities	Unit Weight (pcf)
maximum* allowed	5-10	5-8	7-10	1.0**	0.5	50	18			Plate 3	
Hat Creek results	----------------	low	----------------	0.3-2.7	low	18.0-19.3	5.65-7.43	2.58-2.59	1.7-1.9	Plate 1	120.2-121.4

TABLE 5-3b

TESTS FOR FINE AGGREGATE

	Clay and Friable Particles(%)	Chert(%) (2.40 Sp. Gr.)	Clay and Chert(%)	200 mesh(%) (75 µm)	Coal(%)	L.A. Abrasion(%)	Soundness(%) ($MgSO_4$)	Specific Gravity	Absorption	Organic Impurities	Unit Weight (pcf)
maximum % allowed	3			3-5	0.5-0.1		15	2.6-2.9		Plate 3	
Hat Creek results	----------------	low	----------------	0.3-2.7	low		7.37-10.95	2.69-2.73	3.7-4.0	Plate 3 to 5	

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* The allowable value may be indicated as a range because of the range of uses.

** 1.5 if crushing has increased the fines.

and the sand quarry on Boston Flats. The two quarries produce approximately 15 000 tonnes (16 000 short tons) of aggregate per year. Approximately 1100 tonnes (1200 short tons) of sand are used on roads each winter to prevent skidding. The remainder is aggregate from the gravel quarry which is used for road construction and maintenance. As a result the Department of Highways is the largest consumer of aggregate in the area.

The three remaining quarries meet local demands. The quarry at Pavilion Lake provides aggregate for road maintenance on Highway 12. The Department of Highways uses the quarry on the Bonaparte Indian Reserve No. 2 to repair nearby parts of Highways 12 and 97. It is necessary for the Department of Highways to maintain a number of quarries scattered over the area in order to reduce transportation costs. The gravel quarry at Boston Flats provides aggregate for roads in Cache Creek. Aggregate for building construction is obtained from a quarry approximately 3.2 km (2 mi) east of Ashcroft, outside the Crown reserve.

Appreciable unexploited aggregate deposits of undetermined size are located within the Upper Hat Creek and Thompson River valleys. In the Upper Hat Creek Valley, approximately 600 m (2000 ft) south of White Rock Creek, drilling has encountered an aggregate deposit which is approximately 18 m (60 ft) thick and of unknown extent. Alluvial deposits that constitute the river terraces, alluvial fans and related geomorphic features could provide additional large quantities of aggregate for developments in the Thompson Valley (Figure 4-1).

(d) Future Situation without the Project

It is expected that operation of the Department of Highways' quarry in the Upper Hat Creek Valley would continue without the Hat Creek Thermal Project. However, the amount that is excavated should decrease from recent levels because of the completion of improvements to the Upper Hat Creek Valley road. The amount of aggregate needed for repairing Highway 12 should not change appreciably. Similarly the quantity of sand required for sanding the highway near Cache Creek should not change.

Additional demand for aggregate in the Thompson Valley could be expected with increased demand for housing and services in Cache Creek and Ashcroft should construction begin on a number of projects which are currently deferred. These ventures are the development of the J-A and Valley Copper deposits in the Highland Valley and development of the Maggie Mine in the Bonaparte Valley; in addition studies have been conducted for a copper smelter at Clinton or in the Highland Valley. None of these projects are currently attractive; however this situation could change with an increase in the price of copper. Any of these projects could create a need for increased housing and other facilities at Cache Creek or Ashcroft. The result would be an appreciable increase in the demand for aggregate although no estimate of quantities is available.

(e) Future Situation with the Project

The proposed Hat Creek thermal development would have a number of important effects on the aggregate deposits in the area. These effects can be summarized as follows:

1. Some aggregate resources, notably those forming part of the east bench at Hat Creek and some deposits on Boston Flats, could be sterilized by the project.

2. Some aggregate would be excavated in digging the pit; this material could be stockpiled.

3. Some of the aggregate that would be excavated could be used for on-site facilities. Similarly some of the aggregate from Boston Flats could be used for construction and drainage associated with the proposed water supply system, road and air strip.

Only a small part of the available aggregate in the area would be affected by the project. It is estimated that within the east bench at Hat Creek there is approximately 645 million tonnes (710 million short tons) of ungraded aggregate. Of these reserves approximately 200 million tonnes (220 million short tons) would be mined based on the proposed PD-NCB pit plan. Only about 110 to 115 million tonnes (120 to 125 million short tons) would be needed for the mine, powerplant and offsite facilities. It is expected that the mine and powerplant would become tourist attractions thereby increasing the use of the Upper Hat Creek Valley road; the increased usage would necessitate paving the road. The result would be an initial increase then a substantial decrease below current levels because less aggregate would be required for maintenance. Additional aggregate would be required from Boston Flats to construct the eastern part of the proposed access road, water pipeline, pumphouse and air strip; a small quantity of aggregate at Boston Flats could also be sterilized by these facilities. The demand for housing at Pavilion Lake could increase with the project thereby increasing the demand on the Pavilion Lake quarry if the material is suitable; however because space is limited, the number of potential homes is likewise limited and the quantity of aggregate consumed is expected to be small.

5.4 AGGREGATE DEPOSITS - (Cont'd)

The amount of aggregate that would be needed in the foreseeable future by the project and other uses is moderate compared to the amount that is expected to be excavated within the proposed openpit. Once the mine is depleted of coal reserves the additional 445 million tonnes (490 million short tons) of aggregate could be excavated if required.

(f) Conclusions

Although an appreciable quantity of the aggregate resource of the Upper Hat Creek Valley would be affected by the project, this effect would be mitigated if at least some of the aggregate was stockpiled for later excavation and/or partly compensated by the use of fly ash and bottom ash for road construction. As a result of these considerations the effect of the project on the aggregate resource in the Upper Hat Creek Valley would be minimal and could enhance the project. The use of sand from the quarry at Boston Flats could be partly affected by the water pipeline. The appreciable quantities of sand and gravel in the Thompson River Valley would compensate for the loss of all or part of this sand. It is expected that a small increased cost could result from transportation and possibly royalty payments if an alternate site was considered. Because the quantity consumed is small, the incremental cost would be minimal.

5.5 LIMESTONE

(a) Introduction

Large deposits of limestone are located near the Upper Hat Creek Valley. The limestone of the Marble Canyon formation comprises the bedrock along a discontinuous belt extending from Martel on the Thompson River to Big Bar on the Fraser River, 93 km (58 mi) to the north (Figure 4-8).

5.5 LIMESTONE - (Cont'd)

The area affected by the proposed Hat Creek project is restricted to a small part of the large limestone resource. As a result only limestone more amenable to mining, that is limestone above the valley floor near Houth Meadows, was considered in determining the magnitude of the affected limestone resource.

Geological mapping was undertaken because it was practical as a result of the abundant outcrop on the hillside north of Houth Meadows. A few samples from outcrops were analyzed and literature was examined to determine potential uses that could be made of this limestone. Discussions were held with a representative of Steel Brothers Canada Limited to determine the quality of limestone at their quarry in Marble Canyon, northwest of the Upper Hat Creek Valley (Figure 5-3), and to compare that to the limestone from Houth Meadows.

(b) Inventory

The limestone in the Hat Creek area lies along a north-south trending belt. Within and adjacent to the Upper Hat Creek Valley in excess of 165 km^2 (64 sq mi) is underlain by limestone, including part of the proposed Houth Meadows waste disposal site, northwest of the No. 1 deposit (Figure 4-9). Limestone is exposed north and south of the Hat Creek site (Figure 4-8). Very little is known about this limestone because only a small part of the limestone has been examined in detail with a view to future production. A number of samples from various localities contain in excess of 96 percent calcium carbonate with one sample being as high as 99.05 percent.[28] A typical sample from the Steel Brothers quarry assayed 0.2 percent MgO, 54.6 percent CAO, 0.3 percent Fe_2O_3 plus Al_2O_3, 0.4 percent SiO_2 and loss on ignition 44.2 percent.[51] This analysis is the equivalent of 97.46 percent calcium carbonate.

ALTERNATIVE A
HOUTH MEADOWS WASTE DUMP

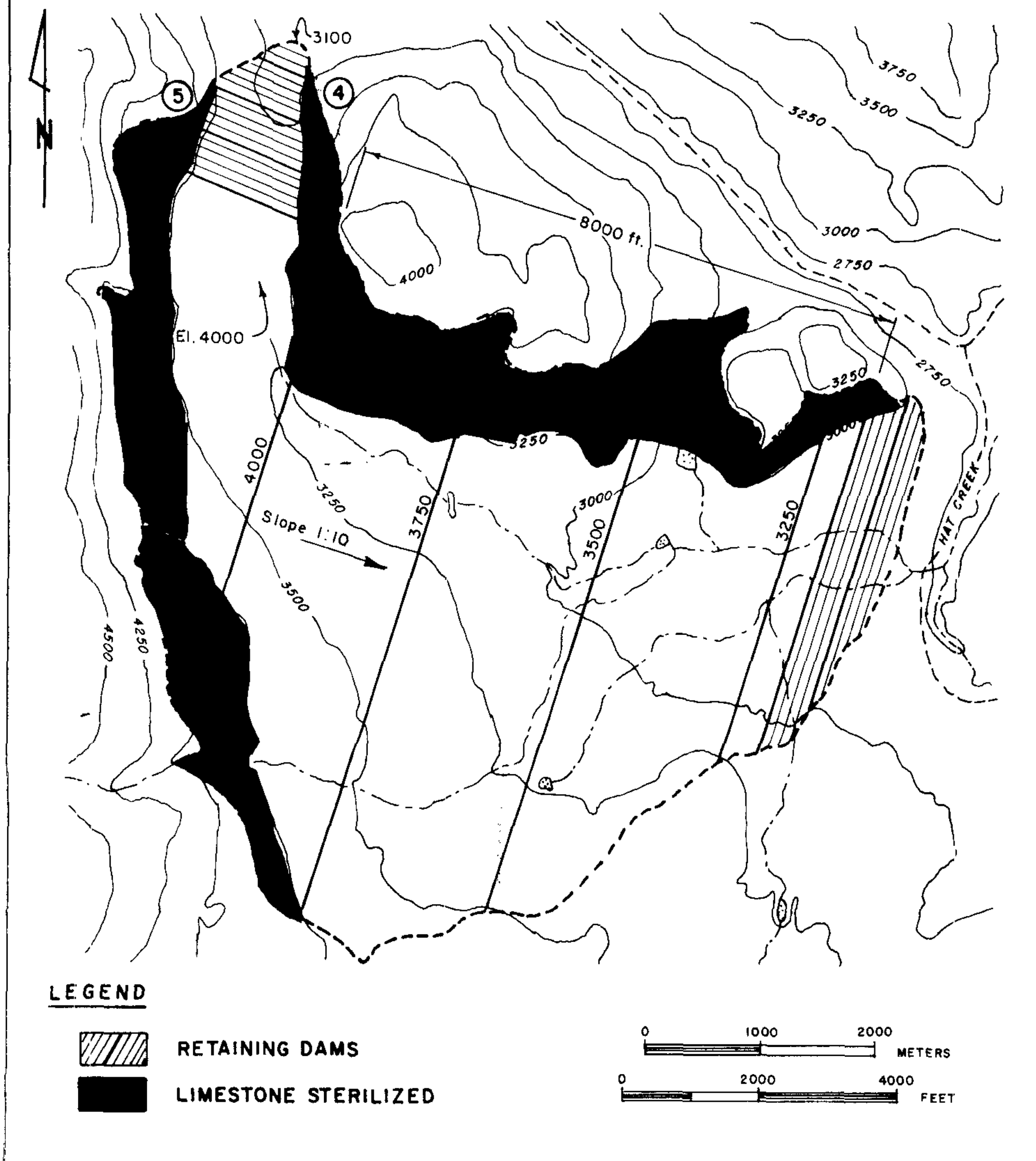


Figure 5-3

5.5 LIMESTONE - (Cont'd)

The limestone north and west of the Houth Meadows waste disposal site is grey, white or white with black streaks. It is finely crystalline and locally brecciated. Solution cavities are usually small and lie at the intersection of bedding planes and joints. Four analyses were obtained from limestone samples collected north of Houth Meadows (Table 5-4). The samples were taken from outcrop and are expected to be high in insoluble residues. As a result the analyses are only a close approximation to the composition of the limestone. The analyses indicate that two of the four samples have acceptable $CaCO_3$ and are low in SiO_2. The amount of MgO in the samples is too high for some uses. Both SiO_2 and MgO are higher in samples from Houth Meadows than in those from the Steel Brothers' quarry. These preliminary results indicate that the limestone is probably acceptable for use in cement, mortar, agricultural lime, industrial waste treatment, animal feed, dust abatement in coal mines, sulphite pulp manufacture, hypochlorite bleach manufacture and water treatment.

TABLE 5-4

ANALYSES OF LIMESTONE FROM HOUTH MEADOWS

Site	MgO(%)	CaO(%)	Fe_2O_3(%)	SiO_2	LOI(%)*	$CaCO_3$ equiv.(%)
HC-3	1.92	52.50	0.08	3.25	42.28	93.71
HC-5	1.40	53.60	0.08	2.15	42.58	95.68
HC-7	1.65	53.90	0.06	0.45	43.90	96.21
HC-13	1.38	54.40	0.05	0.35	43.25	97.10

* LOI means "loss on ignition".

5.5 LIMESTONE - (Cont'd)

(c) Present Situation

Potential reserves of limestone in the vicinity of the Hat Creek Valley are very large. Limestone is currently being mined by Steel Brothers Canada Limited in Marble Canyon. Lime is produced at the plant which has a rated capacity of 320 tonnes (350 short tons) per day.[51] The lime is used principally as a fluxing agent by nearby mine mills and pulp mills. Present demand by the pulp, paper and copper industries is low, therefore the plant is not operating at peak capacity.

(d) Future Situation without the Project

Industrial uses of limestone will probably increase marginally in the near future and this demand could probably be met by expansion of the Steel Brothers plant. If new mines and a smelter were constructed in the Highland Valley the demand for lime as a fluxing agent could be appreciably increased. The possibility would then exist for opening a quarry on the hills north of Houth Meadows.

There are a number of uses for limestone which are not currently promoted in the Hat Creek area. The limestone could be used for making Portland cement, carbide, agricultural lime, whiting, aggregate, railroad ballast, filter stone and for soil stabilization. The distance from markets and the resultant high transportation costs have blocked appreciable utilization of the limestone deposits near Hat Creek. The markets in Vancouver are served by barging limestone from several operating quarries on Texada Island at lesser cost than could be expected from Hat Creek.

5.5 LIMESTONE - (Cont'd)

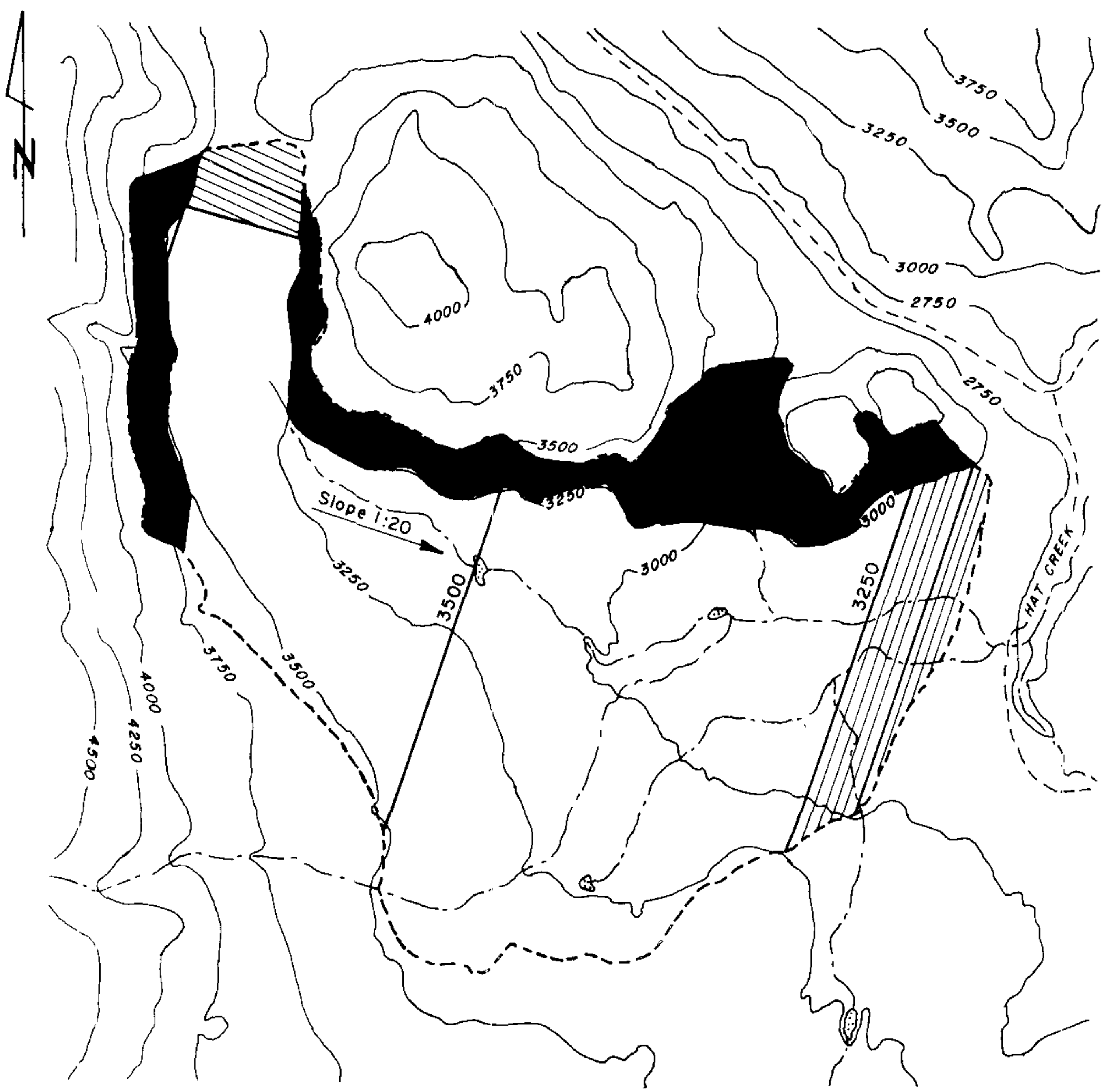
(e) Future Situation with the Project

Limestone is common in the Upper Hat Creek area. The development of any limestone resource would necessitate keeping the stripping ratio to a minimum. Therefore it was considered that, if the limestone at Houth Meadows was developed, only the limestone above the valley floor would be involved. Approximately 360 million tonnes (390 million short tons) of this limestone would be sterilized, based on the PD-NCB alternative A disposal plan, compared with 30 million tonnes (35 million short tons) based on alternative B[27] (Figures 5-3 and 5-4). A wedge of limestone 1200 m (4000 ft) long and as much as 120 m (400 ft) thick lies north of Houth Meadows and above the proposed alternative A waste dump. This wedge contains approximately 150 million tonnes (165 million short tons) of limestone that could be used if a need for limestone arose.

If flue gas desulphurization is necessary for the proposed thermal plant, the Houth Meadows limestone above the top of the proposed dump could be used for this purpose. However, there are other sources of limestone south of the plant site that are closer to the proposed thermal plant. It is estimated that approximately 4.4 million tonnes (4.9 million short tons) of limestone would be required for flue gas desulphurization over the 35-year life of the plant.[25] These figures assume partial scrubbing of SO_2 to 600 ppm (dry) and assumes a 65 percent capacity factor; the coal is assumed to have a heating value of 14 700 kJ/kg (6300 Btu/lb) and 0.45 percent sulphur at 20 percent moisture.

Lime could be used for conditioning tailings and for stabilizing the waste material on the dumps. No estimates are available of the quantities required if these measures should be taken.

ALTERNATIVE B
HOUTH MEADOWS WASTE DUMP



LEGEND

RETAINING DAMS

LIMESTONE STERILIZED

0 1000 2000 METERS

0 2000 4000 FEET

Figure 5-4

5.5 LIMESTONE - (Cont'd)

Large quantities of concrete would be required over an extended period as each of the four generating units is installed. It is estimated that approximately 73 000 m^3 (96,000 cu yd) of concrete would be required for four units.[50] It is assumed that a batch plant would be installed and that the plant would use cement that is hauled to the site by truck. Therefore no demand would be placed on the limestone for construction of the powerplant or other buildings.

(f) Conclusions

Because of the large area of limestone outcrops in the region, the resources of limestone are almost unlimited. However, the quality of this limestone is not well known. The large resources tend to mitigate the loss of limestone in Houth Meadows. Limited use is expected without the project; a substantial increase in limestone use would be expected only if sulphur scrubbing becomes necessary.

5.6 CLAYSTONE DEPOSITS

(a) Introduction

Unlithified claystone and siltstone comprise an appreciable thickness of the Medicine Creek and Hat Creek Coal formations in the Upper Hat Creek Valley. These formations underlie approximately 109 km^2 (42 sq mi) of the valley. Large quantities of these materials would be excavated from a coal mine at Hat Creek.

The method of studying the effect of the proposed Hat Creek Project on the utilization of these claystone resources has been to define the distribution of these rocks based on existing drill cores and drill logs and to quantitatively determine their mineralogy. In the next phase of studies it will be necessary to determine other properties and market factors which could influence their use.

The procedure for quantitative determination of the mineralogy of the claystones involved X-ray diffraction scans and integration of photon counts over the diffractometric peaks. To obtain these peaks the raw samples were first pulverized and homogenized. An X-ray diffraction scan was made between 3 degrees and 95 degrees of 2-theta for all samples. Some glycolated samples were analyzed to differentiate between illite and montmorillonite (bentonite). Attempts were made to identify all of the peaks on the diffractogram. Standard calibration curves were made using synthetic mixtures containing known quantities of minerals identified in the clay samples. An internal standard of 10 percent by weight of magnesia was used for all samples. The photon counts over one peak of each of the minerals was normalized and integrated with respect to the integrated peak density of magnesia. The areas under the curves are proportional to the quantity of that mineral in the rock; therefore the amount of each mineral in the clay sample could be determined.[13,14,15] The estimation of minerals by this technique is considered accurate within ±3 percent for feldspar, quartz and kaolinite and within ±5 percent for bentonite. The following minerals were also checked if they were found: pyrophyllite, serpentine, halloysite, dolomite, calcite, siderite, ankerite, goyazite, apatite, gypsum, magnetite, pyrite, galena, sphalerite, tetrahedrite, chalcopyrite, hyalophane and epidote.

In addition to these quantitative analyses, X-ray diffraction studies were conducted by Dr. R.M. Quigley of the University of Western Ontario[27] and Dr. P.A. Hill of Carleton

University[30] on a large number of samples. The purpose of these latter studies was to determine the cause of certain geotechnical properties of the rocks; however information on the clay as a potential resource was collected simultaneously.

Once the types and distribution of the minerals have been examined it is planned to investigate any potentially marketable clay minerals. The investigation of kaolinite extraction is to be undertaken by Dr. A.C.D. Chaklader and Dr. I.H. Warren of the University of British Columbia. The properties of the kaolinite and their relationship to the following uses will be investigated:

1. Production of mullite and alumina for making high temperature refractory brick or as a feedstock to an aluminum smelter.

2. Production of alumino-silicate catalysts for the petroleum industry.

3. Production of tricalcium aluminate for cement.

4. Production of ceramic-products using kaolinite and bentonitic claystones.

The results of these studies are expected in September 1978.

Another study is to be conducted in Ottawa by Dr. A. Winer of the Canada Centre for Mineral and Energy Technology. The study will determine the properties of the kaolinitic claystone for use in alumina production and the properties of the bentonitic claystone and its potential uses. The former study will involve a determination of the amount of alumina that can be extracted; the methods are described in the environmental report on "Solid Waste Disposal Coal Storage Land Reclamation". The latter study will examine the cation exchange capacity and the nature of the exchangeable cation in the bentonite. The determination involves an ammonium acetate cation extraction, filtration, ammonia distillation into sulphuric acid, and back titration with sodium hydroxide to determine the amount of the ammonium radical (NH_4+) that has replaced the exchangeable cation. The sodium and calcium concentrations in the filtrate are determined by atomic absorption. Considerable care must be taken in sampling to avoid contamination by sodium bentonite from the drilling mud. These studies will also examine the ash from fluidized bed combustion tests to determine if these by-products could be used as a source of alumina.

In addition, several aluminum companies were approached as a result of the Preliminary Environmental Study on Hat Creek.[21] The Preliminary Environmental Study noted that aluminum companies may be interested in clay (and/or fly ash) as a source of alumina. Some analyses of alumina were completed by the Aluminum Company of America Inc. (Alcoa)[47] and Alcan International (1975) Ltd. (Alcan).[48] A total of 15 169 m (49 754 ft) of ash from Hat Creek drill core has been analyzed for alumina as part of the standard mineral analysis. The total aluminum in the ash, expressed as aluminum oxide (Al_2O_3), has been summarized by coal zone in histograms.

(b) Current uses of Clay

Clay for industrial use is divided into several different types based on mineralogy and properties which relate to its potential end use.[4] China clay (kaolin) is white, consists primarily of kaolinite and has a high fusion temperature. Ball clay is plastic, white-firing and consists of kaolinite, sericite and some organic matter. Fire clay is plastic or rock-like and consists of kaolinite with some diaspore, bauxite clay, shale, ball clay, burley and burley flint. Bentonite consists primarily of montmorillonite; the clay is divided into the swelling or sodium-type and the nonswelling or calcium-type; the former will swell as much as 15 or 20 times its dry volume. Fuller's earth is a non-plastic clay-like material with adequate decolourizing and purifying properties; the material is composed of attapulgite or montmorillonite with or without opaline silica. Common clay is a plastic clay or clay-like material which can be readily moulded and which vitrifies below 1100°C; it usually consists of kaolinite, illite, chlorite and montmorillonite. Common clay is usually higher in alkalies and ferruginous minerals and lower in aluminum than the kaolins, ball clays and fire clays.

Clay resources in the world are very large. However most countries, although they may have adequate supplies of some clay types, generally do not have the specialty clays. The United States is an exception in that it has large reserves of all types of clay. Canadian imports of clay are listed in Table 5-5a. Although Canada is the fourth largest producer of clay,[4] principally common clay and fire clay, this production is concentrated in the east; there are only a few small plants in western Canada. Few known deposits of fire clay or ball clay are being utilized. In 1975 Canada imported 257 000 tonnes (283,000 short tons) of bentonite and more than 148 000 tonnes (164,000 short tons) of kaolin.[64]

The degree of processing of the natural clay depends on its quality and the value of the clay for a particular end use. Principal processing methods range from simple crushing of common clay or shale for most structural clay products and refractory cement to a combination of several techniques for specialized kaolin clays including crushing, blunging, sedimentation, water fractionation, ultraflotation, acid treatment, calcination, air floating, attrition grinding and delaminating.

Because of the scarcity of specific types of materials, principally china clay, refractory fire clay and bentonite, these materials can be mined, processed and transported a considerable distance. Mining costs for clays range from $1.00 to over $10.00 per tonne. Processing costs can range from a few cents per tonne for common clays to over $100.00 per tonne for special paper coating and high quality clays.

The amount of clay consumed particularly for cement and for brick manufacture is very large. A summary of demand in the United States by clay type and a forecast of clay demand in the year 2000 are listed in Table 5-5b.[4] The demand is increasing at an average rate of approximately 4 percent per year.

The uses of clays are dictated mainly by local markets; however there are a few exceptions. The types of clay used depends on the availability, cost and properties of the clay. Approximately 40 percent of the clay consumed in the United States in 1975 was common clay and shale for use in building bricks, drain tile, vitrified sewer pipe and a number of other construction materials. Twenty percent of the clay was used in the manufacture of Portland cement; this was primarily common clay and shale. Approximately 15 percent of the clay was used in making lightweight concrete floors and walls because clay provides better insulation than sand and gravel aggregate; these clays were predominantly common clay or shale. Approximately 10 percent of the clays was fire clay for use in refractories. Kaolin for paper filler and

5.6 CLAYSTONE DEPOSITS - (Cont'd)

TABLE 5-5a

CANADIAN IMPORTS IN 1975 BY TYPE OF CLAY
(in thousands)

	Tonnes	Short Tons
Kaolin	148	164
Fire Clay	43	48
Bentonite and Drilling Mud	257	283
Activated Clay (Fuller's Earth)	44	48
Other Clays	137	151

TABLE 5-5b

U.S. DEMAND IN 1973 AND DEMAND
FORECAST FOR THE YEAR 2000 BY TYPE OF CLAY
(in thousands)

Type	1973		2000*	
	Tonnes	Short *Tons*	*Tonnes*	Short *Tons*
Kaolin	4 803	5,295	20 000	22,000
Ball Clay	604	666	3 000	3,000
Fire Clay	3 513	3,872	15 000	16,000
Bentonite	2 288	2,522	6 000	7,000
Fuller's Earth	980	1,080	5 000	5,000
Common Clay	44 756	49,335	116 000	128,000
Total	56 944	62,770	165 000	181,000

* Numbers are rounded to the nearest thousand.

coater filler in cosmetics, fine china, refractories, plastics, etc. accounted for approximately 4 percent of U.S. consumption. About 10 to 11 percent of the clay consisted of bentonite, common clay, ball clay, kaolin and Fuller's earth for miscellaneous special uses such as drilling mud, iron ore pelletizing, pottery and ceramic ware, and as a decolourizer or purifier.

5.6 CLAYSTONE DEPOSITS - (Cont'd)

(c) Inventory

Studies were conducted on rock samples from the Hat Creek Valley to determine the types of clay and their distribution in the No. 1 deposit. This information is essential in order to examine the potential use of the claystone. The claystone in the hanging wall and in the upper half of the coal measures contains appreciable bentonite. The lower half of the coal measures contains predominantly kaolinite both as inherent mineral matter in the coal and as partings as much as 9.4 m (31 ft) or more thick.

Within the lacustrine beds above the coal, bentonite predominates over kaolinite with the sampling distribution skewed toward the less-bentonite end (Figure 5-5). The samples from the A coal zone are generally lower in bentonite, but the distribution is skewed toward the more-bentonite end. Samples from the B, C and D coal zones have low bentonite; most exceptions are associated with the "shale out" on the west side of the deposit. The distribution of clay minerals from below the coal (foot wall) is irregular, but the samples are generally low in bentonite.

Figures 5-6 through 5-9 illustrate the variation of the dominant minerals in the coal measures and adjacent rocks. These histograms were constructed for quartz, kaolinite, bentonite and feldspar from the hanging wall, foot wall and coal zones A, B, C and D. Within the coal zones most of the samples are from carbonaceous or coaly intervals because totally noncarbonaceous intervals are rare. The quartz content increases from the hanging wall through B zone; C and D zones and the foot wall have wide distributions in quartz content (Figures 5-6a through 5-6f). The concentration of kaolinite is related inversely to the concentration of bentonite (Figures 5-7 and 5-8). The kaolinite content is low in

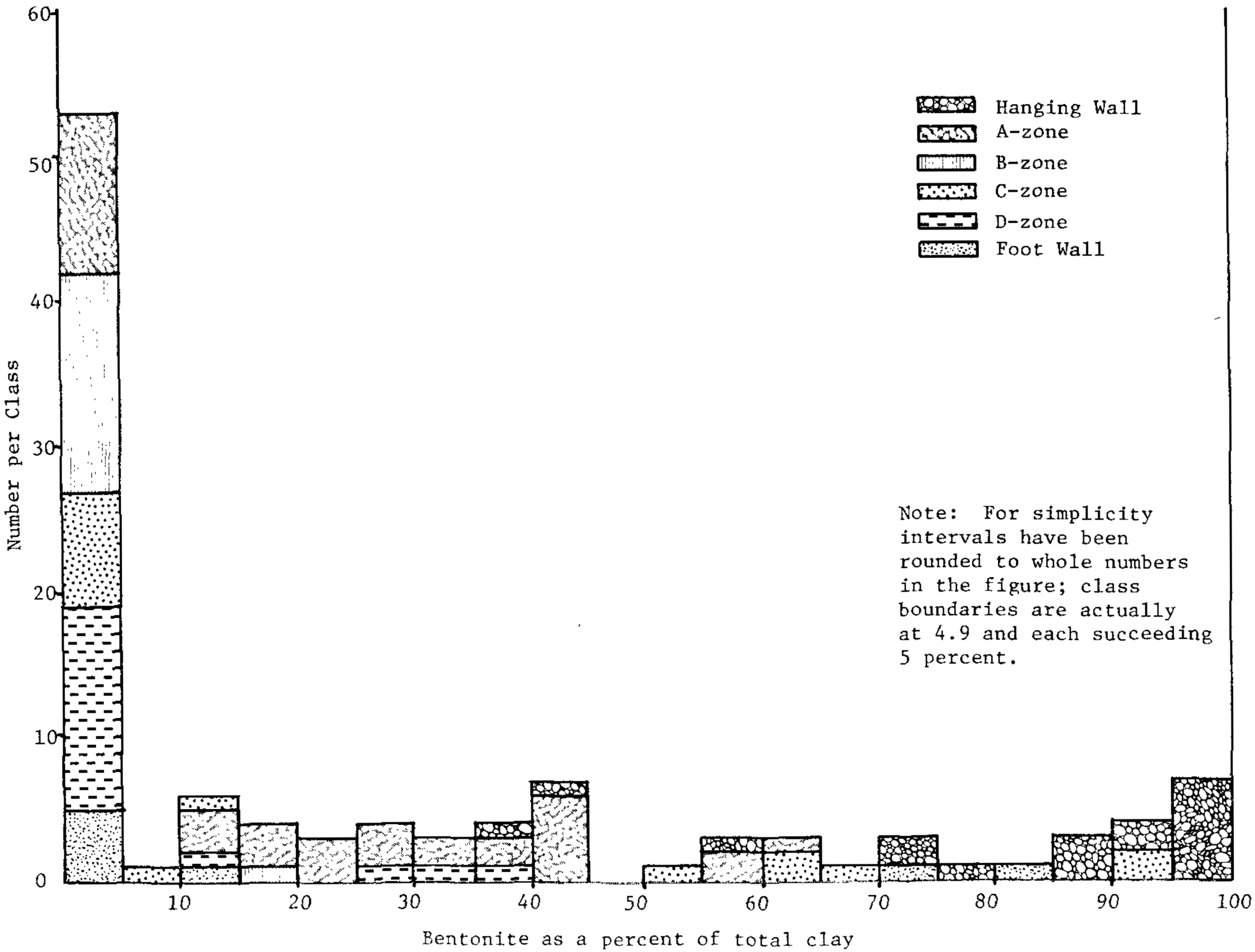


Figure 5-5 DISTRIBUTION OF CLAY MINERALS BY ZONE

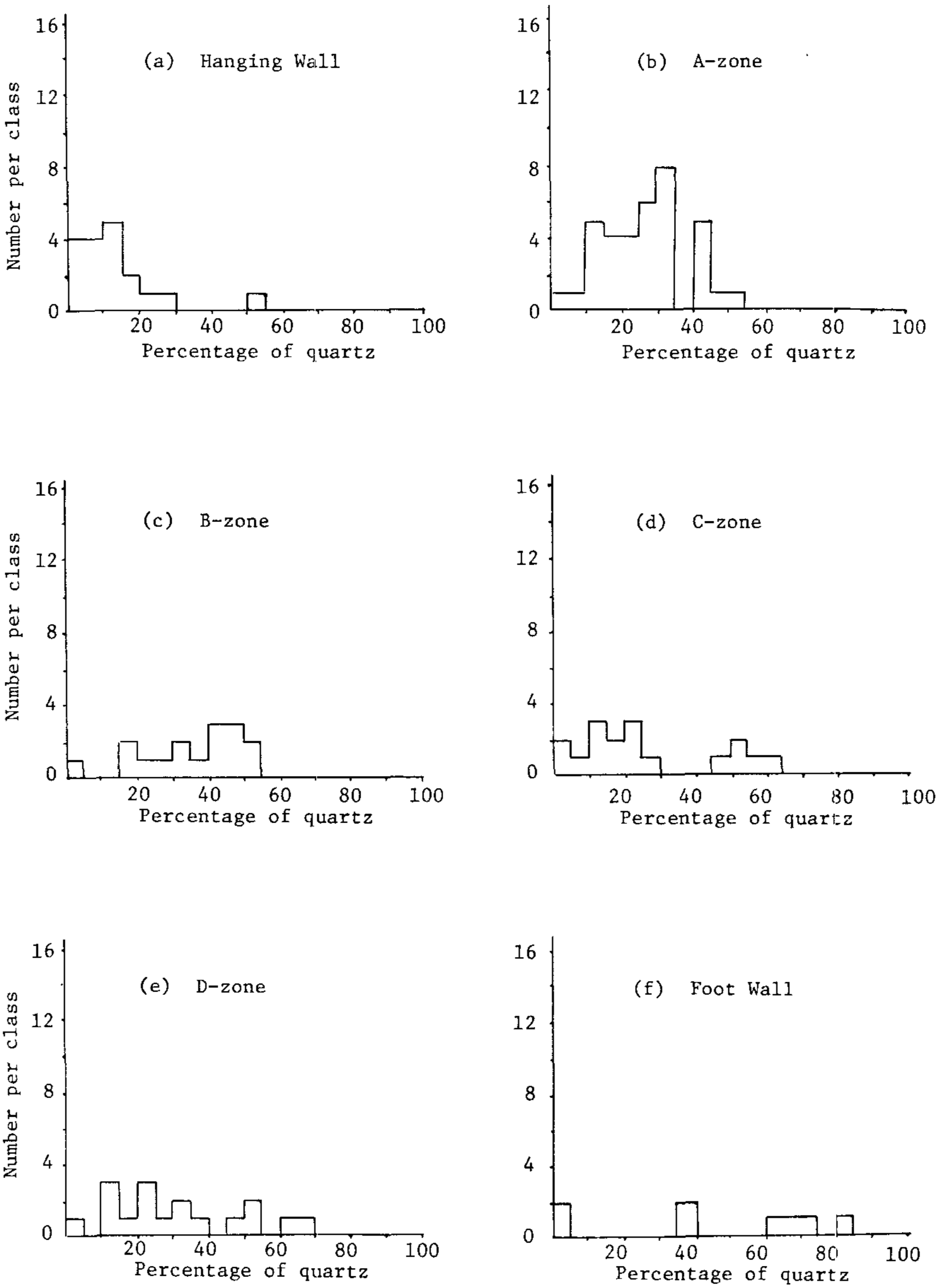


Figure 5-6 Histograms illustrating the distribution of quartz in each zone.

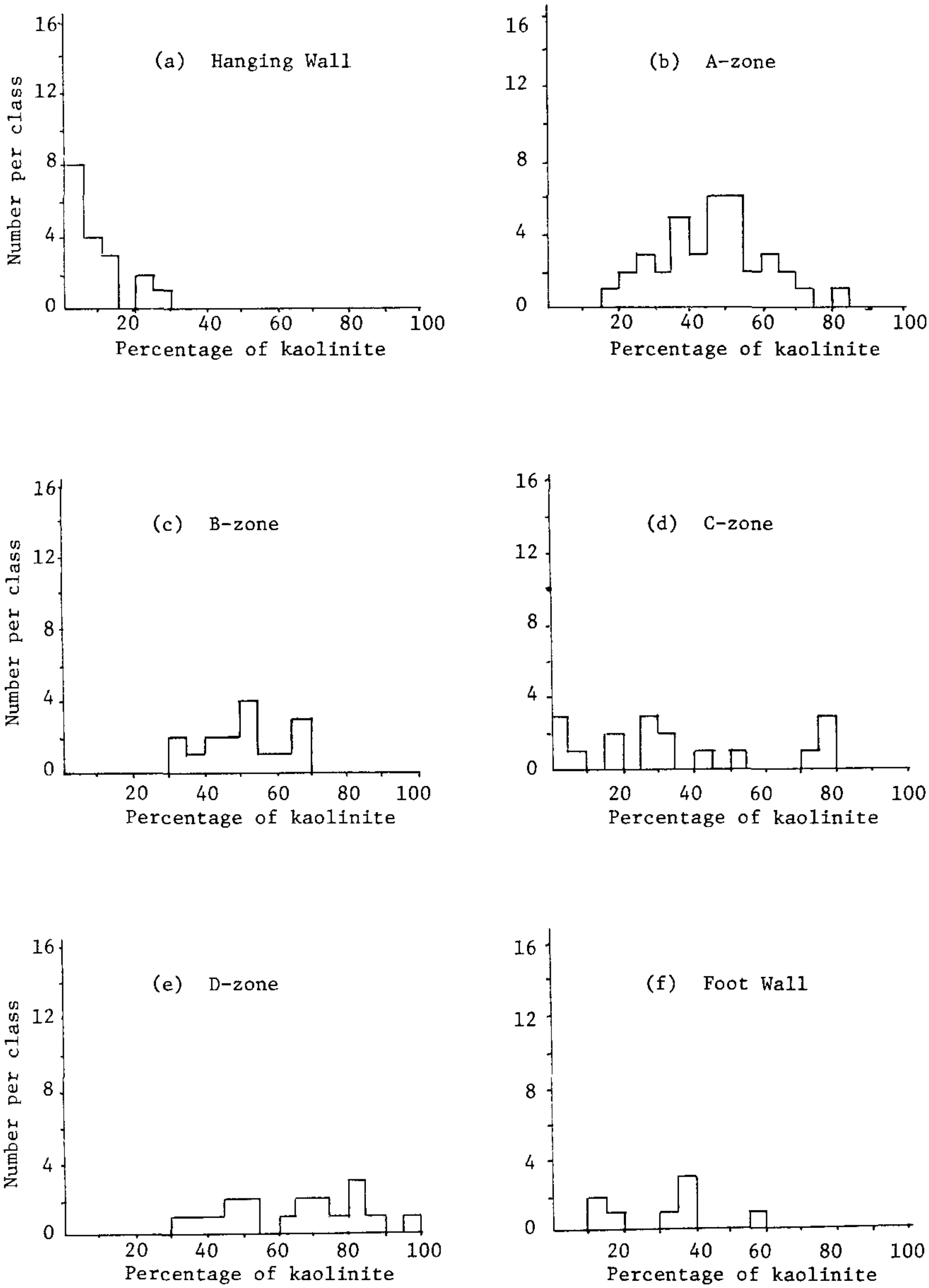


Figure 5-7 Histograms illustrating the distribution of kaolinite in each zone.

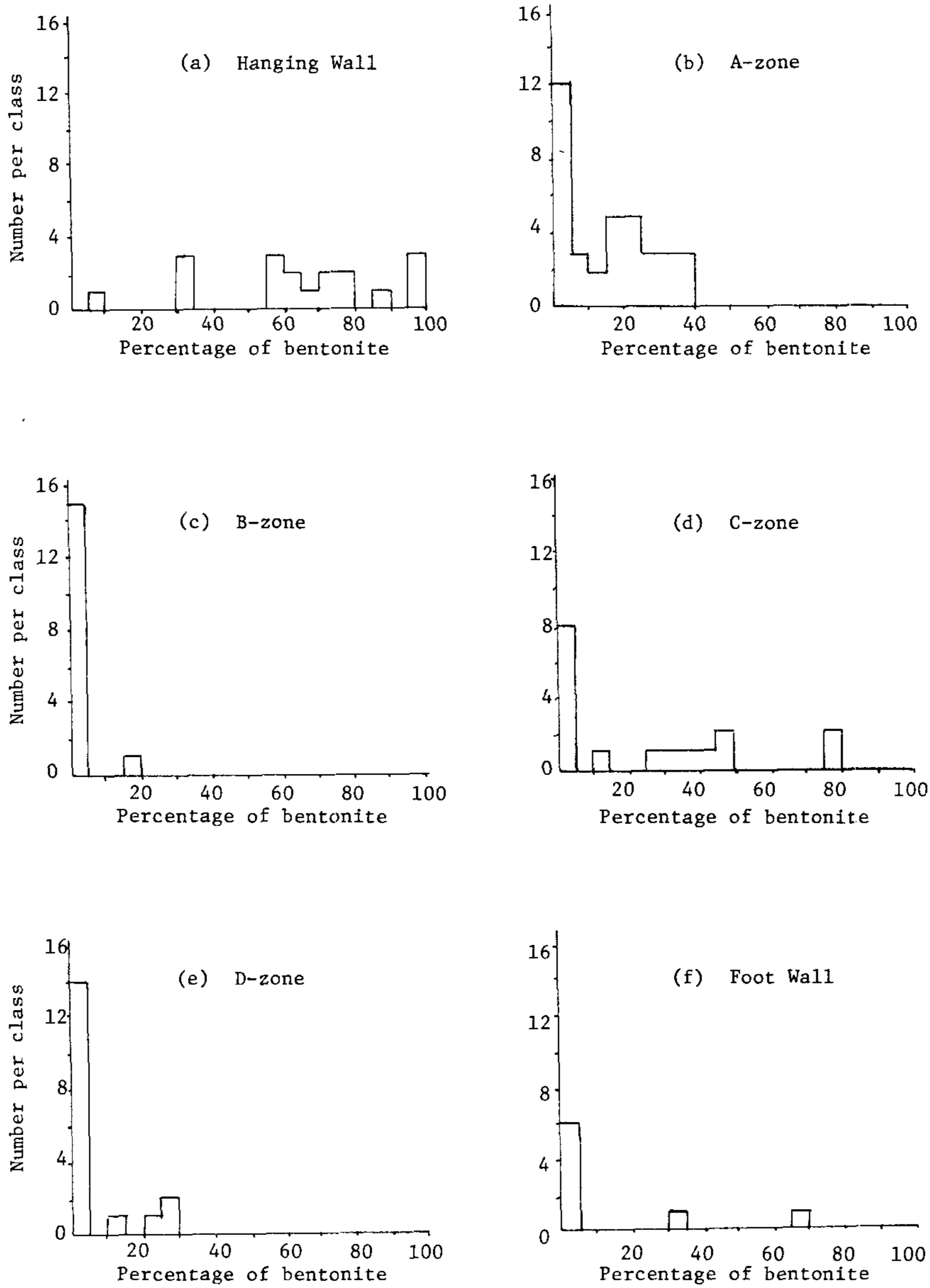


Figure 5-8 Histograms illustrating the distribution of bentonite in each zone.

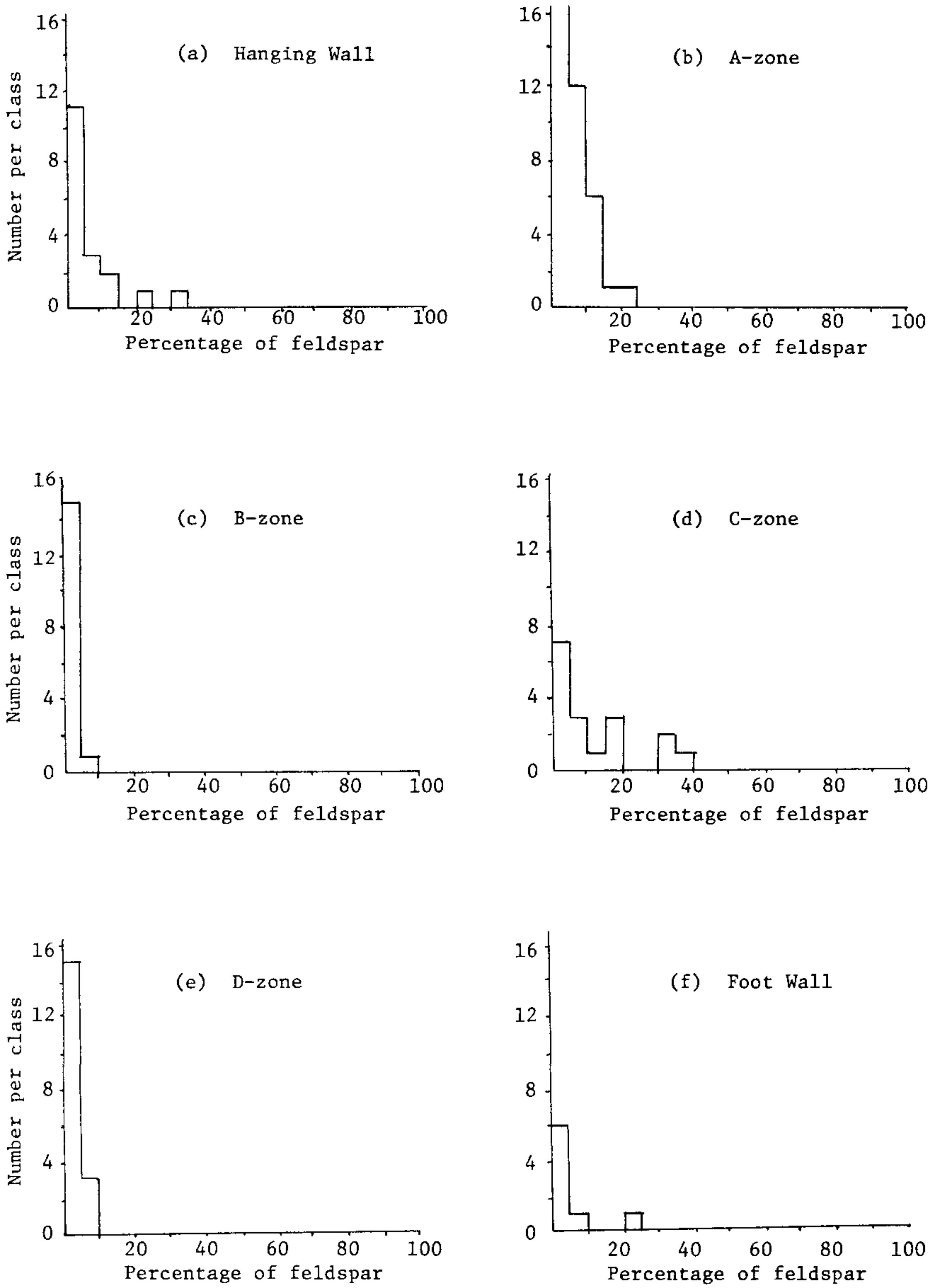


Figure 5-9 Histograms illustrating the distribution of feldspar in each zone.

5.6 CLAYSTONE DEPOSITS - (Cont'd)

the hanging wall and increases through A, B and D zones. C zone has a wide distribution with numerous samples low in kaolinite; as described above, these are related to the "shale out" on the west side of the No. 1 deposit. The samples from the foot wall seldom contain appreciable bentonite; the distribution of kaolinite is scattered. The feldspar content is commonly low with samples from C zone having the most variation (Figure 5-9). The samples commonly have only trace amounts, if any, of epidote, siderite, calcite, ankerite and pyrite; in a few samples these constitute major mineral phases of the rock.

The remainder of the Upper Hat Creek Valley, outside of the No. 1 deposit, contains appreciable claystone with a mineralogical distribution which is probably similar to that in the No. 1 deposit.

Investigations to begin early in 1978 are expected to indicate if kaolinite can be extracted and to determine the properties of this kaolinite. In addition it is planned to examine the nature of the exchangeable cation in the bentonite. These programs will determine possible uses for the kaolinitic and the bentonitic claystones.

The Preliminary Environmental Impact Study for the proposed Hat Creek development noted that aluminum companies may be interested in clay (and/or fly ash) from Hat Creek as a source of alumina. Before the distribution of the types of clay in the deposit was appreciated, samples were examined by the Aluminum Company of America (Alcoa)[48] and Alcan International (1975) Ltd. (Alcan).[47] The results of these analyses are summarized in Table 5-6. The analyses indicate very low alumina in the hanging wall claystone whereas samples from the coal zones contain more alumina. Of the Al_2O_3 in sample 74-37A:1160-1290, the alumina extractable by an acid leach is approximately 80 percent of the total. A summary of the distribution of Al_2O_3 among each of the four coal zones is illustrated in Figure 5-10. The concentrations of Al_2O_3 in the ash have a broad range; however they are generally between 25 and 30 percent. The alumina is enriched in the more kaolinitic intervals of the claystone and siltstone sections and depleted on the west side of the No. 1 deposit and in the sandstone horizons. A plot of the kaolinite-bentonite ratio versus parting thickness is illustrated in Figure 5-11. The purpose of this plot was to determine if selective mining would be possible in some of the areas containing appreciable kaolinite. Of the 24 samples of kaolinitic claystone that were examined, thirteen are from partings greater than 1.5 m (5 ft) thick and seven of these are over 6 m (20 ft) thick. Based on this preliminary information some selective mining could be practical; studies into the uses of these clays are continuing.

A more detailed examination of the feasibility of extracting alumina from mine and plant wastes (claystone and fly ash) is included in the section of the Hat Creek Detailed Environmental Study entitled "Solid Waste Disposal Coal Storage Land Reclamation".

(d) Present Situation

Claystone and siltstone deposits underlie much of the Upper Hat Creek Valley. In addition they are interbedded with the coal sequence, particularly in A and C zones.

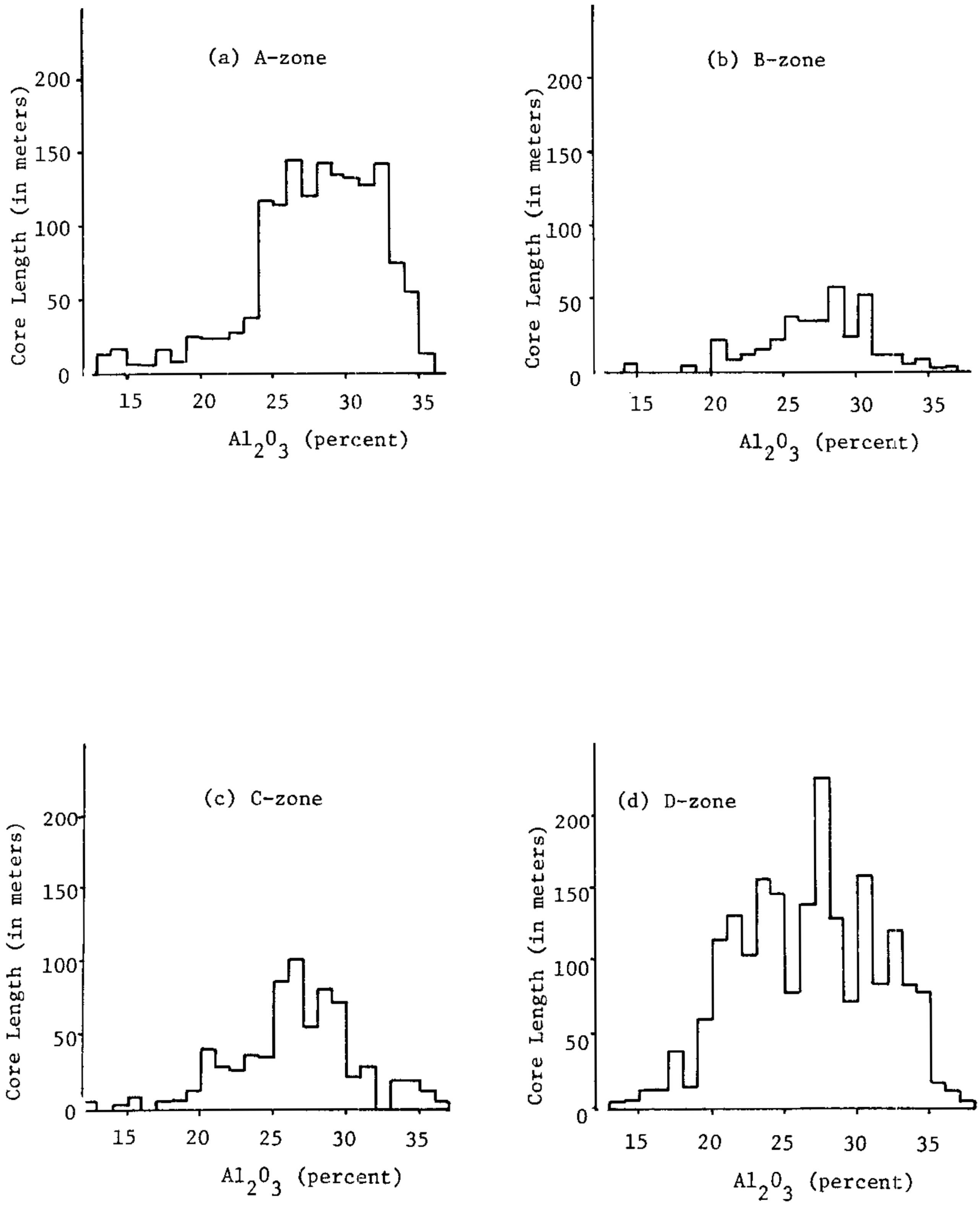


Figure 5-10 DISTRIBUTION OF ALUMINA BY ZONE

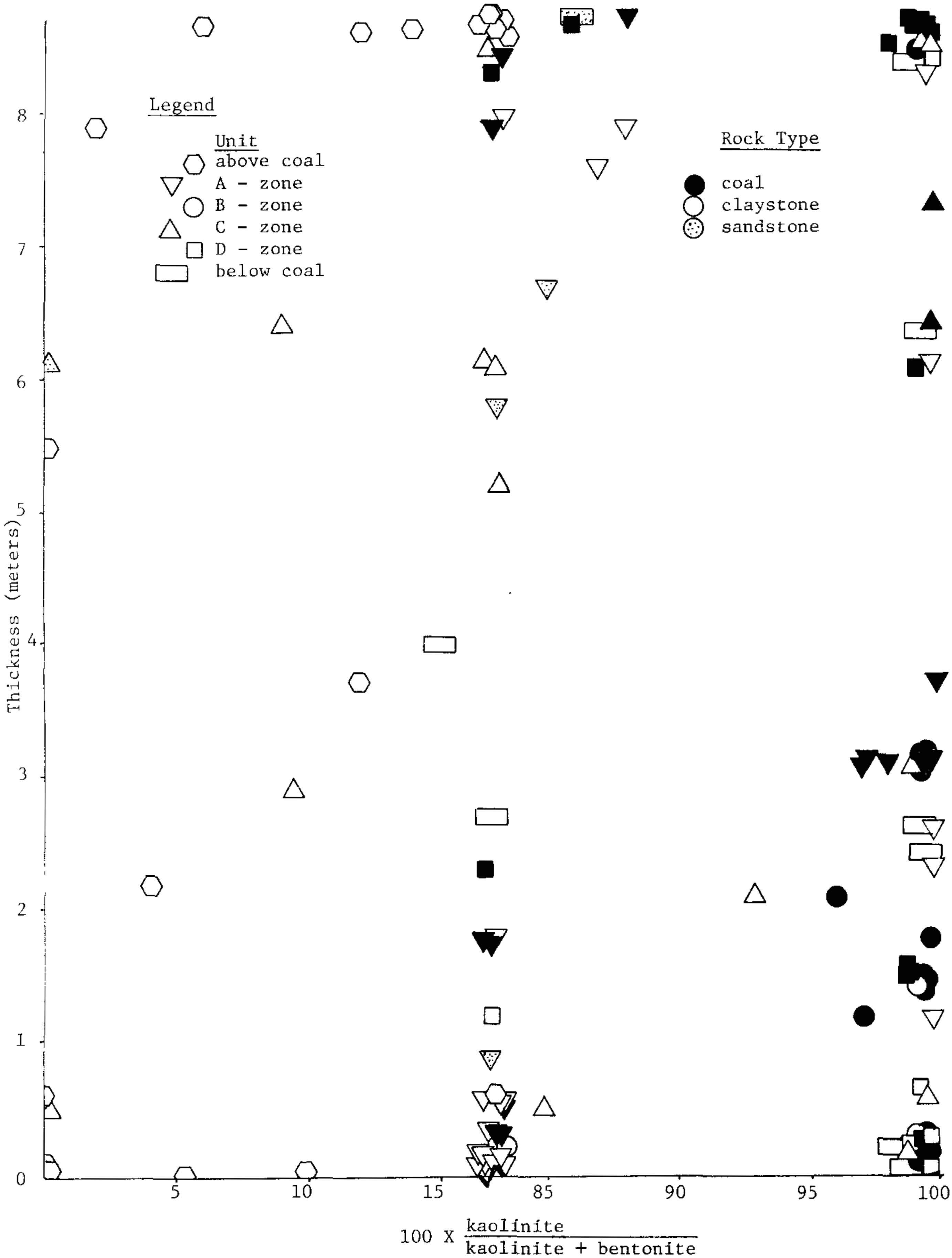


Figure 5 - 11 Kaolinite-bentonite ratio versus parting thickness.

TABLE 5-6

ANALYSES FOR ALUMINA IN CLAY SAMPLES FROM THE UPPER HAT CREEK VALLEY

Hole No.:	Interval (in feet)	Zone	Al_2O_3 (%) in Dry Ash
74-37A:	270 - 430	H.W.*	16.79
74-26:	830 - 1020	H.W.	16.84
74-37A:	1160 - 1290	A	20.59
74-46:	562 - 582	C	29.5
74-46:	670 - 690	C	24.8
74-46:	774 - 802	C	26.8
74-46:	831 - 851	C	28.7
74-46:	956 - 986	C	26.1
74-46:	986 - 1026	D	30.4
74-46:	1106 - 1146	D	28.8
74-46:	1528 - 1540.5	D	26.8
74-106:	1490 - 1835	D	29.3

* H.W. is an abbreviation for the hanging wall lacustrine sedimentary rocks overlying the coal sequence.

No clay has been mined previously in the Upper Hat Creek Valley. The demand for clay depends on marketability based on mining, processing and transportation costs as well as the acceptability of the product. The Hat Creek area is isolated from the Lower Mainland where most of the demand for clay products is centered. The cost of exclusively mining the more kaolinitic clays would involve considerable stripping plus the separation of coal and bentonitic beds. The cost could not be justified under present conditions where neither the coal nor the bentonitic beds could be sold and where the total cost of mining and transportation must be borne by the kaolinitic clay.

5.6 CLAYSTONE DEPOSITS - (Cont'd)

(e) Future Situation without the Project

Without the project it is expected the clay from Hat Creek would not be mined in the foreseeable future. The conditions affecting the uses of clay are not likely to change without the presence of a thermal plant or other industry using the coal and paying most of the cost of mining the clay.

(f) Future Situation with the Project

The coal mine proposed for the Upper Hat Creek Valley would produce appreciable claystone. Once the detailed mine plan is completed, predictions can be made regarding the scheduling of the types of clay and the total amount that could be expected.

Based on the PD-NCB preliminary mine plan, as much as 1060 million tonnes (1170 million short tons) of combined bentonitic and kaolinitic claystone and siltstone, coaly waste, sandstone and conglomerate would be removed.[44] Clay is in discrete partings and as inherent mineral matter in the coal. Some of the thicker clay intervals illustrated in Figure 5-11 could be extracted during mining or by separation in a Bradford Breaker; rejects from a beneficiation plant could provide additional clay from the thinner partings. Feasibility studies on methods of beneficiation are presently being conducted.

Programs are progressing which examine the separation and properties of the clay materials in order to determine their potential end uses. Some of the uses that have been proposed are as follows:

1. Production of mullite and alumina for making high temperature brick; the latter could also be used as a feedstock to an aluminum smelter.

2. Production of alumino-silicate catalysts for the petroleum industry.

3. Production of tricalcium aluminate for cement.

4. Production of drilling muds, moulding sands, etc. provided the bentonites contain sodium as the exchangeable cation; there are also a number of limited uses for calcium bentonite.

5. Production of ceramic products (bricks, tiles, etc.) using kaolinitic and bentonitic claystones.

Only if the claystone waste was used as a source of alumina could an appreciable part of the claystone resource by utilized. The limiting factors are the remoteness from markets and the resulting high cost of transportation.

(g) Conclusions

The clay minerals at Hat Creek have a well defined distribution and would be extracted in large quantities from a mine at Hat Creek. Some of the clays could be removed during mining, crushing or washing. The information on quantities and a schedule for clay types awaits results of the mining studies. Information on practical uses awaits results of the clay extraction study and subsequent examination of the economics and potential marketability of the large quantity of clay expected from the No. 1 deposit. Mine planning relating to waste disposal should remain sufficiently flexible to allow for separation of the clay-waste products into kaolinitic and bentonitic zones for subsequent extraction.

5.7 BAKED CLAYSTONE

(a) Introduction

The northwest and north central parts of the No. 1 deposit and an undetermined part of the No. 2 deposit are overlain by baked claystone. This material consists of red, orange and yellow, brick-like, baked clay and isolated pockets of grey clinker. The baking is the result of a natural coal fire; the baked clay is the adjacent claystone, partings and inherent ash associated with the coal that burned.

Little work has been completed to assess the baked clay. Drill hole information and magnetometer surveys have been used to determine the extent of the deposit. The latter method has proven useful because the baked claystones are more magnetic than the adjacent claystone and coal.

(b) Inventory

The baked claystone overlies a large part of the No. 1 deposit. Drill hole information has indicated that the zone ranges to almost 70 m (230 ft) thick; the quantity is conservatively estimated at 16 million tonnes (18 million short tons). Because of the occurrence of thick claystone partings in the original coal sequence, some clay beds are less baked than others. Colour variations occur within the baked zone due to variations in iron content and to degrees of oxidation during burning and subsequent weathering.

Clayburn Industries Limited is currently testing the baked claystone to determine if it is suitable for brick manufacture. Results of their testing are expected soon.

5.7 BAKED CLAYSTONE - (Cont'd)

(c) Present Situation

In the summer of 1977 a trench was excavated to extract coal for a test burn at the Battle River Powerplant of Alberta Power Company. During excavation of this trench roads were constructed from the baked claystone. The material was found to be useful for that purpose; the baked claystone road material remained relatively dry and the road surface was not slippery even after heavy rains. Similar baked claystones are used elsewhere in place of aggregate for gravel roads.

(d) Future Situation without the Project

Clayburn Industries Limited have indicated that, if the results of their testing are favourable, they would be interested in acquiring baked claystone for use in brick manufacture whether the project is to proceed or not. The amount required by Clayburn would be between 14 000 and 45 000 tonnes (15,000 to 50,000 short tons) per year. Economic factors such as the cost of the baked claystone and the transportation costs influence the potential utilization of this resource.

The baked claystone could also be used to improve conditions on the Hat Creek Valley road. After a rain or in the spring, conditions on the road are hazardous due to the high clay content in the aggregate being used.

(e) Future Situation with the Project

Because of the value of the baked claystone as road building material and possibly for bricks, it is recommended that this baked claystone waste rock be left isolated and retrievable within or adjacent to the waste dump area. Some of the burned material would be required for road building in the early stages of stripping of the pit. Once the powerplant is in production

5.7 BAKED CLAYSTONE - (Cont'd)

this material could be supplemented or replaced by bottom ash. Because of the heavy equipment moving over the roads it may be necessary to lay down a base of coarse aggregate on top of the clayey tills to ensure that a good base is present and that the bottom ash or baked clay is not quickly compacted into the till.

If the tests on the baked claystones indicate that they are suitable for making bricks, this use could absorb a large quantity of the available material. However, even allowing for appreciable loss during mining, there should be sufficient baked clay for both road maintenance and brick manufacture.

(f) Conclusions

Studies are continuing into the properties of the baked claystone. Results are expected soon. The two most probable uses for the baked claystone are in road maintenance and brick manufacture. Neither of these uses would utilize the total of 16 million tonnes (18 million short tons) of baked claystone; however the two uses together would use most of it. The problems of selectively mining and stockpiling plus the requirements of the mine for this material will have to be examined.

5.8 ADDITIONAL COAL DEPOSITS AND COALY WASTE

(a) Introduction

At the beginning of the current series of exploration and development programs on the Hat Creek coal deposits, coal was known to occur only in the No. 1 deposit. This deposit was originally discovered because a few small outcrops were exposed in the bed of Hat Creek. Subsequent exploration determined the limits of the No. 1 deposit, discovered and explored the No. 2 deposit, and determined that coal is expected to underlie most of the Upper Hat Creek Valley. These latter discoveries were made despite the lack of outcrop. Additional clastic rocks of the Coldwater beds are exposed on the hills to the east, adjacent to Medicine Creek, a broad open valley, which lacks outcrops; the dip of the beds is into the valley where the recessive beds of the Hat Creek Coal formation could have been located.

Because of the peculiar nature of the Hat Creek deposits and their immense thickness there are large quantities of low grade coal and carbonaceous rock. A coaly waste with between 59 percent and 65 percent ash could form a future source of energy or raw material for brick. Coaly waste with between 59 and 75 percent ash could be used as a source of kaolinitic clay; the uses were described in Section 5.6.

To investigate the coal potential and to locate areas with favourable stratigraphy a literature survey was undertaken. The favourable areas were investigated by reconnaissance geological mapping. The mapping was supplemented with additional mapping by Dr. T. Höy[31] and Dr. B.N. Church[16] of the British Columbia Ministry of Mines and Petroleum Resources. The most favourable area for coal was near the headwaters of Medicine Creek; this area was examined by gravity[1] and magnetometer[39] surveys. Some drilling was also completed as part of a geotechnical evaluation of possible sites of containment dams for fly ash disposal.

(b) Inventory

Reconnaissance geological mapping indicated that Kamloops group sedimentary rocks underlie several areas where project installations may be located. These installations are the No. 1 openpit, part of the Houth Meadows and Medicine Creek waste disposal areas, the Hat Creek diversion dams and canal, the Medicine Creek fly ash disposal area, parts of the water supply and parts of the possible road access routes. Geological mapping indicated that the only site outside of the Upper Hat Creek Valley, with potential for appreciable quantities of coal, is at the headwaters of Medicine Creek.

The lack of outcrops in this Medicine Creek area necessitated the use of indirect geophysical methods to locate and assess potential drill targets. A magnetometer reconnaissance line was oriented east-west along the axis of the Upper Medicine Creek Valley (Figure 5-12). It was determined that the relief was low and characteristic of areas where glacial till overlies limestone or other sedimentary rocks. A gravimeter was used to determine the intensity of the gravitational field over the same reconnaissance line. Two small anomalies with low gravity were found; such anomalies could be due to coal. A computer modelling study was undertaken in which two models were considered:

1. Two dipping coal seams.

2. Two buried stream channels.

The latter hypothesis proved to fit the data very well indicating that it is unlikely there is any coal in the Upper Medicine Creek Valley. Subsequent geotechnical drilling for the fly ash disposal system has verified this conclusion.

No rock is exposed in the eastern part of Houth Meadows. Magnetic and gravity surveys indicated the presence of limestone or other sedimentary rocks devoid of coal. Limestone is exposed in the eastern part of Houth Meadows as well as along its northern and western margins (Figure 4-9); this limestone formation

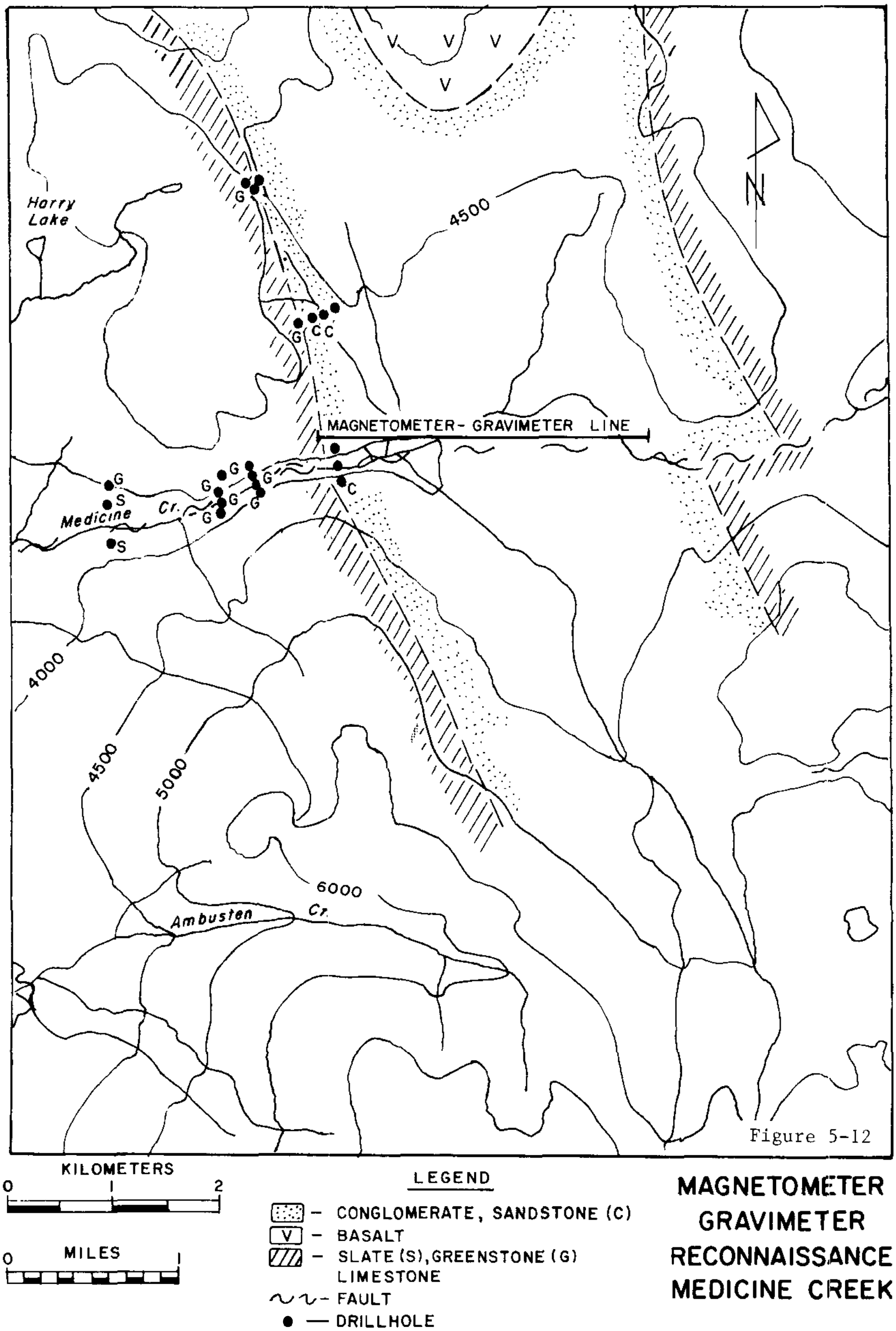


Figure 5-12

MAGNETOMETER GRAVIMETER RECONNAISSANCE MEDICINE CREEK underlies the coal sequence indicating that there is no potential for coal under Houth Meadows. These conclusions have been verified by drilling related to the geotechnical program.

The bench northeast of the No. 1 deposit has been explored by geological mapping, magnetic and gravity surveys and diamond drilling. Only thin seams of "dirty" coal have been encountered at depths of 150 m (500 ft) and more. These beds are part of the Coldwater formation that underlies the coal-bearing sequence (Figure 4-9). Because of the abundance of coal in the valley these seams are not likely to be of interest during the life of the plant. A gravity survey over the Upper Hat Creek Valley indicated no appreciable gravity anomalies in this area that could be attributable to coal.[1]

Coaly waste occurs throughout the deposit, but it is particularly prevalent in A and C coal zones. The A zone forms the upper 180 m (600 ft) of the deposit, B zone the next 75 m (250 ft), C zone the following 90 m (300 ft) and D zone the lower 75 m (250 ft). Because the deposit plunges to the south, the lower coal zone forms the subcrop at the north end of the deposit.

A considerable quantity of coal - quality information has been collected on the Hat Creek deposit. Assuming that material between 58 percent and 75 percent ash on a dry basis is coaly waste, A zone is 12.32 percent coaly waste, B zone is 4.21 percent, C zone is 16.79 percent and D zone is 1.22 percent. Material above 75 percent ash is simply waste. It is currently proposed that material between 44 and 58 percent ash would be blended with better quality coal from elsewhere in the deposit.[62] It is expected that coaly waste with between 58 and 69 percent ash will be stockpiled for future use in a fluidized bed system. Similar stockpiles are recommended for coaly waste with between 69 and 75 percent ash.

(c) Present Situation

In the past, coal was taken from the Hat Creek deposit for heating in the nearby towns and villages. At present the coal is not being utilized principally because of its high ash and moisture content and correspondingly low calorific value.

(d) Future Situation without the Project

The demand for Hat Creek coal could increase in the future. A study on the utilization of Hat Creek coal was completed in 1977.[59] This report examined the following alternate uses for Hat Creek coal and concluded:

1. The manufacture of synthetic natural gas is technically and economically viable.

2. The manufacture of methanol is technically feasible, but markets are uncertain.

3. The manufacture of ammonia is technically feasible, but markets are unsatisfactory.

4. The manufacture of coal liquids is not economically attractive at present.

5. The manufacture of coal solids is not technically feasible because of the high ash content.

6. The technology of in situ gasification is uncertain.

Hat creek coal has a number of potential uses besides thermal power generation. However, there are few uses for material which, for mining purposes, is classified as coaly waste. The cost of mining could not be borne by the coaly waste itself, so only in the event of the coal being utilized could coaly waste become available.

(e) Future Situation with the Project

The construction of mine, powerplant and offsite facilities should not affect any coal deposits. It is planned to drill all sites of permanent installations before construction begins. Geophysical surveys and mapping have not detected any coal in the areas adjacent to the Upper Hat Creek Valley. As indicated in Sub-section 4.2(c) the coal resources of the Upper Hat Creek Valley are very large and have the potential to sustain more than a 2000 MW coal-fired generating station.

It is planned that the lowest grade of coal which could be sent to the powerplant is approximately 16 070 kJ/kg (6900 Btu/lb) or 39 percent ash on a dry basis. A fluidized bed combustion system could be designed for Hat Creek coal at 10 250 kJ/kg (4400 Btu/lb)[17] on a dry basis. Therefore, lower grades of coal should be stockpiled as proposed in current mine planning. When fluidized bed systems become technically feasible this low grade coal could be utilized.[26]

Alternately, some of the coaly waste could be used to make grog for the brick industry. The potential for this use would depend largely on the economics of transportation to the marketplace either as brick or as calcined clay and on studies in progress on the suitability of the material.

5.8 ADDITIONAL COAL DEPOSITS AND COALY WASTE - (Cont'd)

(f) Conclusions

The areas that have coal potential based on geological mapping were investigated by magnetic and gravity surveys and drilling. No significant quantities of coal were encountered outside of the Upper Hat Creek Valley. Therefore no potentially mineable coal will be sterilized by the fixed installations related to the Hat Creek Thermal Project. However, care should be taken to ensure that mine planning is sufficiently flexible to permit extraction of the total resource in the No. 1 deposit and not just the coal above 730 m (2400 ft) elevation. Similarly the other coal resources in the Upper Hat Creek Valley should not be jeopardized.

The coaly waste should be stockpiled for future use in a fluidized bed, to provide calcined clay as the basis for a brick industry either locally or in the lower mainland, or to provide a source for kaolinitic clay.

5.9 BASE METAL DEPOSITS

(a) Introduction

The interior of British Columbia has been an area of very active base metal exploration (Figures 4-9 and 5-2). Large mines are located in the Highland Valley southeast of Ashcroft and large deposits are located in the Highland Valley and north of Cache Creek. Significant showings are located north and south of Cache Creek, in the Thompson and Bonaparte River valleys.

The scope of this study on base metal deposits involved a detailed examination of areas of proposed, permanent facilities such as the openpit, preparation plant, powerplant, reservoirs, waste dumps and ash dumps. Another criterion affecting the scope of this study was the presence of known mineral showings or claims. Because of the effects that could be expected on showings, the studies were site specific.

Based on a literature survey and experience in the area it was concluded that the rocks of the Cache Creek group and the Mount Martley stock have considerable potential for base metal deposits (Figures 4-9 and 4-10). The proposed Houth Meadows waste disposal area, the powerplant site, the water supply route, the pumphouse and possibly the fly ash disposal area lie at least partly within these rock units.

Base metal deposits in the volcanic rocks of the Cache Creek group tend to be related to areas of appreciable hydrothermal alteration adjacent to small stocks. The Mount Martley stock is exposed west of Houth Meadows. Here the stock intrudes limestone with greenstone dykes or sills which are part of the Marble Canyon formation of the Cache Creek group.

The proposed water pipeline and road access routes lie mostly across Cache Creek greenstone which could be intruded by mineralized plutons similar to that at the Maggie Mine (Figure 5-2), north of Carquile. Mineralization has been found at Red Hill, along one of the proposed transmission line routes.

The pumphouse site on the Thompson River is close to the margin of the Guichon batholith (Figure 4-8) which contains numerous large porphyry copper deposits.[23] For this reason the site was designated as having base metal potential.

In addition, mineral claims have been staked over most of the Trachyte Hills during the last 15 years. Most of these claims were staked on speculation associated with discoveries

5.9 BASE METAL DEPOSITS - (Cont'd)

around the Maggie Mine and in the Highland Valley. Assessment reports were filed on some of these claims. These reports were examined to determine the mineral potential of the claims.

To examine the potential for mineral deposits, site investigations were undertaken; existing drill logs were studied; government claim maps, mineral inventory maps and assessment reports were examined. Literature on base metals in the area was studied including British Columbia Ministry of Mines Annual Reports and the series Geology, Exploration and Mining in British Columbia. A favourable area was investigated by geological, geophysical and geochemical surveys.

The area west of Houth Meadows which was examined in some detail was selected as having base metal potential while lying within the PD-NCB alternative A waste dump and an assumed 610 m (2000 ft) buffer around the site. This buffer contained part of the contact between the Marble Canyon limestone and the Mount Martley stock. The stock is a favourable site for porphyry copper-molybdenum deposits and the contact is favourable for contact metasomatic deposits.

The analytical method of trace metal analysis on soil, silt and rock samples consisted of crushing rock samples, drying the soil and silt samples at $38^{o}C$ and separating 1 gram of the minus 80 mesh fraction from these samples. A perchloric-nitric acid ($HClO_4$-HNO_3) digestion was used and Cu, Zn, Mo, Pb and Ag were analyzed by atomic absorption. A bead consisting of $NaCO_3$, KNO_3 and the sample was formed and a colourimetric method was used to determine the amount of tungsten (W). Tin (Sn) was determined colourimetrically using an ammonium iodide (NH_4I) fusion. An aqua regia (HCl-HNO_3) digestion and atomic absorption were used to analyze for gold.

5.9 BASE METAL DEPOSITS - (Cont'd)

(b) Inventory

As a result of the literature and field surveys the following sites were found to be of interest for base metal deposits (Figure 5-2):

1. The Cache Creek chromium showing.
2. The Midas claims.
3. The Cornwall Creek chromium showing.
4. The Red Hill and RJ copper-silver showings.
5. The McLean claims.
6. The Joe claims.
7. The Milk claims.
8. The R claims.
9. The Houth Meadows site.

These sites, showings and claims were researched in the literature and/or examined in the field. The degree of study on any site was related to the influence that a facility for the Hat Creek development would have on the site and to the degree of permanence of that facility.

There are several minor chromite ($FeCrO_3$) occurrences near Cache Creek including the Cache Creek, Midas and Cornwall Creek occurrences. The Cache Creek occurrence is situated on the west bank of the Bonaparte River near the junction of Highways 1 and 97 at Cache Creek.[23] The occurrence consists of lenses of serpentinite as much as 305 m (1000 ft) wide. Serpentinite is often a host rock for chromite ore deposits. The showing contained one mass of chromite weighing 3 tons; no other chromite discoveries were made here. The Midas claims are located south of Cache Creek and west of the Bonaparte River.[36] Magnetometer and electromagnetic surveys were done on the group consisting of the Midas and the Bird claims. The survey examined a small ultrabasic stock, but no mineralization was found. The Cornwall Creek showing is located 4.3 km (2.7 mi) up Cornwall Creek from Highway 1. The showing consists of appreciable serpentinite float and some outcrops.[23] A large boulder of chromite is the only sign of mineralization that was found on the property.

Near the Cornwall chromite deposit there is a diorite stock intruding Cache Creek greenstone and limestone;[5] the diorite is in turn intruded by small serpentinite plutons. The mineralization consists of pyrrhotite ($Fe_{1-x}S$) and limonite ($FeO(OH).nH_2O$) with lesser chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S) and garnierite ($(Ni, Mg)\ SiO_3.nH_2O$). Examination by the owners consisted of geological and geochemical surveys in addition to trenching. The mineralization was not of economic interest.

The Red Hill and RJ[6,8,12] deposits lie adjacent to the Trans-Canada Highway, 18 km (11 mi) south of Cache Creek. The deposits lie within Cache Creek group metavolcanic rocks, quartzite, chlorite schist, sericite schist and limestone. There are quartz diorite intrusions nearby. The mineralization consists of disseminated pyrite (FeS_2) with a few erratic veinlets and/or minor disseminated chalcopyrite ($CuFeS_2$), molybdenite (MoS_2) and limonite ($FeO(OH).nH_2O$). This mineralization is associated with an extensive, well-developed gossan zone. In examining these properties the owners conducted geochemical soil, induced polarization, resistivity, electro-magnetic, magnetic and geological surveys; in addition percussion drilling, diamond drilling and trenching were completed on favourable zones. There is no mineralization of present economic interest. However, this area is still considered to have potential for the development of ore deposits because of its location and geological environment. The Maggie

Mine,[42] near Carquile, which has not been developed as yet, contains in excess of 100 million tons of copper-molybdenum mineralization which assays 0.4 percent copper equivalent. The geological environment is similar to the deposits at Red Hill (Figure 4-8). The Guichon batholith immediately east of Red Hill contains the Highland Valley prophyry copper deposits consisting of Bethlehem and Lornex copper mines, the JA and Valley Copper deposits and numerous smaller deposits.

The site of the proposed pumphouse station is adjacent to the northwestern margin of the Guichon batholith. Because of the abundance of mineral deposits within the batholith the area was regarded as having a potential for copper-molybdenum deposits. Drilling has indicated that the bedrock consists of Middle to Upper Jurassic shale. There was no evidence of mineralization. No showings are known to occur in these rocks. These investigations have substantially reduced the possibility of the pumphouse station affecting exploitation of mineral deposits.

A geochemical survey was conducted over the McLean claims.[35] The soils were analyzed for copper, lead and zinc. A magnetometer survey was completed on the Ed and Joe claims[2] and the Milk claims.[33] The magnetic readings tended to be low suggesting deep overburden and, in the case of the Milk claims, the presence of underlying Tertiary sedimentary rocks. There is no evidence of mineralization described in the published information on these properties.

The R claims are held by Bethlehem Copper Corporation and lie between Bonaparte Indian Reserves Nos. 1 and 2. The claims are underlain by Tertiary sedimentary rocks. There is no published information on mineralization.

5.9 BASE METAL DEPOSITS - (Cont'd)

Mineral claim maps were examined. There was only one set of mineral claims within the Crown reserves set aside for the Hat Creek Thermal Project. The claims were west of McLean Lake near the proposed water supply route. The claims have been cancelled because no assessment was recorded on them prior to their anniversary date.

The slope of Mount Martley, west of the Houth Meadows waste disposal area, was identified from earlier geological mapping as having a potential for base metal mineral deposits. The geological environment is one in which the Mount Martley stock intrudes Marble Canyon limestone resulting in potential for both contact metasomatic type (associated with intrusions of molten rock or magma into limestone) or porphyry type (implying disseminated copper and molybdenum minerals in an intrusive rock) deposits. The contact type of deposit could contain copper, molybdenum, tungsten, lead, zinc, iron, tin and/or gold. In the porphyry type the metals of primary interest are copper and molybdenum. As a result a geochemical survey of the contact between the limestone and the stock was undertaken; all soil and silt samples were analyzed for copper, molybdenum, lead and zinc and some samples were also analyzed for tungsten, tin, gold and silver. These metals were chosen because they are compatible with this geological environment. The contact zone was defined by geological mapping and a magnetometer survey. Rock outcrops and the magnetometer survey on which the contact is based are illustrated in Figure 5-13. These surveys were conducted on a grid comprising a total of 12 100 m (39,700 ft) of line.

The magnetometer survey was used to determine the contact between the Mount Martley stock and the adjacent limestone. Magnetic readings were corrected for drift and diurnal variations by tying into a number of established stations several times in 1 day and also on succeeding days.

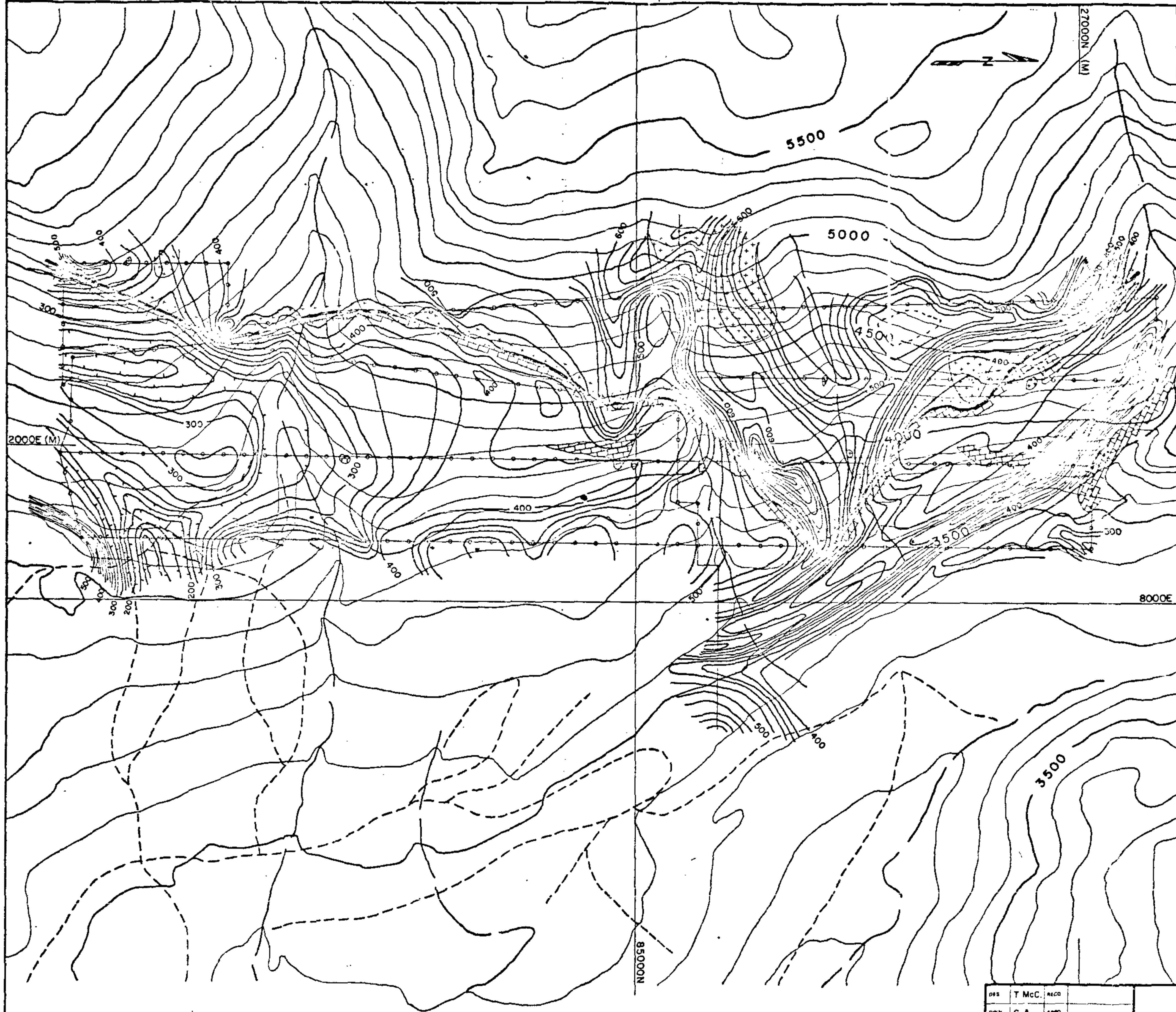
The area underlain by igneous rock is characterized by steeper magnetic gradients than are typical of the limestone terrane. therefore the contact could be defined. The steep gradients in the northeast and southeast parts of the grid are possibly due to greenstone dykes that intrude the limestone; greenstone float is evident in the area.

A geochemical soil and silt survey was undertaken to examine the distribution of copper, molybdenum, lead, zinc, gold, silver, tungsten and tin. Soil profiles were examined to determine the optimum sampling depth. The A soil horizon is rarely developed. Where possible the B soil horizon was sampled; however only the C horizon is developed at most sites where it is interspersed with talus. The soils are brown through light brown to grey brown. Based on the orientation survey better samples were obtained from the brown than from the grey brown samples and from B horizon or till samples than from C horizon samples; the better samples were higher in metals.

The soil and silt samples usually contain only small quantities of the elements that were analyzed. For each element the mean and standard deviation was calculated. Anomalous concentrations are defined as any analyses above two standard deviations from the mean.

The distribution of copper in the soils on Mount Martley is illustrated in Figure 5-14. The mean copper content in the soils is 11.55 ppm and the standard deviation is 5.74 ppm. Therefore any concentration over 23.0 ppm is regarded as anomalous. In

HAT CREEK PROJECT DETAILED ENVIRONMENTAL STUDIES



LEGEND

- ROAD
- CREEK
- TOPOGRAPHIC CONTOUR - ELEVATION IN FEET
- (M) METRIC COORDINATE
- —500— MAGNETIC CONTOUR (IN GAMMAS)
- **NOTE**: ADD 57,000 GAMMAS TO CONVERT TO TOTAL FIELD MAGNETIC CONTOUR
- GRANODIORITE
- LIMESTONE

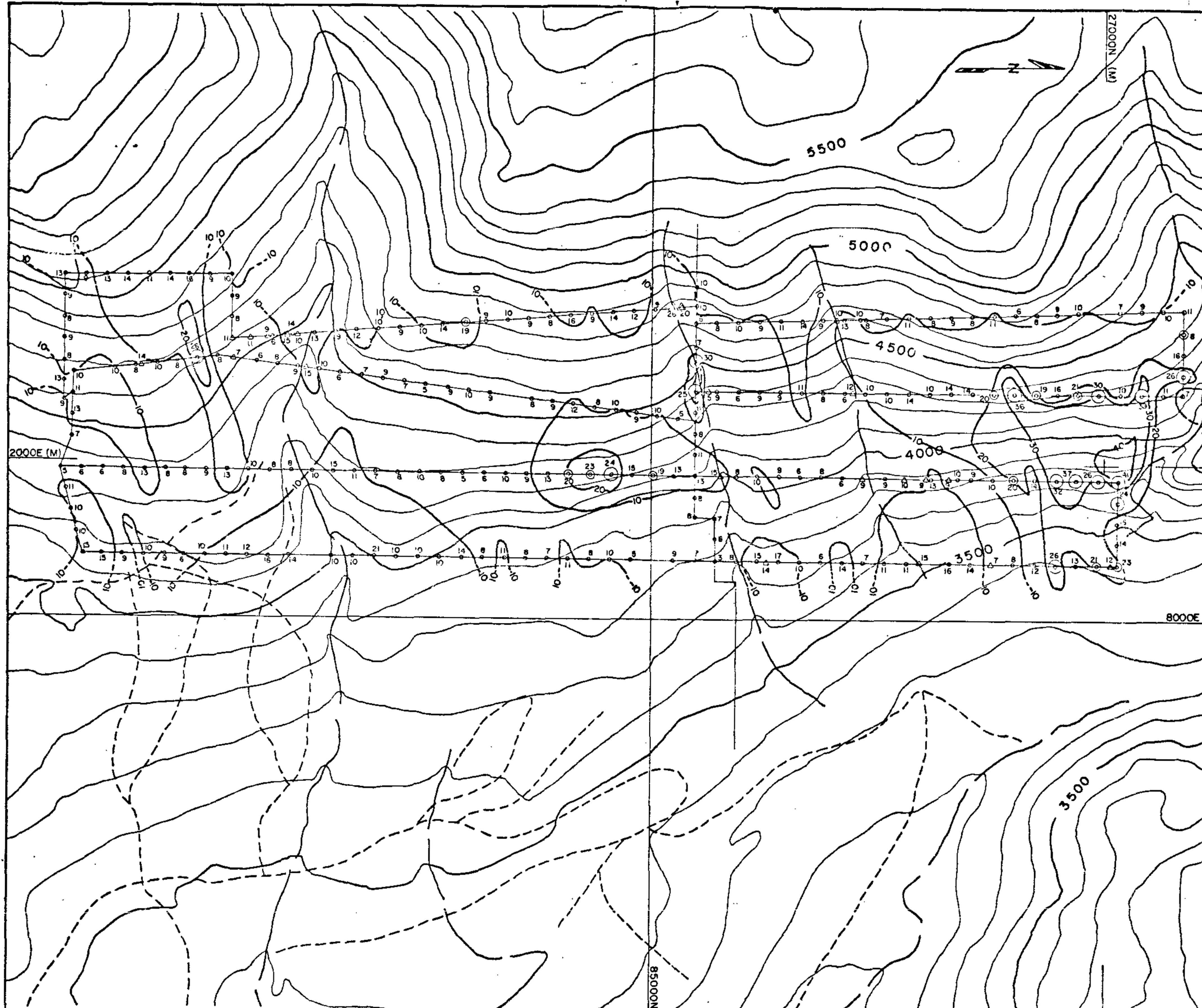
FIGURE 5-13

DES	T McC.	RECD	
DWN	C.A.	APPD	
CHKD		APPD	
INSP		APPD	
SUBD		DATE	21-9-77

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

GEOLOGY & MAGNETIC SURVEY OF WEST HOUTH MEADOWS

REFERENCE DRAWINGS — REVISIONS — REVISIONS — MICROFILMED — DIST'N CODE — SCALE — DWG No — R



HAT CREEK PROJECT DETAILED ENVIRONMENTAL STUDIES

SCALE (IN METERS)
0 100 200 300

SCALE (IN FEET)
0 200 400 600 800 1000

LEGEND

ROAD
CREEK
TOPOGRAPHIC CONTOUR - ELEVATION IN FEET
(M) METRIC COORDINATE
20 COPPER CONCENTRATION (IN PPM.)
-10- CONCENTRATION CONTOURS

SOIL
- BACKGROUND CONCENTRATION
- > 1 STANDARD DEVIATION (> 17 PPM.)
- > 2 STANDARD DEVIATION (> 23 PPM.)

SILT
- BACKGROUND CONCENTRATION
- > 1 STANDARD DEVIATION
- > 2 STANDARD DEVIATION

FIGURE 5-14

DES	T. McC.	RECO	
DWN	C. A.	APPD	
CHKD		APPD	
INSP		APPD	
SUBD		DATE	21-9-77

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

GEOCHEMICAL SURVEY OF WEST HOUTH MEADOWS (COPPER)

REFERENCE DRAWINGS — REVISIONS — REVISIONS — SCALE — DWG. No. — R the central part of the grid there are two small anomalous zones, one on each side of the intrusive contact. A larger anomalous zone in the northern part of the grid extends over three lines. The highest value is 41.0 ppm. Outcrops adjacent to the sample site are composed of limestone. A belt of high magnetics crosses this zone (Figures 5-13 and 5-14).

The concentration of molybdenum in soils over the grid is very low; in most samples none was detected (Figure 5-15). The highest value for molybdenum is 2 ppm. The sample site is in the area of a copper anomaly.

The concentration of lead in the soils was determined over the grid. The mean lead content of the soils is 13.4 ppm and the standard deviation is 3.8 ppm. Therefore all samples above 20 ppm are anomalous. Four lead anomalies were determined (Figure 5-16). One anomaly coincides with the larger copper anomaly. Additional anomalies are located in the centre, the southwestern part, and the southern part of the grid. The anomaly at the north end of the grid extends over three lines and is somewhat similar in form to the copper anomaly. Three of these anomalies are located near the intrusive contact (Figures 5-13 and 5-16).

The concentration of zinc in soils ranges to 188 ppm (Figure 5-17). The mean zinc content is 62.2 ppm and the standard deviation is 33.1 ppm. Therefore all samples above 128 ppm are anomalous. There are five zones of anomalous zinc. The largest zone coincides with part of the copper-lead anomaly at the north end of the grid. There are other smaller anomalies in the north central, south central, western and southeastern parts of the grid. One of these coincides with a copper-lead anomaly. Two of

5.9 BASE METAL DEPOSITS - (Cont'd)

the anomalies are within the intrusion, two lie in the limestone near the intrusive contact and one lies in the limestone 500 m (1640 ft) from the contact.

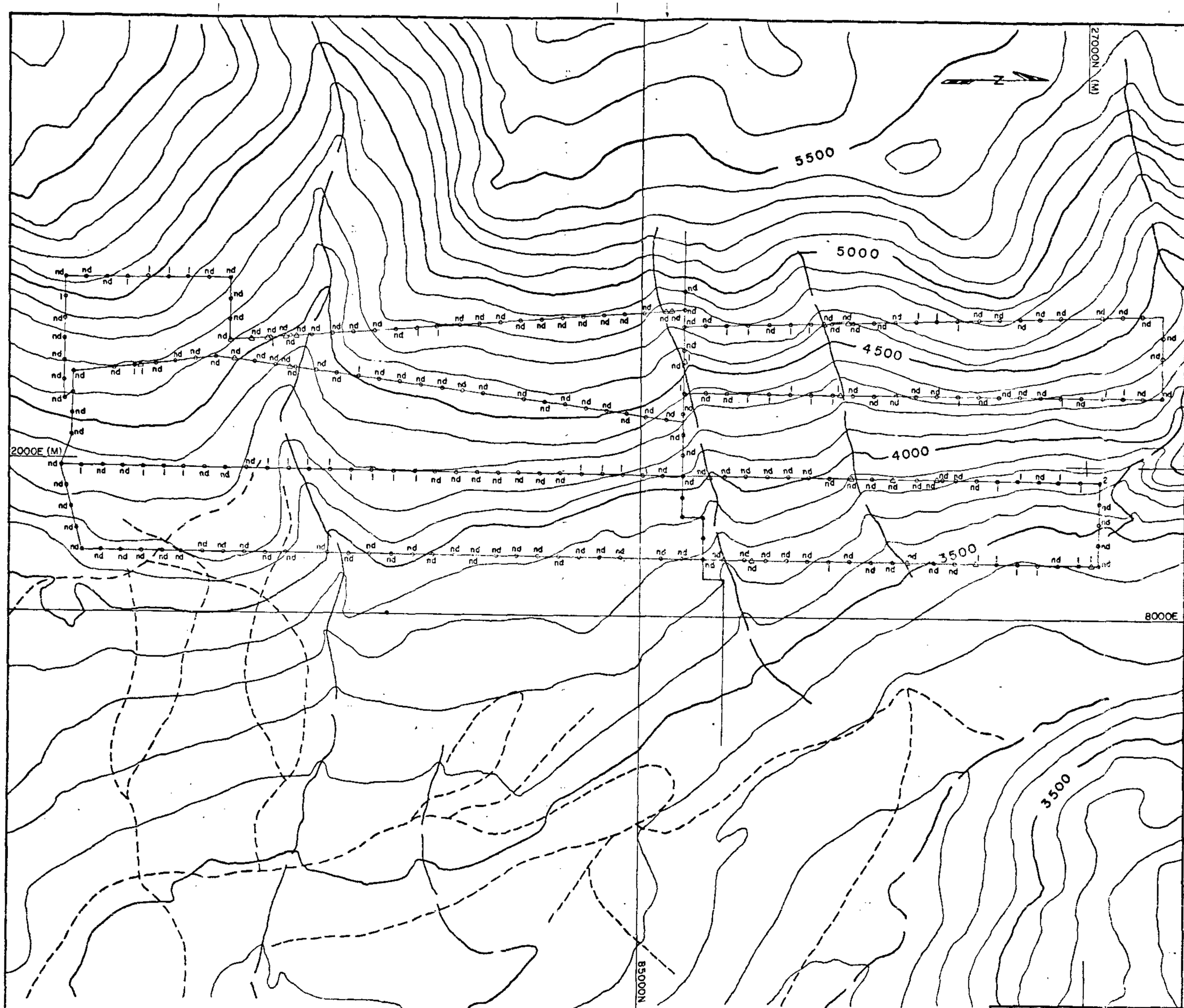
A few silt samples were analyzed for gold, silver, tungsten and tin in addition to copper, molybdenum, lead and zinc (Figure 5-18). The maximum concentrations are 30 ppb for gold, 0.9 ppm for silver, 35 ppm for tungsten and 70 ppm for tin. None of the values are sufficiently high to be of interest.

(c) Discussion

It is evident from the geochemical analyses that the area of most interest is in the northern part of the grid. A copper-lead-zinc anomaly corresponds with the margin of the intrusion in this area. Because the concentrations of all elements are low even in the areas where they are anomalous, it is expected that the anomalies are due to slightly above average concentrations in the underlying rock. Examination in the field indicated that greenstone float is abundant in the most anomalous area, but rare outside the anomaly. Geochemical analysis of the greenstone supports the conclusion that the anomalies are related to the difference in rock type. A sample of greenstone contains 57 ppm Cu whereas the adjacent limestone contains 7 ppm.

(d) Conclusions

There is no evidence of significant base metal deposits or potential for deposits in the area currently proposed for the Hat Creek mine, powerplant and related structures. Therefore it is unlikely there will be any conflicts between exploitation of coal at Hat Creek and base metal deposits. It is possible that a transmission line down Oregon Jack Creek, if this option is chosen, could conflict with development of the Red Hill deposits;



HAT CREEK PROJECT DETAILED ENVIRONMENTAL STUDIES

SCALE (IN METERS) 0 100 200 300

SCALE (IN FEET) 0 200 400 600 800 1000

LEGEND

- ROAD
- CREEK
- TOPOGRAPHIC CONTOUR - ELEVATION IN FEET
- (M) METRIC COORDINATE
- o SOIL
- Δ SILT
- 2 MOLYBDENUM CONCENTRATION (IN P.P.M.)
- nd NONE DETECTED

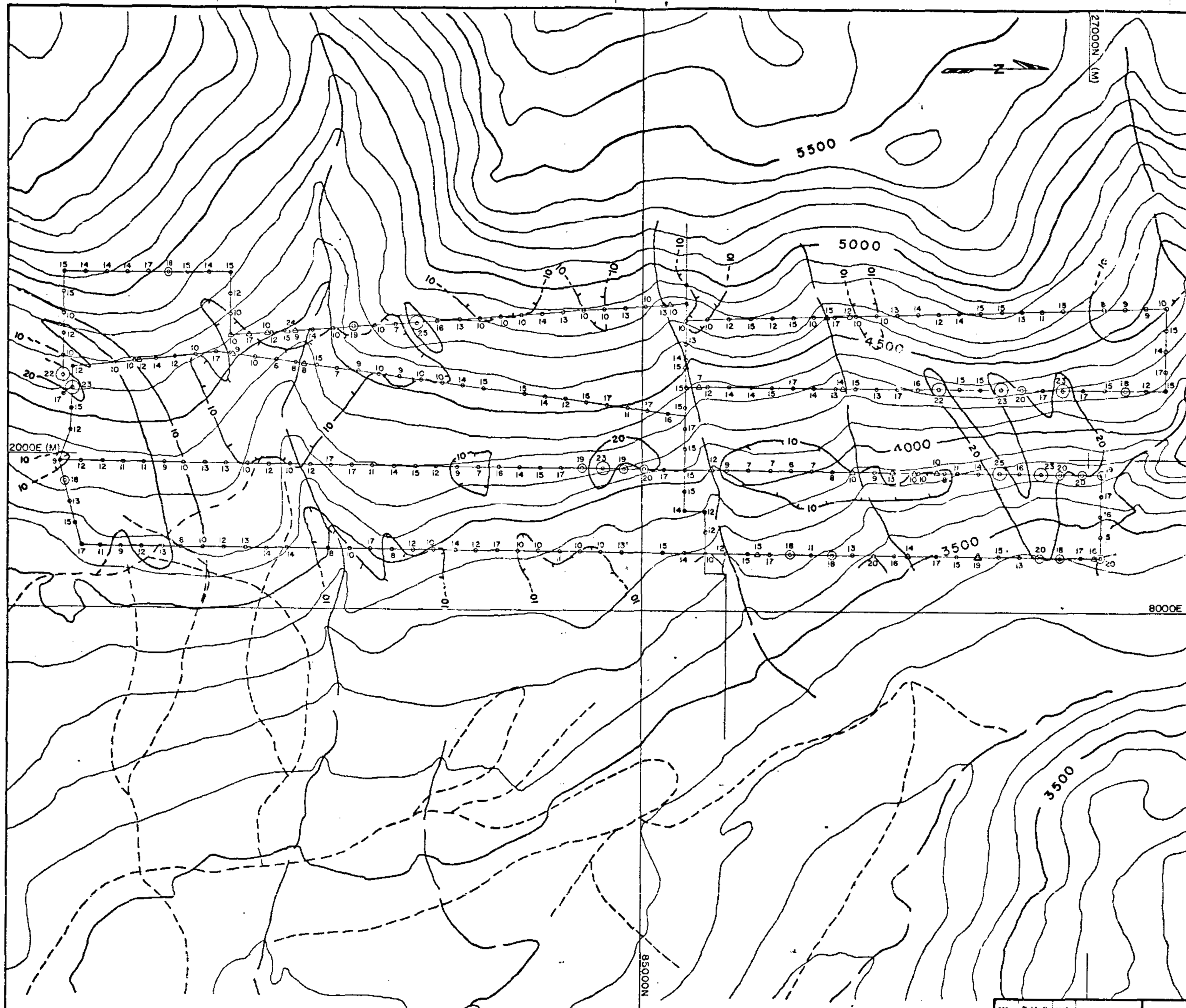
FIGURE 5-15

DES	T. McC.	RECD	
DWN	C. A.	APPD	
CHKD		APPD	
INSP		APPD	
SUBD		DATE	21-9-77

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

GEOCHEMICAL SURVEY OF WEST HOUTH MEADOWS (MOLYBDENUM)

REFERENCE DRAWINGS | REVISIONS | REVISIONS | MICROFILMED | SCALE | DWG No | R



HAT CREEK PROJECT DETAILED ENVIRONMENTAL STUDIES

SCALE (IN METERS)
0 100 200 300

SCALE (IN FEET)
0 200 400 600 800 1000

LEGEND

ROAD
CREEK
TOPOGRAPHIC CONTOUR - ELEVATION IN FEET
(M) METRIC COORDINATE
20 LEAD CONCENTRATION (IN PPM)
—10— CONCENTRATION CONTOURS

SOIL
- BACKGROUND CONCENTRATION
- ◎ >1 STANDARD DEVIATION (> 17 PPM)
- ⊙ >2 STANDARD DEVIATIONS (> 20 PPM)

SILT
- △ BACKGROUND CONCENTRATIONS
- ▲ >1 STANDARD DEVIATION
- △ >2 STANDARD DEVIATIONS

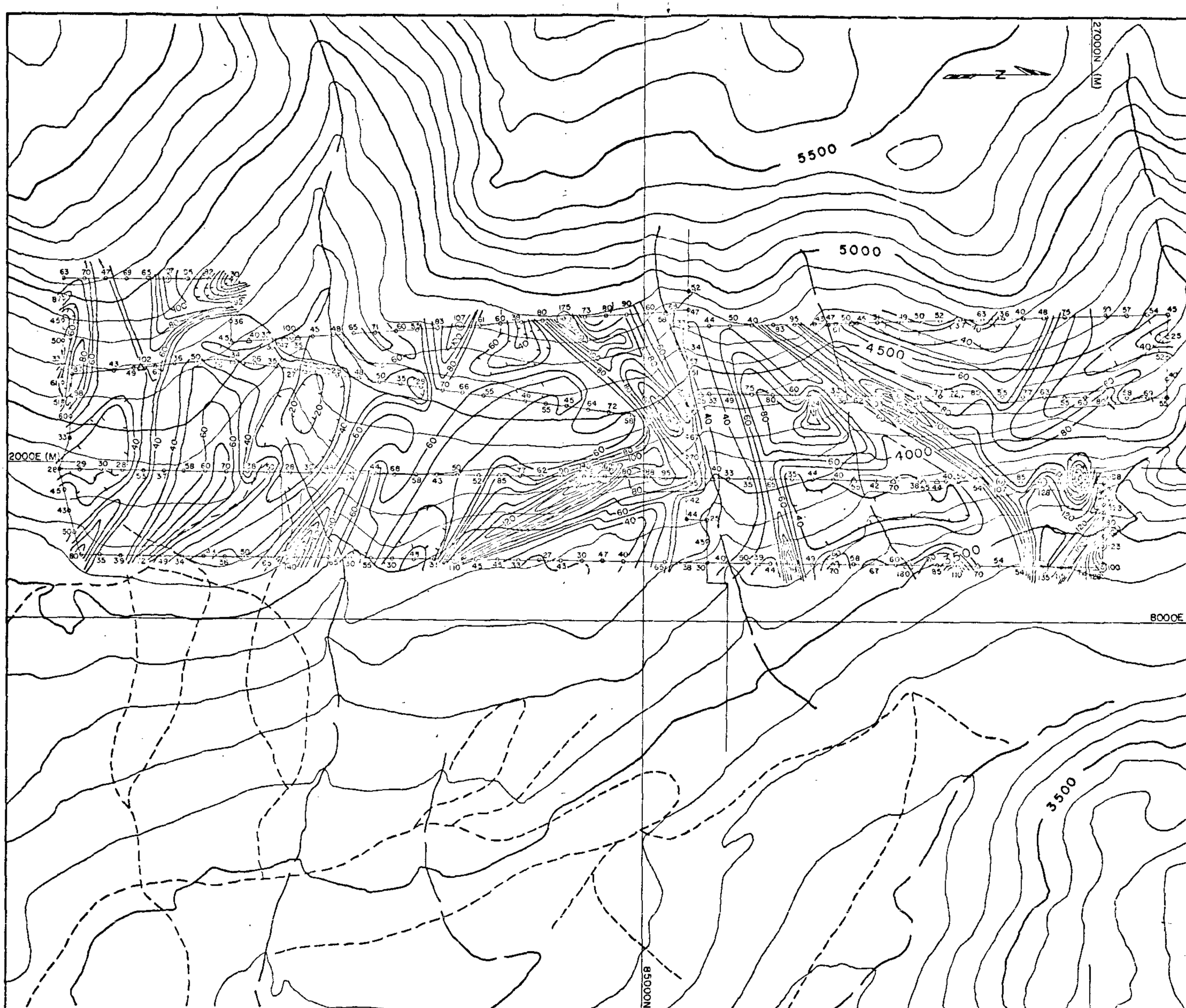
FIGURE 5-16

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

GEOCHEMICAL SURVEY OF WEST HOUTH MEADOWS (LEAD)

DES	T McC	RECD	
DWN	C.A.	APPD	
CHKD		APPD	
INSP		APPD	
SUBD		DATE	21-9-77

REFERENCE DRAWINGS — REVISIONS — REVISIONS



HAT CREEK PROJECT DETAILED ENVIRONMENTAL STUDIES

SCALE (IN METERS)

0 100 200 300

SCALE (IN FEET)

0 200 400 600 800 1000

LEGEND

- ROAD
- CREEK

TOPOGRAPHIC CONTOUR - ELEVATION IN FEET

(M) METRIC COORDINATE

20 ZINC CONCENTRATION (IN PPM.)

-40- CONCENTRATION CONTOURS

SOIL

- BACKGROUND CONCENTRATION
- >1 STANDARD DEVIATION (>95 PPM.)
- >2 STANDARD DEVIATIONS (>128 PPM.)

SILT

- BACKGROUND CONCENTRATION
- >1 STANDARD DEVIATION (>95 PPM.)
- >2 STANDARD DEVIATION (>128 PPM.)

FIGURE 5-17

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

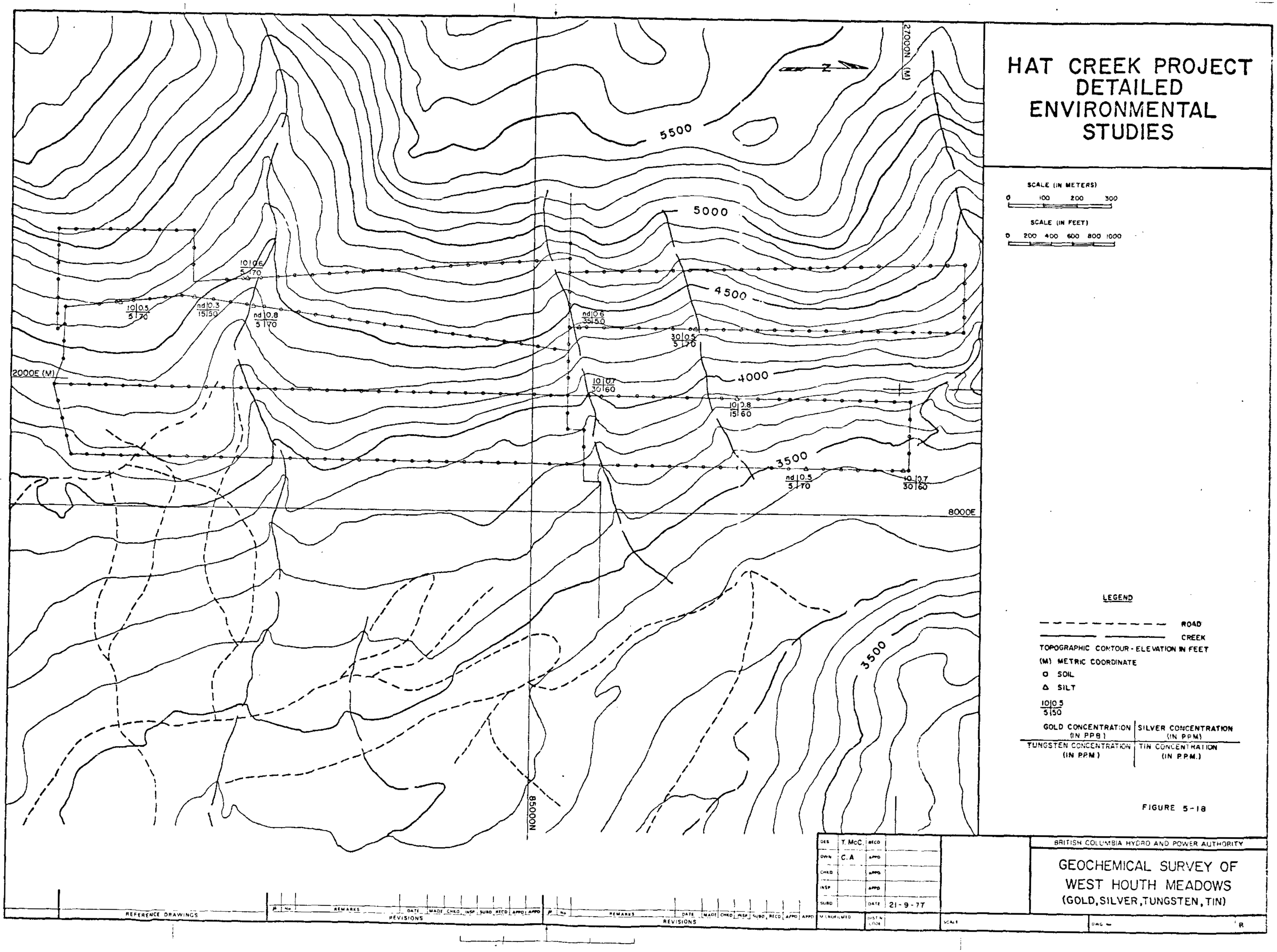
GEOCHEMICAL SURVEY OF WEST HOUTH MEADOWS (ZINC)

DES	T McC.	RECD	
DWN	C. A.	APPD	
CHKD		APPD	
INSP		APPD	
SUBD		DATE	21-9-77

REFERENCE DRAWINGS

REVISIONS

REVISIONS


HAT CREEK PROJECT
DETAILED
ENVIRONMENTAL
STUDIES
SCALE (IN METERS)
0 100 200 300
SCALE (IN FEET)
0 200 400 600 800 1000
5500
5000
4500
4000
3500
3500
2000E (M)
8000E
27000N (M)
8500N
LEGEND
ROAD
CREEK
TOPOGRAPHIC CONTOUR - ELEVATION IN FEET
(M) METRIC COORDINATE
O SOIL
Δ SILT
GOLD CONCENTRATION (IN PPB)
SILVER CONCENTRATION (IN PPM)
TUNGSTEN CONCENTRATION (IN PPM)
TIN CONCENTRATION (IN PPM)
FIGURE 5-18
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
GEOCHEMICAL SURVEY OF
WEST HOUTH MEADOWS
(GOLD, SILVER, TUNGSTEN, TIN)
T. McC.
C.A
21-9-77
REFERENCE DRAWINGS
REVISIONS
REVISIONS

5.9 BASE METAL DEPOSITS - (Cont'd)

however there are no known deposits at Red Hill that are economically viable. Any future conflict could be corrected by moving the transmission line.

5.10 PRECIOUS METAL DEPOSITS

(a) Introduction

As prospectors travelled up the Fraser, Thompson and Bonaparte valleys toward the Cariboo gold discoveries considerable prospecting was undertaken. The only previous metal prospect within the crown reserve or coal licences is the Red Hill copper-silver deposit which was described in Section 5.9.

The AV showing is a fossil placer gold prospect on Maiden Creek, 18 km (11 mi) north of the proposed plant site and outside the area of concern (Figure 5-13). However, the deposit is in Coldwater conglomerate of the type that underlies the coal sequence at Hat Creek and which would be mined in the north and west parts of the proposed pit. The rocks associated with the AV deposit were examined and this deposit was used as a model for studying the Coldwater beds at Hat Creek. Government reports on the property were also examined.[7,40,58]

(b) Inventory

The rocks of the AV deposit on Maiden Creek were examined. The host rock is a fine, yellow, quartz pebble conglomerate; coarser quartz pebble conglomerate is also common. Based on literature research one sample from the property assayed \$3.75 in gold per ton (in 1901).[58] A geochemical soil survey conducted over the property in 1973 encountered samples with as much as 57 ppm gold although most samples assayed .02 ppm.[40]

5.10 PRECIOUS METAL DEPOSITS - (Cont'd)

Because of the discovery of gold in Coldwater beds on Maiden Creek the core at Hat Creek was examined to locate similar material or to find magnetite ("black sand") concentrations. Because of their high specific gravities gold and magnetite are often found together in placer gold showings. No traces of gold or magnetite concentrations were found. Five samples of sandstone and conglomerate from the Coldwater beds at Hat Creek were analyzed. The samples all assayed .001 ounce of gold per ton.

(c) Conclusions

There is only one known deposit of precious metals of concern to the Hat Creek project. The Red Hill deposit contains silver together with copper. The deposit is not of economic grade. Should the transmission line, which may cross the prospect, interfere with development of a major resource, the transmission line could be moved; therefore possible conflict with the resource is not regarded as serious.

5.11 ROCK AND MINERAL COLLECTING LOCALITIES

(a) Introduction

Numerous minerals of interest to collectors occur in the rock units that are found in the Hat Creek Valley and adjacent areas affected by the project.[37] The volcanic rocks of the Kamloops group which outcrop in the Trachyte Hills are known to contain quartz geodes, zeolites, agate, calcite and opal as individual crystals or cavity fillings. The limestone of the Cache Creek group contains rhodonite and the volcanic sequence contains jasper. Agate has been found at various localities in the Spences Bridge group. Chromite and serpentine are found associated with small serpentinite plutons in the Bonaparte and Cornwall Creek valleys. Peridot is associated with some of the Tertiary olivine basalt in the area. Amber and pertrified wood are associated with the coal deposits in the Upper Hat Creek Valley.

To examine the potential for rock and mineral collecting localities, sites found during geological mapping were examined specifically for rocks and minerals of interest to collectors. A literature survey was conducted to find other rock collecting localities.[23,37]

(b) Inventory

Because of the nature of this resource and the distribution of the resource through the rock units, only collecting localities within the mine and powerplant sites could be adversely affected by the development of the Hat Creek coal deposits. The amber and petrified wood are generally soft, brittle and therefore of poor quality. They may still be of limited interest to collectors. Large quantities of petrified wood are expected from the pit. This material is softer than petrified wood from most other localities therefore it is of only limited interest. Some petrified wood could be collected during mining and crushing for distribution to rock collectors.

Jasper has been found as float in the creek beds of the Upper Hat Creek Valley. Quartz geodes, zeolites and agate occur in rocks of the Kamloops group east of the No. 1 deposit although these are generally small and of inferior quality. The serpentine of the Cornwall Creek Valley may be workable and therefore of interest to collectors. No chromite has been found in outcrop in the valley.

5.11 ROCK AND MINERAL COLLECTING LOCALITIES - (Cont'd)

(c) Conclusions

There are numerous rock collecting localities in the area that would not be affected by the development. Known localities that would be directly and adversely affected contain material of inferior quality. The extraction of petrified wood and amber could be enhanced by the project.

5.12 BY-PRODUCT TRACE ELEMENTS

(a) Introduction

The purpose of examining possible by-product trace elements from Hat Creek is to ensure that a resource which is small in volume, but potentially valuable, would not be discarded. Trace elements tend to be concentrated in coal seams through three stages in the formation of the coal:

1. During the life of the plants because some plants extract elements preferentially.

2. During partial decay of the vegetal matter and leaching of the peat.

3. During coalification.

In addition nonvolatile elements can be concentrated in the fly ash resulting from combustion. This aspect is being examined as part of the environmental study on "Solid Waste Disposal Coal Storage Land Reclamation".

The study of trace elements is restricted to the area of the No. 1 coal deposit with particular emphasis on the coal to be mined as part of the current mining proposal.

The method of study involved literature research concerning the distribution of trace elements in coals from various regions, the enriching effect of coals on trace element distribution and the prices and demand for trace elements that are anomalous in Hat Creek coal.

Analyses on trace elements were obtained from the report "*Air Quality and Climatic Effects of the Proposed Hat Creek* Project - The Influence of the Project on Trace Elements in the Ecosystem". Methods of analyses included spark source mass spectroscopy, flameless atomic absorption spectrophotometry, plasma atomic emission spectroscopy and specific ion electrode. The methods of analysis are described in the report "Air Quality and Climatic Effects of the Proposed Hat Creek Project - The Influence of the Project on Trace Elements in the Ecosystem".

(b) Inventory

Trace element concentrations have been determined on three samples from the Canadian Combustion Research Laboratory's test burn and on eleven composite samples of drill core from the Hat Creek No. 1 *deposit. The samples were chosen to give a* satisfactory sampling distribution over the deposit. Additional samples are being analyzed to improve the distribution still further.

The results of the analyses are summarized in columns 1 and 2 of Table 5-7.[49] For comparison average analyses of more than 799 samples from various parts of the United States are summarized in columns 3 through 7. One problem that is encountered in making these comparisons is that data from other deposits is *incomplete. Of the elements in the coal that could be of economic* interest only vanadium and titanium are appreciably higher than in

TABLE 5-7

COMPARISON OF TRACE ELEMENTS BETWEEN HAT CREEK COAL AND AVERAGE COALS FROM FIVE COAL PROVINCES* OF THE UNITED STATES

	1	2	3	4	5	6	7
Aluminum	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Antimony	<0.7	<0.2	1.7	0.9	0.6	0.4	1.2
Arsenic	16	16	21	6	3	2	27
Barium	384	330	70	200	500	200	100
Beryllium	0.3	0.6	3.0	2.0	0.5	0.7	2.0
Bismuth	0.4	<0.2					
Boron	4.0	26.8	100.0	100.0	70.0	70.0	30
Bromine	1.3	<0.4	15.0**				
Cadmium	<0.5	<0.5	7.1	1.3	0.2	0.5	0.7
Calcium	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Cerium	15.6	16.0					
Cesium	1.7	0.8					
Chlorine	24.3	6.0	>1000**				
Chromium	63.3	46.0	15.0	20.0	5.0	5.0	20.0
Cobalt	6.7	5.5	7.0	7.0	2.0	2.0	7.0
Copper	38.3	19.5	20.2	28.0	8.3	9.1	24.0
Dysprosium	1.0	<0.4					
Erbium	0.6	<0.2					
Europium	0.4	0.3					
Fluorine	100.7	117.5	71.0	124.0	45.0	70.0	80.0

TABLE 5-7 - (Cont'd)

	1	2	3	4	5	6	7
Gadolinium	0.9	<0.4					
Gallium	16.0	11.0	5.0	10.0	3.0	3.0	7.0
Germanium	0.4	<0.2	13.0***		1.6***	5.9***	5.8***
Gold	<0.1	<0.2					
Hafnium	1.5	<0.2					
Holmium	0.7	<0.4					
Indium	STD	STD					
Iodine	0.3	<0.2					
Iridium	0.1	<0.2					
Iron	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Lanthanum	13.7	10.3	5.1***		9.5***	6.5***	9.4***
Lead	3.7	<5.0	55.0	20.0	5.3	5.5	15.3
Lithium	13.0	25.5	11.0	28.0	6.0	9.2	27.6
Letutium	0.2	<0.2					
Magnesium	>1000	>1000	890	>1000	>1000	>1000	680
Manganese	138	96	138	240	51	36	620
Mercury	0.1	0.1	0.14	0.18	0.09	0.06	0.24
Molybdenum	3.7	2.3	5.0	3.0	2.0	1.5	3.0
Neodymium	5.7	3.5					
Nickel	19.3	20.0	30.0	20.0	3.0	3.0	15.0
Niobium	7.0	6.8	1.5	7.0	5.0	5.0	5.0
Osmium	<0.1	<0.2					

TABLE 5-7 - (Cont'd)

	1	2	3	4	5	6	7
Palladium	<0.1	<0.2					
Phosphorus	453.3	285.0					
Platinum	<0.1	<0.2					
Potassium	>1000	>1000	>1000	>1000	400	760	>1000
Praesodymium	1.7	2.5					
Rhenium	<0.1	<0.2					
Rhodium	<0.1	<0.2					
Rubidium	14.0	3.8					
Ruthenium	<0.1	<0.2					
Samarium	3.0	1.2					
Scandium	8.0	9.3	3.0	7.0	2.0	2.0	5.0
Selenium	1.6	0.3	4.6	7.0	1.0	1.6	4.7
Silicon	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Silver	<0.2	<0.3					
Sodium	>1000	>1000	350	>1000	>1000	>1000	320
Strontium	99.7	53.0	50.0	200.0	150.0	100.0	100.0
Sulphur	>1000	>1000	>1000	>1000	>1000	>1000	>1000
Tantalum	<0.1	<0.2					
Tellurium	<0.2	<0.2					
Terbium	0.2	0.2					
Thallium	<0.5	<0.2					
Thorium	3.7	<2.3	5.2	8.3	2.7	3.6	4.9

TABLE 5-7 - (Cont'd)

	1	2	3	4	5	6	7
Thulium	0.2	<0.2					
Tin	0.9	<0.6					
Titanium	>1000	>1000	520	>1000	420	610	900
Tungsten	<1.1	<0.2					
Uranium	2.3	<2.0	3.3	3.2	0.9	1.6	1.4
Vanadium	85.7	107.0	20.0	50.0	10.0	15.0	20.0
Ytterbium	0.9	<0.2	0.7	2.0	0.3	0.5	1.0
Yttrium	16.3	11.5	10.0	20.0	5.0	5.0	10.0
Zinc	32.7	18.3	373.0	40.0	25.6	9.9	20.0
Zirconium	77.3	61.5	15.0	70.0	15.0	20.0	50.0

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* Column 1 Mean of three samples of coal from the Hat Creek No. 1 deposit that were analyzed at Commercial Testing and Engineering Laboratories, Golden, Colorado (in ppm).

Column 2 Mean of eleven additional coal samples from the Hat Creek No. 1 deposit analyzed at Commercial Testing and Engineering Laboratories, Golden, Colorado (in ppm).

Column 3 Mean of coal samples from the Interior Coal Province, U.S.A. (in ppm).[60]

Column 4 Mean of coal samples from the Gulf Province, U.S.A. (in ppm).[60]

Column 5 Mean of coal samples from the Northern Great Plains Coal Province, U.S.A. (in ppm).[60]

Column 6 Mean of coal samples from the Rocky Mountain Coal Province, U.S.A. (in ppm).[60]

Column 7 Mean of samples of nonanthracitic coal from the Eastern Province Appalachian Coal Region, U.S.A. (in ppm).[60]

** Mean of samples of Illinois coal, U.S.A. (in ppm).[55]

*** Mean of samples of coal from the Northern Plains, Mid-western, Appalachian and Eastern Interior regions, U.S.A. (in ppm).[66]

the U.S. coals. Burning tends to concentrate these elements in the fly ash along with other non-volatile elements. As a result the fly ash would provide a better potential source of vanadium and titanium.

Vanadium occurs in the coal samples in concentrations ranging from 32 to 400 ppm. Concentration factors in burning the coal range from 2.8 to more than 17.9 times resulting in concentrations of vanadium from 380 ppm to more than 1000 ppm. As a result the vanadium content of the ash samples ranges from 0.38 kg per tonne to more than 1 kg per tonne (0.76 lb per short ton to more than 2 lb per short ton). The price of vanadium in 1977 was approximately $11.99 (U.S.) per kg ($5.44 per lb).[10] The feasibility of extracting vanadium from the fly ash is described briefly in the Hat Creek Project report "Solid Waste Disposal Coal Storage Land Reclamation".

Titanium is present in the coal in concentrations of approximately 1400 ppm. These concentrations are increased in the fly ash to as much as 13,000 ppm or 1.3 percent. Titanium metal is valued at approximately $5.95 per kg or $2.70 (U.S.) per lb.

(c) Discussion

Only two potentially valuable elements, vanadium and titanium, are anomalously concentrated in Hat Creek coal. Vanadium is presently obtained as a by-product of uranium, oil, bauxite, laterite and titaniferous magnetite processing. Some uranium deposits in the Colorado Plateau of the United States contain as much as 5 percent V_2O_5. Vanadium is extracted from asphaltite ash resulting from burning the heavy end members of some crude oils. Argentinian asphaltite ash contains between 0.63 and 38.22 percent V_2O_5.[20] Titaniferous magnetite ores from the Allard Lake region of Quebec contain between 0.1 and 0.2 percent vanadium;[43,54] this potential by-product is not currently recovered. It is evident that there are large reserves of vanadium with grades as good or better than Hat Creek that are currently being processed for other products; in many cases the vanadium is not extracted because of economic considerations.

In addition, ashes from vitrified clay like that expected from Hat Creek probably would not react as readily as most crude oil asphaltic residues, based on the experience of Great Canadian Oil Sands Limited.[65] The process for extracting the vanadium involves a sulphuric acid leach based on a process developed by Petrofina Canada Limited. The process works well on crude oil residues which consist mostly of unburned carbon and V_2O_5, but was not successful on oil sand residues.

Titanium is present in anomalous concentrations relative to other coals. However, there are numerous richer sources of titanium than Hat Creek coal or fly ash. Titanium is the eighth most abundant metal in the earth's crust.[22] Some ilmenite ores from Quebec contain between 20 and 22 percent titanium; iron and other metals are obtained as by-products. Beach sands provide additional large sources of titanium elsewhere in the world. Titaniferous magnetites comprise other large, potential sources of titanium; however as with ashes from Hat Creek it is generally difficult to separate. Titanium ores are normally concentrated by gravity separation, magnetic separation or froth flotation.[18] Because titanium is likely to be intimately associated and bonded with other elements in the crystal lattice of any constituent minerals or glass, or as small exsolved blebs of ilmenite, recovery of titanium oxide from titaniferous magnetite and magnetite-ilmenite deposits or fly ash is very difficult. Liberating titanium metal of sufficient purity is even more difficult.[53]

5.12 BY-PRODUCT TRACE ELEMENTS - (Cont'd)

(d) Conclusions

There are no trace elements in the coal that may be of economic benefit at present. Vanadium is concentrated in some fly ash in quantities in excess of 1 kg per tonne (2 lb per short ton), therefore the technology and economics of vanadium extraction should be watched closely. Similarly, titanium is not of any current value. Because of large resources elsewhere and the difficulties of separation, the extraction of titanium from coal or fly ash is not expected to become of economic interest.

SECTION 6.0 - IMPACT MATRIX

6.1 INTRODUCTION

The purpose of constructing the impact matrix is to provide a tabulated summary of environmental impacts. In this report the effects of the mine, powerplant and offsite facilities on geological resources are examined. The geological resources are site specific; most of the construction of facilities and mining are located within the Upper Hat Creek Valley as illustrated in Figure 2-1. Therefore most of the effects of these facilities occur within the valley. Lesser effects would result from the access road, water pipeline and pumphouse.

The impact on geological resources relates to sterilization of the resources, so that they cannot be exploited. As a result the effects of the project occur primarily during the operating phase of the project. Effects during construction consist of utilization of local aggregate resources for construction purposes, but these effects are not regarded as significant because of the large aggregate resources that are believed to be available in the region and within the Upper Hat Creek Valley in particular.

6.2 MATRIX DESCRIPTION

In the impact matrix the resources are plotted along the ordinate and the various impacts that may affect these resources are plotted along the abscissa. The matrix is illustrated in Figure 6-1.

The aggregate resources that occur in and adjacent to the northeast part of the proposed openpit are the geological resources most seriously affected by the development. It is estimated that 645 million tonnes (710 million short tons) of aggregate are contained

Figure 6-2

ENVIRONMENTAL IMPACT MATRIX - OPERATION

Resource	Mine												Plant						Offsite				
	Coal Excavation	Overburden Removal	Drainage	Waste Dumps	Topsoil Storage	Conveyor System	Preparation Plant	Mine Office and Other Buildings	Roads	Blending & Surge Piles	Water Supply	Camp Facilities	Conveyor Systems	Plant	Switchyard	Cooling Towers	Reservoir	Roads	Roads	Diversion Canal	Water Supply Pipeline	Pumphouse	Airstrip
Aggregate		◢			▲	▲	▲	▲	▲	▲	▲	▲							▲	▲	▲	▲	
Limestone				◢									▲					▲	▲		▲		
Clay	◥	◥	▲		▲	▲			▲		▲		▲					▲		▲			
Burn zone claystone	◥																						
Coaly waste	◥																						
Rock and Mineral Localities	▲																						

Legend: Negative Impact ▲ minor ◢ major; Beneficial Impact ▼ minor ◥ major; No Measurable Impact ☐

6.2 MATRIX DESCRIPTION - (Cont'd)

within the bench northeast of the No. 1 deposit. Of this resource approximately 200 million tonnes (220 million short tons) would be mined based on the proposed PD-NCB pit plan. These materials would be stored in the Houth Meadows waste disposal area. Pit excavation and mine facilities could have a severe effect on the utilization of these resources during operation and through the post-decommissioning phases. These effects would be severe only if no provision was made for isolation of a significant part of the aggregate within the waste dump area. Aggregate resources in the Thompson Valley would be only slightly affected by offsite facilities, namely the proposed Cornwall Creek road and water supply line.

Limestone resources adjacent to Houth Meadows would be appreciably affected. If the PD-NCB alternative A disposal plan was adopted approximately 360 million tonnes (390 million short tons) of limestone would be sterilized. If alternative B was adopted the amount sterilized would be approximately 30 million tonnes (35 million short tons). Approximately 150 million tonnes (165 million short tons) would lie in a wedge north of the waste dump and above the level of the "Plan A" dump should that alternative be adopted. These limestone resources could be utilized if either disposal plan was adopted. In addition, the conveyor systems, roads and water supply pipeline would cross some limestone terrane, but the areas involved consist of only a few narrow strips.

The claystone deposits lie within and above the coal sequence. Although precise quantities are not available it is estimated that between 800 and 900 million tonnes (880 and 990 million short tons) of claystone and siltstone, consisting mainly of clay minerals, lie within the proposed PD-NCB openpit. As yet the potential uses of these materials have not been determined; however these studies are in progress. It is expected that, at best, uses could be found for only a small part of these deposits which consist of both kaolinitic and bentonitic clays. Overburden and coal removal would permit access to this resource which is otherwise inaccessible. However, coal excavation and arbitrary dumping into the waste disposal areas would adversely affect their future recovery. Other lesser and temporary effects result from the construction of installations which would eventually be obsolete; some of these installations overlie claystone which could be excavated when the facilities have been decommissioned.

The only rock and mineral collecting locality directly affected by the Hat Creek Project is on the eastern edge of the No. 1 openpit where thin slivers of agate can be found in the Kamploops volcanic rocks. Agate and amber will be excavated by the mine and some could be recovered for collectors. The locality is of minor importance and is not currently used by collectors.

The only by-product trace element from the coal that could be of any importance is vanadium. It tends to be concentrated in the fly ash and its potential, therefore, has been reviewed in the study on "Solid Waste Disposal Coal Storage Land Reclamation".

Decommissioning would have few special effect on resources. The only significant effect results from filling the pit with water after mining ceases. Only half of the coal would be extracted at the end of the 35-year life of the powerplant. Allowing for some flow downstream during filling, it is estimated that it would take 26 years to fill the pit so that the water could flow down its original course.[46] The difficulties in pumping out the pit should mining be required to recommence during or after filling of the pit would result from the time involved, the instability of the saturated pit walls, the adverse effect on the Hat Creek channel morphology and the possible flooding downstream as a result of the increased water flow.

6.3 MITIGATION AND COMPENSATION

There are several opportunities for mitigation and compensation of resources affected by the Hat Creek Thermal Project. The effects of the project on aggregate resources could be severe; however, the adverse effects can be mitigated by isolating the aggregate in part of the waste dump area. This would allow the aggregate to be re-excavated as required. In addition, bottom ash could be substituted for some aggregate. Bottom ash could be of considerable benefit for reducing skidding on icy, paved roads. By adopting PD-NCB alternative B waste disposal plan only a small part of the limestone resource would be sterilized. In addition, because limestone resources in the area are very large, the total effect of the project on the utilization of limestone resources is small, whether waste disposal alternative A or B is adopted. Claystone at Hat Creek is presently inaccessible; if the claystone is segregated in the waste dump according to clay type, it could possibly be adopted for a number of uses. The project could therefore enhance the excavation and use of the claystone resource. Studies on its suitability for several uses are continuing. There is a potential market for the burned claystone. The mine at Hat Creek would enable more economic extraction of this potential resource. Tests are being conducted to establish its suitability as a replacement for artifically calcined clay; similarily "coaly waste" may be used for producing calcined clay. This mine by-product would not be used without the project because it would not be feasible to mine it. The effects of the project on rock and mineral collecting localities would be minimal.

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APPENDIX A
TERMS OF REFERENCE

A.1 MINERALS AND PETROLEUM

(a) Inventory

1. Describe coal reserves by maps, cross-sections, volume and quality.

2. Describe in general terms the geology of the Hat Creek Valley and its environs.

(b) Effect of the Development

1. Describe mine planning as it affects geological resources.

2. Inventory rock, mineral and petroleum resources other than coal directly affected by the development.

3. Describe the impact of mining, coal processing and thermal power generation on the geological resources of the valley.

4. Provide input to the Hat Creek Project "Resource Evaluation for Environmental Account".

A report on the work will be prepared for integration into the overall Environmental Impact Statement.

(c) Utilization of Mine Waste Products

Describe the potential uses of significant mine waste products and other mineral, rock and petroleum resources that may be affected by the project.