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CONSULTING GEOLOGICAL & MINING ENGINEERS
1000 GUINNESS TOWER
VANCOUVER 1, B.C.

British Columbia Hydro and Power Authority

Exploration Report

NO. 1 DEPOSIT

HAT CREEK COAL DEVELOPMENT

15 June, 1977

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PART I

SUMMARY

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SUMMARY

British Columbia Hydro and Power Authority is the beneficial holder of coal licences encompassing known and suspected coal-bearing areas in Upper Hat Creek Valley which is located in south-central British Columbia. The occurrence of coal in the valley was first reported in 1877; initial exploration was done in 1925 with further, more intensive work in 1957 and 1959. The present exploration and development project was initiated in the summer of 1974 and has been essentially continuous since.

Exploration Conducted

Exploration work undertaken since 1974 primarily has consisted of exploration and development drilling of the two known coal deposits, No. 1 and No. 2, and of other areas in the valley. Since 1925, 209,311 feet of core drilling have been completed including 194,955 feet since 1974. In addition 8835 feet of rotary, 893 feet of auger, and 2259 feet of percussion holes have been drilled. The 1976 totals are: 85,968 feet of core drilling including 10,246 feet for slope stability studies, 4192 feet of rotary holes, and all of the auger and percussion footages.

Related exploration work and study has included: surface geological mapping of the Upper Hat Creek Valley area, geophysical surveys in the valley (magnetometer, electromagnetic, gravity), production of topographic maps, control surveys, drill hole and other location surveys, drill hole site work (access roads, site preparation, reclamation of sites), down-hole geophysical logging, geological logging, sampling and analysing the drill core, slope stability studies, statistical evaluations of analytical data, and engineering evaluations.

Exploration and development costs to date, including costs for analyses, total less than one cent per ton of Proven and Probable reserves in the No. 1 Deposit.

Geology

The valley of Upper Hat Creek is underlain by sedimentary rocks

of the coal-bearing Coldwater Formation, of early Tertiary age, flanked and underlain by older sedimentary, volcanic and igneous rocks of the Cache Creek Group, the Spences Bridge Group and the Mount Lytton Batholith, and capped in several places by later Tertiary volcanic rocks. The valley bottom is blanketed by thick glacial deposits.

The No. 1 Coal Deposit, encompassing an area slightly in excess of one square mile, is situated near the north end of the valley. It is in the form of a fault-modified, southerly plunging (15^{o}-20^{o}) syncline that comprises the middle unit of the Coldwater Formation in the Upper Hat Creek Valley. It is overlain by a thick sequence of claystone-siltstone and underlain by coarse detrital sedimentary units. All of the sedimentary rocks are poorly lithified.

No. 1 Deposit

The No. 1 Deposit is divided into the main synclinal deposit, the shallow dipping east bench area, and the poorly understood but less important east area. Steeply dipping normal and reverse faults, striking northerly and northeasterly, separate these areas and disrupt the main deposit.

The main deposit comprises four coal zones (A, B, C, D) in synclinal form. The uppermost zone, the 600-foot thick A Zone, is characterized by good quality coal, coaly shale and siltstone in beds 20 feet or less in thickness. The zone shales out to the west and south. Approximately 35 percent of the zone could be discarded during the mining process (that percentage being based on rock and carbonaceous rock containing more than 55 percent ash on a dry basis). The B Zone is consistently about 250 feet in thickness and composed of fair to good quality coal. The C Zone ranges in thickness from 200 to 350 feet. It consists of a highly variable unit of thin coal beds intercalated with thin to thick waste beds; it also shales out to the west and south. A large but variable quantity (30-70 percent) could be discarded during mining. The D Zone is the best quality and most consistent coal zone in the No. 1 Coal Deposit. It is 200-350 feet in thickness and continuous throughout the drilled portion of the deposit.

The east bench area consists of D Zone and good quality C Zone coals which form essentially one coal bed ranging in thickness from 200 feet to more than 600 feet. It subcrops but is overlain by deep (up to 500 feet) glaciolacustrine deposits.

The east area is poorly understood. Although substantial tonnages of coal may be present, the depth is too great to make it of immediate economic interest.

Reserves

The reserves were calculated in a manner designed to exclude the major portion of the waste and low quality material which could be discarded during mining. In summary, they are as follows (short tons):

Proven	Probable	Proven & Probable	Possible	Total
454,030,000	191,700,000	645,730,000	44,710,000	690,440,000

The Possible and Total figures do not include 43,700,000 tons of Possible reserves in the east area because of a low confidence in their occurrence. The percentages of reserves by zone are as follows:

	ZONE - %			
	A	B	C	D
Proven, Probable, Possible - all elevations	22.5	14.6	15.2	47.7
Proven, Probable, all elevations	24.0	14.8	15.4	45.8
Proven, Probable, above 2400-ft. elev.	29.4	9.1	18.2	43.3

Mean specific gravities used for each zone are: A - 1.45; B - 1.43, C - 1.54, and D - 1.36. Mean specific gravity of the waste rock is estimated to be in the order of 2.

Quality

Since 1957, the total number of drill-core samples collected at Hat Creek for analyses is 4225. Of these, 3153 were collected from the No. 1 Deposit including 474 high ash samples. The largest group, 2247, was collected during the 1976 summer drilling program and was subjected to the most extensive analyses.

A comparison of footages sampled and percentage of reserves for each coal zone shows that the sampling is reasonably representative.

The mineral matter content of the coal varies widely in composition and concentration and this is believed to have an adverse effect on analytical accuracy. Despite this possible problem, some aspects of analytical precision require improvement.

The coal is ranked as low subbituminous B based on a modified procedure which takes into account the relatively high ash and bonded moisture content of the coal.

Coal attribute means and variabilities are discussed. No attempt is made to develop detailed guidelines for conceptual thermal plant design because comprehensive statistical evaluation of the bulk of the analytical data obtained from the 1976 samples is only now becoming available. Based on information from special test holes 76-135 and 136, the following summary of weighted mean proximate data is presented:

	20% Moisture	25% Moisture
Ash - %	26.1	24.5
Volatile Matter - %	25.8	24.2
Fixed Carbon - %	28.0	26.2
Calorific Value - Btu/lb	6410	6010
Total Sulphur - %	0.39	0.37

Weighting is by the percentage of reserves above the 2400-foot elevation in each coal zone. Dilution is not included. Waste rock and high ash material containing more than about 44 percent ash at 20 percent moisture are excluded.

For conceptual thermal plant design, it is suggested that an estimated in situ moisture content of 20 percent continue to be used until such time as more concrete data are available. For conceptual mine design, it is suggested that both 20 and 25 percent moisture contents be considered.

PART II

INTRODUCTION

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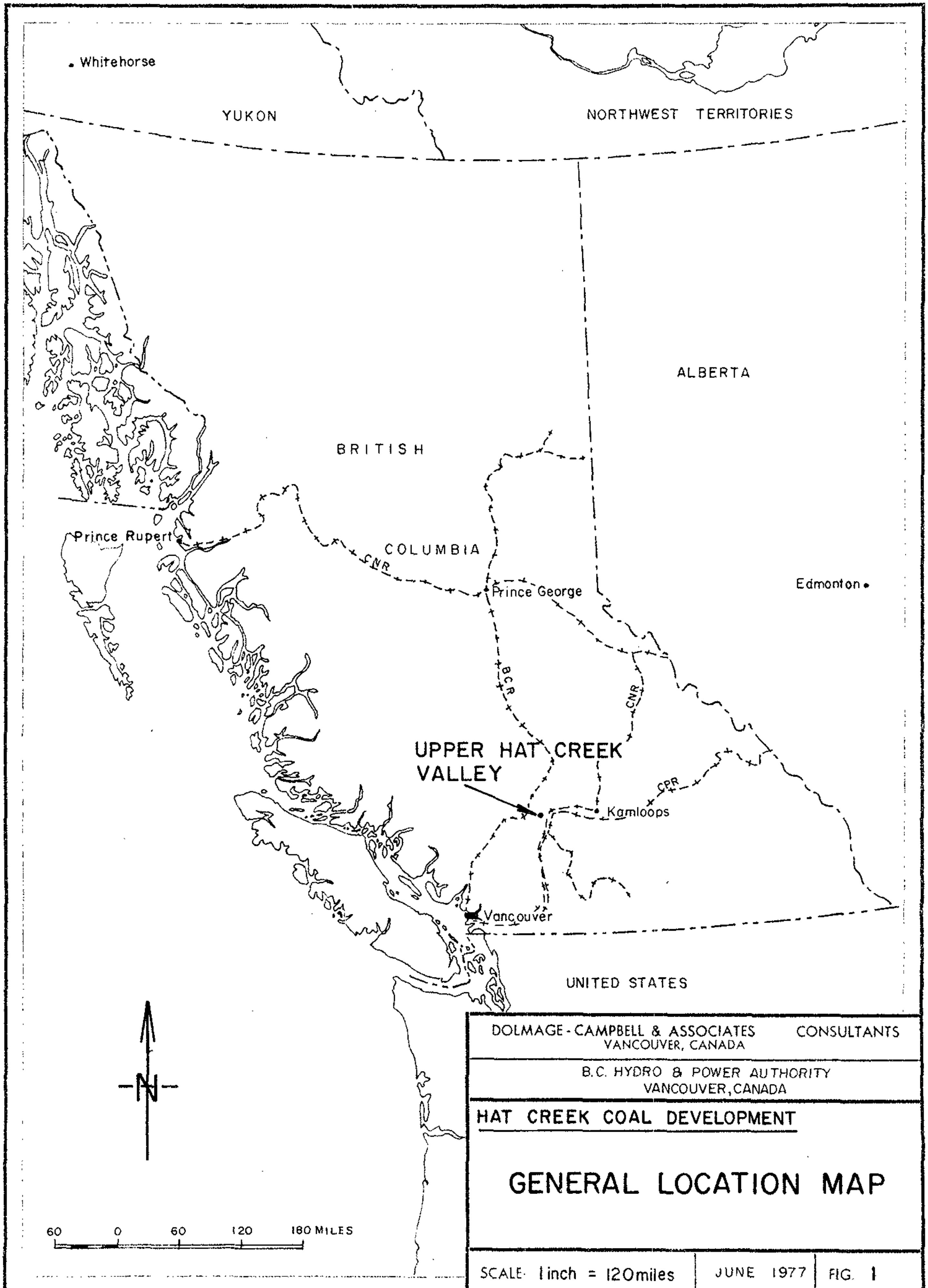
INTRODUCTION

The purpose of this report is to summarize the work conducted and the results obtained during the exploration of the No. 1 Coal Deposit at Hat Creek. For the benefit of those new to the Hat Creek Coal Development project, the report gives some history and background, and summarizes the exploration undertaken since inception of the present project in 1974 by British Columbia Hydro and Power Authority (B.C. Hydro). Discussion is concerned primarily with the No. 1 Coal Deposit although reference is made to exploration elsewhere in Upper Hat Creek Valley. Where applicable, use is made of data obtained from other studies as well, (slope stability, environmental, etc.).

Appendices to this report, if complete, would be voluminous, having to include all written geological logs, graphic geological logs, downhole geophysical logs, analytical certificates and various other data which have been produced. All of these data were distributed to the various users when they were obtained and consequently, need not be appended to this report. They are assumed to be available to the reader. However, a supplement containing 17 north-south geological sections, 14 east-west sections and three elevation plans is provided as a part of the report.

LOCATION

Upper Hat Creek Valley, in which the No. 1 Coal Deposit is situated, is located 120 miles northeast of Vancouver, B.C., midway between the towns of Lillooet and Ashcroft (Figs. 1 & 2). Railheads can be reached at Pavilion, on the B.C. Railroad, 15 miles to the northwest, and at Ashcroft, on the C.P. and C.N. railroads, 30 road miles to the east. Easiest access to the deposit is from the Trans-Canada Highway at Cache Creek, 23 road miles to the east, via the secondary highway (No. 12) between Cache Creek and Pavilion. The closest regularly serviced airport is at Kamloops, 68 miles to the east.



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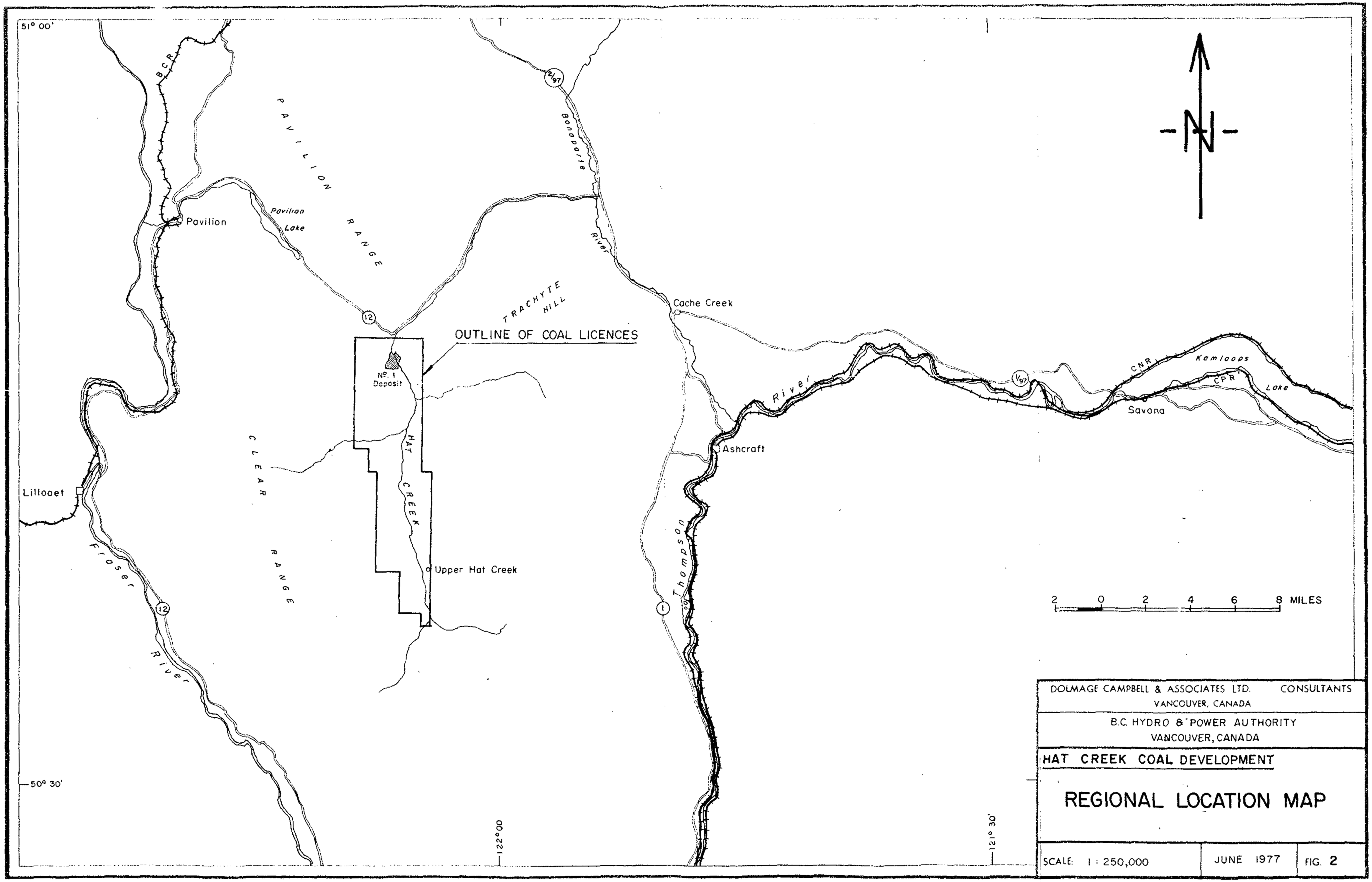
HAT CREEK COAL DEVELOPMENT

GENERAL LOCATION MAP

SCALE 1 inch = 120 miles	JUNE 1977	FIG. 1



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HAT CREEK COAL DEVELOPMENT

REGIONAL LOCATION MAP

SCALE: 1 : 250,000	JUNE 1977	FIG. 2

The Hat Creek property is situated in the broad, north-trending, grassland valley, about 15 miles in length, through which flows the upstream portion of Hat Creek. From the north end of this valley, Hat Creek flows northeastward through a narrow valley into the Bonaparte River which flows south to join the Thompson River at Ashcroft. The No. 1 Deposit is located near the north end of the valley (Fig.2).

Upper Hat Creek Valley lies within the Interior Dry Belt of British Columbia at a mean elevation of about 3500 feet. The valley is flanked by somewhat subdued mountains that rise to elevations of 6000-7000 feet four miles to the west of Hat Creek and to elevations of 5000-6000 feet six miles to the east. The uplands are covered by thin forests and the valleys are sparsely treed, open ranges of grass and sage.

Ranching in the valley bottom and logging on the western slope are the only significant commercial activities presently being carried out in the area.

PROPERTY

The property in Upper Hat Creek Valley consists of 36 coal licences and one Crown Grant claim as listed in Table 1 and shown on Figure 3.

The one Crown Grant claim, (C.G. 83912E), is located near the north end of the valley; it is owned by B.C. Hydro. This 640 acre unit encompasses most of the No. 1 Deposit.

The total area owned or held under licence is 20,405 acres. The unlicenced portions of the valley are under Crown Reserve.

HISTORY

Coal in Upper Hat Creek Valley was reported by Dr. G.M. Dawson of the Geological Survey of Canada in 1877 and 1894. The only coal exposures were along the banks of Hat Creek where the overburden cover had been removed by creek erosion. By 1925, three shallow shafts and two short adits had been driven into the coal along the creek and seven holes (DDH 25-1 to DDH 25-7) had been bored into it. No further work was done on the deposit until 1933.

TABLE 1

COAL LICENCES

Licence No.	Area (acres)	Location
12	640	E½ & E½ of W½ of 1/21/27 & W½ of W½ of 6/21/26
144	320	E½ of W½ of 6/21/26 & E½ of W½ of 7/21/26
2753	640	31/20/26
2754	638	E½ of 6/21/26 & E½ of 7/21/26
2755	636	18/21/26
2756	639	13/21/27
2757	636	14/21/27
2758	630	11/21/27
2759	588	2/21/27
2760	319	W½ of W½ of 12/21/27 & W½ of W½ of 1/21/27
2761	640	35/21/27
2762	640	36/20/27
2991	320	W½ of 17/19/26
2992	316	N½ of 18/19/26
2993	640	19/19/26
2994	321	W½ of 20/19/26
2995	320	W½ of 29/19/26
2996	635	30/19/26
2997	642	31/19/26
2998	320	W½ of 32/19/26
2999	320	W½ of 5/20/26
3000	642	6/20/26
3001	642	7/20/26
3002	640	18/20/26
3003	640	19/20/26
3004	640	30/20/26
3005	320	N½ of 25/19/27
3006	640	36/19/27
3007	640	1/20/27
3008	640	12/20/27
3009	640	13/20/27
3010	320	E½ of 23/20/27
3011	640	24/20/27
3012	640	25/20/27
3013	640	26/20/27
3655	641	W½ of 8 & 17/20/26
36 licences	19,765 acres	

From 1933 until 1942 a few hundred tons of coal a year were produced from the property and sold in the nearby towns and villages. No work was done from 1942 to 1957. In 1957 the property was optioned by Western Development and Power Ltd., a subsidiary of B.C. Electric Co. Ltd., at which time one Crown Grant claim was extensively explored by surface diamond drilling, (DDH 57-8 to DDH 57-15 and DDH 59-16 to DDH 59-22).

Following the acquisition of B.C. Electric by the Province of British Columbia, the ownership of the one explored Crown Grant claim and two coal licences comprising the Hat Creek coal property passed to British Columbia Hydro and Power Authority. No further exploration was done on the property until mid-1974 when B.C. Hydro began definitive drilling of the deposit. In 1974, B.C. Hydro acquired coal licences covering most of Upper Hat Creek Valley. One additional licence was acquired in 1975.

Fieldwork under the current exploration program began in mid-1974 and continued in 1975 and 1976.

GEOLOGICAL SETTING

The valley of Upper Hat Creek is underlain by sedimentary rocks of the coal-bearing Coldwater Formation, of early Tertiary age, flanked and underlain by older sedimentary and igneous rocks of the Cache Creek Group, the Spences Bridge Group, and the Mount Lytton batholith, and capped in several places by later Tertiary volcanic rocks (Fig.3).

BASEMENT ROCKS

The basement rocks in the Upper Hat Creek area comprise three major units: (1) the Cache Creek Group of Permian age, (2) the Spences Bridge Group of Cretaceous age, and (3) the Mount Lytton Batholith of Cretaceous age.

The Cache Creek Group comprises two components. The Marble Canyon Formation, consisting of massive limestone, in places recrystallized, and an unnamed mixed suite of greenstones, phyllites, cherts and other sedimentary and volcanic rocks displaying slight to moderate low-grade metamorphism. The Marble Canyon limestones are in fault contact with Tertiary rocks on the northwest, north, east-central and southeast margins of Upper Hat Creek Valley (Fig.3). The mixed suite abuts against Tertiary sedimentary rocks on the northeast margin, i.e. on the western slopes of the Trachyte Hills, but the nature of the contact is not clear. It is also present in a road cut near the northern limit of the No. 1 Coal Deposit. The Marble Canyon limestones in some places enclose small lenses or pockets of the greenstone suite.

Rocks of the Spences Bridge Group are exposed in a few outcrops along the west-central and southwest margins of the valley. They mostly consist of dacite and andesite volcanics showing a moderate degree of alteration.

Granodiorite and diorite intrusive rocks of the Mount Lytton Batholith flank the northwest corner of Upper Hat Creek Valley but appear to be separated from the Tertiary sedimentary rocks in the valley by a narrow septum of Cache Creek limestones of the Marble Canyon Formation.

COLDWATER FORMATION - EOCENE (EARLY TERTIARY)

Although outcrops are rare, it is known from diamond drilling that the entire valley of Upper Hat Creek is underlain by shales, claystones, siltstones, sandstones, conglomerates and coal that make up the Coldwater Formation. Also, numerous exposures of rhyolitic tuffaceous rocks, in the east-central portion of the valley, may form part of this unit.

The drilled portion of the Coldwater section may total as much as 5400 feet of conglomerate, siltstone, shale and coal; of this the basal 1600 feet includes appreciable sandstone and conglomeratic sandstone which commonly has a clayey matrix and contains pebbles derived from older volcanic rocks, such as the pre-Tertiary Spences Bridge Group. Of the 5400 feet, up to 1800 feet consists of coal with an overall average of 20-25 percent intercalations of claystone, siltstone and sandstone. This thickness for the coal sequence is derived by preliminary correlation of coal strata in drill holes in both the No. 1 Deposit and the No. 2 Deposit.

The coal sequence in the No. 1 Deposit is overlain by about 2000 feet of uniform claystone-siltstone which contains a significant proportion of fine grained volcanic material. This unit may be equivalent to a thick monotonous section (1000-2000 feet thick) of claystone that is adjacent to a fault zone that truncates No. 2 Deposit on its west side. The claystone there is overlain by interbedded siltstone and conglomerate.

The Coldwater Formation in Upper Hat Creek Valley could thus be up to 5400 feet thick, as follows:

Siltstone or claystone (with overlying conglomerate):	2000 feet
Coal-bearing sequence:	1800 feet
Detrital rocks (shales, siltstone, sandstones and conglomerates):	1600 feet

An eroded surface was developed on this sequence and this in turn was covered in part by Late Tertiary volcanic rocks.

VOLCANIC ROCKS

The volcanic rocks, all probably of later Tertiary, e.g. Miocene age, comprise several phases whose interrelationships may be surmised, but cannot be proven because of the lack of contacts between rocks of different phases.

From older to younger (probable order), they are:

i. Flow rhyolite and rhyolite tuff, lapilli tuff, tuffaceous siltstones, sandstone and conglomerate. No estimate of total thickness can be made, but if the cliffs of conglomeratic tuff in Medicine Creek are part of this unit, they may be at least 150 to 200 feet in thickness.

ii. Interfingered breccias and flows of basalt, or of reddish brown volcanic rocks of slightly less basic composition. In places, the breccia matrix consists of well-lithified material of composition comparable with that of the fragments; elsewhere (but commonly in close association with the former) it is a more friable, less cohesive material resembling a volcanic mud.

iii. Dacites and/or andesites, in flows and breccias, medium to light greenish brown or green, in places with a pronounced platy parting habit that may reflect flow structure or the cooling of sheets of molten flow material. In places they are almost cherty.

iv. Basalt flows, dark brown, very fresh-looking, commonly with fine grained olivine phenocrysts.

v. Near Dry Lake on the northwestern edge of the No. 1 Deposit, scoria and breccialike material which may be in part volcanic in origin but includes baked shale and clinker from the burning of coal.

Amygdaloidal basalts that underlie a prominent elongate hill immediately south of Finney Lake appear to be old enough to be possibly Early Tertiary in age, perhaps older than the Coldwater Formation.

Until radioactivity-dating of the various volcanic rocks is available, it is reasonable to assume that all of them, except the last-mentioned, formed part of a series of volcanic episodes that followed Coldwater deposition in late Tertiary time, i.e. they probably correspond generally to the Kamloops Group of volcanic rocks seen near Cache Creek and between there and Kamloops.

OVERBURDEN

Bedrock in the valley is for the most part mantled by overburden ranging from a few feet up to 500 feet in thickness and mostly consisting of glacial till or sands and gravels deposited under conditions associated with the glaciation of the valley. As a result, outcrops generally are sparse, and rocks of the Coldwater Formation, in particular, are exposed in only a few places including the creek-bed outcrops near the north end of the valley that gave rise to the initial discoveries of coal at Upper Hat Creek. Glacial till extends to the west side of the valley for its full length and ranges in consistency from a well-compacted, relatively impermeable basal-type boulder-silt till along the centre of the valley to a loosely compacted ablation till towards the west. Much of the east side is blanketed by silt, sand and/or gravel, some of it having been laid down (as in the northeast corner of the valley) in a glacially-dammed lake, or by streams discharging into such a lake. Drilling has also indicated the presence of poorly consolidated, but well bedded glaciolacustrine sediments on the western slopes of the valley flanking the No. 1 Coal Deposit. These sediments are derived partly from crystalline intrusive rocks (Mt. Lytton Batholith) and partly from coal-bearing Coldwater rocks. Slide material is present on the west side near the northern end of the valley.

STRUCTURE

A prominent feature of the Tertiary bedrock underlying Upper Hat Creek Valley is the presence of major, steeply dipping block faults, two of the more prominent being the east boundary fault and the west boundary fault which lie along each side of the valley. Faults within the Coldwater Formation commonly strike northeasterly and northwesterly; some exhibit considerable vertical displacement, (2000+ feet).

The Coldwater Formation, including the coal sequence, is folded into an open anticline with axis striking approximately north-south. In the northern portion of the valley the eastern limb of the anticline appears to be truncated and the western limb flexed upwards to the west. The result is that the principal portion of the No. 1 Coal Deposit is synclinal in form, although modified somewhat by faulting.

PART III

EXPLORATION WORK CONDUCTED

EXPLORATION WORK CONDUCTED

SURVEYING

CONTROL AND TOPOGRAPHIC

A number of surveys were conducted during 1974 and 1975 to provide topographic maps and control for exploration work. They comprised vertical aerial photography, photogrametric mapping and ground control.

Elevation control was established by running third-order levels from a Dominion Government geodetic bench mark at Carquile, near the junction of Highways 12 and 97. Bearings were derived by solar observations.

The aerial photography carried out during the summer of 1975 resulted in the preparation of the following documents:

1. Three north-south lines of aerial photographs, scale 1" = 2000'
2. Orthophoto of entire Upper Hat Creek Valley, scale 1" = 2000' (McElhanney reference No. 06185-0)
3. Topographic map of entire Upper Hat Creek Valley, scale 1" = 2000'
4. Topographic maps, sheets 1 to 4, of No. 1 Deposit, scale 1" = 400'
5. Topographic maps, sheets 5 to 8, of No. 2 Deposit, scale 1" = 400'.

In October 1976, more ground survey control was established in the north end of Upper Hat Creek Valley by McElhanney Surveying & Engineering Ltd. These control points were required because of the more intense and detailed exploration (primarily diamond drilling) being conducted in the area of the No. 1 Coal Deposit.

The control surveys are on two McElhanney drawings designated A and B for job number 08320-0.

Other surveys have been undertaken, e.g. the water pipeline route from the Thompson River, but they were not done as part of the exploration program.

DRILL HOLE

Drill Holes were surveyed from the control points established by McElhanney and from intermediate points established by closed traverses between the control points. The surveying was done with transit and stadia rod. Hole collar elevations and coordinates were rounded to the nearest foot.

Upon completion of the more dense survey control by McElhanney in October 1976, it was decided to resurvey most of the drill hole collars in and about the No. 1 Deposit including those drilled for slope stability studies. This was done to eliminate discrepancies that were appearing in the original survey data.

The survey results are contained in the "Record of Completed Drill Holes" which lists coordinates, elevations, dips and azimuth of hole collars, down-hole dip tests, drilling dates and overburden, bedrock and total hole footage.

SITE WORK

Site work refers to that work required to provide access to a drilling site, prepare the site for the drill rig, and relaim the site after the hole is completed and the rig removed.

ACCESS ROADS AND DRILL SITES

Figure 4 shows the main roads within and about the No. 1 Deposit and the access trails to the various drill sites. For the most part, the trails and lesser roads were built by a local valley resident, Mr. E. Lehman, employing his own equipment. He also prepared the drilling sites by levelling them and digging pits for collection of the drilling mud. As well, he moved the drill rigs on behalf of the drilling contractor.

RECLAMATION

As a matter of routine all drill sites were cleaned and levelled after drilling finished. The mud pits were pumped out and the pits filled. The mud was removed and placed in old trenches, excavated during earlier exploration periods, where it was allowed to drain and solidify prior to covering with original trench spoil. The mud consists of natural clays with no chemical additives.

The seeding and harrowing of drill sites was completed by using a horse to pull the harrows. This proved to be much more practical than a tractor in the restricted space of the typical drill site. The seeding was completed in the late fall so that the spring moisture would enhance the growth. The species mixture used for reseeding the drill sites and access trails was developed by B.C. Hydro for use in the Hat Creek region. It is a 'dry land mix' consisting of:

Crested wheat	45%
Manchar brome	25%
Sweet clover	10%
Russian wild rye	10%
Ladac alfalfa	10%

Drill hole collars are marked by 4" x 4" posts, painted white and stencilled with the numbers of the drill holes.

DRILLING

Extensive drilling in the forms of coring, rotary, auger and percussion has been conducted on the Hat Creek property since inception of the exploration program in 1974. The 1974 drilling was done within and around the No. 1 Deposit. Most of the 1975 drilling was of a purely exploratory nature done throughout Upper Hat Creek Valley south of the No. 1 Deposit. The 1976 drilling was all directed towards the No. 1 Deposit; the bulk was for exploration and development purposes with a lesser amount for slope stability studies. Drill hole locations are shown on Figure 5.

CORE

Table 2 summarizes the amount and purpose of all core drilling completed on the Hat Creek Property.

To the end of 1976, exploration and development core drilling in and around the No. 1 Coal Deposit has amounted to 123,891 feet. The 1976 development drilling was concentrated within the No. 1 Deposit and was based on an ultimate density of holes at 500-foot centres.

TABLE 2

SUMMARY OF CORE DRILLING

Year	Footage	Purpose
1925	2,475	Initial exploration, No. 1 Deposit
1957	5,681	Exploration, No. 1 Deposit
1959	6,200	Exploration, No. 1 Deposit
1974	35,424	Exploration, No. 1 Deposit
1975	9,168	Exploration, No. 1 Deposit
	64,395	Exploration in valley south of No. 1 Deposit
	73,563	
1976	7,127	Exploration in valley south of No. 1 Deposit
	67,918	Development, No. 1 Deposit
	10,246	Slope stability, No. 1 Deposit
	677	Possible plant site, Harry Lake
	85,968	
TOTAL	209,311 feet	

All of the exploration and development drilling since 1974 was done by D.W. Coates Enterprises Ltd.; the slope stability and plant site drilling was done by Tonto Drilling Co. Both companies employed skid-mounted Longyear 44 and Super 38 diamond drill rigs. NQ-size wireline equipment was used for the exploration holes in bedrock; in most instances overburden was triconed. HQ-size wireline equipment was used for the slope stability and plant site holes and, in most cases, overburden as well as bedrock was cored.

Core recovery was generally good considering the poorly lithified nature of the Coldwater rocks. It did not change appreciably over the three year exploration period (1974-1976). Average recoveries for rock and coal are:

Rock	91.6%
Coal	92.6%
Total	92.2%

The core was photographed and geologically logged at the time of drilling. Both written and graphic geological logs were prepared. Recently, all of the core from drill holes within and near the No. 1 Deposit was relogged in order to incorporate new ideas and interpretations which have gradually developed as the deposit has become better understood. The new logs are in written form only.

All core obtained since 1974 is stored on the property in well constructed core storage sheds mounted on log skids. Some of the 1957 and 1959 core is available but is of little value; it was dumped into bags for storage and now cannot be assessed except in a very gross manner.

ROTARY

A test rotary drill program using reverse circulation equipment for coal sampling was undertaken in December 1974 - January 1975 in the north end of Upper Hat Creek Valley. Four vertical holes totalling 4643 feet were completed. The assessment of this test work is contained in the report, "Assessment of Rotary Drilling Trial Program" dated 28 January, 1975 by Dolmage Campbell & Associates Ltd. Because of the sticky nature of the claystones, the results were not favourable economically and no further rotary exploration drilling has been attempted at Hat Creek.

In 1976, a large rotary rig was employed for data acquisition related to slope stability studies, (installation of slope indicators, permeability testing, pump test observation wells, etc.). A truck-mounted Speed Star FS 15 air-flush rig was used, (A & H Construction Ltd., owner). A total of 4192 feet were drilled in 18 holes, the longest of which were 400 feet in depth.

AUGER

In May 1976 a bucket auger drill rig (owned by Pacific Water Wells) was used to obtain large (several tons) coal samples for various test purposes. Fifteen holes were drilled at five sites near diamond drill holes. Total footage was 893 feet; depth of the deepest hole was 95 feet. A 36-inch diameter bucket was used most commonly but some footage was drilled with 24-inch and 42-inch diameter buckets as well. Approximately 19 tons of coal were acquired in this manner.

Procedures employed and progress attained are contained in "Field Book Notes - J.L. Weatherall, Coal Recoveries - Sampling Program", dated 9 June, 1976 by Wright Engineers Ltd., (Project No. 838-170).

PERCUSSION

A truck-mounted Becker Hammer drill, owned and operated by Becker Drills Ltd., was employed during June and July 1976 for overburden sampling related to slope stability studies. Thirty holes totalling 2259 feet were drilled, the deepest being 110 feet. Many were peripheral to the No. 1 Deposit.

GEOLOGY

The Geological Survey of Canada mapped the bedrock geology of the Ashcroft area, which includes Upper Hat Creek Valley, in the late 1940's; the results are published in G.S.C. Memoir 262. In 1974, they mapped the surficial geology of the Upper Hat Creek Valley area. The British Columbia Department of Mines mapped in and about the valley in 1974 and 1975. Some of their data, through discussion and provision of manuscript maps has been made available. Geological mapping of Upper Hat Creek Valley, at a scale of 1 inch = 2000 feet, was done in 1974 and 1975 by Dolmage Campbell & Associates Ltd. The mapping was hampered by overburden cover, particularly in the valley bottom. Figure 3 represents a compilation of all available geological data for the area.

Geological interpretation was attempted by use of satellite imagery, black/white and color aerial photographs, and infra red imagery. The aerial photographs proved of some use but mainly for indication of structural features of a regional or district magnitude. None of the other data were of significant value.

During the early part of 1977, Mr. J.E. Hughes, consulting coal geologist, was retained to examine the structure and stratigraphy of a portion of the No. 1 Coal Deposit. This was accomplished by detailed logging of the cores from several drill holes located along section 78,000 N. The results of this work are contained in the report "Hat Creek Project, (No. 1 Coalfield), Progress Report: 1 May, 1977".

In compiling the geology of the Coldwater Formation, and more particularly, of the No. 1 Coal Deposit, use was made of all available exploration data. Because very little in the way of surface exposures are present in the valley, most of these data are in the form of surface geophysical survey results and drill hole information such as geological core logs, down-hole geophysical logs and analytical data from core samples.

GEOPHYSICS

SURFACE

A number of surface geophysical surveys have been attempted on the Hat Creek property as listed in Table 3. Some have been successful, others have not.

TABLE 3

HAT CREEK GEOPHYSICAL SURVEYS

Survey Type	Survey Period	Operator*	Remarks
Daedalus - sliced film	Sept., 1974	CCRS	Also airphotos
Infra-red	Sept., 1974	IRP	Three short lines over No. 1 Deposit
Resistivity	Sept., 1974	McPhar	Trial only
Magnetometer	Sept.-Oct., 1974	McPhar	North end, Upper Hat Creek Valley
Magnetometer	Summer, 1975	BCH	All of valley (over 70 line miles)
Gravity	Sept.-Oct., 1974	McPhar	Trial only
Gravity	Summer, 1975	Ager	All of valley (4000' N-S line spacing)
EM	Sept.-Oct., 1974	McPhar	Trial only
EM (VLF)	Oct., 1975	Presunka	No. 1 Deposit
EM (VLF)	Oct., 1976	Crosby	Eleven line-miles over No. 1 Deposit

* CRS - Canada Centre for Remote Sensing
IRP - Integrated Resources Photography Ltd.
McPhar - McPhar Geophysics
BCH - B.C. Hydro
Ager - C.A. Ager & Associates Ltd.
Presunka - S. Presunka (independent operator)
Crosby - Richard O. Crosby & Associates

Figure 6 is a contour plan of the filtered EM 16 results which forms part of the report, "VLF Electromagnetic Survey on the Hat Creek Property", by Richard O. Crosby & Associates, dated 5 October, 1976.

DOWN-HOLE

As standard practice, all exploration drill holes on the Hat Creek property were electro-logged. Exceptions occurred when drill hole conditions prevented such logging, when drill holes did not reach bedrock or when non-exploration holes were drilled in areas known to be devoid of coaly material. The major problem encountered was squeezing of the hole walls which prevented passage of the logging equipment. To minimize the problem, most holes were logged through the casing and/or drill rods before they were pulled out of the hole. Open-hole logging was then attempted after the drill rods were pulled. However, where squeezing became excessive, even the drill stem could not be left in the hole for a long enough period to complete the logging, and geophysical logging was impossible.

All down-hole electro-logging was completed by Roke Oil Enterprises Ltd. employing a truck-mounted recorder and probe winch. The two most common logs recorded were density and natural gamma ray. Examples of these logs are shown on Figure 7. Because the caliper (hole diameter) and resistivity logs could not be obtained through the drill stem, they were less commonly obtained. Results were recorded on transparent logs at a scale of 1 inch = 20 feet. These were later reduced to 1 inch = 40 feet for convenience of handling. The scale of 1 inch = 20 feet is a compromise scale; it is not the best scale for recording all stratigraphic detail but it results in logs which are still manageable for drill holes 2000 feet or more in depth.

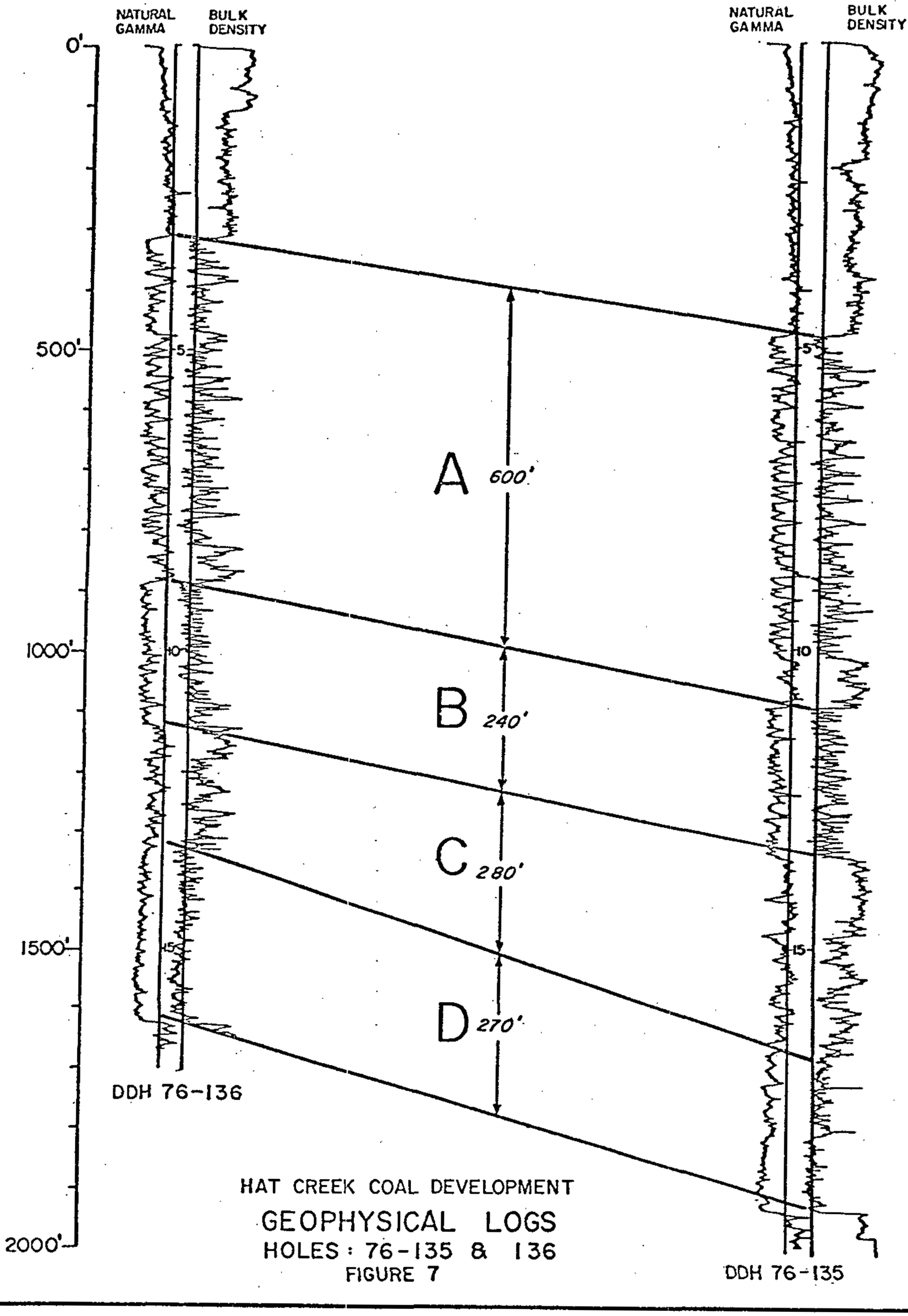
During 1976, approximately 90% of the total footage drilled was electro-logged for natural gamma and density. However, only about 25% of the footage was logged with the caliper and resistivity tools due to open-hole caving and squeezing. The footages logged in each hole for each type of geophysical response are tabulated in the "Geophysical Logging Record".

CORE SAMPLING AND ANALYSES

SAMPLE TYPES AND INTERVALS

1925: No information is available on the type of core sampling conducted during the drilling of the first seven holes into the No. 1 Deposit in 1925.

1957-59: A total of 146 field samples were collected from drill cores during the 1957 and 1959 periods of exploration of the No. 1 Deposit at



HAT CREEK COAL DEVELOPMENT
GEOPHYSICAL LOGS
HOLES: 76-135 & 136
FIGURE 7

Hat Creek (hole Nos. 57-8 to 15 and 59-16 to 22). Individual samples were up to about 100 feet in length and for some drill holes comprised composite samples prepared by combining separate, non-continuous lengths of core into a single sample. Average sample length was about 60 feet.

1974-February 1976: All core samples were obtained by splitting the core longitudinally in the field with a diamond saw, one half of the core being sent for analyses and the other half stored for reference purposes.

The numbers of core samples collected during the period 1974 to February 1976 (from diamond drill holes 74-23 to 48, 75-49 to 53, 75-106, 107 and rotary hole RH 75-4) are as follows:

Area	No. of Samples	Approximate Average Sample Length
No. 1 Deposit	760*	20 feet
No. 2 Deposit	990	27 feet
South of No. 2	82	24 feet

* Includes 11 rotary hole samples.

The samples above include high ash samples. When referring to analytical samples from Hat Creek, the term "high ash" has a special connotation. Because of the continuum of ash values between clean coal and pure (non-carbonaceous) waste, all cores estimated to contain more than about 10 percent carbonaceous material (approximately 1500 Btu/lb) are sampled in order to provide a complete inventory of the heat content of the deposit. The laboratories have been instructed to obtain only ash and moisture values on those samples containing more than 75 percent ash on the dry basis. Such samples are referred to as high ash samples. Obviously, for consideration of plant feed the term high ash may be defined differently.

In the principal coal areas, high ash samples normally constitute about 10 percent of the total samples collected. In fringe areas where the coal has largely shaled out, they may constitute 25 percent or more of the samples.

Individual samples in 1974-75 varied in length from 5-10 feet to 50 feet; the former lengths were taken in sections of intercalated coal and waste and the latter in sections of relatively uniform low ash coal, principally in the D Zone. Partings less than 5-7 feet in thickness, measured along the core axis, were commonly included in the adjacent coal sample.

Laboratory composite samples were prepared in lengths ranging from about 50 to 200 feet. The analyses obtained on these samples are discussed in the following section on Types and Frequency of Analyses.

May-October 1976: During this period of development drilling on the No. 1 Deposit, 2247 core samples were collected for analyses from diamond drill holes 76-120 to 208 and 76-814, 817. The minimum sample length varied from one to three feet, the maximum length was 20 feet, and the average length was about 17 feet.

As for the 1974-75 cores, all samples were obtained by splitting the core in the field.

TYPES AND FREQUENCY OF ANALYSES

1925: Although some analytical data were published in 1925, none can be equated with specific lengths of drill cores.

1957-59: Routine analyses carried out by Coast Testing Laboratories Ltd. on core samples collected in the 1957-59 period were proximate, calorific value and sulphur. On 23 of the 1957 samples, the Department of Mines and Technical Surveys in Ottawa carried out similar tests and also some equilibrium moisture, ash fusibility and grindability index tests.

No other tests are known to have been carried out on 1957-59 samples except for special tests on one sample forwarded to Germany.

1974-February 1976: Routine tests on field core samples during this period were proximate, calorific value and sulphur. Approximately every eighth sample was analysed for Na_2O and K_2O. Some equilibrium moisture, laboratory specific gravity, CO_2, and semi-quantitative spectrographic analyses were also obtained on the proximate samples.

Other analyses, conducted on laboratory composite samples (50 to 200 feet in length), were as follows:

294 samples: Proximate, ultimate, calorific value, sulphur forms, ASTM analysis of ash, 8-pt. ash fusion temperatures, and Hardgrove grindability index. Also, a few semi-quantitative spectrographic analyses were done on whole coal samples ashed at low temperature.

64 samples: Washability tests at three specific gravities.

Ash and moisture determinations were carried out on a number of samples on which specific gravity had been determined in the field. This aspect is discussed in more detail under Field Tests.

All analyses were undertaken in three laboratories: Commercial Testing and Engineering Co., Vancouver; General Testing Laboratories, Vancouver; Loring Laboratories Ltd., Calgary.

May-October 1976: Analyses during 1976 were carried out in the three laboratories listed above. The tests were extensive and are listed in Appendix I under the four assay schedules in use for samples recovered from drill holes 76-120 to 208 inclusive and drill holes 76-814 and 817. The laboratory procedures are listed in Appendix II. A summary of numbers of samples by assay schedule is given below:

Assay Schedule	No. of Samples
High ash	212
No. 1	310
No. 2	634
No. 3	883
No. 4	208
Total	2247

A total of 2485 samples were collected in the field but certain contiguous short samples from drill holes 76-135, 136 and 200 were combined in the laboratory prior to analysis.

During the period 1974-1976, numerous core and some bulk samples were sent to various research facilities for special testing of such aspects as burning and washability characteristics, trace element content, by-product potential, filtration-agent potential thermogravimetric analyses and petrography. No attempt is made in this report to detail those samples or the test results.

SPECIAL TEST HOLES

In order to obtain more definitive information on the variability of the various coal attributes within the entire No. 1 Deposit and within the four coal zones, two special core test holes, drilled in July 1976, were sampled at five-foot intervals. The holes, Nos. 76-135 and 136, were drilled 1000 feet apart near the axis of the syncline in the central portion of the main deposit

(Figure 7; Sections 77,500 N, 78,500 N, 19,500 E). Both holes intersected the entire coal sequence. The 310 analysed samples from these holes are included in the 2247 samples for 1976 listed above (assay schedule No. 1).

After examination of the geological variability as displayed on the geophysical logs, certain contiguous five-foot long samples were combined into 10-foot samples prior to analysis.

The analytical results were statistically evaluated to provide information on coal attribute variability, optimum sample length and optimum frequency of assaying for various attributes.

CHECK (CONTROL) SAMPLES

Only the three laboratories actively engaged in the analyses of Hat Creek core samples were included in check assaying to determine laboratory precision. Although the data provide some information on laboratory accuracy, samples should be sent to other qualified laboratories to better assess this aspect.

From the 1974-75 samples, 133 samples were sent for check assaying of proximate, calorific and sulphur values. From the 1976 samples (DDH 76-120 and up), 63 samples were sent for more extensive testing including proximate, calorific value, sulphur forms, CO_2, ultimate, ash fusion temperatures, and analysis of ash.

Two check analyses were generally obtained on each of the selected samples. In part these check analyses were obtained in the original laboratory and one of the other two laboratories, and in part they were obtained in the other two laboratories. The data were subjected to statistical evaluation.

STATISTICAL EVALUATION

In June 1976, Dr. A.J. Sinclair, geologist-statistician at the University of British Columbia, was engaged to evaluate statistically certain analytical data from Hat Creek. The data evaluated have been referred to above under SPECIAL TEST HOLES, and CHECK SAMPLES.

The progress reports submitted by Dr. Sinclair are as follows:

Date	Title
June 23, 1976	Preliminary Considerations of Sampling Plan Design For The Hat Creek Coal Deposit.

July 12, 1976	Inter and Intra Laboratory Reproducibility, Hat Creek Coal Analyses.
Aug. 18, 1976	An Evaluation of Pre-1976 Proximate Analyses, No. 1 Deposit, Hat Creek.
Sept. 20, 1976	Interim Report on Dry Proximate Analyses of Test Holes 135 and 136.
March, 1977	Evaluation of Analytical Data From Test Holes 76-135 and 76-136, Hat Creek No. 1 Coal Deposit, (with four appendices of histograms).
May 25, 1977	Inter and Intra Laboratory Reproducibility, 1976 Hat Creek Coal Analyses.

FIELD TESTS

The principal field tests, excluding engineering test work carried out by Golder Brawner and Associates Ltd., have been slaking tests and specific gravity measurements.

Slaking tests have been carried out in tap water on approximately 750 Hat Creek core samples, about one third of which were derived from the No. 1 Deposit and the remainder from the No. 2 Deposit and other areas. After immersion in water, the sample was observed at increasing time intervals over a 24-hour period to obtain a qualitative appraisal of the sample disintegration, if any.

The specific gravity of nearly 5000 samples, each about three inches in length, has been determined in the field. The samples were derived from coal and non-coal horizons in the No. 1 and No. 2 deposits.

For about 200 of the samples, all from the No. 2 Deposit, as-received moisture and ash or as-received moisture, ash, equilibrium moisture and specific gravity on pulverized material have been determined in the laboratory.

For about 600 of the samples, principally from drill hole Nos. 76-135 and 136 in the No. 1 Deposit, ash, pseudo equilibrium moisture and air dry moisture loss have been determined. Pseudo equilibrium moisture means: the sample is placed in water at the time of logging; prior to determination of specific gravity it is surface dried; it is then packaged with a slight excess of free moisture in a plastic bag and shipped to the laboratory where it is again surface dried prior to performing the analyses listed above.

The above procedure was adopted to arrive at some standard moisture condition which would obviate making the difficult corrections that would be required if the specific gravity were determined at one moisture content (but of unknown amount) and the laboratory determinations at another moisture content.

Although not a special test as such, it is recorded here that the water level in all uncaved drill holes is measured monthly and the results compiled in tabular form.

COAL ANALYSES COMPUTER DATA BANK

Analytical data are available for the following number of samples:

	Samples		
Area	High Ash	Normal	Total
No. 1 Deposit	474	2679	3153
No. 2 Deposit	58	932	990
South of No. 2	34	48	82
Total	566	3659	4225

For the high ash samples, information available is generally restricted to ash and moisture content. For the normal samples, the information varies from a minimum of proximate, calorific value and sulphur data to comprehensive testing including some sink-float data.

In order to make practical use of this large volume of data, it is necessary that it be stored in a computer data bank. B.C. Hydro commenced such a data bank in the fall of 1974. The data bank and programs initially developed and used were not adequate for accommodation of the more extensive analytical data obtained during the summer of 1976. The storage and programs were completely redesigned during the winter of 1977 and the final data are currently being stored.

Numerous B.C. Hydro computer programs, which permit the assessment of the analytical data by drill hole, zone, elevation, quality and bed thickness, have been or are being developed. The outputs are primarily of a statistical or graphic nature for raw and generated data. The present programs do not permit the projection of data for the output of volumetrically weighted results. However, they do weight data by length of drill hole intersection. No attempt has been made to weight data by true thickness of stratigraphic bed.

During the summer and fall of 1976, while carrying on a preliminary conceptual thermal plant study, Integ-Ebasco developed special computer programs. Their stored data incorporates only a small percentage of the total analytical data obtained from the 1976 drill holes.

SPECIAL STUDIES

PALYNOLOGY

Dr. G.E. Rouse of the University of British Columbia was engaged in mid-1975 for palynological studies of spores and pollen in Hat Creek core samples. The objective was to determine if palynology would assist in the correlation of stratigraphic units, especially in areas where the structure is complicated by faulting, folding or shale-out.

Dr. Rouse reported on the relative stratigraphic position of 75 samples in three reports dated March 5, 1976, January 17, 1977, and March 26, 1977. Work on an additional eight samples to complete the current program has been completed but the results have not been reported formally.

X RAY ANALYSES

Various X ray analyses of the minerals in waste rocks and coal have been carried out since early 1975. Early work, and that done for Golder Brawner and Associates in 1976 was of a qualitative nature in so far as mineral composition is concerned and was conducted by Dr. R.M. Quigley at the University of Western Ontario. Fifty-five samples were analysed.

Prior to the most recent X ray analysis program, three samples were analysed quantitatively at Pennsylvania State University and 33 by Dr. A.C.D. Chaklader, Dept. of Metallurgy, University of British Columbia. The results for the 33 samples are contained in two reports entitled, "Mineral Matter Content and Gross Properties of Hat Creek Coal" dated December 1976 and March 1977. The samples, and those previously mentioned, are all from the No. 1 Deposit.

During the winter and spring of 1977, 187 core samples from holes on section lines 1000 feet apart were collected to give fairly complete stratigraphic and geographic coverage of the No. 1 Deposit. Preliminary quantitative results have been reported by Dr. Chaklader for about 45 of these. Under the present contract, there will be time to complete the work on a total of only 125 to 135 of the samples. Thus, additional results are expected on 80 to 90 samples and 50 to 60 samples of the 187 will remain unanalysed for the time being.

PETROLOGY

Approximately 100 thin sections have been examined under a petrographic microscope by Dolmage Campbell and Associates. A formal report has not been issued. Additional samples for thin section were collected during the winter of 1977 to provide reasonably complete stratigraphic and geographic coverage of the No. 1 Deposit.

SLOPE STABILITY

Fieldwork and associated laboratory testing directed towards rock strengths, the groundwater regime and slope stabilities was conducted by Golder Brawner & Associates during the summer of 1976. Details of this work and the results obtained do not therefore form a part of this report. However, studies related to slope stabilities were done prior to the 1976 field season and some are of an on-going nature.

Ralph B. Peck, consulting geotechnical engineer, was retained in early 1975 to advise on testwork that should be done. The following work resulted from his recommendations.

R.M. Quigley, Faculty of Engineering Science, University of Western Ontario, undertook mineralogical studies. Results of his work are contained in a number of letters and one report: "Preliminary Mineralogical Analyses - Hat Creek Coal Measures, B.C.", May 1975.

Klohn Leonoff Consultants Ltd. conducted Atterburg limit tests and friction tests in early 1975. Their results are contained in a letter report dated 6 February, 1975 and in the report, "Laboratory Testing of Rock Cores", 24 April, 1975.

Several hundred core samples were subjected to simple field slaking tests and observed over a 24-hour period. The results are in tabular form.

PART IV

DISCUSSION OF EXPLORATION RESULTS

DISCUSSION OF EXPLORATION RESULTS

This part of the report is concerned primarily with results of the 1976 exploration work at Hat Creek and related studies. Results of earlier work are contained in previous reports but are incorporated where useful.

Much of the exploration is on-going and, consequently, the discussion and assessment of results are interim in character.

ROCK TYPES

DESCRIPTION OF INDIVIDUAL ROCK TYPES

Overburden

Two types of overburden overlie the No. 1 Deposit; ablation till and glaciolacustrine sediments. Figure 8 is an isopach of overburden thickness, undifferentiated as to type; Figure 9 is a contour map of bedrock surface. The till, which blankets all of the deposit south and west of Hat Creek, consists of rounded pebbles and boulders up to several inches in diameter contained in a clay to sand matrix. The pebbles and boulders are composed of medium to dark grey chert, dark green to black volcanic rocks, occasional light grey to pale olive Coldwater sedimentary rocks and minor dark grey limestone. Landslide material, present on the west side of the deposit, consists of the till containing granodiorite boulders up to several feet or tens-of-feet in diameter. These boulders are so deeply weathered and altered that they commonly degenerate into fine to coarse grained, light olive-green sand. This sand, where compacted, is difficult to distinguish from underlying Coldwater detritals that have been disturbed by the presence of over-riding ice.

Glaciolacustrine deposits are situated northeast of Hat Creek, in the "east bench" area, where they are up to 500 feet in depth. They are composed of light grey, clean silt, sand and lesser amounts of clay. Relatively flat-lying bedding is apparent where they are undisturbed. Other such deposits, derived partly from weathered granodiorite and partly from coal-bearing Coldwater Formation sedimentary rocks, occur in several places on the valley slopes flanking the No. 1 Deposit to the west.

Claystone (Mudstone)

These are extremely fine grained clastic rocks in which bedding can be seen only rarely unless it is enhanced by carbonaceous material. Granularity cannot be observed megascopically. They are soft and most commonly light olive-grey in color with local, rare variations to light grey and pale orangish brown. They are commonly pliable, having a tendency to swell due to montmorillonite (bentonitic) content. Where they are fissile these same rocks are termed shale.

Shale

These are the (slightly) fissile varieties of claystone, mudstone and, to a lesser degree, siltstone. They are not classically fissile shales because they are poorly lithified and thus do not readily sustain fissility. However, the fissility is enhanced by the presence of carbonaceous and coaly material and consequently, these are the most common rocks intimately associated with the coal. Their physical characteristics are similar to the claystones and mudstones; light olive-grey to light grey color, microscopic texture, locally pliable. When carbonaceous or coaly material is present they become brownish grey to brown. The terms 'carbonaceous shale', 'coaly shale' and 'shaly coal' indicate relative degrees of shale content ranging from mostly shale to minor shale in coal.

Siltstone

Within the Coldwater Formation at Hat Creek, siltstone is a common rock type which is intermediate between claystone and fine grained sandstone. Except for grain size, the descriptions which apply to claystone and to fine grained sandstone can be applied to siltstone. Granularity is difficult to observe but usually can be determined by a non-greasy appearance on a finger-polished surface.

Sandstone

This is another common rock type within the Coldwater Formation in the area of the No. 1 Deposit. It is gradational from siltstone to gritstone and conglomerate. It is always granular and, where coarse, the grains consist of andesite or basalt, chert, quartz, altered feldspar and,rarely, carbonate (limestone) and are commonly set in a silty to clayey matrix. The sandstones are poorly sorted and their bedding is often indistinct. They range in color from light olive grey to pale olive with minor variations to light grey and olive green. They are locally cemented into a relatively competent mass by calcite. They only rarely contain carbonaceous material and then in only minor quantities.

Gritstone

The proportion of gritstone in the Coldwater beds is small and consequently the term has not been used at Hat Creek except for descriptive purposes. It is a rock that could be considered a very coarse grained sandstone and, with the presence of a few larger grains, a coarse pebbly sandstone or fine grained conglomerate. It rarely occurs in beds thicker than two or three feet; more commonly the beds are less than one foot in thickness. The proportion of gritstone that is cemented by calcite, perhaps 25 percent or more, is much higher than for any other detrital rocks in the Coldwater sequence. In color it tends to be darker green than most other non-carbonaceous or coaly rocks due to the amount of larger size (2-4 mm) dark grains (volcanics). Bedding is exhibited only by alternating textures, e.g. gritstone to sandstone to gritstone.

Conglomerate

Conglomerate is more common than gritstone but less common than the finer detrital rocks. It generally consists of small pebbles to large cobbles in a sandstone matrix, the pebbles and cobbles comprising 10-50 percent of the rock. They are composed mainly of rock fragments similar to rocks of the basement Cache Creek Group and Spences Bridge Group. The conglomerate is locally cemented by calcite in which case it forms a competent rock unit.

Coal

There is considerable variation in the composition and appearance of the coal. It is most commonly dark brown to blackish with an earthy to silty texture. Vitrain or pre-vitrain content ranges from nil to locally as high as 50 percent (D Zone); it is black or very dark brown, sub-lustrous to rarely highly vitreous in appearance. The vitrain occurs as fine lenses up to 2 or 3 mm in thickness and several centimeters in length which result in a distinct banded appearance, and as thicker, unoriented lenses and masses 1-20 cm in thickness. The non-vitrain portion of the coal, the fusain and attrital portion, is medium to dark brown and rarely black, is massive, has a dull lustre, is satiny to silty textured and contains most of the inherent ash.

Cleating (fine rectangular jointing in the coal) as seen in the drill cores is locally present but is rarely well developed; it is associated almost exclusively with the vitrain. Discing or fissile fracturing is common and probably reflects composition (banded vitrain) and stress relief. It is usually parallel to the vitrain banding but not always so.

The mineral matter content, principally clay and silt with lesser quantities of carbonates, varies widely in concentration and form of distribution. On a scale of a few feet, there can be found within the No. 1 Deposit essentially a continuum between "clean" coal on the one hand and pure rock on the other. Preliminary washability test work on particles less than 3/8 inches in diameter indicates that finely divided inherent ash may vary from a low of 3 to

5 percent to a high of 40 to 50 percent. However, the apparent high inherent ash indicated by some washability tests may be the result of grains of coal and swelling clay sticking together and floating at a low specific gravity to produce a relatively high ash product. Discrete mineral matter, in the form of partings, can vary in thickness from a millimeter to tens of feet. Portions of the coal are descriptively referred to as "silty" coal. This material generally is quite fissile and friable. It appears to be a mixture of mineral and maceral grains which may be coarse enough to be separated by washing.

The coal is one of the most competent rock units within the No. 1 Deposit other than where it is severely crushed or sheared near or within fault zones.

Minor Rock Types

Marl beds 2-5 feet thick are present but are uncommon. They are light to dark grey, silty textured and indistinctly bedded mixtures of clay and carbonate.

Ash beds are highly visible in the coal sequence. They are clayey to silty textured, light tan to occasionally pale grey colored and distinctly lightweight (low specific gravity). Some are in the form of 0.5-1 mm granules either diffuse in the coal or as tightly packed masses; these have been termed "mottled" or "speckled" ashes. Ash beds of all types are usually less than 5-10 cm thick. They are useful local marker horizons. X ray work shows them to be composed of variable percentages of quartz, kaolinite, carbonates, and montmorillonite with kaolinite probably predominating over montmorillonite.

Siderite occurs primarily as replacement of wood in which much of the original cell structure has thus been preserved. It is usually in thin intervals, seldom exceeding 20-30 cm in core length. It is finely crystalline, dark greenish black and heavy (high specific gravity). Siderite is useful for correlating between the lithological and geophysical logs when footage discrepancies occur because it is distinct in both logs.

Calcite is present locally in all rock types but more commonly in the coarser detrital varieties. It occasionally is present as fine fracture fillings within or near fault zones but more frequently as an interstitial cement. It is creamy white to very pale semi-vitreous green.

Burnt Material

Underlying Dry Lake and extending southerly from this distinct topographic feature (located on the northwest boundary of the No. 1 Deposit), is a zone of burnt sedimentary rocks; a smaller zone is situated along the west boundary of the deposit, (Fig.10). The burnt material ranges up to 220 feet in thickness.

The burnt rocks are heterogeneous, looking in part like volcanics and in part like burnt and baked shales and other fine grained sedimentary rocks or like furnace clinker. The material is highly and variably colored with the colors often being pure and distinct in individual pieces of core. The colors are predominantly of reddish hue: white to pale creamy grey, tan, light orangish yellow, oranges, pinks, brick-red, browns, minor dark brownish grey to black. Rocks of these colors range in texture from earthy to aphanitic to glossy and in hardness from quite soft, (1-2 on Moh's hardness scale), to more commonly hard (5) and very hard (> 6). A few white pieces are porcelaineous and very hard. The material that is more volcanic in appearance tends to be purplish to dark greenish purple in color, hard and fine grained. Some is scoriaceous in appearance and highly vesicular, the vesicles being up to 3 cm in diameter. Where not vesicular, this volcanic-like rock often contains welded, pinkish to cream-colored fragments up to several centimeters in diameter.

Other variations of these two basic types of burnt material are present and are probably best described as combinations of the two. The variations are numerous but all generally have some reddish hue and many exhibit some brecciated structure.

Initial microscopic examination indicates the presence of glass that may be slightly to moderately devitrified, hematite, cristobalite (high temperature quartz), feldspar and welded fragments.

All of these rocks are herein termed "burnt material" and there is little question that most, if not all, were formed by burning. However, some of the material may be of volcanic origin and the volcanics may have initiated burning in the coal which then produced the bulk of the burnt rock. No volcanic vent has been discovered. On the other hand, some layers of the melted, glassy, clinker-like rock are so thick that it is difficult to conceive of them having been formed by coal fires.

Dry Lake is apparently a collapse structure resulting from the burn-out of coal. The removal of support from the toe of the slope to the west may have been a factor in permitting landslides to develop.

HANGING WALL

Rocks in the hanging wall of the coal sequence comprise a thick monotonous sequence of claystones and siltstones that exhibit little variety. They are, for the most part, light olive grey in color (as distinct from the pale olive or light yellowish greenish color of the footwall sequence), massive to very indistinctly bedded and fine equigranular textured. Color variations are minor and subtle. They contain sparse scattered plant debris that is normally visible only on bedded surfaces.

Preliminary microscopic study indicates that a significant portion of the hanging wall claystones and siltstones are of tuffaceous origin. As well, thin beds (generally less than two feet) of essentially pure tuff can be identified by a slight change in color and a soapy or greasy appearance. They are slightly buff colored in relation to the light olive grey of the remaining rocks.

In a few places worm casts (?) have been observed but have not as yet proven useful for correlation purposes.

Table 4 shows the progress results of the X ray analysis of 80 core samples from No. 1 Deposit at Hat Creek. These data apply to this and following sections of the report. Further data will be forthcoming in the near future. The percentages shown for the minerals are arithmetic averages; because of variations in sample length from a few inches to 20 feet, weighting of the data by sample length could grossly distort the results. As well, the nature of the sampling does not justify the application of weighting factors. A few samples contain significant percentages of coal but the majority are rock with little or no carbonaceous content.

TABLE 4

X RAY ANALYSIS OF CORE SAMPLES, BY STRATIGRAPHIC UNIT

Strat. Unit	Number of Samples	PERCENT OF TOTAL SAMPLE (1) Q	F	K	M	C	S	Cum.	Coal & Minor Minerals
HW	13	9(2) (0-19)(3)	3 (0-10)	11 (0-87)	54 (15-79)	7 (0-85)	16 (0-64)	100	-
Upper A	16	21 (2-49)	5 (0-15)	43 (15-70)	17 (0-39)	1 (0-15)	3 (0-23)	90	10
Lower A	11	27 (11-45)	4 (0-11)	40 (19-68)	17 (0-38)	-	5 (0-21)	93	7
B	18	23 (0-54)	1 (0-3)	43 (14-89)	2 (0-15)	1 (0-19)	4 (0-25)	74	26
C	10	37 (17-65)	2 (0-8)	54 (28-79)	-	-	4 (0-12)	97	3
D	7	24 (22-53	1 (0-8)	70 (40-80)	3 (0-21)	-	2 (0-13)	100	-
FW	5	51 (35-70)	-	44 (30-65)	-	-	5 (3-24)	100	-

(1) Q - Quartz; F - Feldspar; K - Kaolinite; M - Montmorillonite; C - Calcite; S - Siderite
(2) Mean
(3) Range

Other minerals, usually present in minor concentrations, which were reported but are not shown in the table are epidote, pyrite, ankerite (iron carbonate), cristobalite and goyazite (hydrous strontium aluminum phosphate). Minerals present in concentrations of less than two or three percent are not normally detected by X ray analysis.

The results shown in Table 4 should be viewed as trends only, not as absolute representative percentages. Significant trends are the high proportions of montmorillonite and siderite in the hanging wall claystones and the general increase in kaolinite with stratigraphic depth. The quartz concentration is variable. Within the coal zones, the concentration of CO_2 in the analysed coal samples is a better indicator of the mean percentage of carbonate minerals than are the calcite/siderite percentages shown in Table 4.

Photographs of core from drill hole 76-135 are contained in Appendix III; reference to them may be useful for a better appreciation of the major rock and coal units.

COAL SEQUENCE

In order of decreasing abundance, the main rocks within the coal sequence are: coal, shale, carbonaceous to coaly shale and siltstone. Other rocks, which are present in relatively sparse quantities are: sandstone, marl, siderite and ash beds. Coal is the dominant rock type throughout the bulk of the No. 1 Deposit, accounting for an overall average of about 75-80 percent of the sequence but giving way to shales, siltstones and sandstones to the south and to the west as the limits of the deposit are approached.

FOOTWALL

The footwall rocks, forming the basal unit of the Coldwater Formation, consist of predominantly coarse detrital material. Sandstone is probably the most common rock type although a large proportion of siltstone is also present. Gritstones and conglomerates are common. A few shale beds are present and some of these are carbonaceous or contain thin coal beds. All of the rocks have a distinctive pale olive to light yellowish green color, the change from the preceding greyer tones of the hanging wall and non-coaly or carbonaceous coal sequence rocks taking place within about 20 feet of the bottom of the coal sequence.

Cycles of rudely graded beds occur throughout the drilled portion of footwall zone. The rocks are not well lithified and commonly contain a clayey cement.

STRUCTURE

To assist in understanding the descriptions which follow, reference should be made to the maps and sections in the supplement which accompanies this report.

FOLDING

The main body of the No. 1 Deposit is folded into a syncline with a north-south axial plane and an average 15°-20° plunge to the south, (Sections 79,000 N and 19,500 E). This form is probably due in part to subsidence contemporaneous with deposition, and in part to post-depositional tectonics. The east limb is modified and partially truncated by northeasterly and northerly striking faults such that it is steepened to near vertical at these faults. The west limb, on the other hand, is more continuous and regular at a 20°-40° dip. It is truncated at the subcrop. Small scale drag folds within the No. 1 Deposit may be common but such features are difficult to detect in drill holes spaced 500 feet apart.

To the northeast of the main deposit, but in fault contact with it, is a relatively flat-lying portion of the overall deposit termed the "east bench" area, (sometimes referred to as deposit 1A). The coal sequence in this area is slightly warped (into a local syncline) and dips gently (5°-10°) to the southeast, (Sections 82,000 N and 21,000 E).

East of fault No. 8, shown on the geological sections, are several coal intersections which are believed to represent the west limb of a synclinal structure that is almost certainly modified by faulting. These coal beds are postulated to dip steeply to the east at 40°-90°, (Section 79,000 N).

FAULTING

A number of major faults are known within and about the No. 1 Deposit and numerous lesser faults are surmised. The more prominent faults are shown on the sections and plans. Others of similar magnitude may be present but are not as yet adequately recognized or understood. Some of the faults shown may be diagrammatic in that the single fault line represents a fault zone or several sub-parallel, en echelon (?) faults.

The low rock strengths and poor lithification of the Coldwater rocks complicate the structural interpretation. These rocks do not sustain a "clean" fault break. Instead, they locally fold and shear, resulting in numerous small displacements, perhaps as small as fractions of a millimeter, which, across several feet or tens of feet, accumulate into a displacement of considerable magnitude. Similar movement probably took place along bedding planes as well, thus further complicating the structural picture. As well, some of the movement on these faults may have occurred contemporaneously with deposition of the coal.

Fault No. 8 is the major modifying feature of the No. 1 Coal Deposit. It is probably regional in magnitude and thus not confined to the Coldwater Formation. The horizontal displacement across this structure is not known but the vertical displacement is normal and in the order of 2000 feet. It apparently truncates the east limb of the deposit although intersections in a few drill holes east of the fault may represent the displaced portion of this eastern limb. It strikes N20°-25°E and dips steeply (70°-80°) to the west. It appears to truncate faults No. 5 and No. 7 at their southern ends; however, there is a possibility that fault No. 7 is later and slightly displaces fault No. 8.

Fault No. 7 separates the main body of the deposit from the east bench section. It strikes N10°-20°W and dips 75°-85° west. It is a scissor fault in that it is normal north of section 79,000 N and reverse south of this section. The normal displacement may reach several hundred feet (500 feet?) towards the north end of the deposit. The reverse displacement to the south is difficult to estimate due to drag folding and the proximity to fault No. 8. There is little doubt as to the existence of faulting where fault No. 7 is shown, but the nature and configuration of the faulting (fault zone, several faults, displacement, etc.) are open to question.

Fault No. 5 is a slightly arcuate, northerly striking and easterly dipping (70°-80°) reverse fault with minor vertical displacement but possibly significant strike-slip movement. The apparent limited horizontal extent of the fault, and its somewhat arcuate horizontal trace would appear to refute this statement. However, at its north end, fault No. 5 may branch from fault No. 7 at a low strike angle and thus be of considerably greater strike length than is apparent. At the south end it may have less curvature than shown and, as well, it could have extended farther south, being later truncated by fault No. 8. As for fault No. 7, the single fault simplicity displayed on the plans and sections is more diagrammatic than accurate.

Fault No. 6 is a somewhat hypothetical normal fault located so as to help explain the thickness of the D Zone in drill holes 57-8 (Section 79,000 N) and 76-187 (Section 79,500 N) and the bedding attitudes and possible fault intersections in these and other nearby drill holes. It strikes N15°E and dips 75° west. It is thus parallel to fault No. 8 but confined between faults No. 5 and No. 7.

Faults No. 1 and No. 2 are situated on the west side of the axial plane of the main deposit. South of Section 78,500 N they strike south-southwest, (fault No. 1 joins and becomes part of fault No. 2 north of this section), but No. 2 as it continues north swings to almost due north. Both dip 70°-80° east. Both faults exhibit normal displacement, with the magnitude of the vertical movement increasing from north to south. A possible hinge-point may occur in the vicinity of Section 80,500 N.

CORRELATION

There are three orders of geological correlation at Hat Creek: within the Coldwater Formation, within the No. 1 Deposit, and within individual coal zones. Correlation difficulties are related to geological complexities which are locally multiplied or compounded by a paucity or lack of data. Incomplete data may be due to incomplete (unfinished) exploration, hole squeezing (which results in non-completion of some holes and an inability to geophysically log others), or lack of economic justification for obtaining detailed data. Geological complexities include faulting, folding, drag folding, lensing of units along strike and/or dip, inability of many of the weak rocks to sustain sharply defined structures and progressive movement along bedding planes.

Correlation within the Coldwater Formation is relatively simple, with minor problems arising only near the western margin of the No. 1 Deposit. The formation is subdivided into three large units: the hanging wall fine detrital rocks, the underlying coal sequence, and the basal coarse detrital rocks. Each of these units is described previously in the report (ROCK TYPES).

Within the coal sequence, two of the coal zones, B and D are particularly useful for correlation purposes because they comprise relatively clean, good quality, continuous coal, and are thus readily recognizable. Major problems arise where faulting has thickened and folded the zones along the eastern side, and where the zones (primarily the A and C) shale out towards the western and southern limits of the deposit. The most useful data are general lithology, bedding attitudes, down-hole geophysics and coal quality. Of lesser importance are ash beds, palynological dating, surface geophysical trends, subcrop topography and possible tectonic features (i.e. pulverized or brecciated rock). The palynological dating is useful for gross correlation of stratigraphic units 200 to possibly 400 feet in thickness. The zone correlations are shown on the plans and sections in the supplement.

Within the central part of the main No. 1 Deposit area (i.e. between fault No. 5 on the east and the shale out area on the west and south) reasonably dependable subzone correlations can be made within the zones at distances of 500 to 1000 feet. At greater distances, correlations may or may not be dependable. That distance, 500 to 1000 feet, thus gives an indication of the degree of geological variability within individual beds in the central part of the deposit. No attempt has been made to divide the coal sequence systematically into subzones. In many places they could be divided into subzones as thin as a single parting. Ideally, they will be divided into arbitrary subzones which will best fulfill the requirements for conceptual mine design.

Significant chemical differences exist among the various coal zones but detailed use of these data has not been made yet for correlation purposes.

CONFIGURATION AND CHARACTER OF THE DEPOSIT

GENERAL

The No. 1 Coal Deposit consists of a fault-modified syncline plunging southerly at an average 15°-20°, (Sections 79,000 N and 19,500 E). It encompasses an area approximately 8000 feet in north-south dimension and 5000 feet east-west. The base of the syncline extends from bedrock surface at the northern limit of the deposit to depths in excess of 2000 feet below bedrock surface at its southern end. The deposit can be divided into three units: 1) the main deposit which extends westerly from fault No. 7 and thus comprises the bulk of the No. 1 Deposit, 2) the east bench area which lies to the northeast of the main deposit between faults No. 7 and No. 8, and, 3) the eastern area which consists of a few intersections immediately east of fault No. 8.

The eastern area is neither well delineated nor understood; however, from present drilling it is known that no appreciable tonnage of near-surface coal is present. The coal intersections (in drill holes 74-26, 76-126, 128, 164) are tentatively considered to be in the A Zone because of the overlying thick siltstone typical of the hanging wall unit. The coal zone appears to have been displaced downwards, in relation to the remainder of the deposit, as a result of normal vertical movement on fault No. 8. The configuration of the zone is shown somewhat hypothetically on the sections and plans. The strike, slightly east of north, is based upon the several intersections obtained. The dip, steep easterly but becoming less steep with depth, is based primarily on the intersections and bedding attitudes in drill hole 74-26.

The east bench area consists of D Zone and good quality C Zone coals which are difficult to differentiate because they form one thick coal bed of reasonably consistent quality. The area they underlie is in the shape of a modified triangle with base to the north that is confined between faults No. 7 and No. 8. It is approximately 5000 feet from apex to base and 2000 feet across the base. The coal ranges in thickness from about 200 feet to more than 600 feet. It is relatively flat lying, except near faults, having a gentle dip of 5°-10° to the southeast. It is directly overlain by glaciolacustrine deposits ranging up to 500 feet in depth. The east bench area thus constitutes an appreciable resource of good quality coal.

The main deposit comprises the four coal zones (A, B, C, D) in a fault-modified syncline which lies west of fault No. 7. The axial plane of the syncline strikes slightly east of north and dips steeply east. The axis plunges southerly at 15°-20°, from subcrop at section 83,000 N to in excess of 2000 feet of section 76,000 N. Data are sparse south of section 77,000 N, particularly for the more readily definable and continuous B and D zones and consequently, the southern limits of the main deposit are not known. However, because of increasing depth along the axis of the deposit, the southern limits are of economic interest only to the west where the coal zones (and most probably only the D Zone) may be near-surface on the west limb of the syncline. At maximum stratigraphic thickness, the coal zones are 1450 feet in thickness and comprise 75-80 percent coal (Fig. 17, drill hole 76-135).

Towards the north in the main deposit, the A, B, C and D zones progressively disappear as a result of erosion. At the subcrop level, all zones are thus horseshoe-shaped in configuration, with the open end of the horseshoe pointing southerly.

"A" ZONE

The A Zone is the uppermost coal unit in the No. 1 Deposit, being directly overlain by the thick, monotonous claystone-siltstone unit that constitutes the upper portion of the Coldwater Formation. The contact between these units is conformable and abrupt over a few feet, usually less than five feet. The zone is about 600 feet in thickness and is characterized by irregular sequences of good quality coal, coaly shale (claystone) and siltstone in beds generally 20 feet or less in thickness. Approximately 35 percent of the zone comprises rock and carbonaceous units containing more than 55 percent ash on a dry basis. Most of this material will have to be discarded as waste during mining if a product of sufficient quality for thermal plant feed is to be obtained without washing the coal.

At the bottom of the A Zone (and considered a part of the zone) is a rock unit, termed the A-B rock unit, which can be traced throughout much of the main deposit. It is 30 to 80 feet in thickness, the thicker portions being on the southwestern side of the deposit.

The A Zone is confined primarily to the main deposit and occurs mostly to the west of fault No. 5; it is not present in the east bench area. To the west it shales out and/or is truncated by fault No. 2; it shales out to the south.

"B" ZONE

The B Zone is a consistently fair to good quality coal unit that is conformably overlain by the A Zone (and the A-B rock unit) and immediately underlain by the C Zone. The contact between the B and C Zones may be disconformable locally. The B Zone is consistently about 250 feet in thickness and is composed of relatively clean coal with little in the way of rock partings. The ash content increases somewhat towards the base of the unit. Only about seven percent of this zone would need to be discarded during the mining process.

The B Zone is confined to the main deposit west of fault No. 1. It extends southerly to the limits of data on Section 76,000 N. To the west at Sections 76,000 N to 77,000 N it appears to weaken (shale out). However, some unresolved faulting in this area may account, at least in part, for the apparent termination of the B Zone to the west.

"C" ZONE

The C Zone consists of the stratigraphic interval between the overlying B Zone and the underlying D Zone. It is a highly variable unit of thin coal beds intercalated with thin to thick waste beds. It ranges in total thickness from 200 feet to 350 feet. A large but variable quantity (30-70 percent) of this zone would have to be discarded during the mining process in order to maintain an acceptable thermal plant feed. The B-C rock unit at the top of the zone increases progressively in thickness to the south and west.

The typical C Zone is confined to the main coal deposit. However, in the east bench area good quality C Zone (apparently) overlies and is virtually indistinguishable from D Zone coal. Within the main deposit the C Zone becomes progressively "shaly" to the southwest to the point where it can no longer be termed a coal zone. In effect, it becomes a thick rock unit, locally containing a few thin coaly or carbonaceous beds, which separates the B and D zones.

"D" ZONE

The D Zone is the best quality and most consistent coal zone in the No. 1 Deposit at Hat Creek. It is the basal unit of the coal sequence and conformably overlies the coarse detrital basal unit of the Coldwater Formation. The transition from C Zone to D Zone is abrupt within one to two feet. The zone is 200-350 feet in thickness and comprises all clean coal.

The D Zone has the greatest areal extent of the four zones constituting the No. 1 Deposit and, except for the eastern area (east of fault No. 8), it is present in all segments of the deposit. It is essentially the only zone present west of the No.1 fault and the northerly portion of the No. 2 fault. At no place does it shale out within the drilled portion of the No. 1 Deposit; it is either truncated at the subcrop or is at too great a depth to intersect. Between faults No. 2 and No. 8 it has been located as far south as Section 77,000 N where it is 1500-2000 feet below surface. It probably extends farther south at these and greater depths.

Based on geophysical logs and analytical data, the D Zone can be divided into roughly equal upper and lower subzones in the main area of the deposit.

ORIGIN

The Hat Creek coal deposits are unique in that no other known deposit in the world approach them in thickness. Genetically, the unique aspect was probably the prolonged period during which conditions favourable for the accumulation and preservation of peat persisted (several million years), with periods of interruption during the deposition of the partings and thicker rock beds. In all, some 6000 to 7000 feet of peat must have accumulated.

The conditions required for the accumulation of peat and subsequent conversion into coal are as follows:

1. Fresh, clear water for high grade coal; muddy waters produce high ash coal as in parts of the A Zone and C Zone.
2. Favourable climate.

3. Accumulation of organic material.
4. Balance between the groundwater table and the depositional interface. If the site of accumulation is well drained, the organic material is oxidized; if it is flooded, only transported organic material can accumulate.
5. Persistence of conditions in time and space.
6. Ultimate burial and coalification of the organic material.

The Hat Creek coal deposits are continental or protected continental margin in origin; marine fossils have not been found and no significant beds of limestone are present. Most of the observed carbonates (calcite and siderite) are secondary in origin. Deposition occurred in a subsiding, poorly drained swamp or basin. The rate of subsidence and the rate of accumulation had to be in almost perfect balance for extremely long time periods while the B and D zone peat beds were being deposited.

The original areal extent of the deposits is not known but it was undoubtedly much greater than the presently known extent. No. 1 and No. 2 deposits were probable continuous or nearly so. The deposits presently exist in a graben (down faulted) structure. The history of formation of the graben is open to speculation but at least part of the basin subsidence probably resulted from down faulting contemporaneous with organic deposition. Subsidence over the entire basin of deposition need not have been uniform. The apparent scissor movement on some of the faults may be explainable by basin tilting during deposition. Palynology work by Dr. Rouse suggests that the D Zone coal in the central part of the No. 1 Deposit basin is older than elsewhere. Hence, stratigraphic correlations are not necessarily time correlations. An exception would be volcanic ash beds which normally would be deposited over the entire basin as an instantaneous event.

Little in the way of river-or stream-channel fill material has been recognized in the deposit. This is surprising even allowing for the fact that most of the geological information is derived from drill holes. The principal source of inorganic material was apparently from the southwest in which direction the deposit shales out. The presence of ash beds throughout the coal sequence attests to volcanic activity contemporaneous with peat accumulation. The ash could have been borne by the wind from distant volcanoes, but tuffaceous material which was probably derived from less distant volcanoes is common in the coal sequence. Increased volcanic activity may have been the principal cause of the cessation of coal deposition. The hanging wall claystones contain a large component of volcanic-derived debris. They were probably deposited in a lake or well drained swamp which did not favour the preservation of organic material.

The contribution of volcanic material to the coal sequence undoubtedly affects the chemistry of the coal ash.

ENGINEERING ASPECTS

Golder Brawner and Associates carried out extensive field and laboratory engineering tests on core samples and reported the results separately. No attempt is made here to discuss detailed geotechnical aspects of the Coldwater Formation rocks.

Discounting the occasional thin, hard calcified bed in the Coldwater Formation at Hat Creek, coal which has not been affected by faulting, is the most competent rock. NQ - size (1.875 inches diam.) core pieces of the other rocks can be broken by hand. The hanging wall claystone-siltstone unit contains significant percentages of montmorillonite, has a low shear strength, and is susceptible to swelling and breaking down on exposure. The footwall detrital rocks appear to be more competent but are poorly lithified because of the clay content in the matrix and can be readily broken down. Both rock types have low permeabilities.

Drill hole water level measurements carried out since 1974 show that the groundwater table is high, generally within 100 feet of the surface, except in the east bench area where it is as much as 300 feet below the ground surface in the glaciolacustrine deposits. Small artesian flows have been encountered in a few drill holes.

Table 5 summarizes the results of field slaking tests on core samples from the No. 1 Deposit. The cores from hole Nos. 26, 27, 32 and 40 were three to seven months old at the time of testing and this may have had some bearing on the results. The results show an interesting difference between hanging wall rocks which break down primarily by fracturing but to a much less severe extent than the footwall rocks which break down primarily by crumbling and powdering. An open pit at Hat Creek would encounter, of course, much less of the footwall than the hanging wall rocks in the excavation. The predominant break down by fracturing of the hanging wall rocks is probably due to in situ micro brecciation and the presence of swelling clay minerals on the micro fractures.

RESERVES

METHOD OF CALCULATION

Reserves were calculated for the coal zones as outlined on the plans and sections in the supplement to this report. The zones, on each east-west

TABLE 5

NO. 1 DEPOSIT - FIELD SLAKING TEST RESULTS (1)

Type and Degree of Disintegration(2)	HANGING WALL Samples No.	HANGING WALL Samples %	FOOTWALL Samples No.	FOOTWALL Samples %
FRACTURING				
Negligible	42	37.8	2	1.3
Substantial	43	38.7	-	-
Complete	5	4.5	-	-
Sub-total	90	81.0	2	1.3
CRUMBLING & POWDERING				
Negligible	-	-	12	7.6
Substantial	-	-	18	11.4
Complete	10	9.1	117	74.1
Sub-total	10	9.1	147	93.1
FRACTURING PLUS CRUMBLING & POWDERING				
Negligible	4	3.6	1	0.6
Substantial	1	0.9	7	4.4
Complete	6	5.4	1	0.6
Sub-total	11	9.9	9	5.6
TOTAL (combined)				
Negligible	46	41.4	15	9.5
Substantial	44	39.6	25	15.8
Complete	21	19.0	118	74.7
TOTAL	111	100.0	158	100.0

(1) Samples derived from the following drill holes: 74-26, 27, 32, 40, 49 and 50.

(2) After soaking in tap water for 24 hours.

section, were subdivided by elevation intervals (2000 ft., 2400 ft., 2800 ft.) and data density, thus resulting in a number of reserve blocks within each zone. The area of each block was obtained by planimetry. To obtain volumes for the blocks, a north-south projection distance for the area was assigned to each block. This distance was determined from surrounding data; it was usually 500 feet (half the distance to adjacent sections north and south). Tonnage was calculated by dividing the block volume by the appropriate tonnage factor. Finally, the block tonnages were tabulated and then summed in various ways.

Prior to planimetering the areas of the blocks, the larger waste sections within the A and C zones, e.g. the A-B and B-C rock units, were outlined and eliminated from the area determinations. As well, an estimate was made, on an individual block basis, of the proportion of internal waste and high ash coal (over 44 percent ash at 20 percent moisture) in beds or partings greater than ten feet in true thickness. This material was mathematically excluded from the blocks with the result that the tonnages calculated could grossly represent the tonnage of selectively mined thermal plant feed available in each reserve block. The volumetric proportion of material excluded from each zone is approximately: A Zone - 35 percent, B Zone - 7 percent, C Zone - 50 percent, D Zone - essentially none. The mean specific gravity of this material will be in the order of 2.

Potential mining dilution has not been considered in these reserve determinations because of the imprecise nature (in detail) of the calculations and because dilution will vary depending upon the physical character and configuration of the material being mined and the ash and calorific value of the diluting material.

Different tonnage factors were employed for each coal zone because of different specific gravities related to the different mean coal quantities in each zone. The specific gravities used are based on the mean ash contents for the four coal zones obtained from combined data from drill holes 76-135 and 76-136 and on a preliminary regression analysis of ash versus specific gravity for drill hole 76-135. A reasonably linear relationship is present in the lower ash ranges. When the ash - specific gravity data can be assessed in greater detail, it is intended to develop an equation for use in computer reserve calculation programs which will permit assigning a calculated specific gravity to each sample. The specific gravities and tonnage factors employed in these present reserve calculations are as follows:

Zone	Estimated Mean Specific Gravity	Pounds Per Cubic Ft.	Cubic Ft. per Ton
A	1.45	90.5	22.1
B	1.43	89.2	22.4
C	1.54	96.1	20.8
D	1.36	84.8	23.6

The reserve calculation method employed is accurate if sufficient data are available and if the individual reserve blocks are well defined and small.

For the No. 1 Deposit, many gaps are present in the data base, the zones, though reasonably well defined, are imprecise, and the reserve blocks are large in many instances. Consequently, the reserves as determined are not precise in detail although in grosser aspects they are good estimates of the "mineable" reserves. (The term "mineable" is not meant to include depth and other limitations to practical and economic mining considerations.) Excluding significant changes in zone interpretations, the reserve figures listed in Tables 6 and 7 should be accurate to within five percent. In general, the larger the reserve tonnage, the better the estimating accuracy.

CLASSIFICATION

The reserves were classified on an individual block basis, into three standard categories, Proven, Probable and Possible. The categories are defined as follows:

> Proven Reserves - coal for which there is a high degree of confidence in its occurrence; the zone is well defined and correlation and interpretation are well established. Maximum projections of 250-300 feet beyond drill intersections.
>
> Probable Reserves - coal for which there is a moderate degree of confidence in its occurrence; the zone is reasonably well defined. Maximum projections beyond proven reserves of 500 feet.
>
> Possible Reserves - coal for which there is a relatively low degree of confidence in its occurrence; zone correlation and interpretation are based on geological projection. Projections beyond probable reserves but within zone boundaries.

TONNAGE

The coal reserve tonnages are shown in Table 6 and Table 7.

The zone referred to as A-east consists of coal intersected in a few drill holes east of fault No. 8. Although an interpretation for this zone is shown on the sections and plans, it is of such a speculative nature that considering the tonnage involved (43.7 million), it is considered more conservative to exclude it from the main reserve summations.

Almost half the proven, probable and possible reserve tonnage (47.7 percent) is contained in the D Zone because, although it is stratigraphically

TABLE 6

NO. 1 DEPOSIT - COAL RESERVES - SUMMARY

(short tons x 10^6)

UNIT	PROVEN Tons	PROVEN %	PROBABLE Tons	PROBABLE %	PROVEN & PROBABLE Tons	PROVEN & PROBABLE %	POSSIBLE Tons	POSSIBLE %	TOTAL Tons	TOTAL %
Above 2800'	69.61	10.1	9.63	1.4	79.26	11.5	0.42	--	79.68	11.5
2400'-2800'	225.85	32.7	58.15	8.4	284.00	41.1	7.29	1.1	291.29	42.2
Above 2400'	295.46	42.8	67.80	9.8	363.26	52.6	7.71	1.1	370.97	53.7
2000'-2400'	110.23	15.9	53.66	7.8	163.89	23.7	3.31	0.5	167.20	24.2
Above 2000'	405.69	58.7	121.46	17.6	527.15	76.3	11.02	1.6	538.17	77.9
Below 2000'	48.34	7.0	70.24	10.2	118.58	17.2	33.69	4.9	152.27	22.1
Zone A	105.03	15.2	50.22	7.3	155.25	22.5	--	--	155.25	22.5
Zone A-east	--	--	--	--	--	--	43.70	--	43.70	--
Zone B	55.35	8.0	40.37	5.8	95.72	13.8	5.13	0.8	100.85	14.6
Zone C	70.85	10.3	28.30	4.1	99.15	14.4	5.91	0.8	105.06	15.2
Zone D	222.80	32.3	72.81	10.5	295.61	42.8	33.67	4.9	329.28	47.7
Total (-A-east)	454.03	65.8	191.70	27.7	645.73	93.5	44.71	6.5	690.44	100.0
Total (+A-east)	454.03	61.8	191.70	26.1	645.73	87.9	88.41	12.1	734.14	100.0

Note: (1) % refers to portion of total tonnage (-A-east); (2) Elev. totals do not include A-east Zone.

TABLE 7

NO. 1 DEPOSIT - COAL RESERVES - ZONES BY ELEVATIONS

(short tons x 10^6)

ZONE	PROVEN	PROBABLE	PROVEN & PROBABLE	POSSIBLE	TOTAL
			Above 2800 ft. Elevation		
A	26.81	3.07	29.88	--	29.88
B	8.53	0.26	8.79	0.42	9.21
C	6.49	0.62	7.11	--	7.11
D	27.78	5.70	33.48	--	33.48
Total	69.61	9.65	79.26	0.42	79.68
			Above 2400 ft. Elevation		
A	80.82	25.87	106.69	4.30*	106.69
B	29.68	3.52	33.20	1.50	34.70
C	52.61	13.51	66.12	0.99	67.11
D	132.35	24.90	157.25	5.22	162.47
Total	295.46	67.80	363.26	7.71	370.97
			Above 2000 ft. Elevation		
A	101.93	46.30	148.23	14.10*	148.23
B	49.01	19.33	68.34	2.62	70.96
C	64.37	18.82	83.19	2.34	85.53
D	190.38	37.01	227.39	6.06	233.45
Total	405.69	121.46	527.15	11.02	538.17
			All No. 1 Deposit		
A	105.03	50.22	155.25	43.70*	155.25
B	55.35	40.37	95.72	5.13	100.85
C	70.85	28.30	99.15	5.91	105.06
D	222.80	72.81	295.61	33.67	329.28
Total	454.03	191.70	645.73	44.71	690.44

* A-east zone not included in totals

thinner than the A or C zones, it contains virtually no waste and is the most continuous and widespread of the four coal zones in the deposit. The A and C zones on the other hand, comprising 22.5 percent and 15.2 percent of the reserves respectively, contain appreciable waste beds or partings which, when removed, reduce their productive stratigraphic thickness. Furthermore, these zones shale out to the west and south and are therefore not as widespread as the D Zone. The B Zone (14.6 percent of the reserves), which is stratigraphically the thinnest zone in the No. 1 Deposit, is somewhat similar to the D Zone in that it contains very little waste or low quality coal and is more continuous than the A or C zones. This accounts for its apparently disproportionate reserve tonnage in relation to the A and C zones.

COAL QUALITY

INTRODUCTION AND DEFINITIONS

Moderate to large volumes of data are available for some 45 coal attributes in 2679 samples collected from the No. 1 Deposit alone. This does not include the large volume of sink-float data, collected primarily during the summer of 1976, nor the multiplicity of coal attribute information obtained on various sink-float fractions. Any problem in regard to processing, analysing and drawing conclusions from the huge volume of analytical data is essentially quadrupled by the zone concept whereby the 1450-foot thick coal sequence has been subdivided into four coal zones. Data available justify the continued use of the zone differentiation.

For coal utilization, the measured coal attributes have varying significance. Important aspects of the attributes are their means, variabilities (dispersions), mutual relationships (positive or negative correlations of two or more attributes), and, for some physical, chemical or mineralogical aspects of the organic and inorganic matter, the form of occurrence. Variabilities for all attributes are large because of the physical characteristics of the deposits.

It is not possible in this exploration report to present a complete assessment of the analytical data suitable for thermal plant design specifications for two reasons. First, the volume of data to be processed outweighs all other aspects of the report and should constitute a separate report. Second, because of revisions to the computer storage data bank and to the output programs, little in the way of statistically evaluated data are available for the more than 2000 coal samples collected during the 1976 development drilling program. Based on the relogging of the drill cores, many stratigraphic correlations of the coal zones have been changed recently. The new zone data are only now being incorporated into the data bank.

When the new computer outputs become available, a thorough, comprehensive assessment of the coal quality will be possible.

Much of the following discussion in this report is based on the following:

1. Hat Creek Coal Deposits, Proposed No. 1 Openpit, Statistical Tables of Proximate Analysis Data, by Dolmage Campbell and Associates Ltd., July 15, 1975.

2. Statistical evaluations of laboratory precision and of coal attribute variability by Dr. A.J. Sinclair (See Statistical Evaluation, Part III of this report and excerpts of Dr. Sinclair's reports in Appendix IV).

3. Miscellaneous information from Integ-Ebasco during the summer and fall of 1976.

4. Miscellaneous letters and brief reports prepared by Dolmage Campbell and Associates Ltd. for B.C. Hydro during the period 1974-76.

5. Assessment of coal characteristic by zone for special test hole Nos. 76-135 and 136.

The remainder of this introductory section provides information on the limitations of the analytical data and on the interpretations which can be placed on it because of the current stage of processing of the data. It thus provides a perspective by which to judge the reliability of conclusions drawn. It also provides a partial list of definitions of terms used in subsequent sections.

Data Precision

A comparison of ash-calorific value regression analyses of 1957-59 data with those from more recent data shows that the earlier data has a lower precision; the data plots exhibit more scatter on the regression graphs. Also, a comparison of the proximate analysis data for 1957-59 with those from 1974-75 suggests a small bias in the earlier data. Volatile matter appears to have been reported, on the average, about two percent high and ash and fixed carbon each about one percent low.

Dr. Sinclair evaluated the precision of the check sample results from the three laboratories in which Hat Creek coal samples have been analysed (see excerpt, Appendix IV). Table 8 is a copy of a table recently prepared by Dr. Sinclair showing a comparison of ASTM tolerances and within laboratory precisions. For the full range of coal attributes checked, only three fall within ASTM tolerances at the 95 percent confidence level. For attributes present in small concentrations, such as phosphorous and chlorine, this is not surprising since a small error in accuracy produces a large standard deviation. Also, the ASTM tolerances were developed for lower ash and much less heterogeneous coals. The accuracy of subsample preparation in the laboratory, even though it be done under rigid ASTM procedures, may be the single most critical factor affecting precision of results for the heterogeneous Hat Creek coals; the more heterogeneous a material, the more difficult it is to obtain accurate subsamples for analyses.

The Hat Creek coals, similar to most lower rank coals, are termed "sparking" coals. During the heating of a sparking coal, volatile matter tends to escape from the sample in a series of minute explosions which eject ash. This can result in too high a reported value for volatile matter and too low a value for ash. Although all three laboratories use the modified ASTM procedure designed to overcome this problem, it may still contribute to lower analytical precision.

One other aspect of the Hat Creek coals may have a bearing on the precision of the analytical results. The coals contain variable amounts of different carbonates which have different dissociation temperatures. Under ASTM procedures, the sample is heated to 950°C for volatile matter determination at which temperature both calcite and siderite should dissociate (although the high temperature residence time is only seven minutes). For ash analysis, which is performed on a separate sample, the maximum temperature is only 700 to 750°C and there may be variable but incomplete dissociation of carbonates. The end result can be volatile matter reported correctly, ash too high, fixed carbon too low and oxygen by difference too low. Thus, the ASTM procedures may not permit a high level of precision and accuracy for heterogeneous high ash coals containing variable quantities of carbonates. The possibility of systematic differences (bias) between laboratories is increased if small differences in procedures result in variable dissociation of carbonate minerals.

Even allowing for the above, Table 8 shows that particular analyses performed in each of the laboratories fall outside acceptable levels of precision. Procedures for the analyses in question must be improved in order for the results to be acceptable.

The data on check samples show that there may be systematic differences in determinations for volatile matter, pyritic sulphur, and TiO_2 for one pair of laboratories and for Btu, CO_2, H_2, TiO_2 and SO_3 for another pair of laboratories.

TABLE 8

COMPARISON OF ASTM TOLERANCES AND WITHIN LAB PRECISIONS

Variable	ASTM Tolerances		Errors (2 Std. Devs.) and Means					
	Within Lab	Between Lab	Commercial		Loring		General	
			2s	$\overline{X}$	2s	$\overline{X}$	2s	$\overline{X}$
H_2O (res)	0.3	0.5	2.48	9.53	2.68	7.42	2.70	7.37
Btu/#			104.9	6604	439.5	5529	311.1	8173
Ash	0.5	1.0	1.32	42.8	1.02	45.6	0.62	31.5
F.C.			2.44	28.8	3.00	22.1	7.46	38.5
V.M.	0.7	1.4	2.14	28.8	2.84	32.0	7.24	30.0
S (py)	0.05	0.3	0.02*	0.26	0.06	0.19	0.16	0.08
S (org)			0.10	0.38	0.20	0.43	0.18	0.32
Carbon	0.3		1.12	39.3	0.74	35.1	2.60	48.1
Hydrogen	0.07		0.24	3.32	0.26	2.75	0.54	4.36
Nitrogen	0.05		0.42	0.86	0.10	0.70	0.22	0.97
Chlorine	0.03	0.06	0.08	0.06			0.04	0.03
CO_2	0.1	0.2	0.88	2.15	5.60	4.85	0.94	0.80
O_2(diff)			1.75	13.5	0.88	15.2	2.98	14.6
SiO_2	1.0	2.0	4.38	53.3	1.88	51.7	2.36	55.6
Al_2O_3	0.7	2.0	3.10	30.6	1.62	24.3	4.22	28.6
TiO_2	0.1	0.25	0.34	0.74	0.18	1.04	0.34	0.77
Fe_2O_3	0.3	0.7	1.62	7.51	1.26	10.2	2.40	6.67
CaO	0.2	0.4	0.70	4.64	1.70	4.60	0.90	2.32
MgO	0.3	0.5	0.30*	1.38	0.94	1.73	0.50	0.90
Na_2O	0.1	0.3	0.22	1.01	1.86	2.43	0.68	1.15
K_2O	0.1	0.3	0.28	0.57	0.12	0.68	0.08*	0.38
Mn_3O_4			0.24	0.13	0.88	0.76	0.10	0.11
V_2O_5			0.02	0.04	0.20	0.19	0.06	0.07
P_2O_5	0.05	0.15	0.30	0.34	0.34	0.09	0.52	0.26
SO_3		0.2	1.00	1.43	0.68	1.71	1.12	1.61

* Analytical precision within ASTM tolerance.
Tolerances are quoted as absolute percentages.
Precisions (except residual H_2O) are based on dry coal or dry ash data.
All means and precisions (except Btu/#) are percentages.

Note: Table reproduced from one by Dr. A.J. Sinclair

Representativeness of the Sampling

Tables 9 and 10 show sample footages broken down in various ways. For comparison, the percentage of the total Proven and Probable reserves in each zone is also shown. The reserves were prepared in a manner such that rock and coaly material containing more than about 55 percent ash, dry basis, are largely excluded. A comparison of the reserve percentages by zone with the percentages of core containing less than 55 percent ash from each zone shows that the B Zone has been relatively slightly undersampled and the D Zone slightly over sampled.

TABLE 9

NO. 1 DEPOSIT - FEET CORED BY ZONE AND ASH CATEGORY [1]

Coal Zone	Total Feet	Total %	Unsampled[2] Feet	Unsampled[2] %	>55% Ash[3] Feet	>55% Ash[3] %	<55% Ash[3] Feet	<55% Ash[3] %	% of Reserves[4]
A	15710	27.8	1760	39.1	3820	44.8	10140	23.3	24.0
B	5020	8.8	20	0.4	360	4.2	4640	10.6	14.8
C	13300	23.5	2710	60.3	3910	45.9	6680	15.3	15.4
D	22580	39.9	10	0.2	430	5.1	22140	50.8	45.8
TOTAL	56610	100	4500	100	8520	100	43600	100	100

Notes: (1) The following fringe-area drill holes are not included in the table: 29, 32, 40, 42, 45, 47, 48, 52, 125, 140, 186 and 814.

(2) Includes the footages intersected in the thick A-B and B-C rock beds. The longest such continuous, unsampled section included in the table is 292 feet in hole No. 179, C Zone.

(3) Dry basis.

(4) Proven and Probable, all elevations.

TABLE 10

NO. 1 DEPOSIT - PERCENTAGE OF CORE BY ZONE AND ASH CATEGORY

	ZONE A %	ZONE B %	ZONE C %	ZONE D %	TOTAL %
Unsampled	11.2	0.4	20.4	0.04	8.0
55% Ash	24.3	7.2	29.4	1.91	15.0
55% Ash	64.5	92.4	50.2	98.05	77.0
	100	100	100	100	100

Table 10 shows the approximate percentages of material which might be wasted by selective mining in each zone. The percentage varies from about two percent for the D Zone to 50 percent for the C Zone and averages 23 percent for all zones in the entire No. 1 Deposit. Similar figures have not been prepared for that portion of the deposit lying above the 2400-foot elevation.

The choice of the 55 percent dry ash cut-off is somewhat arbitrary but appears reasonable for selective mining based on studies carried out to date and assuming a coal washing plant is not installed. The final figure will depend on the results of detailed economic studies and will probably be based on a calorific value rather than an ash value cut-off. The Btu value equivalent to 55 percent ash is about 4700 (dry basis).

Table 6 shows total Proven and Probable reserves of 645.73 million tons for the No. 1 Deposit. Table 9 shows that this material was sampled by 43,600 feet of core. An estimated 2150 samples were taken from that core. Therefore, for the material which falls in the general classification of less than 55 percent ash, the following are derived:

Tons reserves per foot sampled:	15,000
Tons reserves per sample:	300,000

A figure of one sample per million tons of thermal coal is sometimes suggested as being adequate to define the quality. The present density of sampling is three times as high but is justified on the basis of the more heterogeneous than average character of the coal at Hat Creek.

The cost for all aspects (including analyses) of all exploration and development work completed to date on the No. 1 Deposit is less than one cent per ton of Proven and Probable reserves.

As discussed under Reserves, a single factor for dilution can not be realistically applied to the entire No. 1 Deposit. Many factors related to mining and geology must be considered. The 1974-75 samples include more dilution than the 1976 samples because waste beds up to five to seven feet in thickness were commonly included in the adjacent coal sample.

Limitations on Summarized Analytical Data

In the following sections, certain analytical data are presented in summary form. The summaries are subject to limitations which must be appreciated when appraising the validity of the results. These are discussed below.

Statistical summaries by drill hole of the 1957-59 and 1974-75 proximate analysis data for the No. 1 Deposit were prepared in 1975. Dr. Sinclair summarized by zone all the data for special holes 76-135 and 136. Integ-Ebasco summarized the early data and a small portion of the 1976 data. The most important point is then, that zone summaries have not been prepared for the majority of the 1976 samples. Mean values given in this report are based, therefore, on only a portion of the total data now available. No summaries have been prepared for samples from the east-bench area which was discovered in 1976. Coal assigned to the C Zone there is of better quality than C Zone coal in the main part of the deposit. A possible up-grading of C Zone mean values can be expected when the east-bench samples are included.

When considering mean values and dispersions, much weight is placed on the stratigraphic concept of four coal zones. Differences between zones are assumed to be projectable over considerable distances and elevations. Although this assumption is valid for the central part of the deposit for most coal attributes, it remains to be proven for the entire deposit.

The conventional method of calculating geological reserves is to assign quality values to each reserve block and then determine the mean quality by a weighted summing of all blocks. This has not been possible yet for the Hat Creek deposits. Information on mean quality is based on statistical summaries. The preliminary use of a 55 percent (dry) ash cut-off to determine mean quality for the "mineable" coal is also a statistical approach. Even if the 55 percent figure became accepted, it would not always be possible to selectively mine to the statiscally selected boundaries.

Despite the above discussed limitations on the possible accuracy of the analytical data, it is concluded that presently known mean values and dispersions will not be changed greatly when available data have been fully assessed.

Definitions

Some of the terms defined below are given a unique meaning in this report. Others are subject to confusion because of varying usage in the literature.

Waste: All unanalysed material plus material represented by high ash samples.

High ash sample: Analysed sample, generally for ash and moisture only, containing more than about 75 percent ash, dry basis.

High ash coal, (coaly shale): Material falling in the general range of 55 to 75 percent ash, dry.

Coal: Material containing less than about 55 percent ash, dry, (44 percent ash at 20 percent moisture).

Clean coal: D Zone-type coal containing few partings and usually containing less than about 30 percent ash, dry.

Pure coal substance: Mineral matter free coal; for several of the coal attributes, their values to be determined by regression rather than by usage of standard formulae.

In situ moisture, (bed moisture): Existing (pre-excavation) moisture condition of the coal; includes pore moisture, surface moisture on fractures, etc., but not chemically bonded moisture.

Run-of-mine (ROM) moisture: Moisture condition of the coal as loaded; may be lower than in situ moisture because of draining from the excavation face (or higher during periods of inclement weather).

Plant feed moisture: Moisture condition of coal as delivered to the plant; may be lower than ROM moisture because of further draining and drying (or higher because of inclement weather or benefication of coal by washing).

As received moisture (total moisture): Moisture condition of a sample as received at the laboratory. Does not include bonded moisture which reports with the volatile matter.

Residual moisture, (air dry moisture, inherent moisture): Moisture condition after drying of the sample in the laboratory at air temperature or in a low-temperature oven.

Surface moisture, (free moisture): Moisture on bedding planes, fractures, etc.

Bonded moisture: Moisture chemically bonded, principally in clay minerals, and not released at a temperature of 105°C. During analyses, it reports with the volatile matter fraction of the coal and is rarely measured directly.

Equilibrium moisture, (capacity moisture): Moisture condition of a sample when all the pores in the coal are filled and no surface moisture is present. Test results questionable for samples containing a large percentage of ash unless they are run on a lower specific gravity, float fraction.

Combustible volatile matter: As the name implies.

Incombustible volatile matter: Comprised principally of bonded moisture and CO_2 from dissociated carbonates; forms part of the total volatile matter reported on laboratory data sheets.

Mineral matter: All incombustible matter in the coal; greater than the ash content of a sample because of weight losses due to loss of bonded water from clay minerals, CO_2 from carbonates, and sulphur from pyrite during the ashing process.

MOISTURE

In situ moisture and bulk density are perhaps the two most difficult parameters to establish accurately for coal deposits. The majority of the samples obtained during exploration are disturbed physically and by drilling fluids prior to recovery. Also, the history of the samples after recovery and before analysis is important. Knowing the in situ moisture content precisely is not necessarily important; the ROM moisture and the plant-feed moisture are the important figures. But knowing the in situ moisture content reasonably well gives greater confidence to estimates of the other two moistures.

In situ moisture varies with rank of coal, amount and type of mineral matter, fracture density, and position relative to the water table. For heterogeneous coal as at Hat Creek, variations will be large. Clean coal of the rank of the Hat Creek coal, and not highly fractured, would be expected to have an in situ moisture content of 25 to 30 percent. As the mineral matter content increases, the in situ moisture content normally decreases to a low of about 10 percent for pure rock. (This does not take into consideration that Hat Creek coals have a relatively high bonded moisture which increases with increasing mineral matter content.)

Although it may be ideal for calculations of ash content, calorific value, etc. to assign specific moisture values to each sample, this is not possible because of lack of information. The as received moisture values are not always dependable because of varying sample history. An alternative is to assign estimated mean moisture contents for, say, the in situ, ROM, and plant-feed conditions. This is the approach which has been adopted to date for Hat Creek data.

Presently summarized moisture data are listed in Table II. Trenches A and B listed on the table refer to two trenches presently being excavated to obtain bulk samples for burn tests. (DDH = diamond drill hole; AH = auger hole). The coal in Trench A is above the water table. It lies below a burnt coal zone and is partially oxidized. The coal in Trench B is below the water table and is low-ash (D Zone) and unoxidized.

TABLE II

Moist. Type	Data Source	No. of Samp.	Moisture - % Mean	Minimum	Maximum	Std. Dev.
As Rec'd	1957-59	134	19.1	7.4	41.5	4.6
As Rec'd	1974-75	409	20.4	1.5	30.6	4.3
As Rec'd	Integ-Ebasco	415	21.6	3.5	36.0	3.8
As Rec'd	76-135, 136	309	21.6	8.4	30.0	3.6
As Rec'd	Trench A, DDH's	61	31.0	19.0	50.4	
As Rec'd	Trench A, AH's	80	29.2	18.0	39.7	
As Rec'd	Trench B, DDH's	13	27.6	18.3*	32.8	
Equilib.	1957-59	22	24.4	20.9	28.0	
Equilib.	1974-75	49	22.9	16.8	35.5	
Equilib.	Integ-Ebasco	26	25.4	21.6	27.0	
Equilib.	Trench A, DDH's	49	26.0	12.6	38.6	
Equilib.	Trench B, DDH's	13	24.1	18.5*	25.8	

* Sample contains 18% CO_2.

The high, as received moisture values for Trenches A and B may result from winter drilling conditions (less drying of samples) and, for Trench A, from a greater moisture capacity caused by the effects of the burning of the formerly superimposed coal. If it were not for the latter possibility, the results for the auger hole samples would be considered to be the most dependable to date for in situ moisture; water was not used during the drilling and the samples were bagged immediately on recovery.

The data in Table II do not refute the possibility that the overall mean in situ moisture content of the No. 1 Deposit may approach 30 percent. This would allow for up to an average of about five percent surface moisture (on fractures, etc.) plus an average of 25 percent equilibrium (pore) moisture. Most calculations to date on Hat Creek samples have been based on a preliminary, estimated average 20 percent moisture. This value was selected as a compromise between possibly somewhat higher ROM moistures and lower plant-feed moistures, assuming that significant draining and drying would occur under the favourable Hat Creek climatic conditions.

Although the figure of 20 percent still appears reasonable as a compromise moisture value, the following conclusions are drawn:

1. For calculations on the sizing of mining equipment, moisture values of both 20 and 25 percent should be used.

2. Tests should be run on the coal stockpiles presently being built to determine to what extent draining and drying does occur. If the amount is small for the small stockpiles, then higher than 20 percent moisture values will have to be considered for thermal plant design.

3. If the data as they accumulate support it, computer outputs should be based on one moisture basis for mine design purposes and on another moisture basis for plant design purposes.

4. Every opportunity should be taken to obtain reliable in situ moisture data.

RANK

In North America, the rank of a subbituminous coal is based on the calorific value of moist (equilibrium), mineral-matter-free coal (ASTM, Parr formula). Hat Creek samples ranked in this manner vary between low grade lignite and high grade subbituminous C; the higher the ash content, the lower the rank.

If, alternatively, the same philosophy is applied, but the slope of the ash-calorific value regression line for Hat Creek (Figs. 11 to 15) is used, the sample rankings fall in a narrow band, partly high subbituminous C and principally low subbituminous B. Only a small percentage of the samples, particularly those with a high carbonate content, fall outside this range.

The latter method of ranking is considered to be more meaningful for Hat Creek.

Cumulative probability plots of calorific values show two or more distributions. These are believed to represent relatively minor variations for which there could be a variety of explanations. The evidence does not suggest the presence of two or more fundamentally different ranks of coal in the No. 1 Deposit.

PROXIMATE AND CALORIFIC VALUES

For thermal plant design, the dispersion (variability) of coal attributes is of extreme importance. For special drill holes 76-135 and 136,

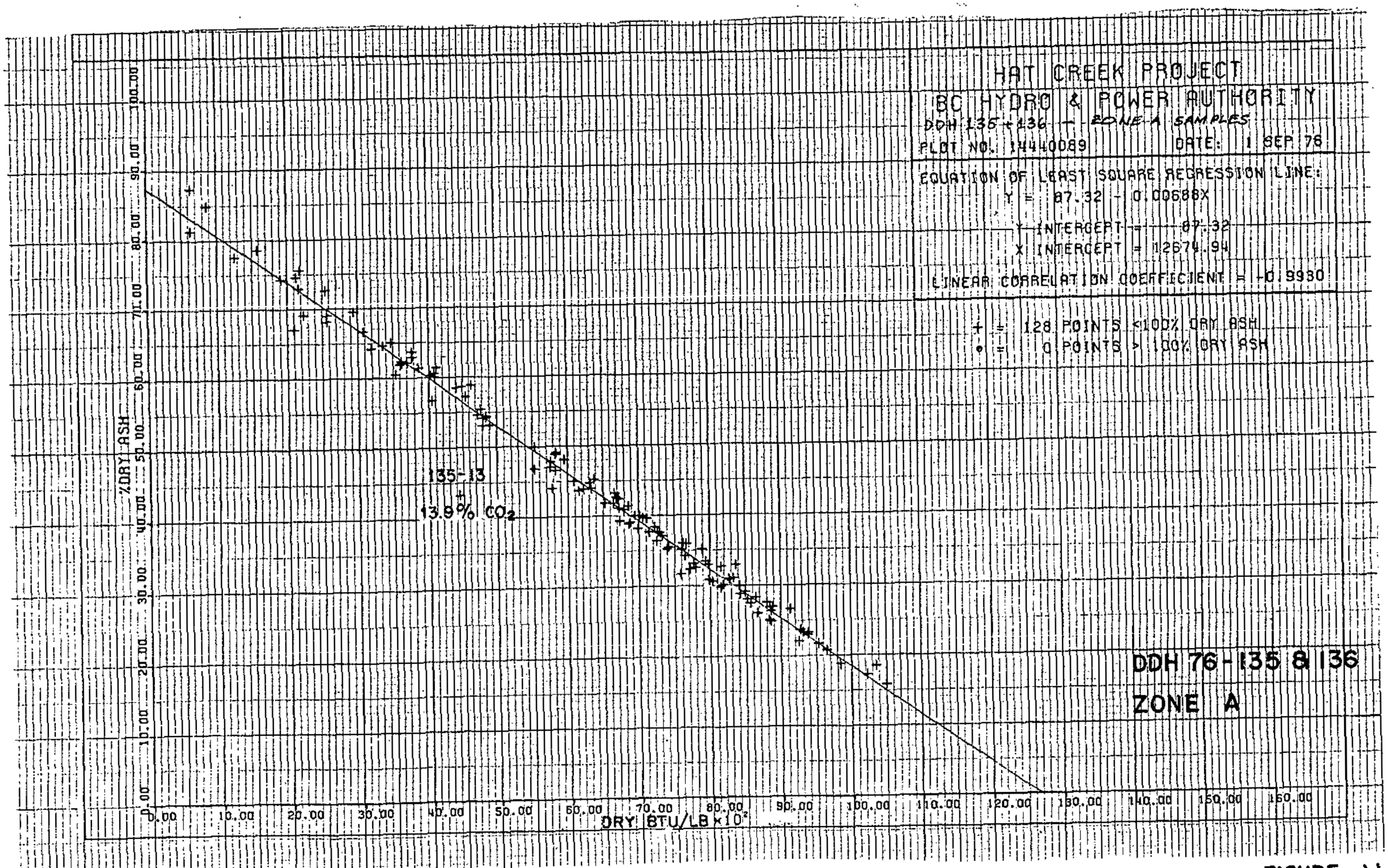

HAT CREEK PROJECT
BC HYDRO & POWER AUTHORITY
DDH 135 + 136 — ZONE A SAMPLES
PLOT NO. 14440089 DATE: 1 SEP 76
EQUATION OF LEAST SQUARE REGRESSION LINE:
Y = 87.32 - 0.00688X
Y INTERCEPT = 87.32
X INTERCEPT = 12674.94
LINEAR CORRELATION COEFFICIENT = -0.9930
+ = 128 POINTS <100% DRY ASH
• = 0 POINTS > 100% DRY ASH
135-13
13.9% CO2
DDH 76-135 & 136
ZONE A
%DRY ASH
DRY BTU/LB ×10²

FIGURE 11

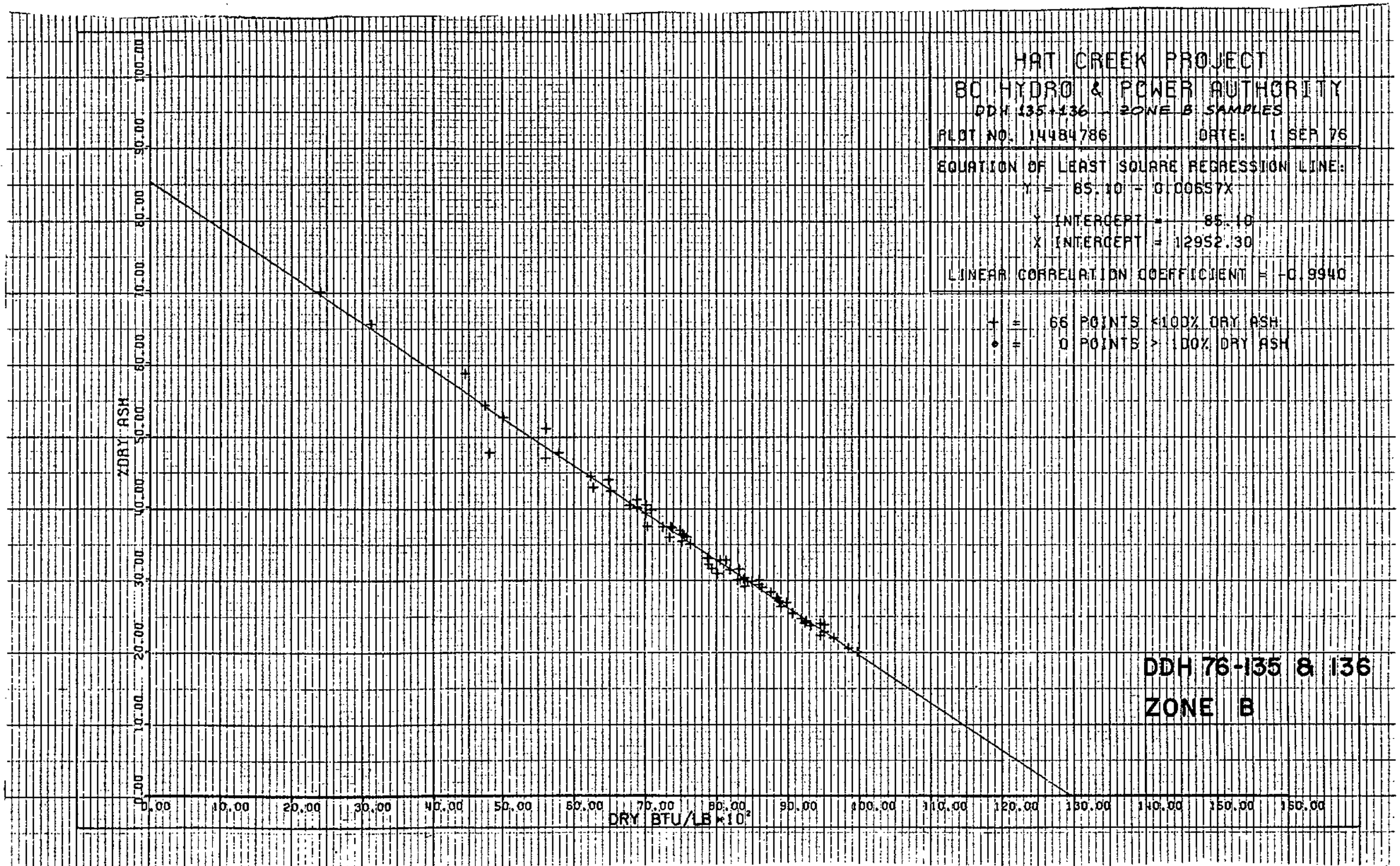

HAT CREEK PROJECT
BC HYDRO & POWER AUTHORITY
DDH 135+136 - ZONE B SAMPLES
PLOT NO. 14484786 DATE: 1 SEP 76
EQUATION OF LEAST SQUARE REGRESSION LINE:
Y = 85.10 - 0.00657X
Y INTERCEPT = 85.10
X INTERCEPT = 12952.30
LINEAR CORRELATION COEFFICIENT = -0.9940
+ = 66 POINTS <100% DRY ASH
• = 0 POINTS > 100% DRY ASH
DDH 76-135 & 136
ZONE B
%DRY ASH
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
DRY BTU/LB ×10²
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
130.00
140.00
150.00
160.00

FIGURE 12

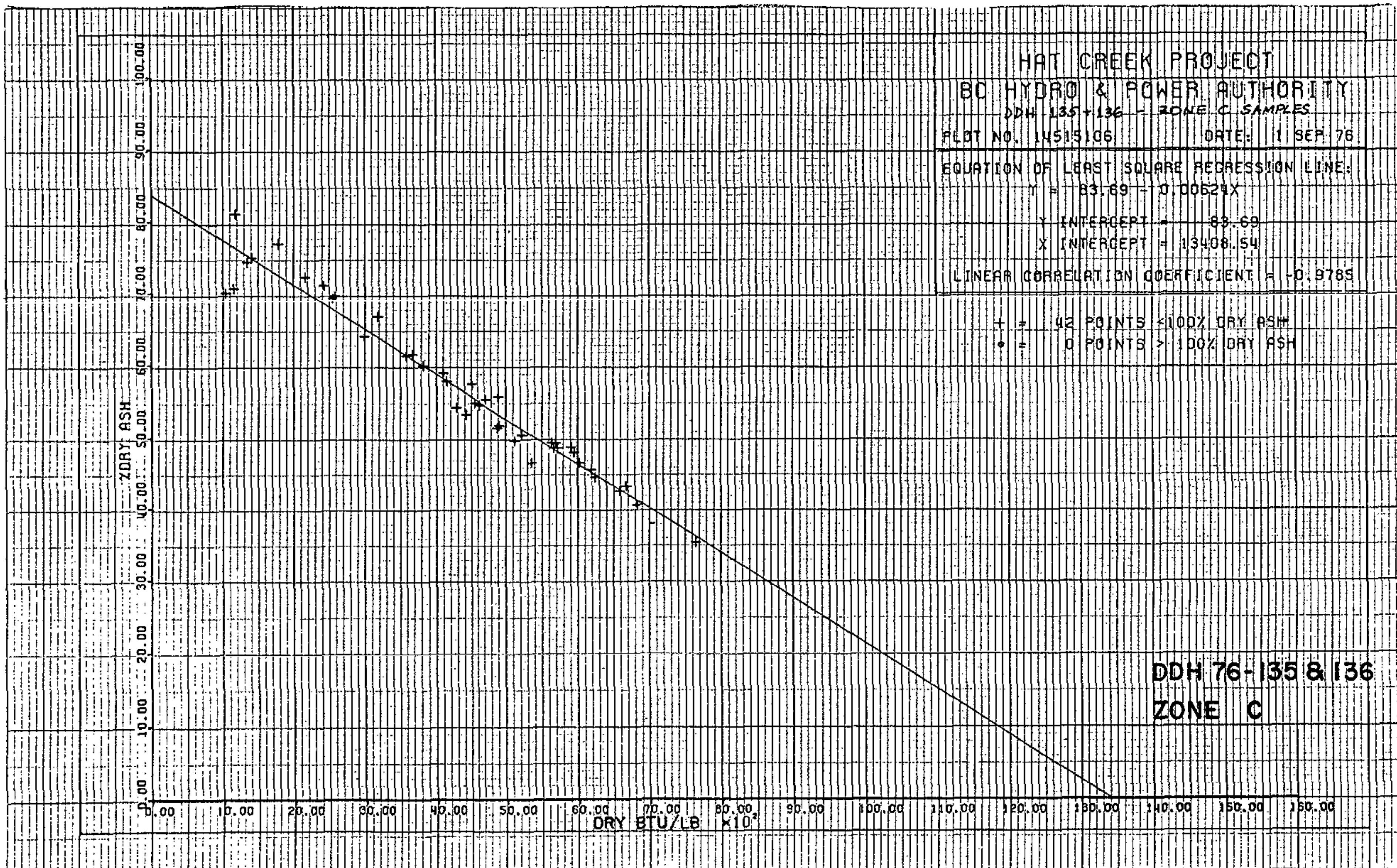

HAT CREEK PROJECT
BC HYDRO & POWER AUTHORITY
DDH 135+136 - ZONE C SAMPLES
PLOT NO. 14515106 DATE: 1 SEP 76
EQUATION OF LEAST SQUARE REGRESSION LINE:
Y = 83.69 - 0.00624X
Y INTERCEPT = 83.69
X INTERCEPT = 13408.54
LINEAR CORRELATION COEFFICIENT = -0.9785
+ = 42 POINTS <100% DRY ASH
• = 0 POINTS > 100% DRY ASH
%DRY ASH
DRY BTU/LB ×10²
DDH 76-135 & 136
ZONE C

FIGURE 13

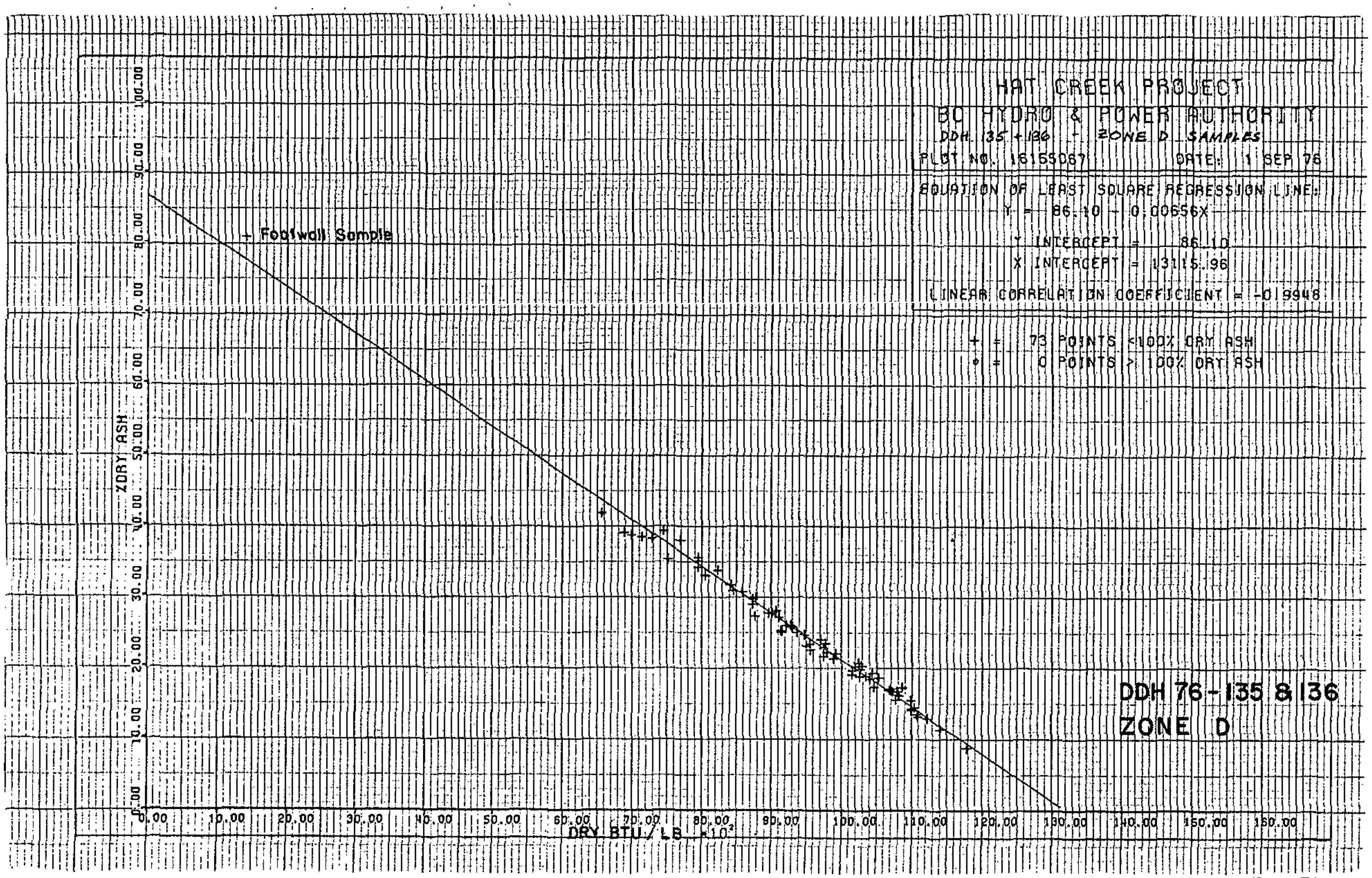
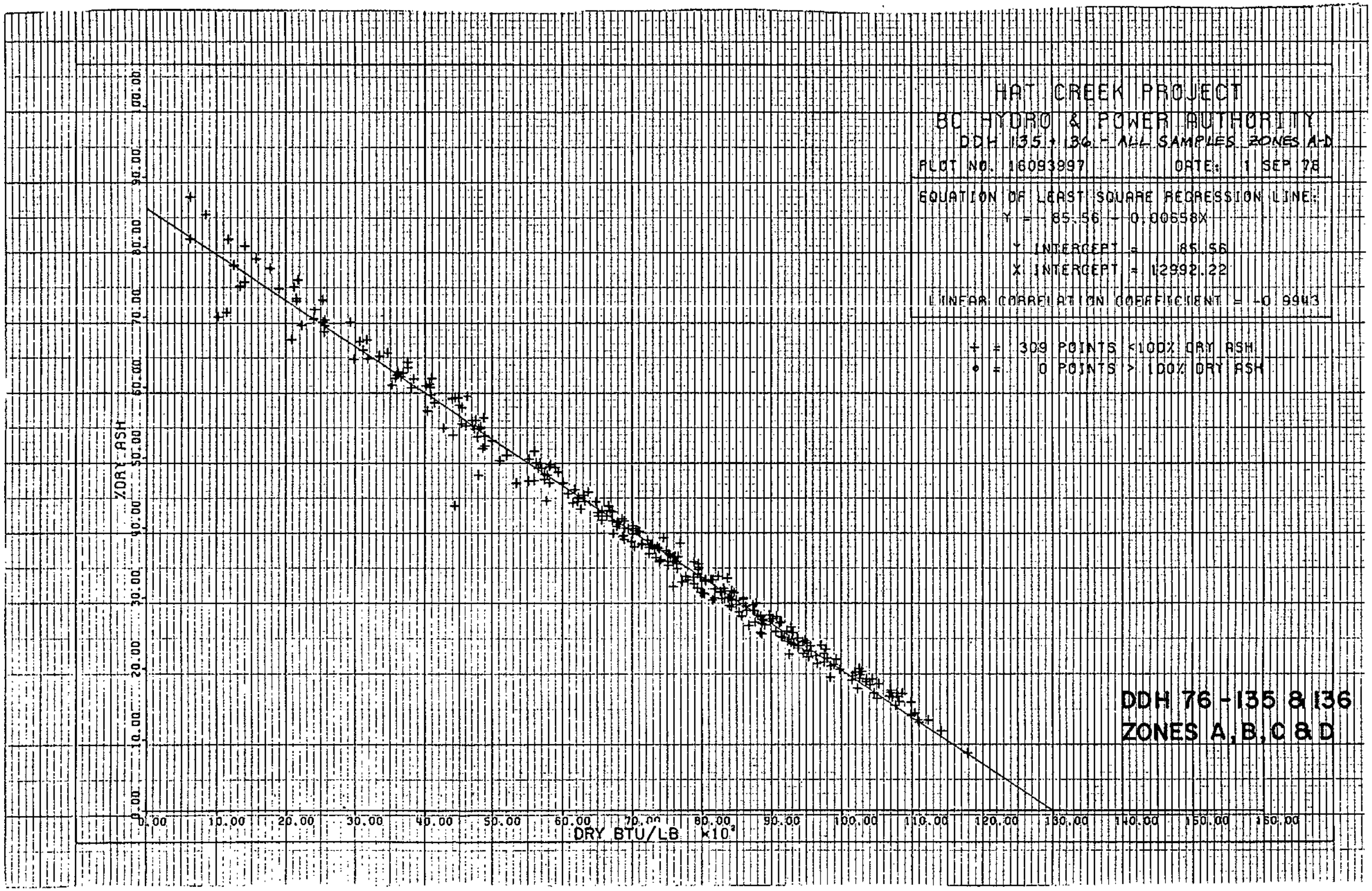

HAT CREEK PROJECT
BC HYDRO & POWER AUTHORITY
DDH 135 + 136 - ZONE D SAMPLES
PLOT NO. 16155067
DATE: 1 SEP 76
EQUATION OF LEAST SQUARE REGRESSION LINE:
Y = 86.10 - 0.00656X
Y INTERCEPT = 86.10
X INTERCEPT = 13115.96
LINEAR CORRELATION COEFFICIENT = -0.9948
+ = 73 POINTS <100% DRY ASH
◊ = 0 POINTS > 100% DRY ASH
+ Footwall Sample
%DRY ASH
DRY BTU / LB x10²
DDH 76-135 & 136
ZONE D

FIGURE 14



HAT CREEK PROJECT
BC HYDRO & POWER AUTHORITY
DDH 135 + 136 - ALL SAMPLES ZONES A-D
PLOT NO. 16093997 DATE: 1 SEP 78
EQUATION OF LEAST SQUARE REGRESSION LINE:
Y = 85.56 - 0.00658X
Y INTERCEPT = 85.56
X INTERCEPT = 12992.22
LINEAR CORRELATION COEFFICIENT = -0.9943
+ = 309 POINTS <100% DRY ASH
• = 0 POINTS > 100% DRY ASH
%DRY ASH
DRY BTU/LB x10²
DDH 76 - 135 & 136
ZONES A, B, C & D

FIGURE 15

which were drilled in the central part of the No. 1 Deposit and which sampled completely all four coal zones, Dr. Sinclair's comprehensive report of March 1977 provides a detailed evaluation of dispersions. No attempt is made here to summarize his voluminous data. Instead, the summary from his report is included in Appendix IV with tables showing means and standard deviations by coal zone for each of the coal attributes. High ash coal is included in the means. The statistical evaluation of dispersion should now be extended to include all the 1976 analytical data.

Figure 16 presents most of the available data concerning drill hole 76-135 in graphic form and thus permits a visual assessment of variabilities. Figures 11 to 15 inclusive, show, for drill holes 76-135 and 136, ash-calorific value regressions for the four coal zones separately and for all zones combined. Table 12 is a summary of proximate analysis data at 20 and 25 percent moisture, respectively. The mean values, if calculated to the dry basis, are higher than Dr. Sinclair's because he did not exclude high ash coal from his statistical evaluation.

The mean quality of the coal as shown in Table 12 is slightly better than previously reported. This results entirely from the increased percentage of D Zone coal now calculated to be present above the 2400-foot elevation.

The volatile matter shown in Table 12 includes incombustible volatile matter from bonded moisture in clay minerals and from CO_2 in carbonates. For a large group of samples, the mean incombustible volatile matter is equal to approximately 17 percent of the mean ash content. The approximate mean percentage of combustible volatile matter can then be determined by subtraction. The calculation is applicable under dry or standard moisture conditions. If applied to an individual sample, the error will be large if the mineralogy of the sample is abnormal.

Coal in Trench A, which is being excavated for a burn test sample from below a burnt coal zone, is oxidized to a depth of 30-35 feet. The most strongly oxidized coal shows a decrease in calorific value of up to 2000 Btu/lb.

Coal now overlain by unconsolidated overburden may have been at one time exposed to the elements and subject to oxidation. To assess this, all drill hole samples collected from immediately below overburden were tested for unexpectedly low calorific values. Seven out of 40 samples (17%) showed possible Btu loss in excess of five percent with the highest apparent loss being 33 percent. Before much significance can be attached to these numbers, the percentage of all samples not directly overlain by overburden but having unexpectedly low calorific values will have to be determined.

TABLE 12

MEAN PROXIMATE, CALORIFIC AND SULPHUR VALUES

DDH 76-135 and 136

Coal Zone	% of Reserves(1)	Moist. %	Ash %	Vol. Mat. %	F.C. %	C.V. Btu/lb	Tot. S %
A	29.4	20.0	28.9	25.7	25.3	5900	0.58
B	9.1	20.0	26.6	25.6	27.8	6300	0.66
C	18.2	20.0	38.4	22.4	19.2	4500	0.35
D	43.3	20.0	19.0	27.4	33.6	7580	0.22
Mean(2)	100.0	20.0	26.1	25.8	28.0	6410	0.39
A	29.4	25.0	27.2	24.1	23.7	5530	0.54
B	9.1	25.0	24.9	24.0	26.1	5910	0.62
C	18.2	25.0	36.0	21.0	18.0	4220	0.33
D	43.3	25.0	17.8	25.7	31.5	7110	0.21
Mean(2)	100.0	25.0	24.5	24.2	26.2	6010	0.37

Notes: (1) Proven and Probable containing less than 55% ash (44% at 20% moisture or 41.25% at 25% moisture) above the 2400-foot elevation.

(2) Weighted by % of reserves.

SULPHUR

Table 12 presents mean total sulphur values for the four coal zones. The calculated mean for the combined zones, 0.39 percent at 20 percent moisture, appears to present no problems. However, about 15 percent of the values exceed 0.8 percent sulphur. If these high sulphur values are randomly distributed, special stockpile or plant procedures will have to be developed to avoid excess discharge in the plume. If the high sulphur values are confined generally to particular coal beds, as is more likely, then selective mining or blending should provide the required control. The uppermost bed in the A Zone is one bed which commonly appears to be enriched in sulphur.

The average percentage distribution of sulphur forms is as follows: Organic - 72; Pyritic - 25; Sulphate - 3. High total sulphur is almost always reflected in a higher percentage of pyritic sulphur. This can be seen on Figure 16.

Figures 17 to 20 show that for all zones there is a slight increase in sulphur values with increase in calorific values.

CARBON DIOXIDE

Siderite and to a lesser extent calcite are common in Hat Creek coal samples. Ankerite is present but rare. The carbonates contribute CO_2 to the volatile matter while at the same time decrease the apparent inorganic matter (ash) content. They also result in values being recorded for ultimate carbon and oxygen that are too high. Zone C contains almost twice as much CO_2 as the other zones. About 80 percent of all samples contain less than two percent CO_2 at 20 percent moisture. Values as high as 30 to 40 percent have been recorded.

The presence of CO_2 affects the ash-calorific value regression line by tending to lower it and flatten the slope. As an example, on Figure 11 one sample containing 13.9 percent CO_2 is plotted well below the regression line. If the CO_2 and ash are combined for plotting, the point moves up to the regression line.

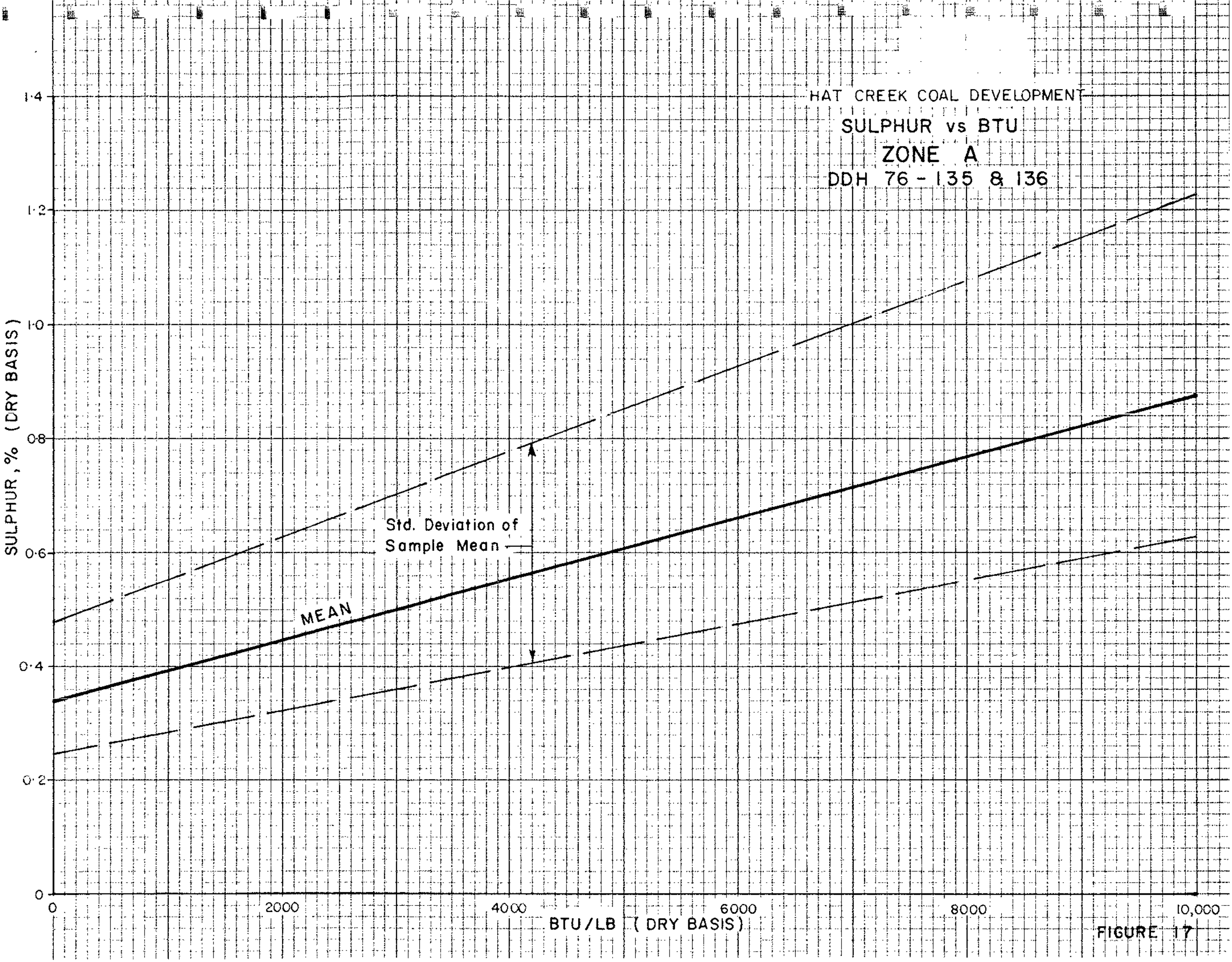
ULTIMATE VALUES

Ultimate analyses were performed on a small number of composite samples prepared from No. 1 Deposit, 1974-75 samples. Since statistical analyses of the large number of 1976 samples will be available shortly, the 1974-75 ultimate analysis data are not summarized here.

In 1976, ultimate analyses included the direct measurement of oxygen in samples from drill holes 76-135 and 136. The mean measured values are one to two percent higher than the values determined conventionally by difference. The discrepancy may be explained partially by incomplete carbonate dissociation during ash analyses, resulting in too high an ash value and too low an oxygen by difference value.

The high bonded moisture content of Hat Creek coals results in higher than normal H_2 and O_2 values. Also, CO_2 in the coals results in higher O_2 and carbon values.

The high bonded moisture content increases the spread between high and low heat values.



HAT CREEK COAL DEVELOPMENT
SULPHUR vs BTU
ZONE A
DDH 76 - 135 & 136
SULPHUR, % (DRY BASIS)
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
Std. Deviation of
Sample Mean
MEAN
0
2000
4000
6000
8000
10,000
BTU/LB (DRY BASIS)

FIGURE 17

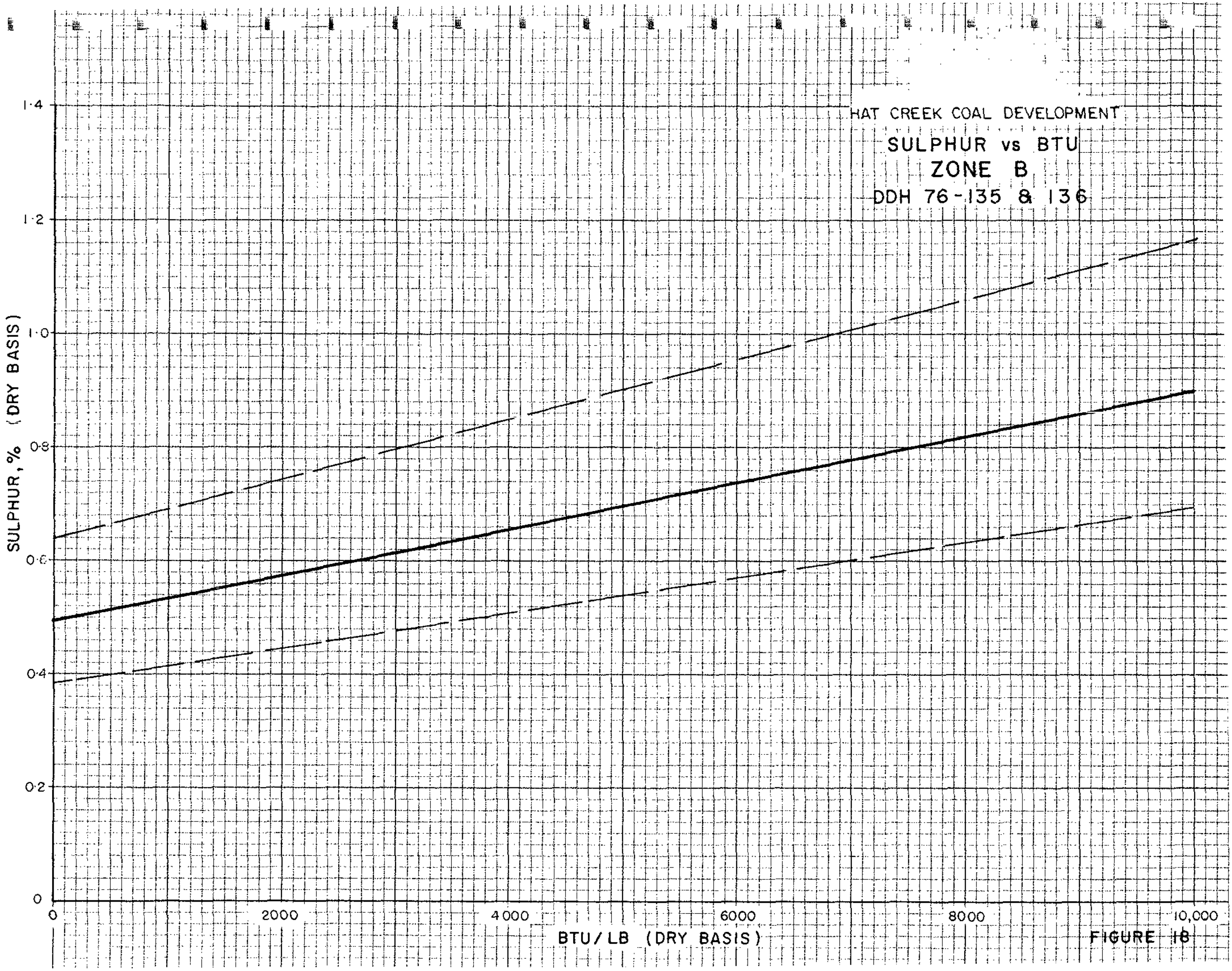
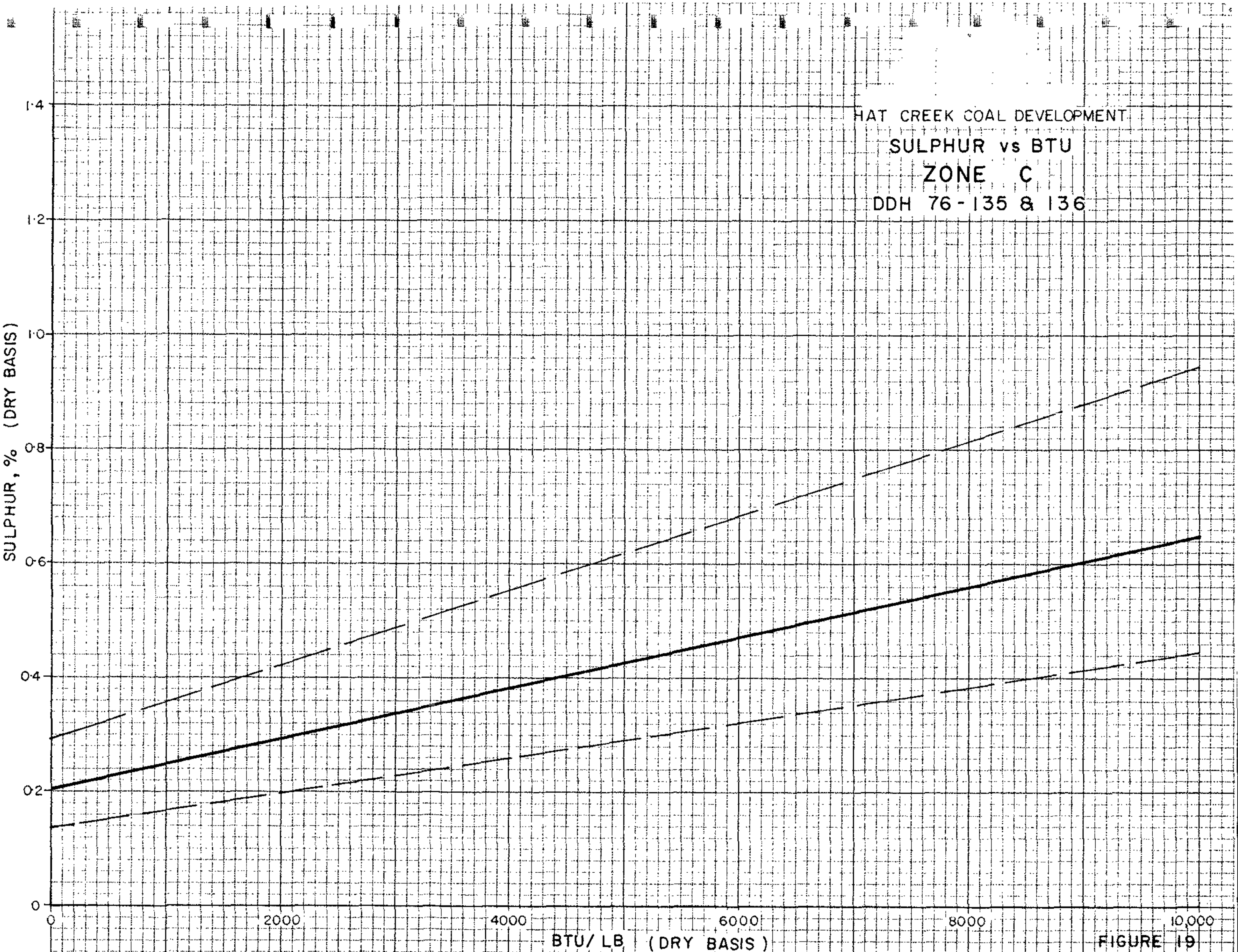
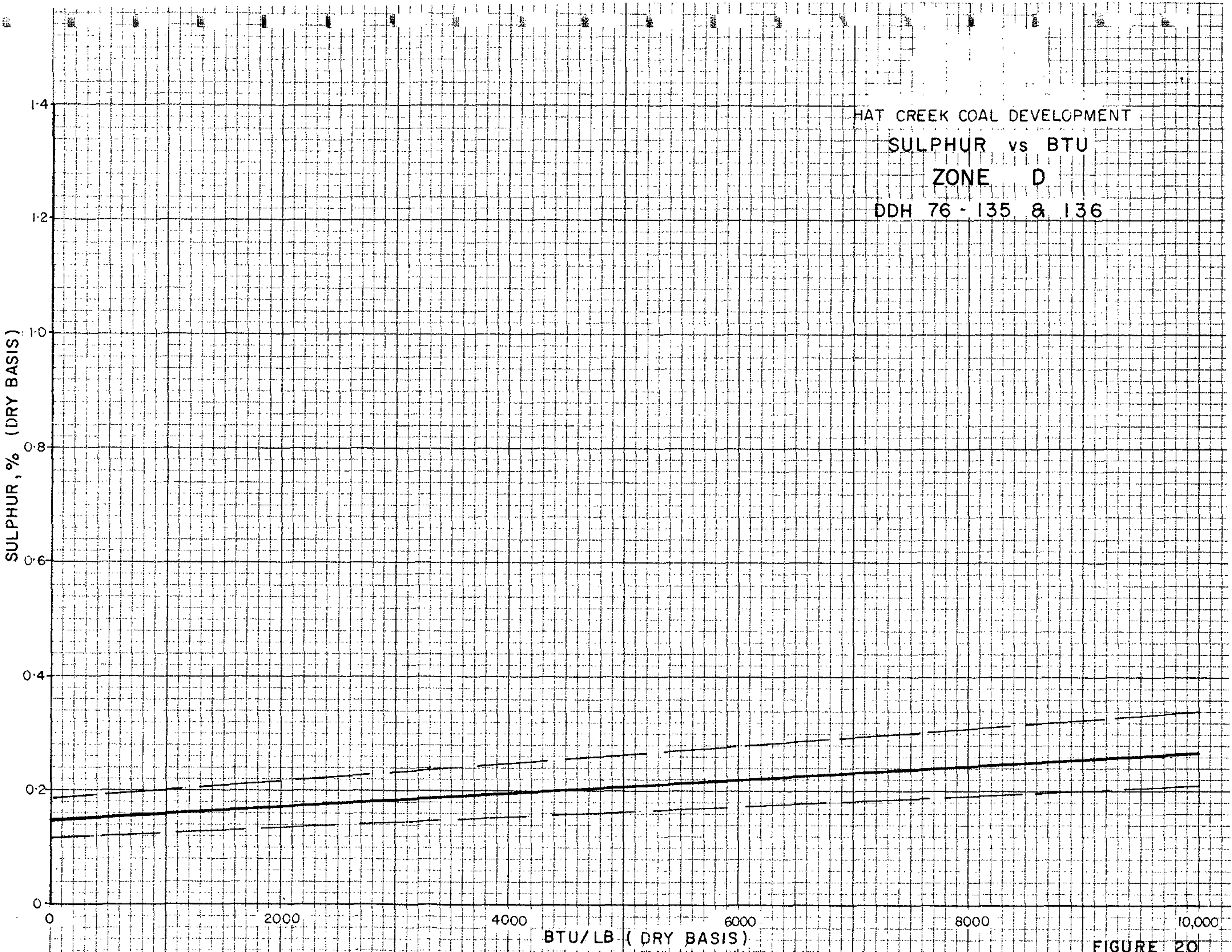

HAT CREEK COAL DEVELOPMENT
SULPHUR vs BTU
ZONE B
DDH 76-135 & 136
SULPHUR, % (DRY BASIS)
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
0
2000
4000
6000
8000
10,000
BTU/LB (DRY BASIS)

FIGURE 18



HAT CREEK COAL DEVELOPMENT
SULPHUR vs BTU
ZONE C
DDH 76-135 & 136
SULPHUR, % (DRY BASIS)
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
0
2000
4000
6000
8000
10,000
BTU/ LB (DRY BASIS)

FIGURE 19


HAT CREEK COAL DEVELOPMENT
SULPHUR vs BTU
ZONE D
DDH 76 - 135 & 136
SULPHUR, % (DRY BASIS)
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0
2000
4000
6000
8000
10,000
BTU/LB (DRY BASIS)
FIGURE 20

ASH ANALYSIS

In addition to the 10 standard elements specified in ASTM procedures, vanadium and manganese were analysed in the 1976 Hat Creek samples. Means and standard deviations for the elements are given in the excerpts from Dr. Sinclair's report, Appendix IV. Figure 16 displays graphically the variations in concentration of each element.

Percentages of elements listed below are based on their concentrations in drill holes 76-135 and 136.

Because of the high proportion of clay in the mineral matter, the percentage of Al_2O_3 in Hat Creek coal ash is high - about 30 percent for the combined zones. The mol ratio of SiO_2 to Al_2O_3 shows interesting trends. In the D Zone it is about two, which corresponds to the ratio in kaolinite; X ray analyses show a high percentage of kaolinite to be present in the D Zone. In the other zones, the ratio is three to four which corresponds to montmorillonite or mixtures of kaolinite and quartz with or without montmorillonite.

The variable percentages of Fe_2O_3, CaO and MgO result largely from variations in carbonate content.

The Na_2O and K_2O percentages in the ash average 0.75 and 0.59 for the combined coal zones. However, the percentages and the ratios of the two elements within zones vary significantly.

FUSION TEMPERATURES OF ASH

The lowest recorded ash fusion temperatures are about 2000°C and 2100°C for initial deformation, reducing and oxidizing, respectively. At the high end, they exceed 2700°C, the highest temperature used in any of the laboratories. Variations in I.D. temperatures are presumably related to variations in mineralogy. A number of anomalous results, for which there are still not good explanations, have been recorded.

Figure 16 shows that there is a strong correlation, although not perfect, between ash fusion temperature and base mol percent. An apparent similar correlation between temperature and SO_3 concentration is probably a secondary correlation; higher base mol percent is partly the result of increased CaO which forms complexes in the ash with sulphur.

A preliminary multi-regression analysis of initial deformation reducing temperatures with the ash elements shows significant correlations for the B, C and

D zones. The regression was performed on only the samples from drill holes 75-135 and 136 and should be extended to include all samples and various element molecular ratios.

HARDGROVE GRINDABILITY INDICES

The limited number of grindability tests carried out give a mean index of about 45. With decreasing ash content the index decreases, indicating that, in general, the purer the coal the greater the energy required to pulverize it.

Abrasiveness tests have not been conducted.

PLANT FEED

As stated in several of the previous sections, until such time as the bulk of the analytical data collected in 1976 is computer-processed in a comprehensive manner, it is difficult to establish high-confidence means and dispersions for all the coal attributes. The figures presented in this report are based primarily on data from 1974-75 and from drill holes 76-135 and 136. It is expected that the final results, particularly for proximate, calorific and sulphur values, will differ significantly from those presented here only as a consequence of changing one or more of the main parameters or conditions used. The parameters are neither recommendations nor expected practices; they simply define the calculation procedures used in this report. The principal ones are listed below:

1. Ash cut-off of approximately 55 percent, dry basis (44 percent at 20 percent moisture).

2. Dilution not included (i.e. it is possible to selectively mine to a statistically established cut-off, an unlikely probability).

3. The relative percentages of coal in each zone remain much the same. (In this report, values were weighted on the basis of the relative percentages of Proven and Probable reserves above the 2400-foot elevation).

4. Some draining and drying of the coal will occur prior to it reaching the plant.

5. The ash and moisture regimes are those extant for coal not washed or beneficiated by other means.

It is obvious that in depth economic studies are required in order to establish the final parameters.

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1000 GUINNESS TOWER
VANCOUVER 1, B.C.

CONCLUSIONS

GEOLOGY

The general configuration and character of the No. 1 Coal Deposit in Upper Hat Creek Valley has been defined by the exploration drilling completed to date. However, in detail some areas have not been well defined due to combinations of data density, structural complexity and shale outs. Areas in which correlation, interpretation and reserve calculations can be done with reasonable confidence are the north, northwest and central portions of the main synclinal deposit and the western portion of the east bench. Areas of low confidence in these aspects are the southwestern and southern portions of the main deposit, the northeastern part of the east bench, and the east area (east of fault No. 8). Below approximately the 2000-foot elevation, confidence in configuration and interpretation decrease rapidly with depth. Drilling on 500-foot centres, with some supplementary holes in structurally complex areas, provides a density of data with which correlation, interpretation and reserve calculations can be done with a confidence level considered adequate for conceptual mine design.

Further exploration is required in the east area. Any appreciable tonnage occurring above 2000-foot elevation should be located and defined.

Completion of the exploration specified in the RECOMMENDATIONS should result in geological knowledge of most areas of the deposit (above 2400-foot elevation) being brought to relatively equivalent and acceptable confidence levels. Some local areas, such as fault intersections, may not be understood with equal confidence, but these areas can be identified and, if critical with regard to mine planning and operation, further, more detailed drilling can be undertaken to bring them to an acceptable level of understanding.

No practical drill hole spacing would provide complete information on geological details. To accommodate the smaller unknown structures, a "design-as-you-mine" approach will be required.

QUALITY

The No. 1 Deposit is highly variable in quality as a result of variations in amount, distribution and composition of the inorganic contaminants. By comparison, the organic portion is much more homogeneous. Despite the variability, the deposit is a major fossil fuel resource which can be economically exploited.

The concept of subdividing the No. 1 Deposit into four coal zones is a valid approach which will assist in the understanding of the variabilities within the deposit and in the systematic exploitation of it.

The present large volume of analytical data, when computer-processed, is expected to provide sufficient information on coal attribute means and variabilities to permit conceptual design of a thermal plant. Major additional analyses are those which may be required to provide the level of detail necessary for conceptual design of a mine.

For considerations of conceptual plant design, an estimated mean moisture of 20 percent still appears to be acceptable but every opportunity to obtain more concrete data should be pursued. For considerations of conceptual mine design, the consequences of using both 20 and 25 percent moisture should be investigated.

Because the deposit is so heterogeneous, accurate analyses can be obtained only if laboratory sample preparation is carried out with extreme care.

RECOMMENDATIONS

The recommendations listed below are directed principally towards the further exploration and development and the coal quality aspects of the Hat Creek Coal Development project.

1. Complete approximately 50,000 feet of additional drilling necessary to provide the geological framework for design of a 30-year-life coal mine. (The proposed drill holes are listed in Appendix V)

2. Undertake exploration drilling in waste disposal areas which are potentially underlain by coal-bearing strata; holes designed to test for the presence of coal.

3. Attempt to delineate the burnt coal areas with a magnetometer survey.

4. Extend the statistical evaluation of coal attribute variability, as performed on special test holes 76-135 and 136, to all samples in each coal zone. Data adequate for plant design should be obtained; improved data for mine design would be expected.

5. Undertake a multiple regression analysis of ash fusion temperature versus ash element mol percentages and ratios.

6. Complete the current program of X ray analysis of mineral matter and extend it as required to provide information on special aspects of coal mineralogy or chemistry.

7. Investigate in greater detail the character of the inherent ash in the coal.

8. Obtain reliable data whenever possible on in situ moisture and bulk density.

9. Carry out additional palynology studies only as required to resolve uncertainties in gross stratigraphy.

10. Enlarge the control analyses (check sampling) program to include government and other private laboratories.

11. Formulate plans for research and test work on in situ analyses of coal by geophysical methods. The equipment visualized includes both face-scanning and down-hole and would be used to provide quality control during the mining operation.

Respectfully submitted,

DOLMAGE CAMPBELL & ASSOCIATES (1975) LTD.

Lisle T. Jory

Lisle T. Jory, Ph.D., P.Eng.

C.R. Saunders

C.R. Saunders, P.Eng.

APPENDIX I

COAL ANALYSIS SCHEDULES

HAT CREEK DEVELOPMENT

COAL ANALYSIS SCHEDULE No. 1 - STAGE 3B

DRILL HOLES 76-135 and 136
(July - August, 1976)

1. Every analytical sample (Every field sample or composite field sample).
   a. Proximate, calorific value, sulphur, air dry moisture.
   b. Ultimate including chlorine, oxygen by direct determination.
   c. Analysis of ash including Mn, V.
   d. Sulphur forms.
   e. CO_2.
   f. 8 - pt. ash fusion temperatures.
   g. Sink-float tests at 1.3, 1.5, 1.7 gravities on 3/8" x 0 coal.

2. All of above analyses on float fractions as follows:

   A Zone - 1.3 float - every 3rd sample.
   - 1.5 float - every 9th sample.

   B Zone - 1.3 float - same as A Zone.
   - 1.5 float - same as A Zone.

   C Zone - 1.3 float - on two out of every three samples.
   - 1.5 float - on one out of every three samples.

   D Zone - 1.3 float - same as A Zone.
   - 1.5 float - same as A Zone.

   (Note: "1.5 float" is all material floating at 1.5).

3. Water soluble alkalies; Hardgrove grindability indices.

   On 11 selected samples from each drill hole.

4. Small field specific gravity samples.
   a. Total (psuedo equilibrium) moisture.
   b. Ash

5. Other on 49 samples, not included above, from two thick high-ash beds in each hole.
   a. More than 75% ash, dry basis: ash and moisture only on most samples; ash analysis and CO_2 on a few.
   b. Less than 75% ash, dry basis: full analyses listed under No. 1 above.

Notes:
(1) Schedule applies only to samples from holes 76-135 and 136.
(2) Schedule is reproduced from a letter to C.Guelke from L.T.Jory, dated July 9, 1976.

HAT CREEK DEVELOPMENT

COAL ANALYSIS SCHEDULE No. 2 - STAGE 3B
(July - August, 1976)

1. Samples containing more than 75% ash, dry basis.

   a. Total (as received) moisture.
   b. Ash.

2. Samples containing less than 75% ash, dry basis.

   a. Proximate, calorific value, sulphur, air dry moisture.
   b. Ultimate including chlorine; oxygen by difference.
   c. Sulphur forms.
   d. CO_2.
   e. Analysis of ash including Mn, V.
   f. 4-pt. reducing ash fusion temperatures.
   g. Sink-float tests at 1.3, 1.5, 1.7 gravities on 3/8" x 0 coal.

3. 1.3 gravity float.

   4-pt. reducing ash fusion.

4. Small field specific gravity samples.

   a. Total (psuedo equilibrium) moisture.
   b. Ash.

Notes:

(1) This schedule is reproduced from a letter to C.Guelke from L.T.Jory, dated July 9, 1976.

(2) The schedule is applicable to all samples from drill holes other than Nos. 76-135 and 136. Following discussions with the laboratories, work on Schedule No. 2 was terminated early in September except for completion of specific items of work well advanced for any drill hole.

HAT CREEK DEVELOPMENT

COAL ANALYSIS SCHEDULE No. 3 - STAGE 3B
September 7, 1976

1. <u>Samples containing more than 75% ash, dry basis.</u>
   a. Residual moisture (Reporting of as received moisture at discretion of laboratory).
   b. Ash.

2. <u>Samples containing less than 75% ash, dry basis.</u>
   a. Residual moisture (As for 1.a. above).
   b. Ash.
   c. Calorific value.
   d. Sulphur and pyritic sulphur.
   e. CO_2.
   f. 4-pt. reducing ash fusion temperatures.

3. <u>Samples from above for which I.D. reducing temperature is 2600°F or less.</u>
   a. Volatile matter.
   b. Ultimate including chlorine; oxygen by difference.
   c. Analysis of ash including Mn, V.
   d. Sink-float tests at 1.3, 1.5, 1.7 gravities on 3/8" x 0 coal.

4. <u>1.3 sink - 1.5 float fraction.</u>
   a. Analysis of ash including Mn, V.
   b. 4-pt. reducing ash fusion temperatures.

5. <u>Small field specific gravity samples.</u>
   a. Total (psuedo equilibrium) moisture.
   b. Ash.

Notes: (1) Schedule No. 3 replaces Schedule No. 2.

(2) The schedule is interim and subject to change at anytime by B.C. Hydro.

HAT CREEK DEVELOPMENT

COAL ANALYSIS SCHEDULE No. 4 - STAGE 3B
September 7, 1976

1. Samples containing more than 75% ash, dry basis.
   a. Residual moisture (Reporting of as received moisture at discretion of laboratory).
   b. Ash.

2. Samples containing less than 75% ash, dry basis.
   a. Residual moisture (As for 1.a. above).
   b. Ash.
   c. Calorific value.
   d. Sulphur and pyritic sulphur.
   e. CO_2.
   f. 4-pt. reducing ash fusion temperatures.

3. Small field specific gravity samples.
   a. Total (psuedo equilibrium moisture).
   b. Ash.

Notes:

(1) Schedule No. 4 is an abbreviated version of Schedule No. 3.

(2) The schedule is applicable in place of Schedule No. 3 at the discretion of L.T.Jory to coal samples as follows:

(a) Samples from holes drilled northeast of the original No. 1 coal deposit.
(b) Samples from below the 2400 foot elevation.
(c) All samples, at some future time, should it appear possible from cost projections that total assay costs may exceed the budget estimate for such costs.

APPENDIX II

LABORATORY PROCEDURES

METHODS OF ANALYSIS FOR DOLMAGE CAMPBELL & ASSOCIATES LTD.

I. TOTAL MOISTURE

Two Stage: Air Dry Loss @ 85°F
Residual @ 105°C

II. ASH CONTENT

ASTM D 3174-73. Note 2, Paragraph (a)

III. VOLATILE MATTER

ASTM D3175-73 Modified Procedure for Sparking Fuels

Following Deviation:

1. 0.5 gram of analysis sample mixed with 0.5 gram of coal (referred to as standard sample). Standard sample contained approximately 18% volatile matter.

IV. CALORIFIC VALUE

ANSI/ASTM D 2015-66

V. TOTAL SULFUR

ASTM D 3177-75, Method A, Eschka Method

VI. CARBON DIOXIDE

ASTM D 1756-62

VII. ULTIMATE ANALYSIS

a) Carbon and Hydrogen ASTM D 3178-73
b) Nitrogen ASTM D 3179-73
c) Chlorine ASTM D 2361-62
d) Oxygen = 100 - Sum of Carbon, Hydrogen, Nitrogen, Chlorine, Sulfur and Ash

VIII. FUSIBILITY OF COAL ASH

ASTM D1857-68

Continued Page 2 ...

IX. MINERAL ANALYSIS OF ASH

ASTM D 2795-69
a) Manganese and Vanadium by Atomic Absorption
b) Sulfur D 1757-62

X. EQUILIBRIUM MOISTURE

ASTM D 1412-74

XI. FREE SWELLING INDEX

ASTM D720-67

XII. GRINDABILITY

ASTM D409-71

XIII. WATER SOLUBLE ALKALIES

Babcock & Wilcox Method

XIV. WASHABILITY

Commercial Testing & Engineering Co. Methods
a) Mixed solutions of perchlorethylene, ethylene dibromide and naptha to establish specified density.

XV. SPECIFIC GRAVITY

Water Displacement Method

March 14, 1977

GENERAL TESTING LABORATORIES, VANCOUVER

SUMMARY OF STANDARDS FOR SAMPLE PREPARATION AND ANALYSES FOR HAT CREEK COAL DEVELOPMENT

ASTM D2013*	Preparing Coal Samples for Analysis Crushing Samples for Float-Sink Tests Pulverizing Samples for Analysis
ASTM D3302*	Total Moisture in Coal Procedure A: Drying Floor Presently in Use Procedure B: Oven Drying on First 250 Samples

* Sample Preparation and Air Drying are closely interrelated.

ASTM D3302	Loss on Air Drying
ASTM D3173	Moisture in the Analysis Sample of Coal and Coke
ASTM D3286	Gross Calorific Value of Solid Fuel by the Iso Thermal-Jacket Bomb Calorimeter
ASTM D3174	Ash in the Analysis Sample of Coal and Coke
ASTM D3172*	Proximate Analysis of Coal and Coke

* The calculation of fixed carbon is defined in this Standard.

ASTM D3175	Volatile Matter in the Analysis Sample of Coal and Coke
ASTM D1756	Carbon Dioxide in Coal
ASTM D3177	Total Sulphur in the Analysis Sample of Coal and Coke (Eschka Method)
ASTM D2492	Forms of Sulphur in Coal
ASTM D3178	Carbon and Hydrogen in the Analysis Sample of Coal and Coke
ASTM D3179	Nitrogen in Analysis Sample of Coal and Coke
ASTM D2261	Chlorine in Coal
ASTM D1857*	Fusibility of Coal and Coke Ash

* A Gas Fired Burrell Furnace is used for ash fusions.

ASTM D2795*	Analysis of Coal and Coke Ash

* This method deals with the determination of Silica, Alumina, Titanium Oxide, Ferric Oxide, Calcium Oxide, Magnesium Oxide, Sodium Oxide, Magnesium Oxide and Phosphorus Pentoxide.

........../2

Sodium, Potassium, Vanadium and Manganese are determined by atomic absorption. The method specifies flame emission for Sodium and Potassium, but experience has proved that atomic absorption gives more reliable results.

ASTM D1752	Sulphur in Coal Ash
ASTM D1412	Equilibrium Moisture of Coal at 96 to 97 % Relative Humidity

REMARKS:

1. The specific gravity is determined with a Pycnometer.
2. Sink-Float tests are performed in mixtures of Perchloroethylene and Ethylene Dibromide

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629 Beaverdam Rd. N.E.
Calgary 67, Alberta

Methods of Analysis of Coal

1. Air Drying and Sample Preparation: ASTM-D-2013 (Referee Method)
2. Proximate Analysis: ASTM-D-271
3. Sulphur: Escka Method ASTM-D-271
4. BTU: Parr Oxygen Bomb Calorimeter ASTM-D-271
5. Ash Analysis: ASTM-D-2795 (TiO_2, P_2O_5)

    SiO_2 - gravimetric method using HF to obtain SiO_2 by difference.
    Al_2O_3 - Atomic Absorption.
    Fe_2O_3 - Atomic Absorption and dichromate titration.
    CaO - Atomic Absorption and ASTM-D-2795.
    MgO - Atomic Absorption and gravimetric.
    Na_2O - Atomic Absorption.
    K_2O - Atomic Absorption.
    Mn_3O_4 - Atomic Absorption.
    V_2O_5 - Colourmetric.
    SO_2 in Ash - ASTM-D-1757

6. CO_2 in Coal - ASTM-D-1756
7. Sulphur Forms - ASTM-D-2492
8. Ash Fusion Temperatures - ASTM-D-1857
9. Hardgrove Index - ASTM-D-409
10. Sink-Float Analysis - DEMR Mines Branch. "Procedure for Float-Sink Analysis" by J.L. Picard and C.E.J. Rozenhart.

APPENDIX III

CORE PHOTOGRAPHS, DRILL HOLE 76-135

RELATION OF PHOTOGRAPHS TO STRATIGRAPHIC UNITS

Stratigraphic Unit		Photograph		
Unit	Footage	Number	Footage	Remarks
HW	105-475	49-11	397-476	
A	475-1095	49-18	630-701	
B	1095-1340	49-28	1065-1336	A-B rock unit above 1095'
C	1340-1680	50- 1	1567-1641	
D	1680-1935	50-17	1855-1928	
FW	1935	50-18	1928-1996	Includes bottom of D Zone

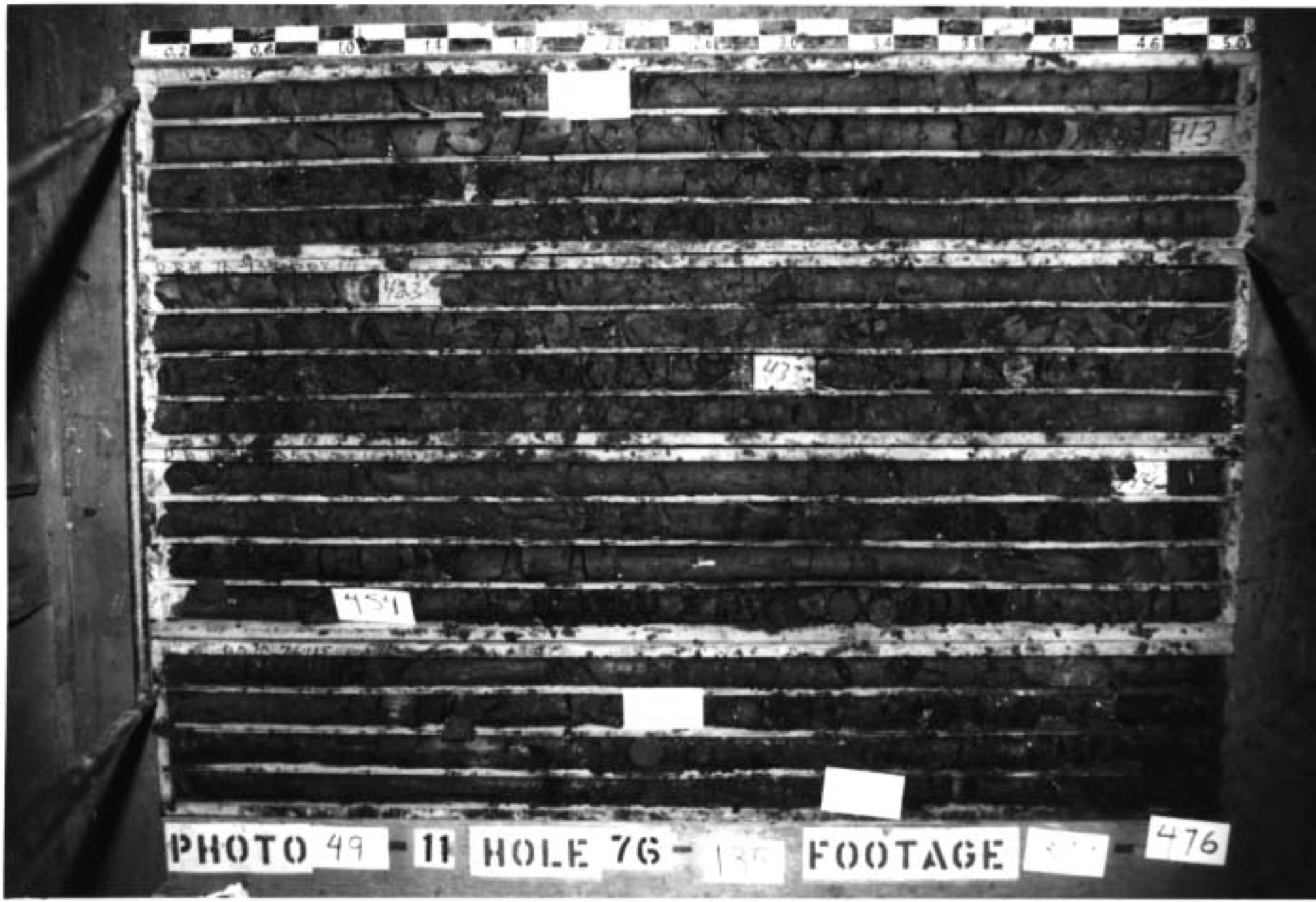


PHOTO 49 - 11 HOLE 76 - 135 FOOTAGE - 476
413
423
454

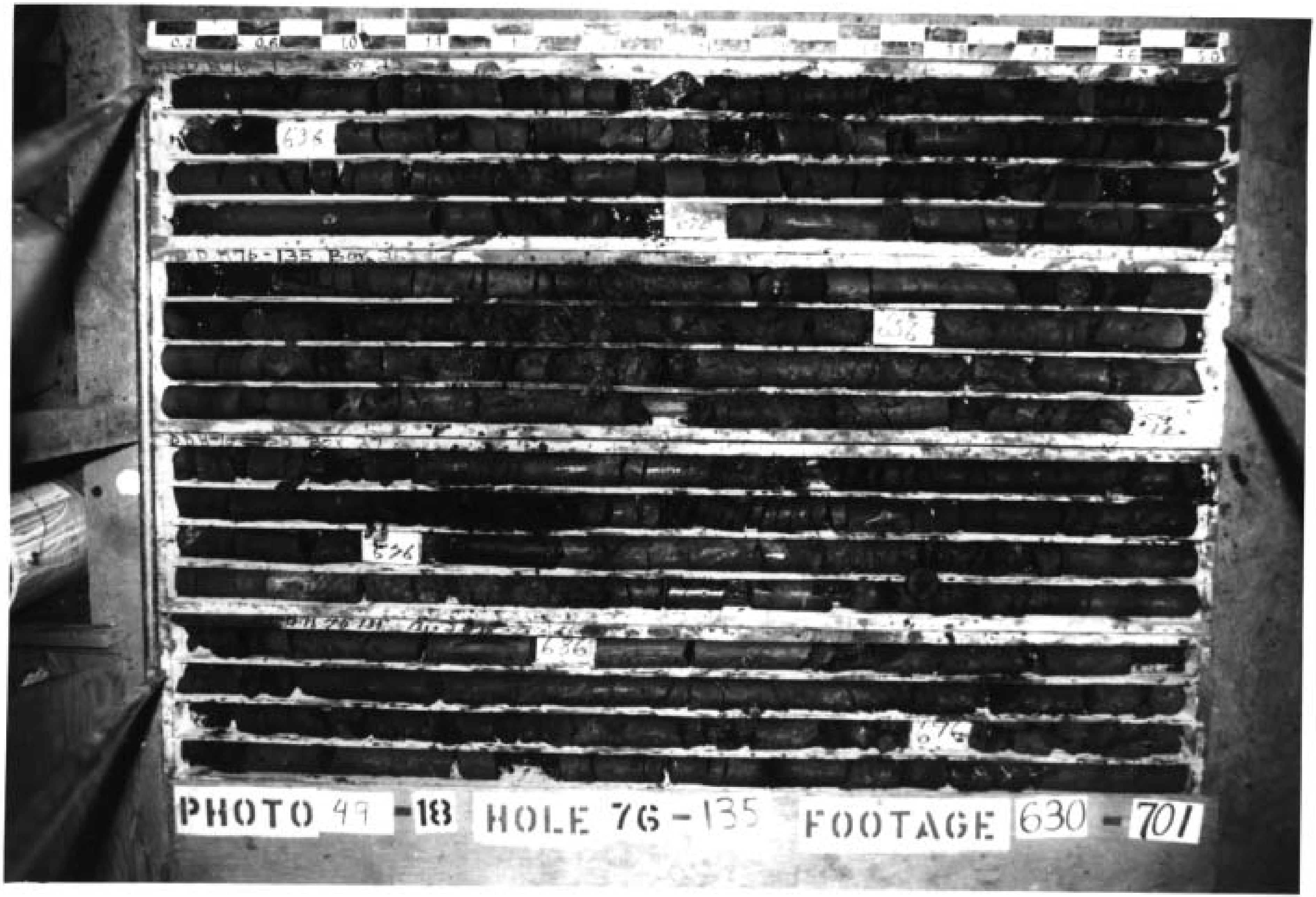


PHOTO 49 -18 HOLE 76-135 FOOTAGE 630 - 701

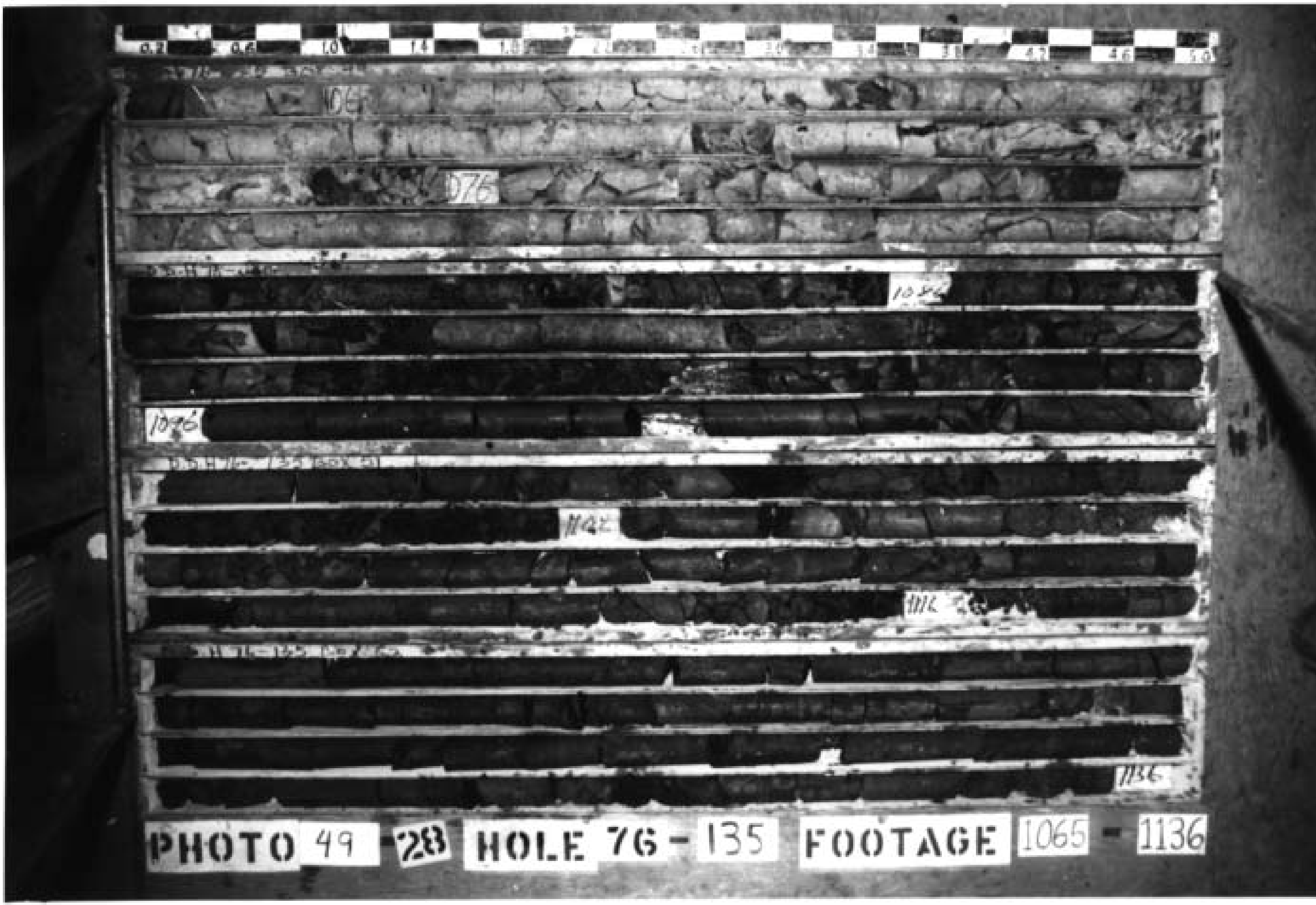


PHOTO 49 28 HOLE 76-135 FOOTAGE 1065 - 1136

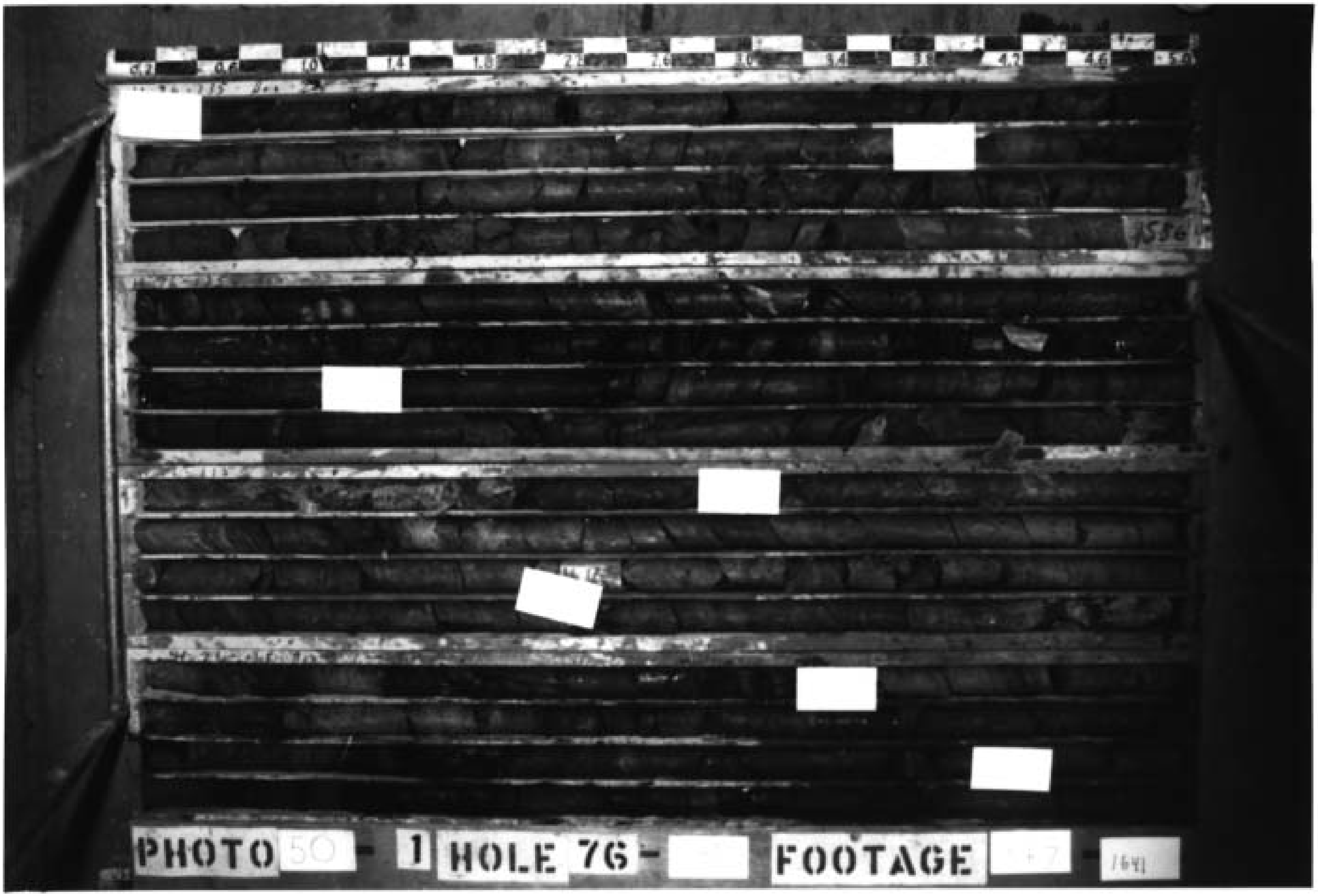
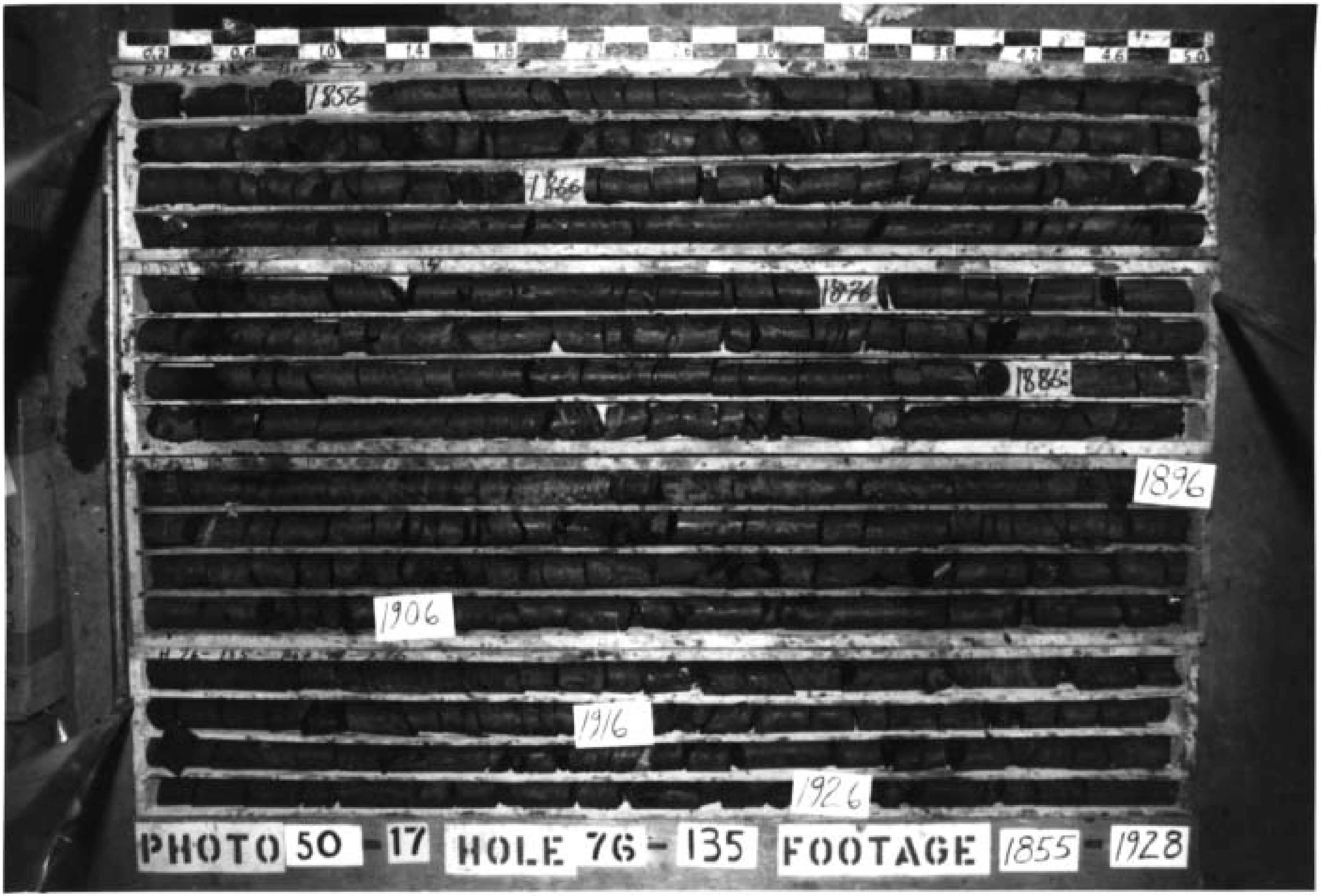


PHOTO 50 - 1
HOLE 76 -
FOOTAGE - 1641


1856
1866
1876
1886
1896
1906
1916
1926
PHOTO 50 - 17 HOLE 76 - 135 FOOTAGE 1855 - 1928


1936
1946
1956
1966
1976
1986
1996 END
PHOTO 50
HOLE 76 - 135
FOOTAGE 1928 - 1996

APPENDIX IV

EXCERPTS FROM REPORTS BY DR. A.J. SINCLAIR

Excerpted from a report by Dr. A.J. Sinclair dated 20 September, 1976, entitled:

HAT CREEK DEVELOPMENT

INTERIM REPORT ON DRY PROXIMATE ANALYSES

OF TEST HOLES 135 and 136

Comprising: 5 pages
2 tables
4 small graphs

HAT CREEK DEVELOPMENT

INTERIM REPORT ON DRY PROXIMATE ANALYSES

OF TEST HOLES 135 AND 136

Statistical parameters for dry proximate data for drill holes 135 and 136 are summarized in Tables I and II. An evaluation of these data along with probability plots and semivariograms of all the variables produce the following preliminary conclusions.

1. Statistical parameters (mean and standard deviation) for all variables are indistinguishable at the 95% confidency level from one hole to the other, with the exception of B-zone ash.

2. This apparent uniformity over a distance of 1000 feet should be interpreted as applying only to parts of the coal that can be divided into zones (A, B, C or D) unabiguously. Greater variations are to be expected in areas of greater geological complexity such as areas of pronounced facies changes or faulting.

3. The principal variability in proximate data is along the lengths of drill holes (i.e. across the layering of the coal beds) as opposed to along the layering. This across-strata variability appears to be a reasonable first approximation of 3-dimensional variability that can be used for design purposes.

4. Dispersions (standard deviations) are shown in Figure 1 as a function of sample lengths. These variations in dispersion closely approximate an exponential form by empirical observation (i.e. a linear plot on log paper), which can be used for interpolation (e.g. to study expected variability of blocks 13' x 13' x 13' which approximate 100 tons of production).

5. An examination of cumulative probability plots shows that each proximate variable except total sulphur has a density distribution that can be approximated by a single normal distribution or a combination of two normal distributions. Total sulphur values approximate a lognormal distribution.

6. Experimental semivariograms constructed for each of the variables for each hole separately and for each zone separately show that only a few variables can be treated to advantage for estimation purposes using such techniques for data from holes spaced at 500 feet or more. In general the semivariograms show that most variables can be treated as random. Some variables show a drift or trend but these only become significant for sample spacings in excess of 80 feet.

A. J. Sinclair

Dr. A.J. Sinclair, P.Eng.
September 20, 1976

Excerpted from a report by Dr. A.J. Sinclair, dated March, 1977, entitled:

EVALUATION OF ANALYTICAL DATA
FROM TEST HOLES 76-135 AND 76-136
HAT CREEK NO. 1 COAL DEPOSIT

Comprising: 65 pages
17 tables
4 volumes of appendices

SUMMARY AND CONCLUSIONS

A statistically-oriented evaluation of analytical data for diamond drill holes 76-135 and 76-136 1000 feet apart in the Hat Creek No. 1 coal deposit was undertaken by the writer. Data were grouped and analyzed by major stratigraphic zones (A, B, C and D zones - A is the youngest zone in a right-side-up sequence that is extensively faulted and characterized by marginal zones of extreme facies changes).

Emphasis in the writer's study was on dispersion (variability) of variables, evidence of trends and/or autocorrelation along the drill holes, comparison of data from one hole with data from the second hole, and the question of an appropriate sampling scheme for future drill core analyses. Very few guidelines were provided with regard to boundary conditions for a sampling program.

Proximate and Btu Data

Proximate variables and Btu/# are, in general, comparable from one hole to another within a single zone. However, large differences exist among the principal stratigraphic zones - A, B, C and D.

For most proximate variables A and C zones show general similarities as do B and D zones. A and C zones are low quality coals compared with B and D zones.

Probability plots of proximate variables (incl. Btu/#) commonly show a multi-modal form. In the case of A-zone this is consistent with other data (especially variograms) and leads to a useful conceptual model of cyclical variations of, for example, high ash and low ash coals. The cyclical character is important in sample design. Although the model differs slightly in detail in the two test holes, a simple view of the model is - a repetitive cycle in which one cycle consists of a 40 to 50-foot layer of high Btu/# coal followed by a 20 to 25-foot layer of lower Btu/# coal.

C-zone appears cyclical but the pattern is not as clear cut as for A-zone. A probable ideal model for C zone is - a 10 to 15-foot low Btu/# layer followed by a 30 to 50-foot thick higher Btu/# layer.

B and D zones also appear to contain multiple populations of proximate variables but these are interdispersed in random (rather than cyclical) fashion throughout the thickness of the respective zones. Of course, cyclical interbeds either of coal or waste would not be recognized over distances of a few feet because they would be smoothed out in the 10-foot sample lengths on which much of this study is based.

Most proximate variables have comparable variability in each of the two test holes. An analysis of variance on ash (% dry) illustrates the fact that local variations are greater than variations between the two test holes (which are separated by 1000 feet). This test has not been made rigorously for all proximate variables but by inspection shows that comparable results would be obtained for other variables. Consequently, an important generalization is that where zones A, B, C and D can be recognized unambiguously the local variability (10's of feet) across stratification is high relative to lateral variability (100's of feet). In fact, locally the "across stratification" variability is a good approximation of the total variability.

Autocorrelation studies show that proximate variables are largely random in nature; although note the presence of cyclical variations of some proximate variables in A and C zones. The main implication of this dominant random nature is that short range variability (over 10's of feet) is the same as the total variability occurring throughout a particular zone.

Sulphur and CO_2

Total sulphur, organic sulphur and pyritic sulphur were examined. All are random variables in all four zones and have lognormal density distributions. In most zones a few percent of S_{total} values are much higher than most, of the order of one percent or more. For zones A, B and C about two-thirds of S_{total} is organic sulphur - for D zone about 88 percent total sulphur is organic sulphur. Analytical data show that pyritic sulphur is the only other significant component of total sulphur. All zones show a slight increase in mean total sulphur content as Btu/# increases.

Sulphur contents and variability are comparable from one test hole to the other. The principal exceptions are total sulphur and organic sulphur in D zone. However, both variables are lower in D zone than any other zone and evidence of a slight trend laterally in sulphur values is not critical in D zone.

Carbon dioxide contents of zones A, B and D are comparable. Zone C has a much higher carbon dioxide content and variability than the other three zones. Virtually all CO_2 is derived from siderite layers that seem to be distributed randomly throughout each of the four main stratigraphic zones.

Mineral Ash

Most mineral ash variables show comparable means and dispersions in each of the test holes. TiO_2 and K_2O variability, however, differ from one hole to another in zones B and D. Similarly, P_2O_5 and CaO variability differ from one hole to another in zones A and C. Such differences would seem to imply that ash of zones B and D have features in common, which, in turn differ somewhat from ash in zones A and C.

There is a surprising statistical uniformity of mean values of mineral ash variables for the two test holes. The implication is that vertical variability (i.e. across stratification) is large and lateral variability is relatively slight. This generalization should be applied only where zones A, B, C and/or D can be identified unambiguously, and not where grossly different facies prevail.

Virtually all mineral ash variables are random in character. Hence, the total variability can be found locally.

Probability plots for mineral ash variables are, in general, more complex in make-up than are those of proximate variables. Their complexity (multi-modal character) arises through contributions to variability from fundamentally different types of ash (e.g. silt, kaolin, illite, montmorillonite), rather than simply different percentages of two end members. It is probable that different normal and/or lognormal mixed populations represent interlayered and fundamentally (mineralogically) different types of ash in the coal sequence.

Ultimate Variables

Ultimate variables show the greatest disparity in means and standard deviations from one test hole to the other. Nitrogen and chlorine trends are probably of little practical significance because of the low levels of abundances of these variables in all zones. Carbon, Hydrogen and oxygen values are multi-modal, probably because their variabilities derive from grossly different ash-coal populations and partly from different mineralogies. Oxygen by difference is consistently less than is oxygen by analysis. The differences for all zones are significant statistically and indicate a systematic error in one or the other of the oxygen estimation procedures. If the error lies with oxygen by difference then the basic error occurs in the estimation of some other variable(s). Surprisingly, D zone shows the most statistically significant differences for ultimate variables (nitrogen, chlorine, oxygen) between test holes. Despite their statistical significance the differences are small quantitatively and arise from a small local dispersion of values relative to other zones.

Comments on Populations

Analysis of probability graphs, particularly for proximate data, show that each zone is characterized by two populations, high ash - low Btu/# and low ash - high Btu/# respectively. These populations do not correspond in mean values or dispersions from one zone to another. Furthermore, these populations tell us little or nothing about the possibility of fundamentally different types of coal or ash.

Some mineral ash variables appear to have simple density distributions but many have complex (i.e. multi-modal) distributions that probably relate to fundamentally different types of ash (e.g. montmorillonite, kaolinite, silt). Variables that appear to have potential for classifying ash into fundamentally different groups are MgO, Na_2O, K_2O, CaO, Al_2O_3, Fe_3O_4, TiO_2 and possibly P_2O_5. Combinations of these variables might relate to various clay types, silt or fine sand. To show such relationships with certainty requires detailed mineralogical study of a variety of ash types. There are no data available to the writer at the present time that lead to recognition of two or more fundamental types of solid hydrocarbon in Hat Creek coal.

Variability

Variability of all variables decreases as the sample length increases. For samples from 10 to 40 feet long this decrease of dispersion closely approximates an exponential form. Empirical exponential relationships thus provide a means of interpolating dispersions for sample lengths other than 10-foot, 20-foot, etc. lengths if such are required.

Lateral variability (parallel to stratification) is substantially less than vertical (across strata) variability. Thus, local vertical samples taken contiguously (as along a drill hole) provide a good approximation of total local variability.

In general, the variability shown by A and C zones is substantially greater than that shown by B and D zones. Zone D, in particular, is relatively uniform in character. For a few variables different relations exist among zones.

Autocorrelation

Autocorrelation has been studied by examining semivariograms for 10-foot samples along the direction of the drill holes. For proximate variables, Btu/# and total sulphur there is no significant difference between the two test holes. The results indicate a cyclical autocorrelation function for zone A and, more ambiguously, zone C. This pattern can be ascribed to a regular interlayering of high ash and low ash layers.

Mineral ash and ultimate variables show essentially no autocorrelation - that is, they are random variables on the scale on which they have been studied (10-foot samples).

The important implication of the random aspect of nearly all variables is that local variability is essentially the same as variability throughout the drill intersection of an entire zone.

Optimal Sampling Plan

An optimal sampling plan to provide estimates of mean values and local variability (dispersion) requires continuous sampling with 15-foot sample lengths in A and C zones and 20-foot sample lengths in B and D zones. Twenty-foot sample lengths in all zones would be nearly as good but would not monitor local variability in A and C zones as well. The optimal sampling plan is recommended for proximate analyses, Btu/#, total sulphur, pyritic sulphur and CO_2.

In cases where local variability is not required for a variable, sample lengths of 40 feet (bench height) are adequate. Hence, in such cases two adjacent 20-foot samples can be combined to form a 40-foot composite to be analyzed for particular variables. Such a procedure will be more readily evaluated when all analytical results for the 1977 drilling program have been appraised - such an appraisal may even obviate the necessity of certain variables being determined.

The recommended sampling plan will be superceded by practical considerations relating to such features as faults, zone contacts, pronounced facies changes, etc.

TABLE 1

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE A

Variable*	DDH 135 (n=55)		DDH 136 (n=54)		Combined (n=108)	
	$\overline{x}$	s	$\overline{x}$	s	$\overline{x}$	s
Btu/#	6415	2068	6227	2176	6321	2115
Ash	42.92	14.00	45.68	16.41	44.32	15.27
F.C.	27.46	9.54	26.15	10.01	26.80	9.75
V.M.	29.63	5.08	29.41	5.78	29.52	5.42
S total	0.680	0.244	0.671	0.383	0.676	0.320
Sorg	0.498	0.174	0.438	0.210	0.468	0.194
CO_2	1.61	2.14	1.64	1.50	1.62	1.84

* Btu/# of dry coal, other variables % dry coal.

Variable*	DDH 135 (n=55)		DDH 136 (n=54)		Combined (n=109)	
	$\overline{x}$	s	$\overline{x}$	s	$\overline{x}$	s
P_2O_5	0.260	0.208	0.345	0.382	0.302	0.308
SiO_2	54.45	6.05	53.21	4.20	53.84	5.23
Fe_2O_3	7.03	2.71	7.95	4.38	7.48	3.65
Al_2O_3	28.45	4.29	29.66	3.64	29.05	4.01
TiO_2	0.888	0.317	0.820	0.383	0.854	0.351
CaO	3.08	5.73	2.29	1.25	2.69	4.16
MgO	1.53	0.603	1.51	0.448	1.52	0.530
SO_3	1.60	0.775	1.61	1.10	1.61	0.947
K_2O	0.773	0.189	0.886	0.373	0.829	0.299
Na_2O	0.775	0.256	0.885	0.256	0.830	0.261
Mn_3O_4	0.074	0.085	0.099	0.156	0.087	0.123
V_2O_5	0.056	0.016	0.051	0.015	0.054	0.016

* All variables are % dry ash.

Variable	DDH 135(n 55)		DDH 136(n 54)		Combined(n 109)	
	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
Nitrogen	0.968	0.382	0.719	0.260	0.845	0.194
Chlorine	0.066	0.123	0.048	0.029	0.057	0.090
O_2 (Diff.)	14.32	2.13	13.96	2.58	14.14	2.36
O_2 (Anal.)	15.00	2.41	15.30	2.50	15.15	2.48

All variables are % dry coal

*See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE II

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE B

Variable*	DDH 135 (n=24)		DDH 136 (n=26)		Combined (n=50)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Btu/#	7679	1229	7639	1645	7658	1446
Ash	34.84	8.35	40.34	17.72	37.90	14.48
F.C.	33.78	5.69	33.78	7.45	33.78	6.60
V.M.	31.37	3.24	31.48	3.88	31.43	3.55
S total	0.792	0.190	0.817	0.256	0.805	0.225
Sorg	0.524	0.082	0.557	0.160	0.541	0.128
CO_2	1.68	1.53	1.67	2.14	1.68	1.85

* Btu/# of dry coal, other variables % dry coal

Variable*	DDH 135 (n=25)		DDH 136 (n=26)		Combined (n=51)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
P_2O_5	0.178	0.260	0.227	0.317	0.203	0.289
SiO_2	51.51	5.87	52.77	4.01	52.15	5.00
Fe_2O_3	7.25	5.10	6.59	4.49	6.92	4.76
Al_2O_3	32.41	3.27	31.57	4.34	31.98	3.84
TiO_2	0.711	0.092	0.822	0.175	0.768	0.150
CaO	2.30	1.56	2.90	3.13	2.60	2.48
MgO	1.53	0.967	1.51	0.577	1.52	0.780
SO_3	1.42	1.51	1.22	0.904	1.32	1.23
K_2O	0.639	0.072	0.593	0.152	0.616	0.121
Na_2O	1.37	0.281	1.18	0.303	1.27	0.305
Mn_3O_4	0.056	0.151	0.061	0.091	0.059	0.123
V_2O_5	0.054	0.010	0.048	0.012	0.051	0.011

* All variables are % dry ash.

Variable*	DDH 135 (n=25)		DDH 136 (n=26)		Combined (n=51)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Nitrogen	1.09	0.180	0.933	0.156	1.012	0.185
Chlorine	0.011	0.011	0.037	0.022	0.024	0.018
O_2 (Diff.)	14.03	1.12	14.65	1.49	14.35	1.34
O_2 (Anal.)	15.73	1.42	16.01	1.69	15.87	1.55

* All variables are % dry coal.

See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE III

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE C

Variable*	DDH 135 (n=22)		DDH 136 (n=15)		Combined (n=37)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Btu/#	4111	1567	4924	1731	4413	1653
Ash	58.42	10.46	51.83	10.48	55.75	10.83
F.C.	17.31	7.38	21.59	7.53	19.06	7.64
V.M.	24.27	4.49	26.58	3.58	25.21	4.25
S total	0.377	0.163	0.402	0.192	0.387	0.173
Sorg	0.234	0.113	0.301	0.142	0.261	0.128
CO_2	4.71	3.73	3.78	2.27	4.34	3.23

* Btu/# of dry coal; other variables % dry coal.

Variable*	DDH 135 (n=23)		DDH 136 (n=15)		Combined (n=38)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
P_2O_5	0.215	0.227	0.247	0.137	0.228	0.195
SiO_2	52.72	6.43	52.66	4.22	52.70	5.60
Fe_2O_3	8.90	6.25	8.09	3.44	8.58	5.28
Al_2O_3	29.00	4.78	30.72	1.88	29.68	3.95
TiO_2	0.759	0.174	0.828	0.157	0.786	0.169
CaO	2.96	3.00	2.43	1.34	2.75	2.47
MgO	1.78	1.11	1.81	0.540	1.79	0.9116
SO_3	0.919	0.434	0.789	0.600	0.867	0.502
K_2O	1.00	0.292	0.757	0.196	0.906	0.283
Na_2O	0.764	0.185	0.717	0.165	0.745	0.176
Mn_3O_4	0.153	0.231	0.137	0.096	0.147	0.188
V_2O_5	0.038	0.009	0.047	0.005	0.042	0.009

* All variables are % dry ash.

Variable*	DDH 135 (n=23)		DDH 136 (n=15)		Combined (n=38)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Nitrogen	0.729	0.269	0.743	0.127	0.734	0.222
Chlorine	0.013	0.029	0.009	0.017	0.011	0.025
O_2 (Diff.)	11.85	1.62	13.05	1.31	12.32	1.60
O_2 (Anal.)	14.31	2.63	14.43	1.69	14.36	2.28

* All variables are % dry coal.

See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE IV

COMPARISON OF STATISTICAL PARAMETERS
FOR TEST HOLES 135 AND 136

ZONE D

Variable*	DDH 135 (n=25)		DDH 136 (n=29)		Combined (n=54)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Btu/#	9211	1371	9665	1010	9455	1201
Ash	25.99	8.65	22.17	6.36	23.94	7.68
F.C.	41.10	6.86	42.44	5.06	41.82	5.94
V.M.	32.91	2.45	35.39	1.81	34.24	2.45
S total	0.231	0.067	0.296	0.061	0.266	0.071
Sorg	0.191	0.055	0.272	0.062	0.235	0.071
CO_2	1.36	1.63	1.18	1.18	1.26	1.40

* Btu/# of dry coal; other variables % dry coal.

Variable*	DDH 135 (n=25)		DDH 136 (n=29)		Combined (n=54)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
P_2O_5	0.163	0.148	0.197	0.187	0.181	0.169
SiO_2	51.10	6.10	51.76	5.77	51.46	5.88
Fe_2O_3	6.21	4.77	5.52	4.06	5.84	4.38
Al_2O_3	33.98	4.57	33.64	4.55	33.80	4.52
TiO_2	0.798	0.121	0.822	0.195	0.811	0.164
CaO	3.04	1.75	3.11	1.34	3.08	1.53
MgO	1.19	0.672	1.12	0.631	1.15	0.645
SO_3	1.08	0.742	1.13	0.761	1.11	0.745
K_2O	0.325	0.139	0.271	0.046	0.296	0.103
Na_2O	1.57	0.444	1.86	0.577	1.724	0.535
Mn_3O_4	0.166	0.195	0.154	0.234	0.159	0.215
V_2O_5	0.048	0.009	0.052	0.007	0.051	0.008

* All variables are % dry ash.

Variable*	DDH 135 (n=25)		DDH 136 (n=29)		Combined (n=54)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Nitrogen	0.932	0.152	0.991	0.099	0.964	0.128
Chlorine	0.007	0.009	0.028	0.020	0.018	0.016
O_2 (Diff.)	14.89	0.903	15.33	0.476	15.12	0.733
O_2 (Anal.)	16.35	1.16	16.77	0.679	16.58	0.946

* All variables are % dry coal.

See Table V for S_{py}, ultimate carbon and ultimate hydrogen

TABLE V

STATISTICAL PARAMETERS FOR
PYRITIC SULPHUR AND ULTIMATE C AND H_2

Zone		H_2 (ult.)	C (ult.)	Pyritic Sulphur
A	n	109	109	109
	$\overline{X}$	3.30	36.96	0.203
	s	0.725	11.91	0.206
B	n	51	51	51
	$\overline{X}$	3.71	45.24	0.257
	s	0.503	7.93	0.172
C	n	38	38	38
	$\overline{X}$	2.46	27.85	0.118
	s	0.678	9.40	0.093
D	n	54	54	54
	$\overline{X}$	4.27	55.41	0.027
	s	0.378	6.76	0.016

Means (X's) and standard deviations (s's) are percent dry coal

Excerpted from a report by Dr. A.J. Sinclair, dated 25 May, 1977, entitled:

INTER AND INTRA LABORATORY REPRODUCIBILITY
1976 HAT CREEK COAL ANALYSES

Comprising: 29 pages
14 tables

INTER AND INTRA LABORATORY REPRODUCIBILITY 1976 HAT CREEK COAL ANALYSES

SUMMARY AND CONCLUSIONS

1. Duplicate samples from the 1976 drilling program on the Hat Creek No. 1 coal deposit, taken to monitor and evaluate analytical quality, were as follows: General Testing--24 sample pairs, Commercial Laboratories--20 sample pairs, and Loring Laboratory--12 sample pairs, General and Commercial--25 sample pairs, and Loring and Commercial--16 sample pairs.

2. In general, precisions of pre-1976 proximate, Btu/# and total sulphur analyses were better or as good as precisions of comparable 1976 variables. The only exception to this is total sulphur by General Testing for which poor pre-1976 precision was improved more-or-less to the level of precision for the other two labs.

3. A general evaluation of the internal precisions of the three labs indicates that Loring and Commercial labs are more-or-less equivalent in terms of numbers of variables for which they show good relative precision and both are substantially better than General Testing. This conclusion assumes equal importance to all variables measured and ignores the possibility of systematic differences among the three laboratories. A different conclusion could well be drawn for a particular subset of variables.

4. A comparison of sample pairs analyzed by Loring and Commercial labs indicates:
   (a) Commercial analyses are more precise for Btr/#, CO_2, pyritic sulphur, organic sulphur, CaO, MgO, Na_2O, Mn_3O_4 and V_2O_5.
   (b) Loring analyses are more precise for N_2, O_2(diff), SiO_2, Al_2O_3, TiO_2 and K_2O.
   (c) Precisions of the two labs cannot be distinguished statistically for ash, fixed carbon, volatile matter, carbon, H_2, Fe_2O_3, P_2O_5 and SO_3.

4. (d) Systematic differences seem to exist between the two labs for fixed carbon, volatile matter, pyritic sulphur, and TiO_2. Available data do not show which lab is more accurate for any of these variables.

5. A comparison of sample pairs analyzed by General Testing and Commercial labs indicates:
   (a) Commercial Laboratory analyses are more precise for fixed carbon, volatile matter, pyritic sulphur, organic sulphur, carbon, H_2, O_2(diff), Fe_2O_3, MgO, Na_2O, V_2O_5 and P_2O_5.
   (b) General Testing analyses are more precise for ash, N_2, Cl_2, SiO_2, K_2O and Mn_3O_4.
   (c) Precisions of the two labs cannot be distinguished for Btu/#, CO_2, Al_2O_3, TiO_2, CaO and SO_3.
   (d) Systematic differences seem to exist between the two labs for Btu/#, CO_2, H_2, TiO_2 and SO_3.

6. A comparison of precisions for each of General Testing and Loring Labs indicates:
   (a) General analyses are more precise for ash, CO_2, CaO, MgO, Na_2O, Mn_3O_4 and V_2O_5.
   (b) Loring analyses are more precise for fixed carbon, volatile matter, pyritic sulphur, carbon, H_2, N_2, O_2(diff), Al_2O_3, TiO_2 and Fe_2O_3.
   (c) Precisions of the two labs cannot be distinguished statistically for Btu/#, organic sulphur, SiO_2, K_2O, P_2O_5 and SO_3.
   (d) No comparison was done for Cl_2. Systematic differences between the two labs could not be investigated because no samples analyzed were common to both labs.

APPENDIX V

PROPOSED DEVELOPMENT DRILLING - 1977

HAT CREEK COAL DEVELOPMENT

PROPOSED DEVELOPMENT DRILLING - 1977

DRILL HOLE TYPE

S — Structural Holes - primary purpose is to aid in the specific location of (major) faults; may also be useful in determining the deposit limits, for correlation and for acquisition of analytical data.

L — Limiting Holes - required to determine or confirm deposit limits; in special cases, primarily of an exploratory nature - beyond the presumed limits of the deposit.

C — Correlation Holes - required to determine the configuration and extent of the coal zones; also provide analytical data.

A — Analyses Holes - designed to provide an adequate density of analytical data.

DRILL HOLE PRIORITY

1 — Required - location, attitude and length are fixed.

2 — Probable - holes, which in most cases will be drilled but their timing, location, attitude or length could be altered as a result of information obtained from prior drill holes.

3 — Possible - holes which may be required depending upon the results of prior drill holes; holes which could be drilled at some future time without adversely affecting on-going studies or planning.

HAT CREEK COAL DEVELOPMENT

PROPOSED DEVELOPMENT DRILLING — 1977

SUMMARY

PRIORITY	DRILL HOLE TYPE						TOTALS	%
	S	L	S + L	C	S + L + C	A		
1	10,400 10	4900 10	15,300 20	4800 5	20,100 25	1600 2	21,700 27	43 %
2	5400 6	2900 6	8300 12	11,600 11	19,900 23	2400 3	22,300 26	44 %
1 + 2	15,800 16	7800 16	23,600 32	16,400 16	40,000 48	4000 5	44,000 53	87 %
3	700 1	2600 5	3300 6	1200 1	4500 7	2300 3	6800 10	13 %
1 + 2 + 3	16,500 17	10,400 21	26,900 38	17,600 17	44,500 55	6300 8	50,800 63	100 %
%	33 %	20 %	53 %	35 %	88 %	12 %	100 %	

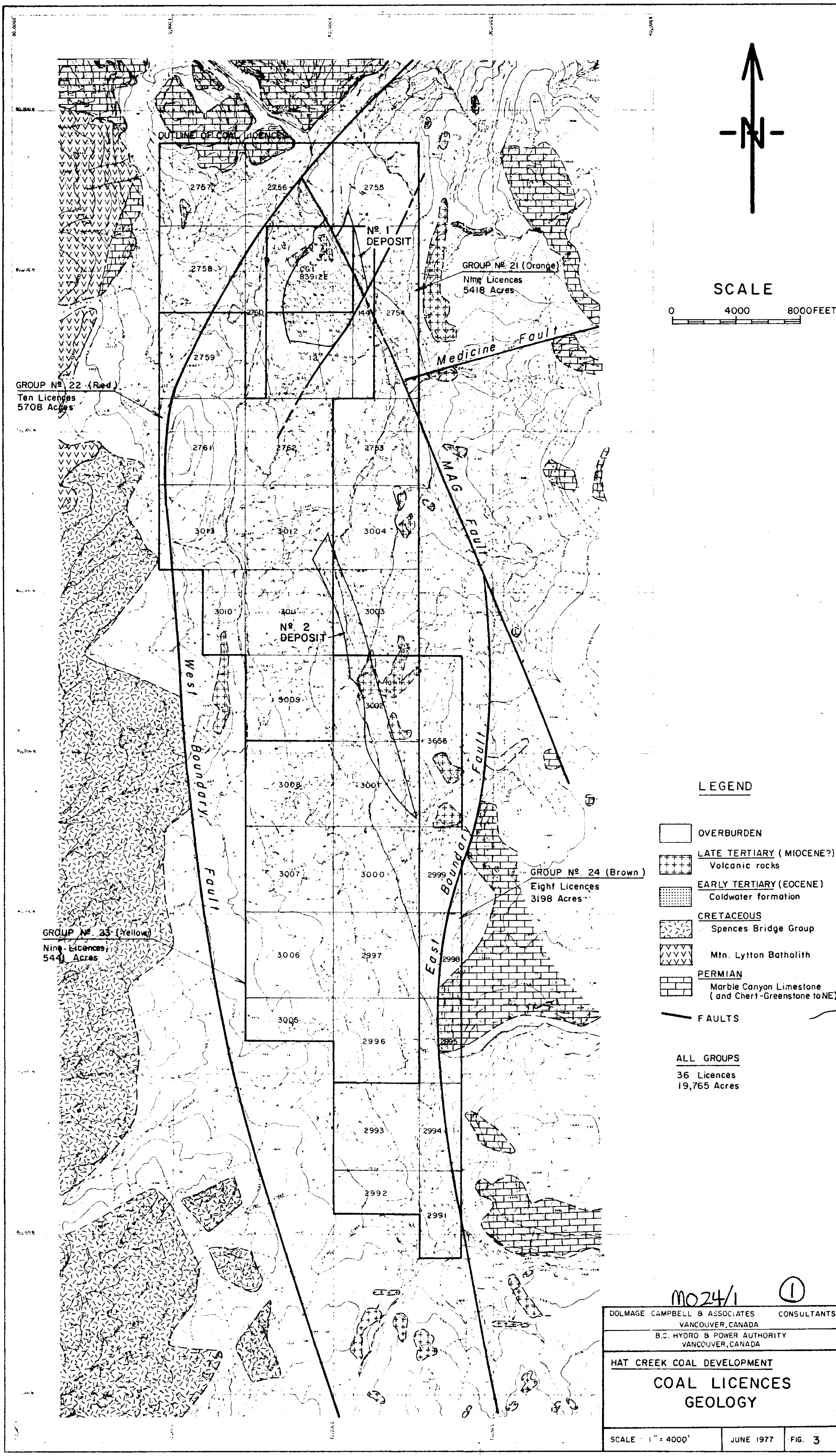
HAT CREEK COAL DEVELOPMENT

PROPOSED DEVELOPMENT DRILLING - 1977

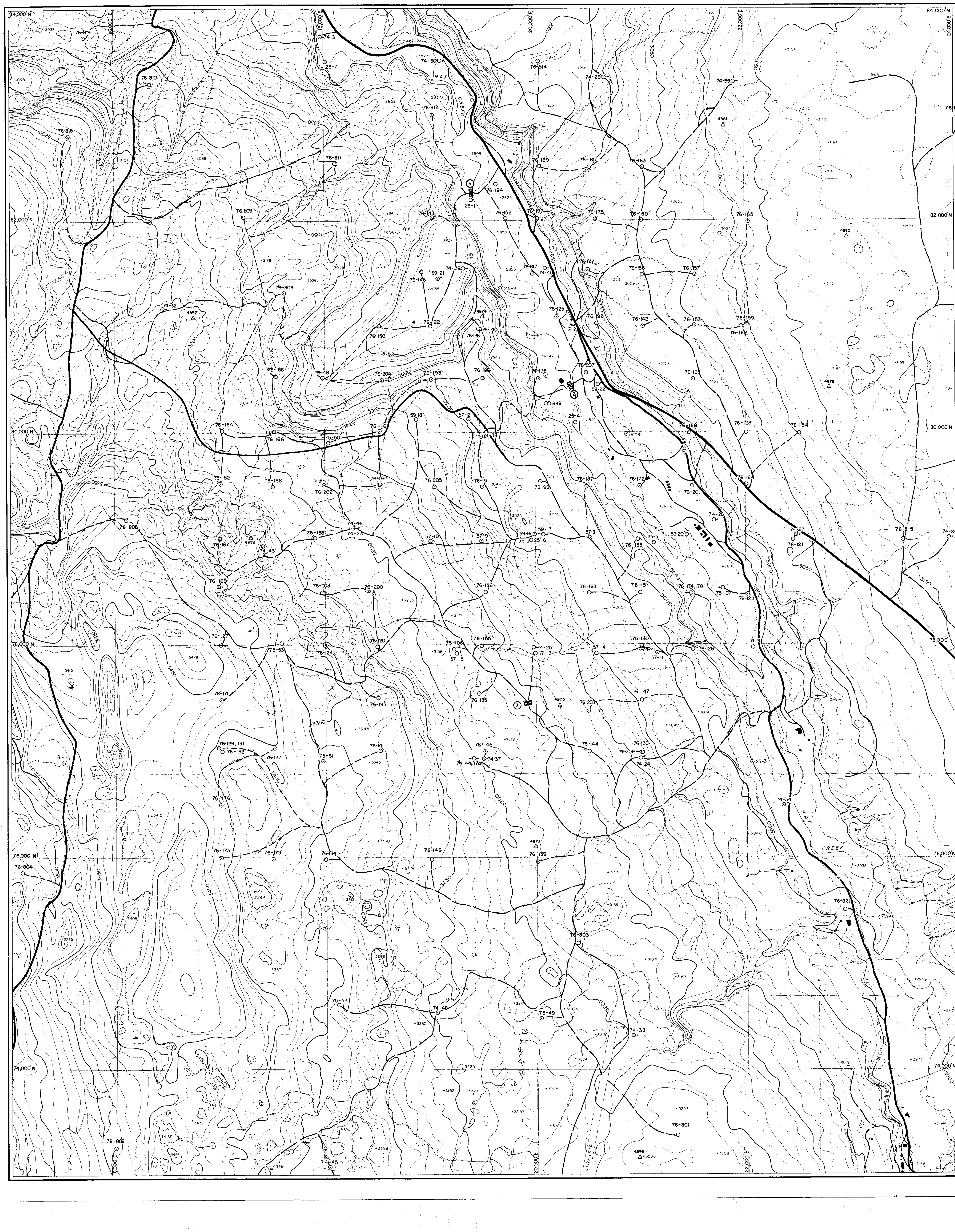
DETAILS

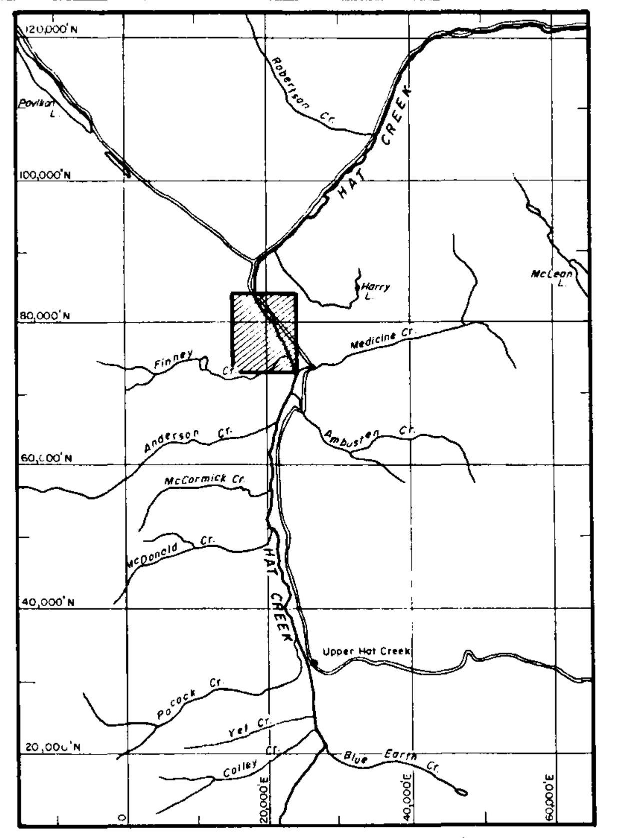
LOCATION		AZ.	DIP	LENGTH		PRIORITY	CLASS	REMARKS
LAT.	DEP.			FEET	METRES			
74,000	17,000	--	90	400	120	3	L3	southwest limits
74,000	17,500	--	90	600	185	1	L1	southwest limits
74,500	17,000	--	90	400	120	2	L2	southwest limits
74,500	17,500	--	90	600	185	1	L1	southwest limits
75,000	16,500	--	90	400	120	2	L2	southwest limits
75,000	17,000	--	90	700	215	1	L1	southwest limits
75,000	17,500	--	90	1000	300	2	C2	
75,000	18,500	--	90	1100	335	2	C2	
75,000	19,500	--	90	1600	490	2	C2	key northsouth section
75,500	16,500	--	90	400	120	2	L2	west limit
75,500	17,000	--	90	900	275	1	C1	west limit
76,000	16,500	--	90	400	120	2	L2	west limit
76,000	17,500	270	60	800	245	1	S1	fault 1
76,000	18,500	--	90	1100	335	2	C2	to 'B' zone
76,000	19,500	--	90	1000	300	2	C2	key northsouth section
76,000	20,200	90	60	800	240	1	S1	fault 8
76,500	16,500	--	90	400	120	3	L3	west limit
76,500	17,500	--	90	1200	365	2	S2	fault 1
76,500	18,000	--	90	1200	365	2	C2	
76,500	18,500	--	90	1200	365	3	C3	to 'B' zone
76,500	19,000	--	90	1300	400	1	C1	into 'B' zone
76,500	20,000	--	90	1000	300	2	A2	
76,500	20,500	--	90	1400	430	2	S2	fault 8
76,500	20,500	90	60	600	180	2	S2	fault 8
77,000	16,500	--	90	300	90	1	L1	west limit
77,000	19,000	270	55	1500	455	1	S1	faults 1 and 2

LOCATION		AZ.	DIP	LENGTH		PRI-ORITY	CLASS	REMARKS
LAT.	DEP.			FEET	METRES			
82,500	19,300	--	90	200	60	1	L1	northwest limit
82,500	21,500	--	90	600	185	1	A1	
82,500	22,000	--	90	700	210	1	C1	
82,500	22,500	--	90	600	185	2	L2	northeast limit
82,500	23,000	--	90	600	185	3	L3	northeast limit
83,000	21,000	--	90	500	150	1	L1	north limit
83,000	21,500	--	90	500	155	2	L2	north limit
TOTAL	64 holes			50,800	15,460			



OUTLINE OF COAL LICENCES
N
SCALE
0 4000 8000FEET
2757
2756
2755
Nº. 1
DEPOSIT
2758
CGT 8391ZE
GROUP Nº 21 (Orange)
Nine Licences
5418 Acres
2760
144
2754
2759
Medicine Fault
GROUP Nº 22 (Red)
Ten Licences
5708 Acres
2761
2762
2753
MAG Fault
3013
3012
3004
3010
3011
3003
Nº. 2
DEPOSIT
West Boundary Fault
3009
3002
3656
East Boundary Fault
3008
3001
LEGEND
OVERBURDEN
LATE TERTIARY (MIOCENE?)
Volcanic rocks
EARLY TERTIARY (EOCENE)
Coldwater formation
CRETACEOUS
Spences Bridge Group
Mtn. Lytton Batholith
PERMIAN
Marble Canyon Limestone
(and Chert-Greenstone to NE)
FAULTS
3007
3000
2999
GROUP Nº. 24 (Brown)
Eight Licences
3198 Acres
GROUP Nº. 23 (Yellow)
Nine Licences
5441 Acres
3006
2997
2998
3005
2996
2995
ALL GROUPS
36 Licences
19,765 Acres
2993
2994
2992
2991
MO24/1
1
DOLMAGE CAMPBELL & ASSOCIATES CONSULTANTS
VANCOUVER, CANADA
B.C. HYDRO & POWER AUTHORITY
VANCOUVER, CANADA
HAT CREEK COAL DEVELOPMENT
COAL LICENCES
GEOLOGY
SCALE 1" = 4000'
JUNE 1977
FIG. 3





INDEX MAP Scale 1:250,000

MAJOR ROADS

EXISTING PASSABLE ROADS

ROADS, REQUIRED MAJOR WORK

NOTES

1. SEMI-PERMANENT BRIDGE INSTALLED ACROSS HAT CREEK AT 82,250'N FOR ACCESS TO HOLES 76-122, 143, 146, 148, 150 ETC.
2. TEMPORARY CULVERT INSTALLED ACROSS HAT CREEK AT 80,450'N FOR ACCESS TO 76-198
3. CATTLE GUARD INSTALLED AT 77,450'N, 19,450'E DUE TO LARGE AMOUNT OF TRAFFIC FOR A RELATIVELY LONG PERIOD. THIS ROAD IS A MAIN ARTERY. CATTLE GUARD TAKEN FROM OLD ACCESS ROAD IN Nº. 2 DEPOSIT.

CONTOUR INTERVAL 10 FEET

N

400 0 400 800 1200 FEET

M024/1 (2)

DOLMAGE CAMPBELL & ASSOCIATES LTD. VANCOUVER, CANADA	CONSULTANTS
B.C. HYDRO & POWER AUTHORITY VANCOUVER, CANADA	
HAT CREEK COAL DEVELOPMENT	
DRILL SITE ACCESS ROADS	
SCALE 1" = 400'	JUNE 1977 FIG. 4

LEGEND

Spot Elevation	•5275	Lake	
Main Road		Creeks	
Secondary Road		Swamp	
Track or Trail		Ditch	
Buildings		Contours	3500
Fence	x	Depression Contour	
Dams		Trees	
Denotes Iron Bar with Numbered Identification Tag.	△4871		

COMPILATION NOTE

This map was compiled by McELHANNEY SURVEYING & ENGINEERING LTD. from aerial photography taken May 13, 1975 at an approximate scale of 1 inch to 2000 feet.

CONTROL NOTE

Mapping is based on ground control surveys established to 3rd order accuracy.

Coordinate origin is based on the prior D.C.A. drill hole survey with addition of 70,000 feet to Northings and 10,000 feet to Eastings.

Grid bearing is astronomic north through station 6259.

Horizontal distances are reduced to 3,000 foot elevation datum.

Elevation datum is geodetic, established from Geodetic Bench Mark 563J at Carquile.

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DOLMAGE CAMPBELL & ASSOCIATES LTD.

HAT CREEK COAL DEVELOPMENT

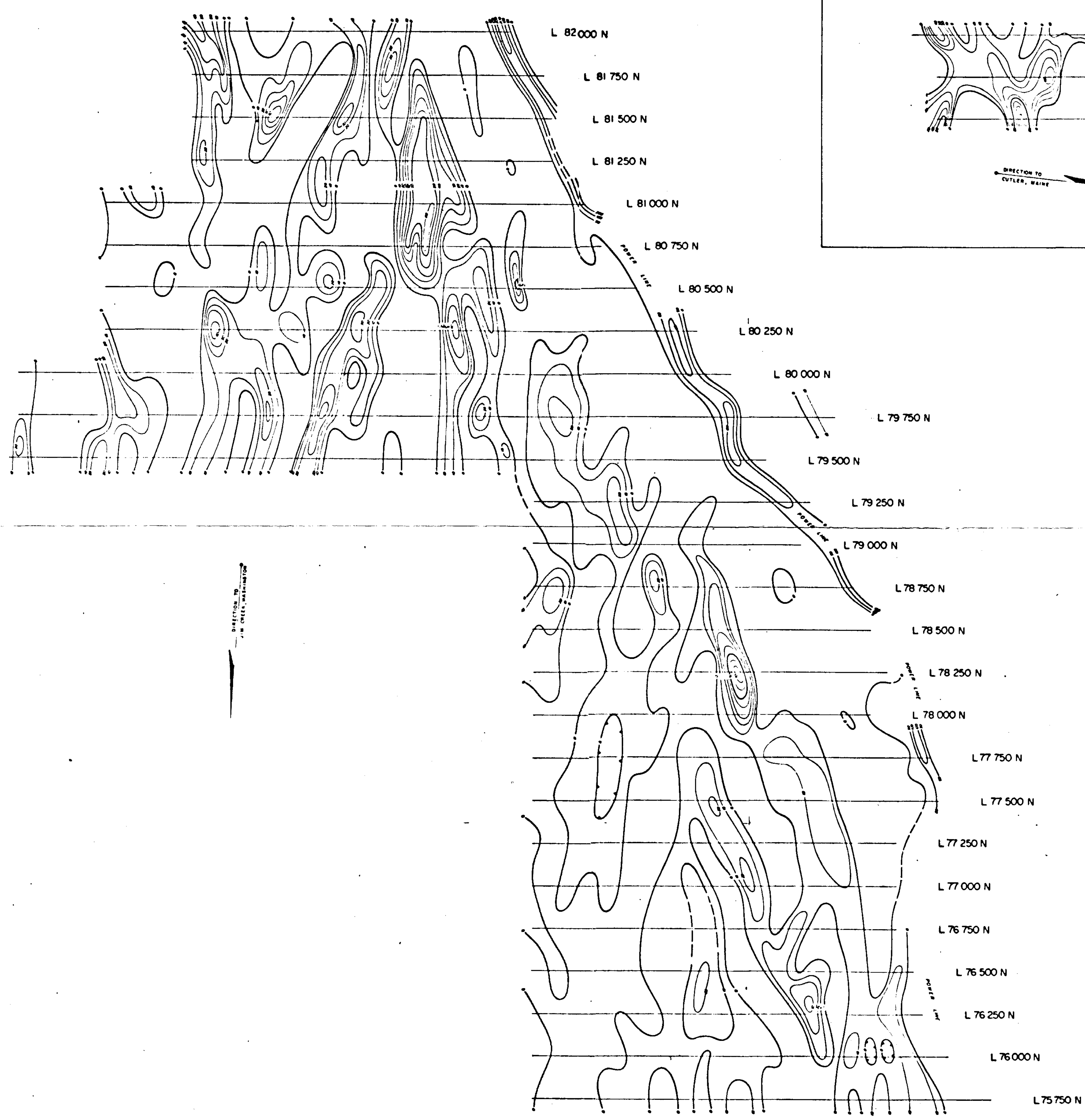
DRILL HOLE LOCATIONS

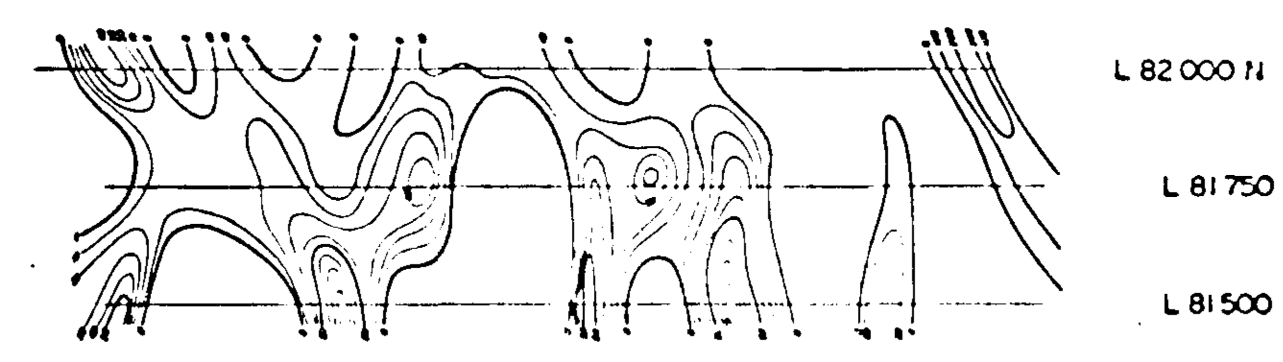
SCALE :- 1 INCH TO 2000 FEET

2000 1000 0 2000 4000 6000 8000 FT.

CONTOUR INTERVAL 50 FEET
(UP TO 4500 FEET)
100 FT. INTERVAL ABOVE 4500 FT.

MO24/1 3 JUNE 1977 FIGURE 5





FRASER FILTERED DATA
E.M. - 16
ELECTROMAGNETIC DATA
CUTLER, MAINE 17.8 KHz
SCALE: 1" = 400'

PLATE I

DOLMAGE, CAMPBELL & ASSOCIATES LIMITED

HAT CREEK PROPERTY
CACHE CREEK AREA, KAMLOOPS M.D. B.C.

CONTOUR PLAN

FILTERED
E.M. 16
ELECTRO MAGNETIC SURVEY
SEATTLE 18.6 KHz

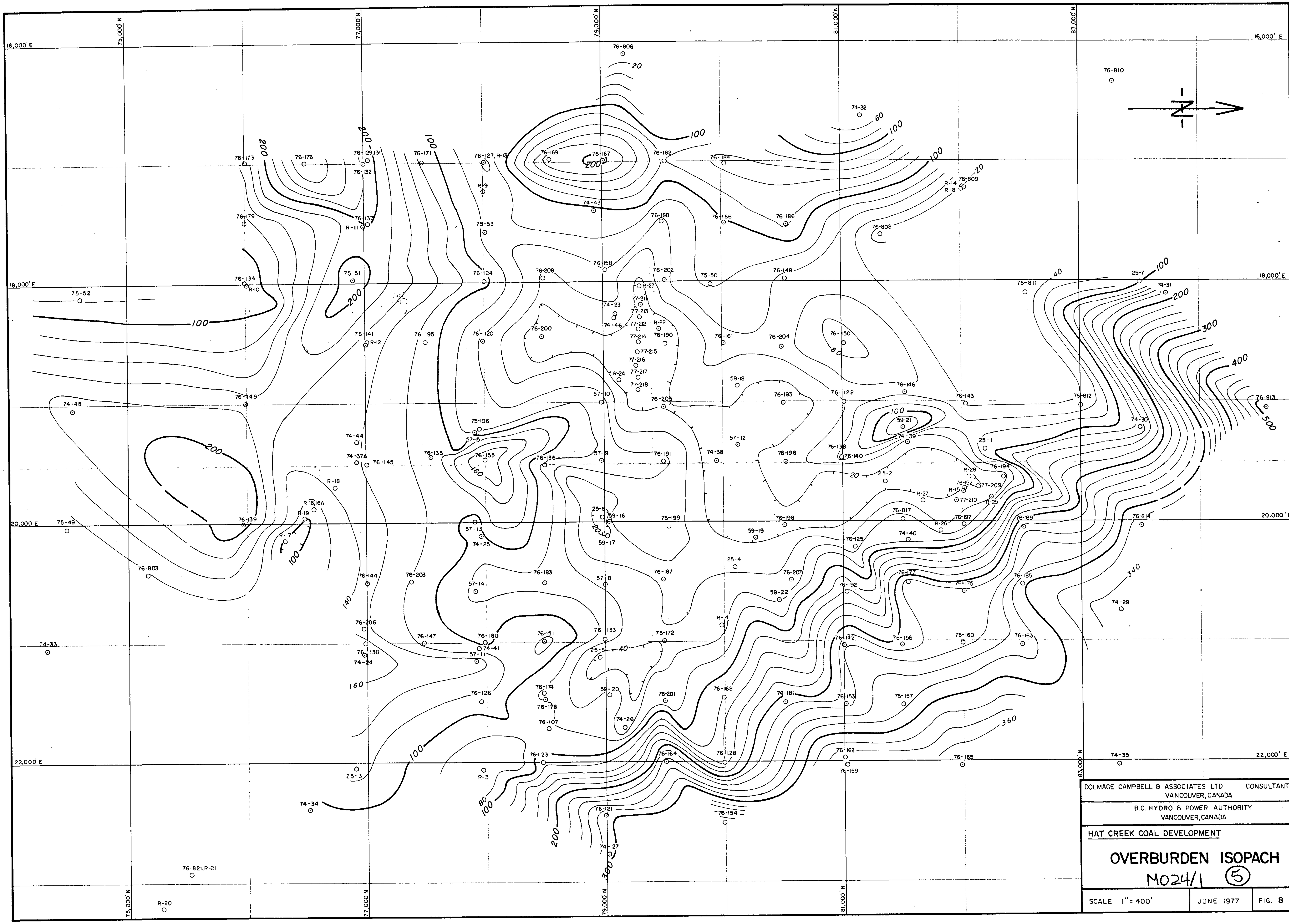
Scale:
1 inch = 400 feet

M024/1 (4)

DATE OCT. 5, 1976

RICHARD O. CROSBY & ASSOCIATES
JUNE 1977

FIG. 6



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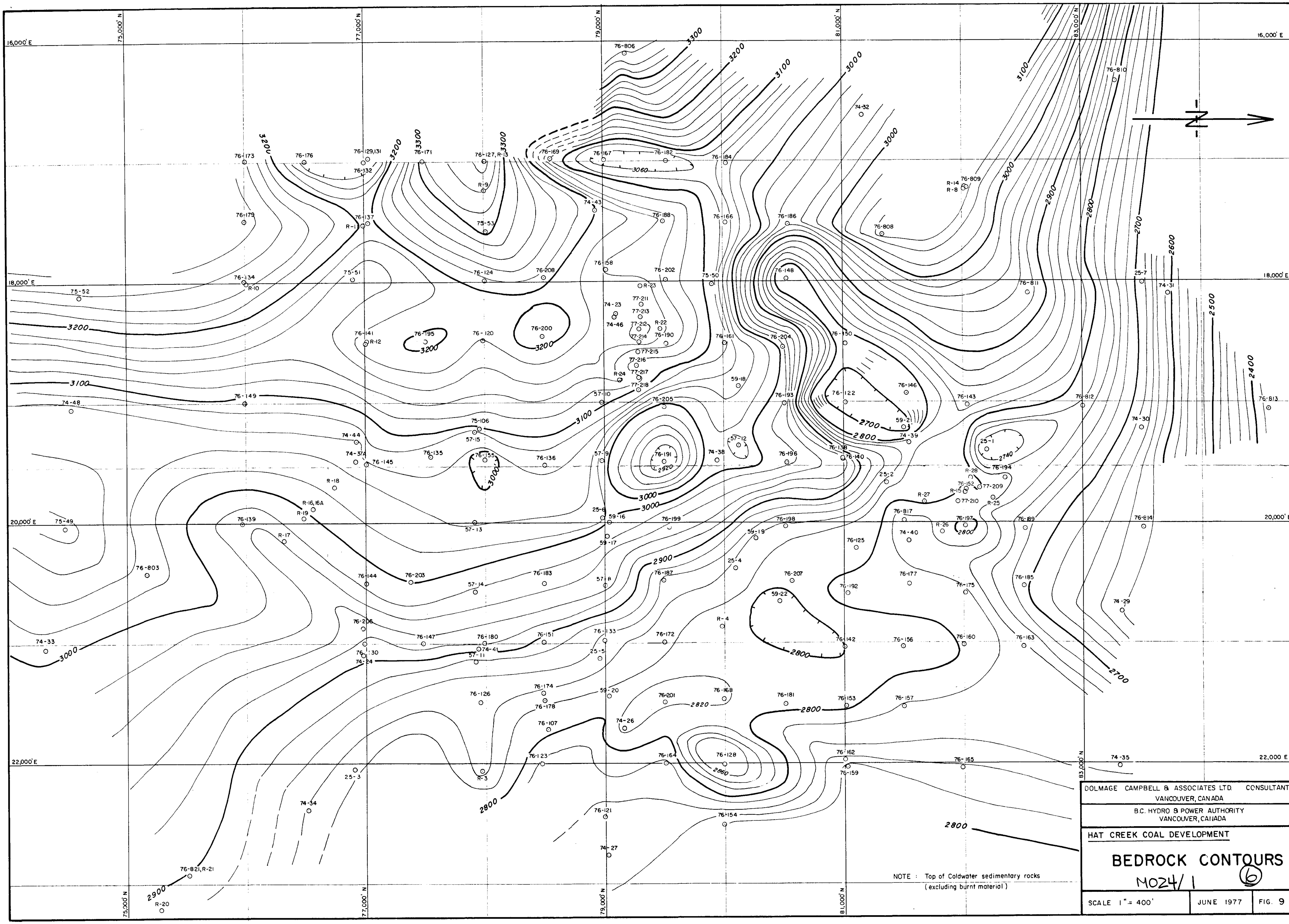
HAT CREEK COAL DEVELOPMENT

OVERBURDEN ISOPACH

M024/1 5

SCALE 1" = 400'	JUNE 1977	FIG. 8



NOTE : Top of Coldwater sedimentary rocks (excluding burnt material)

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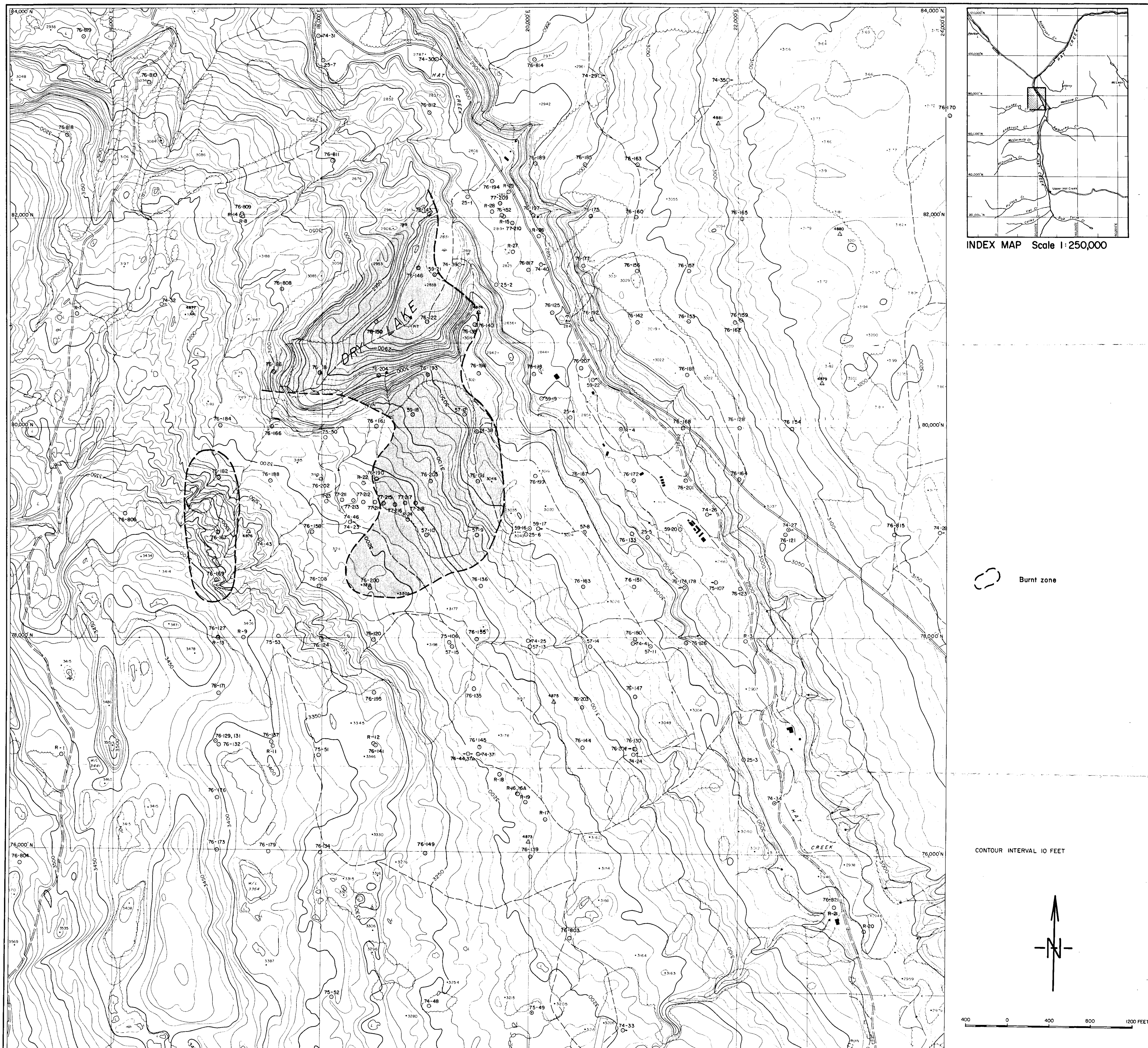
HAT CREEK COAL DEVELOPMENT

BEDROCK CONTOURS

M024/1 6

SCALE 1" = 400'	JUNE 1977	FIG. 9



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HAT CREEK COAL DEVELOPMENT

BURNT ZONE

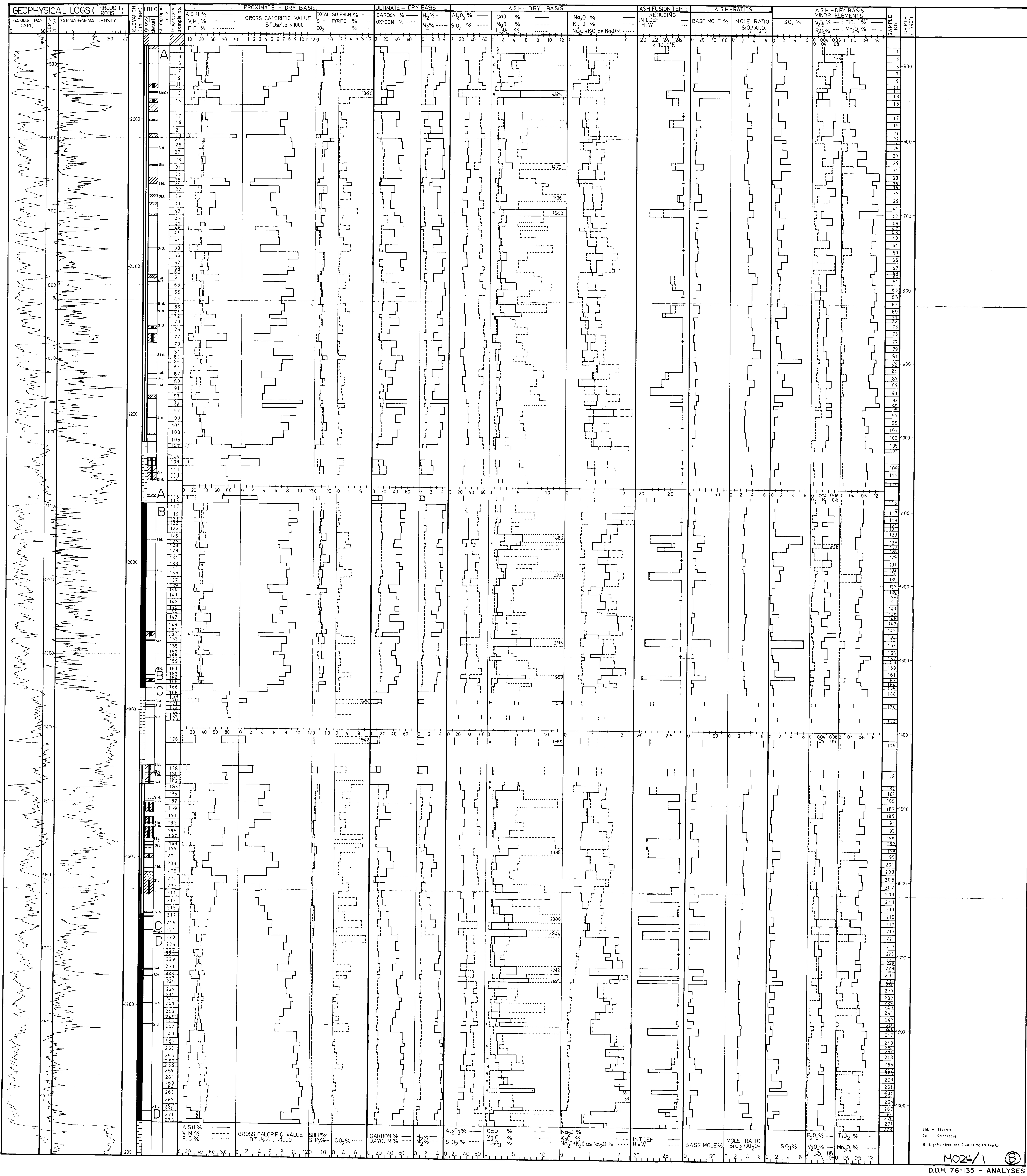
M024/1 (7)

SCALE 1" = 400' | JUNE 1977 | FIG. 10

B.C. HYDRO & POWER AUTHORITY

HAT CREEK DEVELOPMENT
D.D.H. 76-135 : ANALYSES

DOLMAGE CAMPBELL & ASSOCIATES



M024/1 (8)

D.D.H. 76-135 - ANALYSES

FIGURE 16