BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

GEOLOGICAL REPORT

NO. 1 DEPOSIT

VOLUME I - MAIN TEXT

THERMAL DIVISION

MINING DEPARTMENT

HAT CREEK PROJECT

GEOLOGICAL REPORT

VOLUME I

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SUMMARY AND CONCLUSIONS

This report summarizes the existing geological, geophysical and analytical data and related studies conducted in the No. 1 deposit Hat Creek valley.

The reserves, quality and structure presented are based on a 152.4 m (500 ft) grid drilling. Statistical studies for these parameters show a high level of confidence, from which it is concluded that the geological data are adequate for mine planning.

FUTURE WORK

The next phase of geological work will be directed towards mining-geology and economic evaluation of the mineable coal sections within the proposed pit.

Based on statistical evaluation of the geophysical, lithological and analytical data, bench plans and sections will be developed.

A detailed study of the surficial material will be incorporated into the geological sections and bench plans.

The geotechnical data, from the Golder Associates' Report, will be evaluated for application to mining.

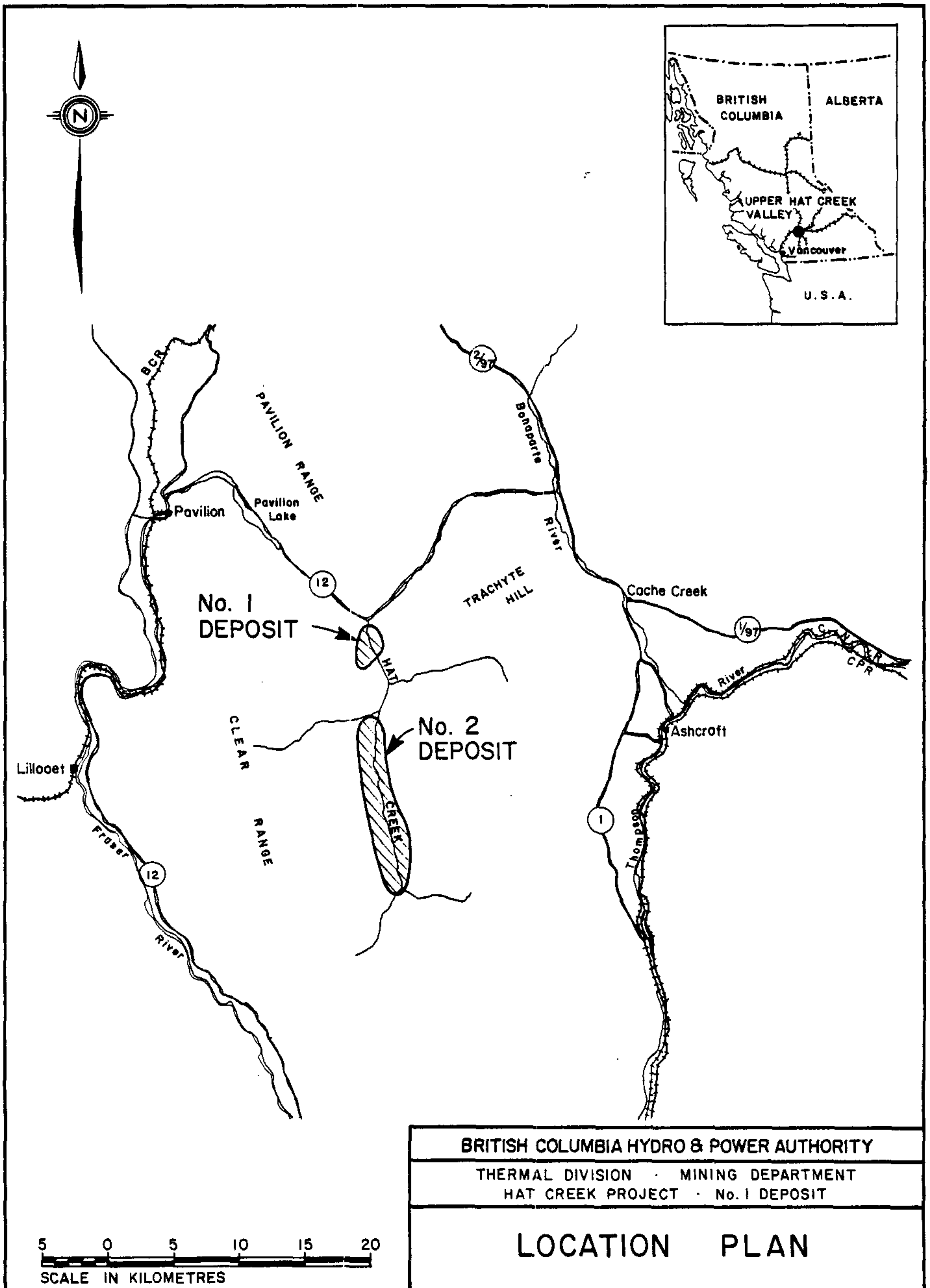
Although no further chemical tests for quality evaluation are envisaged, some tests may be required for material studies or for boiler design parameters.

Experience gained from the geological evaluation of the No. 1 deposit will be applied in interpreting the data of the No. 2 deposit and other potential deposits along the same trend.

1.0 - HISTORY OF EXPLORATION AND DEVELOPMENT

1.1 INTRODUCTION

The discovery of coal in the Hat Creek valley (Plate 1) was first reported in 1877 by G.M. Dawson[24] of the Geological Survey of Canada. In 1889, a drift of 18 feet in length was driven into the outcrop. The title to the property was acquired by Mr. Finney, a local rancher, in 1893. Mr. Finney sank a shaft to a depth of 125 feet near the lower exposure. Some coal was sold locally, but due to Finney's disappearance no further work was done until the property was acquired by a Chinese syndicate in 1923. They sank three shallow shafts, drove a 188-foot tunnel into the uppermost exposure, and sliced a 200-foot open-cut into the coal, 1800 feet downstream from the exposure. Two small tipples were erected, but before shipping operations commenced, the syndicate ran out of funds. The Clear Mountain Coal Company Limited took over the property and shipped three carloads of coal to Vancouver. The company went into bankruptcy due to slump in coal market. In 1925 the property was acquired by Hat Creek Coal Company Limited. They drove a tunnel 105 feet into the same exposure, about 600 feet north of the first tunnel and opened up a "room" on its north side. In addition, they completed seven diamond drill holes to prove up their holdings. From 1933 to 1942 there was limited coal production, but attempts to market the coal failed due to high ash content of the coal. In 1944 Western City Co., Ltd. optioned it to St. Eugene (of the Ventures Limited Group). In 1947, the Wilson Mining Corporation negotiated the formation of Inland Resources Co. Limited and obtained Crown lease for the development of the Hat Creek coal deposit. The 640 acres involved were held under lease by Mrs. Alfreda A. Leonard since 1937. In 1957, the property was optioned to Western Power and Development, Ltd. (a subsidiary of B.C. Electric Co., Ltd.). They excavated a number of trenches, completed eight diamond drill holes in 1957 and seven holes in 1959. In 1974 and 1975, B.C. Hydro obtained



BRITISH COLUMBIA HYDRO & POWER AUTHORITY

THERMAL DIVISION · MINING DEPARTMENT
HAT CREEK PROJECT · No. 1 DEPOSIT

LOCATION PLAN

SEPTEMBER 1979	PLATE 1

1.1 INTRODUCTION - (Cont'd)

coal licences covering most of the Upper Hat Creek valley (Plate 2). Active exploration and development of the property has continued since then.

Table 1 summarizes total metres drilled related to the development of the Hat Creek coal deposit from 1925 to 1978.

TABLE 1

SUMMARY OF HAT CREEK DRILLING
1925 to 1978

	No. 1 Deposit		No. 2 Deposit	
	No. of Holes	Meters	No. of Holes	Metres
Exploration	DH 228	58 412.8	DH 64	21 799.9
Geotechnical:				
Slope stability, foundation including geohydrological and offsite	DH 74 RH 77	9 714.9 7 996.7		
Miscellaneous:				
Surficial material investigation				
Washability sampling etc.	BAH) AH) 117 P)	2 117.7		
TOTAL	474	78 236.1	64	21 799.9

Legend: DH - Diamond drilling; RH - Rotary; BAH - Bucket auger hole; AH - Auger hole; P - Percussion

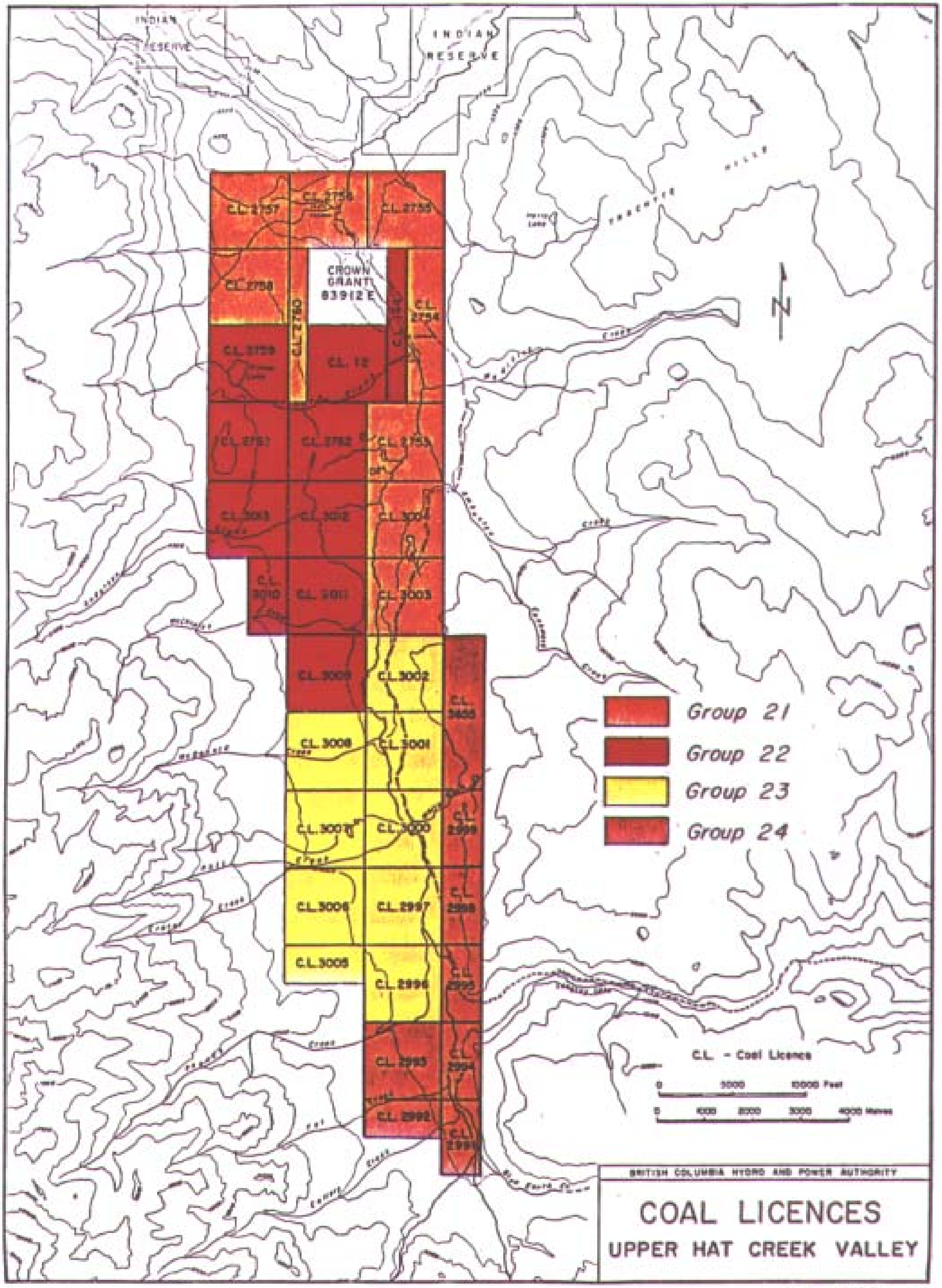

INDIAN RESERVE
INDIAN RESERVE
C.L. 2757
C.L. 2756
C.L. 2755
CROWN GRANT 83912 E
C.L. 2758
C.L. 2760
C.L. 2754
C.L. 2759
C.L. 12
C.L. 2751
C.L. 2752
C.L. 2753
C.L. 3013
C.L. 3012
C.L. 3004
C.L. 3010
C.L. 3011
C.L. 3003
C.L. 3009
C.L. 3002
C.L. 3008
C.L. 3001
C.L. 3007
C.L. 3000
C.L. 2999
C.L. 3006
C.L. 2997
C.L. 2998
C.L. 3005
C.L. 2996
C.L. 2995
C.L. 2993
C.L. 2994
C.L. 2992
C.L. 2991
Group 21
Group 22
Group 23
Group 24
C.L. - Coal Licence
0 5000 10000 Feet
0 1000 2000 3000 4000 Metres
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
COAL LICENCES
UPPER HAT CREEK VALLEY

PLATE 2

1.2 DRILLING

Since 1974 the types of drilling used in the Hat Creek property included core, rotary, auger and percussion drilling. The 1974 drilling was done for the evaluation of the No. 1 deposit; in 1975 exploratory drilling was undertaken for the No. 2 deposit to the south. Since 1976, all exploration and drilling programs were directed towards the development of the No. 1 deposit.

The core drilling program since 1974 was conducted by D.W. Coates Enterprises Ltd. The slope stability and plant site coring program was performed by Tonto Drilling Co. Both companies employed skid-mounted Longyear 44 and Boyles Super 38 diamond drill rigs. For the exploration and development coring, NQ-size wireline equipment was used; usually overburden was triconed. Some of the geotechnical holes used HQ-size wireline equipment and generally the overburden was also cored. All the core has been photographed and geologically logged. The core is stored on the property in core storage sheds mounted on log skids. Some of the 1957 and 1959 core was sampled by rejecting the interbedded clay fractions and treating the underlying and the overlying coals as one samples. A split of this coal and the intervening clay partings have been stored. Obviously, these are of limited value for proper quality evaluation.

Rotary drilling was carried out for slope stability studies which included installation of slope indicators, permeability testing and pump test observation wells. A & H Construction Ltd., the Contractors, used a truck-mounted Speed Star FS 15 air-flush rig.

Large coal samples for coal washability and combustion tests were obtained in 1976 by drilling a series of 36-inch diameter bucket auger holes. These were drilled by Pacific Water Wells using a Caldwell Model 200. In addition, auger holes were drilled in 1977 to predict the coal quality in Trench "A" before commencing the mining operation for the Bulk Sampling Program.

1.2 DRILLING - (Cont'd)

The percussion holes were drilled by Becker Drills Ltd. with a truck-mounted Becker hammer drill. Data from the percussion holes were used for the foundation related studies of the ash dam.

Fig. 1 summarizes total drilling by diamond, rotary auger and percussion methods for the No. 1 deposit.

1.3 TOPOGRAPHIC AND CONTROL SURVEYS

Aerial photography surveys were carried out in 1975, 1976 and 1978 to provide topographic maps and control for exploration work.

The 1975 survey was carried out by McElhanney Surveying and Engineering Ltd. and consisted of:

1. Aerial photographs of three N-S lines on a scale of 1 inch = 2000 feet.

2. An orthophoto of the entire upper Hat Creek valley on a scale of 1 inch = 2000 feet (McElhanney reference No. 06185-0).

The 1976 survey, which was also done by McElhanney, consisted of:

1. Three east-west lines of aerial photographs on a scale of 1 inch = 2000 feet.

2. Ten north-south lines of colour aerial photographs on a scale of 1 inch = 2000 feet.

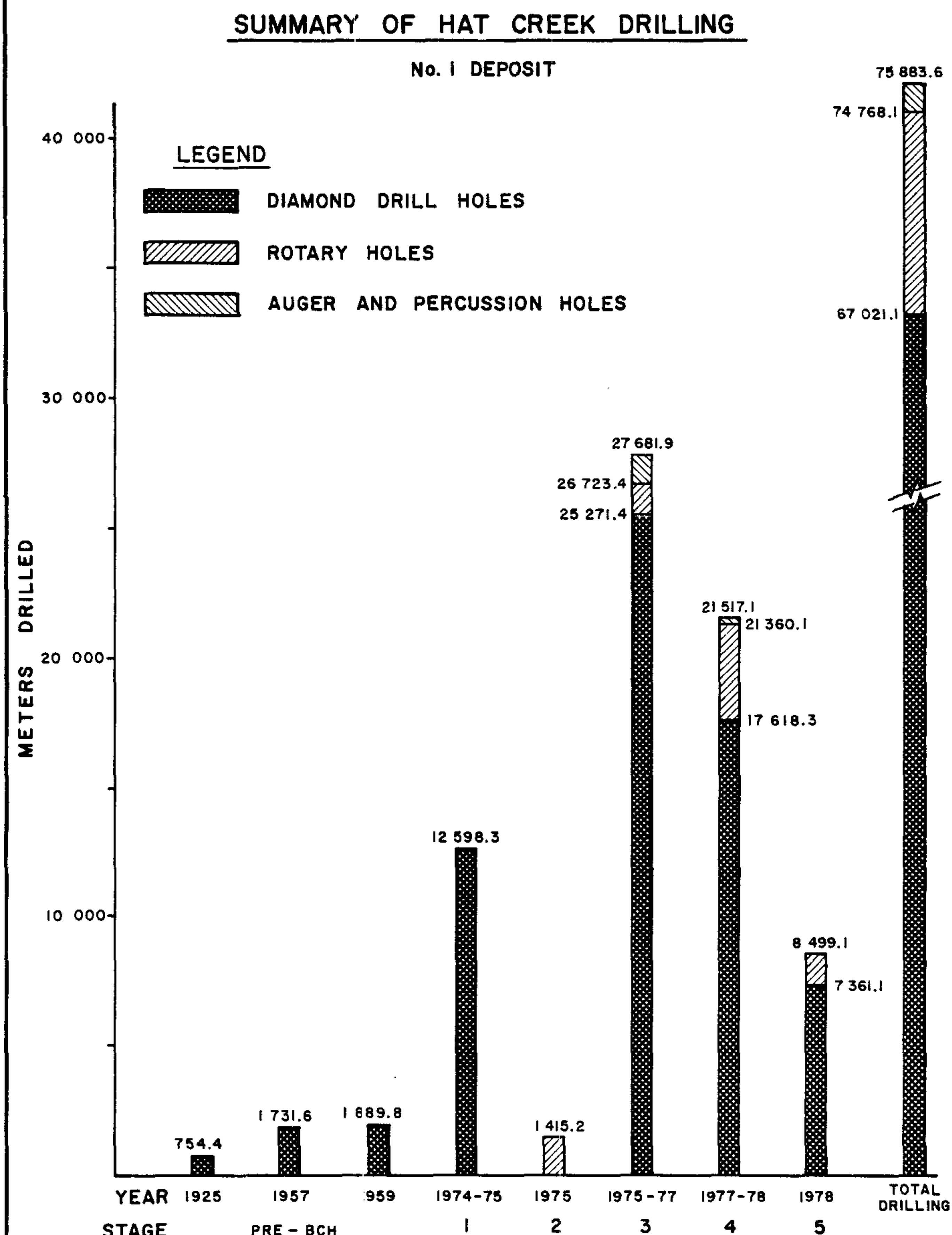

SUMMARY OF HAT CREEK DRILLING
No. 1 DEPOSIT
LEGEND
DIAMOND DRILL HOLES
ROTARY HOLES
AUGER AND PERCUSSION HOLES
METERS DRILLED
40 000
30 000
20 000
10 000
754.4
1 731.6
1 689.8
12 598.3
1 415.2
27 681.9
26 723.4
25 271.4
21 517.1
21 360.1
17 618.3
8 499.1
7 361.1
75 883.6
74 768.1
67 021.1
YEAR
1925
1957
1959
1974-75
1975
1975-77
1977-78
1978
TOTAL DRILLING
STAGE
PRE - BCH
1
2
3
4
5

FIG. 1

1.3 TOPOGRAPHIC AND CONTROL SURVEYS - (Cont'd)

The 1978 survey produced:

1. Three north-south lines and one east-west line of aerial photographs by the provincial government on a scale of 1;46 000.

2. Twelve north-south lines of aerial photographs by Integrated Resources Photography Ltd., Vancouver, B.C. on a scale of 1;10 000.

Elevation control was established by running third-order levels from a geodetic bench mark near the junction of Highways 12 and 197. The survey bench marks established by McElhanney Surveying and Engineering Ltd. in 1976 served as ground control in the area of the No. 1 deposit.

1.4 DRILL HOLE SURVEYING

The drill holes were surveyed from control points established by McElhanney. Survey results are contained in the "Record of Completed Drill Holes" (Appendix 2).

1.5 ACCESS ROADS, DRILL SITES AND RECLAMATION

The trails and some roads were built by E. Lehman, a local resident. He also prepared the drill sites, access roads, and moved the drill rigs for the drilling contractor.

Drill sites were cleaned and levelled after drilling finished. Mud pits used for the collection of drilling fluids were pumped out and restored to the natural ground contours. The drill sites were seeded with a mixture developed by B.C. Hydro for use in the Hat Creek region. Drill hole collars are marked by 4 inch x 4 inch posts.

1.6 GEOPHYSICS

The geophysical work at the Hat Creek property included surface geophysical surveys, an airborne magnetometer survey, and downhole geophysical survey.

The surface geophysical surveys which were done on an experimental basis included gravity, magnetic, vertical loop electromagnetic, induced polarization, resistivity, infrared and daedalus-sliced film. The gravity survey was useful in defining the boundaries of the coal basin. The magnetic survey was found useful for regional geologic mapping and effective in delimiting the outcrops of the Tertiary volcanics and burned zones below the overburden. The electromagnetic survey detected some fault zones, while induced polarization, resistivity, infrared and daedalus-sliced film gave poor results. Induced polarization was not useful because of the scarcity and lack of orientated polarizable minerals in the deposit. The resistivity method was not practical, because both the host rock and the coal have comparable low electrical resistivities. The infrared method failed to pick up any potential hot spots, and the daedalus-sliced film showed nothing significant.

Listed below is a chronological list of the surface geophysical surveys:

1. Magnetometer survey to outline the extent of the deposit in September-October 1974 by McPhar Geophysics over the Hat Creek valley.

2. An additional magnetometer survey to outline the volcanic rocks and burned zone in the summer of 1975 by B.C. Hydro covering the entire Hat Creek valley.

3. Gravity survey to locate the presence and extent of coal deposits in the summer of 1975 by C.A. Ager and Associates Ltd. covering the entire Hat Creek valley.

1.6 GEOPHYSICS - (Cont'd)

4. Vertical loop electromagnetic survey designed to trace faults in October 1976 by Richard O. Crosby and Associates over the No. 1 deposit.

5. Magnetometer survey for embankment foundation investigations in the fall of 1977 by Klohn Leonoff and Associates Ltd. over the Medicine Creek and Houth Meadows disposal sites.

The airborne magnetometer survey was done in 1972 by Geoterics for the Dept. of Energy, Mines and Resources as part of a major mapping project.

The downhole geophysical survey included natural gamma ray, density, caliper, spontaneous potential, neutron, resistance and acoustical logging.

1.7 SLOPE STABILITY

Slope stability studies have been carried out since 1975. R.M. Quigley undertook mineralogical studies, which are summarized in a number of letters and a report titled, "Preliminary Mineralogical Analyses - Hat Creek Coal Measures, B.C.", in May 1975. Klohn Leonoff Consultants Ltd. conducted Atterberg limit tests and strength tests in early 1975. Simple field slaking tests were carried out on several hundred core samples over a 24-hour period. Golder Associates Ltd. carried out field and laboratory works to obtain rock strengths, groundwater conditions and related geotechnical data during the summer of 1976. In the 1977 program, the following aspects were emphasized:

1. obtaining additional data on the pit slope angles made in the 1976 study,

2. investigating groundwater pressure relief to stabilize the pit slope walls, and

1.7 SLOPE STABILITY - (Cont'd)

3. investigating foundation stability of the proposed waste dump embankment locations and possible interaction with the excavated pit.

In 1978, Golder Associates carried out additional work to:

1. verify conclusions regarding the groundwater pressure relief in previous works,

2. investigate the retaining embankment foundations for an enlarged waste dump at Medicine Creek,

3. continue with proposed pit slopes investigations,

4. define the deep slide material in the slide areas to the south-west of the pit,

5. continue the program of material strength testing in the laboratory, and

6. seismic survey for embankment foundation investigations over the Medicine Creek and Houth Meadows disposal sites by Klohn Leonoff, a sub-consultant to Golder Associates.

Since the 1978 Golder Associates' field program, field-monitoring the instrument installed during the course of earlier investigations has been continued to the present.

2.0 - REGIONAL GEOLOGY

The geology of the Hat Creek area was first reported by Dawson[24] in 1877, followed by MacKay[71] in 1926. In 1951, Duffell and McTaggart[38] mapped the geology of the Hat Creek area and the neighbouring Fraser and Thompson River valleys. Part of the Fraser valley between Lillooet and Big Bar Creek was mapped by Trettin[95] in 1960, but this work did not extend to the No. 1 deposit. The surficial geology in the Fraser and Thompson River valleys has been studied by Ryder[87,88] in 1968 and 1976, and by Aylsworth[3] in 1975. Two reports on the "Geology of the Hat Creek Coal Basin" were published by B.N. Church[19,20] in 1975 and 1977. T. Höy[55] (1975) published a paper, "Geology of a Tertiary Sedimentary Basin NE of Hat Creek".

Since undertaking detailed geological and geotechnical investigations in the Hat Creek valley in 1974, Dolmage Campbell & Associates (Geological Consultants), Golder Associates (Geotechnical Consultants) and B.C. Hydro personnel have been actively involved in geological mapping, exploration drilling and coal quality studies. These studies are presented in various reports for B.C. Hydro.

Extensive deposition of surficial materials during glaciation in the Pleistocene epoch left most of the area of the upper Hat Creek valley devoid of bedrock exposures. Structural and stratigraphic features lie buried beneath glacial deposits and/or post-Eocene volcanics. As a result, the geological interpretation of the Hat Creek coal basin has been based primarily on drilling and geophysical data. The bedrock geology in the No. 1 deposit area is shown on Fig. 7.

2.1 STRATIGRAPHY

The stratigraphic sequence shown in Table 2 covers a span of over 200 million years of sedimentation processes and igneous activities.

Table 2

REGIONAL STRATIGRAPHY - HAT CREEK COAL BASIN

Period	Epoch	Million Years	Formation or Group	Thickness (m)	Rock Types
Quaternary	Recent			Not Determined	Alluvium, Colluvium, fluvial sands and gravels, slide debris, lacustrine sediments.
	Pleistocene	1.5 - 2			Glacial till, glacio-lacustrine silt, glacio-fluvial sands and gravels, land slides.
Unconformity					
Tertiary	Miocene	7 - 26	Plateau Basalts	Not Determined	Basalt, olivine basalt (13.2 m.y.), andesite, vesicular basalt.
	Unconformity (?)				
	Miocene or Middle Eocene ?		Kamloops Group: Finney Lake Formation	Not Determined	Lahar, sandstone, conglomerate.
			Unconformity		
	Late Eocene		Kamloops Group: Medicine Creek Formation	600+	Bentonitic claystone and siltstone.
			Paraconformity		
	Late Eocene to Middle Eocene	* 36 - 42	Kamloops Group: Hat Creek Coal Formation	550	Mainly coal with intercalated siltstone, clay-stone, sandstone and conglomerate.
			Kamloops Group: Coldwater Formation	375	Siltstone, claystone, sandstone, conglomerate, minor coal.
			Fault Contact or Nonconformity		
	Middle Eocene	43.6-49.9	Kamloops Group	Not Determined	Rhyolite, dacite, andesite, basalt and equivalent pyroclastics.
Unconformity (McKay 1925; Duffell & McTaggart 1952)					
Cretaceous or Later	Coniacian to Aptian **	88.3±3 m.y.	Spences Bridge Group	Not Determined	Andesite, dacite, basalt, rhyolite; tuff breccias, agglomerate.
	Erosional Unconformity (Duffell & McTaggart 1952)				
		98	Mount Martley Stock	Not Determined	Granodiorite, tonallite.
Intrusive Contact (Duffell & McTaggart 1952)					
Pennsylvanian to Permian or earlier		250-330	Cache Creek Group: Marble Canyon Formation	Not Determined	Marble, limestone, argillite
			Cache Creek Group: Greenstone	Not Determined	Greenstone, chert, argillite; minor limestone and quartzite, chlorite schist, quartz-mica, schist.

* Based on palynology by Rouse 1977

** Based on plant fossils by Duffell & McTaggart 1952.

2.1 STRATIGRAPHY - (Cont'd)

The lowest stratigraphic unit is the Cache Creek Group, which has been divided into the Marble Canyon Formation and the Greenstone. The Marble Canyon Formation consists mainly of limestone, forming the Pavilion Range to the north, and the Cornwall Hills to the southeast (Plate 3). The Greenstone outcrops in the Trachyte Hills between the two limestone belts. The limestones near Marble Canyon have been intruded by the Mount Martley stock which is composed of granodiorite and tonalite of the Cretaceous period, coeval with the Lytton Batholith intrusion (MacKay[71]). The foliation and relict bedding in these rocks are nearly vertical to steeply dipping towards the west and trend north and northwest (Traverse,[94] 1978).

The Spences Bridge Group of the Cretaceous period is poorly exposed in the Clear Range of the Hat Creek valley. It consists of gently dipping lavas and pyroclastics composed mainly of dacite and andesite (Church[19,20]). The general trend of these volcanic layers conforms to those of the Cache Creek Group. The lower contact of the Spences Bridge volcanics with the Mount Martley stock appears to be an erosional unconformity. The upper contact relationships are not exposed but are assumed to be unconformable (MacKay[71]).

The Kamloops Group of the Miocene and/or Eocene epoch consists of a wide variety of rock units. The lowest lithologic unit of the Kamloops Group is exposed on the hills of the western and eastern flanks of the Hat Creek valley. These exposures are generally composed of rhyolite, dacite, basalt lavas and bedded pyroclastic rocks. The attitude of these layers varies throughout the valley and are in fault contact with the overlying sedimentary successions.

The sedimentary assemblage of the Tertiary period has been subdivided, in descending stratigraphic order, into "Finney Lake Beds, Medicine Creek Formation, Hat Creek Coal Formation and Coldwater Beds" by Church.[19,20]

2.1 STRATIGRAPHY - (Cont'd)

The term "Coldwater Beds" appeared in Dawson's Annual Report[25] to represent the basal Tertiary sandstone, conglomerate, the coal formation (Hat Creek Coal Formation) and the younger sedimentary rocks (Medicine Creek Formation). Since then, the term "Coldwater Group" has been used for the Nicola Lake coal deposit by Charles Camsell in his report on the Princeton coal area. He has also used the term "Coldwater Series" for a series of rock members of Oligocene age lying in the drainage basin of Collins Gulch and extending over the divide to the Granite Creek Slope (Camsell, C., GSC, Memoir 26). Such variation in the use of the term "Coldwater Series" arose because the formation included a large thickness of undefined sedimentary mass.

Extensive drilling and analytical work clearly established the non-coal-bearing unit at the bottom, the coal bearing unit in the middle followed by a barren unit at the top. It is therefore suggested that the term "Coldwater Formation" be used to represent the unit underlying the Hat Creek Formation. In this report "Formation" is used for the Coldwater Beds and Finney Lake Beds.

Generally, the sedimentary rocks in the Kamloops Group are semi-indurated and are derived from the underlying igneous, sedimentary and metamorphic assemblages, viz Cache Creek Group, Kamloops Group, Mount Martley stock and Spences Bridge Group (Dawson;[25] Duffell and McTaggart[38]).

The lowermost clastic unit of the Eocene epoch is the Coldwater Formation consisting of sandstone, siltstone, claystone, conglomerate and minor coal. The section exposed along Highway 12 near the Bonaparte Indian Reserve measures 1360 m (Höy[55]). In the upper Hat Creek valley, the Coldwater Formation is faulted against the Marble Canyon limestone on the northwest and the Medicine Creek Formation on the east and northeast. The contact relationship with the Spences Bridge Group southeast of the Finney Lake may be an unconformity.

2.1 STRATIGRAPHY - (Cont'd)

Conformably overlying the Coldwater Formation is a thick succession of about 550 m of coal measures known as the Hat Creek Coal Formation. In the No. 1 deposit, the formation undergoes rapid lithofacies change from coal to waste rock in a southwest direction. The interbeds in the coal measures are composed of claystone, siltstone, sandstone and conglomerate. These lithologic interbeds represent a break in the normal cycle of peat deposition. The lowermost coal sequence suggests a quieter period of deposition in a slow sinking basin. In the later phases, a turbulent and oscillatory condition followed, resulting in the deposition of siltstone, claystone and bentonitic clay with varying thickness of coal.

The Hat Creek Coal Formation is overlain by the Medicine Creek Formation - a uniform succession of bentonitic claystone and siltstone formed in a lacustrine environment. The claystones are semi-indurated. The unit is generally olive grey when wet and cream coloured when dry. Due to the soft nature of these rocks, very few exposures of this unit are found in the Hat Creek valley. The sharp paraconformable contact of the Medicine Creek Formation with the coal measures indicates a rapid facies change from moor (marsh) to lacustrine depositional conditions. The thickness of the formation is unknown due to the upper contact being either eroded or faulted. Hole DDH 130 on Section U (Plate 29) indicates a thickness in excess of 550 m.

The Finney Lake Formation represents the uppermost stratigraphic unit of the Kamloops Group of the Miocene and/or the Eocene epoch. This unit unconformably overlies the Medicine Creek and/or the Hat Creek Coal Formations. It consists principally of sandstone and conglomerate in the lower section, overlain by lahar beds. These sandstones and conglomerates appear to be lithologically similar to the Coldwater Formation. The sandstones are, for the most part, reported to be well sorted and stream-worked (Church[20]). The lahars are made up of angular to sub-rounded boulders in a clayey matrix derived from the

2.1 STRATIGRAPHY - (Cont'd)

lower Kamloops volcanics. They may be in part related to slide debris and volcanic rubble flows deposited near the volcanic activity. The lahar beds outcrop immediately east of Finney Lake and above the main roads, about 250 m south of the Medicine Creek junction (Plate 3).

The youngest volcanic rocks in the area are olivine basalt, basalt, vesicular basalt, andesite (locally) and the equivalent pyroclastics of the Miocene epoch. A flow or dyke of these rocks occurs in the headwall of the active slide and apparently overlies the Kamloops Group and the Coldwater Formation. Potassium-argon dating of the olivine basalt indicates a Mid-Miocene epoch of 13.8 ± 0.5 million years (Church[20]).

During the Pleistocene epoch the entire Hat Creek area, along with much of the Interior Plains, underwent extensive glaciation. This resulted in the deposition of a variety of glacial and glacio-fluvial sediments, ranging in thickness from a few metres to 200 m. The area between Finney Lake and Houth Meadows has been recognized as a post-glacial slide zone. Parts of the slide to the northwest of the deposit are still active and appear to be partly associated with the bentonitic claystones predominating throughout the Hat Creek valley.

2.2 STRUCTURE

The Hat Creek No. 1 deposit lies in a northerly-trending topographic depression within the southwest part of the Intermontane Belt of the Canadian Cordillera. The Fraser River separates the Intermontane Belt from the Coast Plutonic Complex. Published reports indicate that the tectonic elements in the Intermontane valleys during the Tertiary Period were subdued and different in character from the eastern and northern structural elements of the Cordilleran Region. During the Eocene epoch, non-marine, synorogenic and syntectonic clastic sediments were deposited, succeeded and/or preceded by the accumulation of sub-aerial volcanics. Mid-Tertiary erosional

2.2 STRUCTURE - (Cont'd)

activities resulted in widespread surfaces of low relief. The main physiographic features of the Fraser and Thompson River drainage systems were well established at this time.

The general structure of the Tertiary Coal Basin in the Hat Creek valley is a graben, flanked on either side by gravity faults. This interpretation of the structure is based on the regional tectonic trend and the available geological records.

Some evidence of post-Miocene uplift and rejuvenation along the Fraser River was noted by Drysdale and Duffel and McTaggart.[38] But this subsequent uplift of "the rise of the region" would not have been significant enough to produce reverse faulting with large-scale displacement (Eisbacher[42]).

These "grabens" were formed principally by downward movement on a series of north-south tensional faults. Transverse faults trending northwest and northeast have offset the graben in places. It may be that the vertical or steep south-eastward-dipping attitudes of the normal faults were modified by secondary faulting, resulting in an apparent westerly attitude, which is reflected in the Finney Fault. Subsequently, under various conditions of stress, additional shear fractures and strike-slip faults showing little displacement might have been utilized for later differential vertical movement.

An alternate explanation of the south-westerly-dipping attitude of the Finney Fault is simply a "steep reverse fault transverse to the graben" (Billings[4]). Within these fault blocks, the sedimentary strata are broadly folded, forming a pair of southerly-plunging synclines near the north end of the valley. In the vicinity of Harry and Aleece Lakes, the beds are steeply folded and affected by transcurrent faults.

2.2 STRUCTURE - (Cont'd)

The widespread occurrence of strike-slip faulting, internal thrust-faulting and local overturning in the A-Zone may be explained by "compressive forces acting upwards". However, these compressive forces do not appear to be strong enough to cause a major regional uplift. For the same reason, it would be highly speculative that the Marble Canyon Formation forming the Pavillion Mountain north of the Hat Creek coal deposit has been elevated in excess of 2000 m by compressive forces with high-angle reverse faulting. It should be also noted that there is no definite geo-chronological record for a large regional uplift of post-Eocene time (Price and Mountjoy[83] and Eisbacher, Corrigy and Campbell[41,42]). Further, the structure of a Tertiary sedimentary basin northeast of the Hat Creek coal deposit studied by Höy 1954 in detail was stated to be "half-graben" down-dropped along its eastern margin.

3.0 - GEOLOGY OF NO. 1 DEPOSIT

The upper Hat Creek valley contains the thickest known low-grade coal deposit in the world. Of the two deposits studied, No. 1 deposit in the north has the greater potential for open-pit mining. Most of the exploration activities to date have been directed towards its development. No. 2 deposit to the south contains coal resources much greater than No. 1 deposit, but is less favourable because of its higher stripping ratio.

3.1 STRATIGRAPHIC SUBDIVISION OF THE HAT CREEK COAL FORMATION

The sediments within the basin have been divided, in ascending stratigraphic order, into three formations: the Coldwater Formation, the Hat Creek Coal Formation and the Medicine Creek Formation.

Based on lithological and geophysical logs and core quality, four zones, A, B, C and D were recognized within the Hat Creek Coal Formation. Further work identified two distinct waste zones between A and B, and B and D, which have been correlated over the entire deposit. With close pattern-drilling and a further interpretation of the geophysical logs, it was possible to subdivide it further into 16 sub-zones. The development of the stratigraphy of the Hat Creek Coal Formation is shown in Table 3. The concept for the stratigraphic subdivision was developed from the principal of differential natural gamma ray emission of claystone and coal, where the former contains more radio-active material than coal. Such variation in the natural gamma ray variation and bulk density (grams/cc) and the corresponding variation in lithology have provided the basis for the 16 sub-zones (Plate 7) and their correlation in cross sections.

Table 4 shows the thickness range of the sub-zones in the No. 1 deposit.

Table 3

DEVELOPMENT OF STRATIGRAPHIC SUBDIVISION IN HAT CREEK COAL FORMATION

STAGE I	STAGE II	STAGE III	STAGE IV
A	A_1	A_{1-1} A_{1-2} A_{1-3} A_{1-4}	A1 A2 A3 A4 A5
	A_2(waste zone)	A_{2-1}	A6
B	B_1	B_{1-1} B_{1-2}	B1 B2
C	C_1(waste zone)	C_{1-1}	C1
	C_2	C_{2-1} C_{2-2}	C2 C3 C4
D	D_1	D_{1-1} D_{1-2} D_{1-3} D_{1-4}	D1 D2 D3 D4
Recognition of four broad zones in the No. 1 Deposit.	Identification of two waste zones - A_2 and C_1.	A_1 - divided into four subzones separated by three waste partings. B_1 - divided into two subzones. C_2 - divided into two subzones separated by a lenticular waste parting. D_1 - divided into four subzones of varying quality.	For uniformity and convenience each subzone was assigned its own suffix. Thus A_{2-1} and C_{1-1} the principle waste zones are represented by A6 and C1 respectively. Four additional subzones were introduced: A5, C2, C3 and C4.

TABLE 4

THICKNESS VARIATION OF SUB-ZONES

Zone	Thickness (m)
A1	15 to 35
A2	20 to 55
A3	25 to 45
A4	20 to 45
A5	30 to 45
A6	0 to 90
B1	25 to 35
B2	25 to 35
C1	0 to 170
C2	5 to 20
C3	5 to 15
C4	5 to 20
D1	15 to 25
D2	15 to 30
D3	15 to 25
D4	15 to 20

3.1 STRATIGRAPHIC SUBDIVISION OF THE HAT CREEK COAL FORMATION - (Cont'd)

A-Zone

The A-Zone represents the uppermost and youngest stratigraphic unit in the Hat Creek Coal Formation. Deposition of A-Zone was interrupted by periodic flooding or sediment influx from the south. This is reflected in the numerous lithologic interbeds in the coal measures and their increasing thickness in the south.

For this study, A-Zone was divided into six sub-zones:

A1: This sub-zone grades upward from sandy siltstone, through carbonaceous and coaly shale or claystone to coal. It is approximately 80 percent coal and 20 percent waste. The top of this unit is the bottom of the Medicine Creek Formation in the geophysical logs. It is characterized by the sharp contact with the claystone of the latter.

A2: This contains mainly coal with relatively little rock. The sub-zone is roughly 95 percent coal, 5 percent mixed carbonaceous shale, siltstone and/or claystone. The upper and lower contacts are sharp.

A3: This sub-zone consists of mixed coal, carbonaceous shale, siltstone and claystone. It is about 50 percent coal, 10 percent carbonaceous shale and 40 percent non-coaly rock. The upper and lower contacts are sharp. The lower contact grades from waste rock to coal. Towards the upper contact the grading cycle is reversed, going from coal to waste.

A4: This sub-zone is similar to the A1 unit in lithologic character, and the distribution of coal to waste is roughly the same. The top of this unit is sharply defined by a siltstone or claystone bed, which is readily identified by its high density (near 2.2 grams/cc).

A5: The A5 unit is roughly 60 percent coal, 35 percent carbonaceous shale and 5 percent other rocks. The top is sharply defined by claystone or sandstone.

A6: This is essentially a waste rock unit consisting of siltstone, sandstone, conglomerate and minor carbonaceous claystone. It thins to the northeast, but thickens up to 90 m to the southwest (Plate 9). A6 marks the second major sediment influx in the Hat Creek coal deposit - the first one being C1 which indicates a break in peat deposition between B2 and C2 coal horizons.

The thickness of A6 sub-zone in various sections is given in Table 5.

TABLE 5

THICKNESS VARIATION OF A6 ZONE

Hole No.	Section	True Thickness of A6 (m)	Composition
120	S	50	Claystone, siltstone, minor carbonaceous shale
195	T	75	Sandstone, siltstone, claystone, minor carbonaceous shale
52	Z	115	Siltstone, conglomerate
254	X	+70	siltstone, sandstone

B-Zone

B-Zone consists mainly of coal with minor interbeds of carbonaceous claystone. It has been subdivided into two sub-units, B1 and B2, and ranges in thickness from 50 m to 70 m and tends to thin to the south. Subdivision of B was based on the following geophysical criteria:

B1: The top of this unit is the bottom of the A6 claystone/ siltstone bed, which shows conspicuously high gamma and density values in contrast to B1 coal zone. This sub-zone represents the transitional phase, where the ratio of the coal interbeds to their aggregate thicknesses decreases, in general, towards the top, denoting an end of the peat depositional phase.

B2: This sub-zone is characterized by a thick coal section with a few interlayered siltstone and claystone bends. The upper contact with B1 is marked by a high gamma ray shift (45-50 API range).

The virtually uninterrupted thickness of coal seam is indicative of a quiet period of deposition, where the slowly sinking basin kept pace with peat deposition.

C-Zone

C-Zone represents a pause in the peat deposition which had continued uninterrupted during the D-Zone period. Its lower members (C2 to C4) represent the transitional periods due to influx of fluctuating amounts of sediments, as reflected by numerous interbeds of claystone, siltstone, sandstone and conglomerate. Due to lack of consistency in correlatable beds for C2 to C4, it is difficult to establish defined boundaries.

C1: This unit consists essentially of claystone/siltstone, sandstone, conglomerate and occasionally minor carbonaceous shale. The thickness of the C1 members gradually decreases towards the northeast (Plate 8). Table 6 shows the varying thickness of this sub-unit in different sections.

C2: This sub-zone has several sideritic partings progressively thickening upwards. At the top there is almost a complete absence of carbonaceous material.

TABLE 6

THICKNESS VARIATION OF C1 ZONE

Hole No.	Section	True Thickness of C1 (m)	Composite
127	S	+80	S.S. Cgl., slst.
240	T	+160	Slst, S.S. cgl, carb. sh.
248	T	+90	Clst.
171	T	+70	S.S., Slst.
44	U	75	S.S.
259	U	75	Clst., s.s. some carb. sh.
51	U	130	Slst., s.s. some carb. sh.
137	U	+100	Clst., slst., cgl.
132	U	+100	Clst., slst., cgl.
249	V	+170	Slst., s.s. cgl., some carb.
176	V	+170	Slst., s.s. cgl., some carb.
236	W	120	Clst., s.s. cgl.
179	W	+120	Clst., slst., some carb. sh.
173	W	+120	Slst., s.s.
237	X	+140	Slst., s.s. minor clst.
241	Y	+170	S.S., cgl.

3.1 STRATIGRAPHIC SUBDIVISION OF THE HAT CREEK COAL FORMATION - (Cont'd)

C3: This is a shaly coal unit. Its upper section consists of claystone and locally developed conglomerate and sideritic bands.[3]

C4: This is the bottom-most unit and contains coal showing the highest gamma ray API value for the C-Zone. The top of C4 is identified by a claystone band showing up to 55 API.

D-Zone

D-Zone is the lowest and oldest stratigraphic coal member in the Hat Creek Coal Formation. It varies in thickness from 60 m to 100 m and contains the best quality of coal in the entire Hat Creek coal measures. The D-Zone coal is commonly black, hard, bright with conchoidal-fracture. At its base there is a pronounced transition from green-coloured claystone/siltstone, to dark-coloured mudstone or coal. Such coaly mudstone at the base of D-Zone indicates that the Hat Creek peat was deposited in a eutrophic lake environment. The contact between D and C-Zone is characterized by petrified wood/ironstone. This marker-horizon is pronounced in gamma-density logs because of their density differential. This is also borne out by the D-Zone being predominantly coal-bearing (hence low-density). The overall logs are in sharp contrast with the overlying C-Zone. The D-Zone coal generally contains very few rock partings except some siderite or petrified wood, so that the visual (macroscopic) differentiation of D into further sub-zones is not always well defined. However, with geophysical correlation it is possible to discern four sub-zones: D1 to D4.

3.2 DEPOSITIONAL ENVIRONMENT OF HAT CREEK COAL FORMATION

Some 40 million years ago, at the inception of peat deposition of the late Eocene epoch, the area now known as the Hat Creek region was generally a broad north-trending marsh with little or no circulating water. The climate at that time was temperate in which sub-tropical plants flourished.

The favourable climatic condition aided by the slowly sinking basin throughout the period of D-Zone deposition accounts for the immense thickness of the virtually uninterrupted coal mass. During this period, accumulation of the vegetal matter was balanced by the subsidence.

When the equilibrium was disturbed by rapid sinking, the whole area was cyclically flooded by fresh water, leading to the deposition of numerous rock interbeds in the coal measures, following the deposition of "D" coal zone.

Along with the intermittent but slow and progressive subsidence, there formed a slightly low relief on the west and southwest of the present coal basin, which encouraged the development of the drainage pattern northwards. Most of the west and southwest of the Hat Creek peat basin was apparently inundated by this system during the post D-Zone depositional period. Continued peat deposition was interrupted due to the constant fluctuation of the water level or turbid current. This resulted in rapid facies change from "main coal" to "main gyttja and rock" towards the southwest, like the rock member units C1 and A6. This further indicates that the C1 and A6 rock members might have been deposited at the same time as those of the peat sequence in the main Hat Creek marsh towards the north. It may also be that a stagnant morass, or the initial peat deposited on the edges of the basin, was partially or totally eroded by the stream current and filled by the sediment. The stream force resulting in "cut and fill sedimentation" for the C1 and A6 rock units might have varied with location and time during the period of peat deposition, depending on the environmental changes caused by various factors such as climate, the rate of subsidence, quantity and grain size of the sediment load being transported, runoff, etc.

In the centre and northeast of the peat basin, the rate of subsidence and deposition were about equal, and the effect of the silty sediment from the western stream was minimal, allowing the continued accumulation of plant debris to proceed uninterrupted. The peat deposit in the northeast was virtually free from extraneous mineral matter, i.e. clay or silt.

The Interior Plateau region was affected by volcanic activity, contemporaneous with the Hat Creek peat deposition. Dust and ash composed primarily of very fine pyroclastics were ejected from volcanic vents and blown intermittently over large portions of the Hat Creek peat basin. The volcanic ash was accumulated over the plant debris or peat body and later decomposed to bentonite and other clay. The widespread occurrence of ash beds in the coal measures reflects these episodes of volcanic eruptions.

The close of the coal-depositional phase was followed by a pronounced regional sinking of the basin resulting in the deposition of a thick layer of lake sediments. Accumulation of this uniform sequence of the lake silts up to 550 m thick continued to the late Eocene or early Miocene epochs.

Palynological analysis of 65 samples from the No. 1 deposit indicates that the coal-forming plants at the inception of the peat basin were sub-tropical types of alnus, walnut and fungus, growing under moist or waterlogged conditions (D coal horizon). As the Eocene epoch (or possible early Miocene) drew to a close, the climate cooled, so that the character of the plant life gradually changed from moisture-loving vegetation to massive tree types of alder, cypress, pine and oak, growing under relatively dry conditions ("A" coal horizon).

The broad synclinal feature of the Hat Creek coal deposit began to develop as the accumulation of peat and lake sediment continued through long periods of time, thereby creating a gradual down-warping of the peat basin.

3.3 LOCAL STRUCTURE

The general structure of the No. 1 deposit is presented on Plates 10 to 16 which show the sub-surface structural contours for five of the main stratigraphically correlatable horizons, i.e. top of bedrock, A1, base of A5, B2, C4 and D. The major tectonic elements are shown on structural contours for faults (Plate 17), EW geological cross sections, H to AA inclusive (Plates 18 to 35), and NS geologic cross sections 18E and 23E (Plates 36 to 39).

Folding

1. Hat Creek Syncline - The main structure of No. 1 deposit is characterized by a broad synclinal feature, the Hat Creek Syncline. It strikes north-south and plunges southerly at 15° to 25°. The west limb is fairly continuous and dips 20° to 40° to the east. The east limb, which parallels the synclinal axis, is modified to a broken anticline with the bedding dips steepening to 70° to 90°, and partially truncated by the northwesterly trending "Creek Fault". The Hat Creek synclinal structure is truncated in the south by the northeasterly tending "Finney Fault".

2. Harry Syncline - This consists of gently folded beds immediately east of the Créek Fault. It strikes N 20° W and plunges gently to the southeast. This syncline is truncated by the northeast trending Finney Fault, bringing the Hat Creek Coal Formation into juxtaposition with the stratigraphically overlying medicine Creek Formation.

3. Syncline on Sections N, P, Q - The geological, geophysical and chemical data from DDH 78-271 on Section Q indicate the presence of a steep syncline between Holes 76-121 and 77-235. A steepness of the eastern synclinal limb is indicated by Hole 271, where the 358.4 m total length consists of the same lithologic sequence of C1 or C2 zones. This structure is subsidiary to the Harry Fault systems, (Plates 23-25) and of either contemporaneous, or of later origin.

4. West Limb Overturning on Section T - The overturning structure of the Al horizon is indicated in the lithological and geophysical logs for DDH 77-242 on Section T (Plate 28).

5. Structural Anomaly between Aleece East No. 1 and Allece West No. 1 Faults - The west limb of Hat Creek syncline generally continues with a normal easterly dip, but appears to be locally steepening in the vicinity of the Aleece east and west Fault System. Hence, a structural anomaly with the steep easterly dip is inferred between Aleece east No. 1 and Aleece west No. 1 Faults on Sections T, U and V (Plates 28 to 30).

Faulting

1. Finney Fault - The Finney Fault is one of the major tectonic elements modifying the structure and coal reserves of No. 1 deposit. As described in Section 2.0 Regional Geology, the steeply-dipping westerly attitude of the Finney Fault is interpreted as the result of a normal faulting, the plane of which has been deformed by the subsequent regional tectonic activity. It postdates Hat Creek syncline and precedes the Creek Fault in age. The Finney Fault is offset in places by the secondary transcurrent faults, i.e. Creek Fault, Harry Faults No. 1 to 6 as described in the succeeding section. The position of Finney Fault is determined by the following drill data:

76-128	(Section N)
74-26 and 77-270	(Section Q)
76-107 and 78-288	(Section R)
78-272	(Section T)
77-251	(Section V)

2. Creek Fault - The Creek Fault separates the coal sequence contained in the Harry Syncline from the main body of the Hat

3.3 LOCAL STRUCTURE - (Cont'd)

Creek deposit. Its strike and dip are N 15° E and 80 to 85° to the east, respectively. The Creek Fault appears to be a hinged fault with a right lateral strike slip movement. It appears to postdate and displace the Finney Fault at Section T (Plate 28). The position and attitude of the Creek Fault is established by DDH 76-192 on Section J (Plate 19) and DDH 78-269 on Section M (Plate 22).

3. Harry No. 1 Fault - Harry No. 1 Fault explains the anomaly encountered in DDH 76-162, which intersected the footwall Coldwater rock at a higher elevation than the predicted projection from DDH 76-153, located about 150 m west of DDH 76-162 (Plate 21).

4. Harry No. 2 Fault - This fault explains the occurrence of Medicine Creek claystone above and below the Hat Creek Formation (at C and D-Zone levels) in Hole DDH 76-128 on Section N (Plate 23). It generally strikes at N 15° W with a dip of 80° E to E. In the vicinity of Sections N, P and Q, where it displaces the Finney Fault, it tends to be sub-parallel to the latter due probably to drag effect.

5. Harry No. 3 Fault - Harry No. 3 Fault is postulated to explain the repetition of D1 Zone in Hole 76-168 on Section N (Plate 23).

6. Harry No. 4 Fault - The coal encountered in DDH 78-270 and 271 Section Q can be explained by this fault, which has displaced the Finney Fault (Plates 17 and 25).

7. Harry No. 5 Fault - Harry No. 5 Fault is proposed for the same reason as Harry No. 4 Fault (Plates 17, 25 and 26).

3.3 LOCAL STRUCTURE - (Cont'd)

8. Harry No. 6 Fault - Harry No. 6 Fault explains the juxtaposition of Medicine Creek Formation with D-Zone coal in DDH 76-126 on Section S. Harry No. 6 displaces the Finney Fault and runs sub-parallel to the Creek Fault, dipping between 85° and vertical to the east (Plate 27).

9. Fault "A" - Fault A explains the repetition of D-Zone in DDH 76-817 on Section K (Plate 20).

10. Fault "B" - The repetition and steepening of D-Zone in DDH 76-151 (Section R) is explained by Fault B (Plate 26).

11. Fault "C" - Fault C explains the local anomalous structural contours between Sections K and L, 24E and 25E. It strikes roughly east-west and dips vertically. The structural contours drawn for the base of B2, C4 and D4 indicate the presence of this fault between Sections K and L, and 24E and 25E (Plates 14, 15 and 16).

12. Proposed Minor Fault West of Creek Fault on Section S - This is a tanscurrent fault causing the repetition of D4 coal zones in Hole 76-180 on Section S. It is truncated by the Creek Fault at depth (Plate 27).

13. Aleece West No. 1 Fault - Aleece West No. 1 Fault is essentially a strike-slip fault with apparent vertical movement. As shown on Sections R and S, the fault has a downthrow of 50 m on the west side. Structural contour of the fault and top of the various sub-zones indicates that Aleece West No. 1 Fault is slightly arcuate, southwesterly-striking and westerly-dipping (80°) and extends over more than 1.5 km along the strike. It explains the D2 sub-zone being faulted against Coldwater Formation in DDH 76-120 (Plates 26 and 27).

3.3 LOCAL STRUCTURE - (Cont'd)

14. Aleece West No. 2 Fault - Aleece West No. 2 Fault explains the indicated structural steepness of the lower D coal horizon and the down-dropped coal block formed by the above-mentioned Aleece West No. 1 Fault. Aleece West No. 2 may branch from Aleece West No. 1 (Plates 17 and 25).

15. Aleece East No. 1 Fault - Aleece East No. 1 Fault on Sections T and U is a strike-slip fault, with downward curvature and apparent reverse movement. It is evident from the geologic log of DDH 77-259 (Plates 28 and 29).

16. Aleece East No. 2 Fault - Aleece East No. 2 Fault is also a strike-slip fault similar to the Aleece East No. 1 Fault. On Sections V, W and X and believed to be contemporaneous, or slightly post-dating, the Aleece East No. 1 Fault. It is proposed on the basis of the data from DDH 78-279 (Section V), 22-236 and 76-134 (Section W) and 77-254 (Section X) (Plates 30 to 32).

17. Aleece East No. 3 Fault - Aleece East No. 3 Fault is essentially the same strike-slip fault as above, contemporaneous, or slightly post-dating the two Aleece East faults. The presence of this fault is confirmed by the description of the tectonic features in DDH 77-243 on Section Y (Plate 33).

18. Aleece East No. 4 Fault - Aleece East No. 4 Fault explains the repetition of A1 Zone in DDH 77-253 on Section X (Plate 32).

19. A Steep Fault West of Hole 77-236 on Section W - A minor fault with steep westerly dip is inferred between Holes 76-134 and 77-257 to explain the occurrence of Medicine Creek Formation abutting against the Hat Creek Coal Formation on Section W. This fault appears to predate the Aleece East No. 2 Fault and to be truncated by the latter (Plate 31).

3.4 BURN ZONE

The burned zone in the Hat Creek valley resulted from combustion of near-surface coal and baking of inherent clay and the associated claystone partings in the coal seam. It is exposed in the eastern part of Trench A. Its presence has also been noted in the drill cores and outcrops adjacent to Dry Lake. A geophysical (magnetic) survey carried out by B.C. Hydro in 1977-78 delineated the sub-surface distribution of the burn zone (Plate 5).

The most striking effect of baking or burning of coal seam is the reddening of the adjoining rock. The claystone in the burned zone has a bright yellow colour. A total of eight coal samples in Trench A were taken to B.C. Hydro's Hat Creek site lab and burned at 1100°C. The resulting colour and textural characteristics were identical to the "Burn Zone" material now seen in Trench A and drill cores.

The ignition of coal could have been caused by spontaneous combustion, lightning, volcanic flows or forest fires. Burning extended through the whole sequence of coal, continuing down to a depth of 50 m (Plates 20 to 25), (Section K to Q inclusive).

The burned zone in Trench A is believed to be the burned B coal zone of the Hat Creek Coal Formation. It shows a contoured structure resembling somewhat a crumpled schist. A part of this structure might have been caused by a slumping down of the baked clay partings in the coal bed as the burning progressed.

The sharp contact between the burn zone and the overlying till indicates that the burning preceded Pleistocene glaciation.

3.5 TRENCH GEOLOGY

In the Summer of 1977, two trenches, (Trench A and B) were excavated to provide an average grade coal for testing the burning characteristics of coal at the Battle River Powerplant in Alberta. The overall quality of this coal was found to be lower than the projected value.

Valuable information was obtained on geological structure, coal washability, material handling and their characteristics, waste dump disposal and vegetation for reclamation. Spontaneous combustion and water leachate studies are still being monitored.

About 6500 tons of coal was obtained from these two trenches.

Trench C, a third trench, was excavated for geotechnical stability studies in the slide area.

Trench "A"

The trench was excavated from east to west straddling Sections P to Q (E-W) and 16E-18E (N-S). It was cut 274 m long, 90 m wide and 24 m deep. The benches are 6 to 7 m high with 60° slope. The bottom of the trench is about 60 m above the local water table.

Detailed geological mapping of the trench (Plate 6) shows the contact of B2 coal with C1 at its western end, and burnt B coal with the overlying A6 (?). The various tectonic features and the surficial materials exposed in the walls contribute significantly to the understanding of the general geology of the Hat Creek deposit.

Overburden in the trench consists mainly of glacial till, sand and gravel beds, which were in most part easily removed by a D8 caterpillar. The overburden soil is composed of soft, brown plastic remoulded clay containing white specks identified as soluble gypsum crystals by mineralogical analyses with x-ray and Atterburg limit tests (5 August 1977 letter from R.M. Quigley, University of Western Ontario).

3.5 TRENCH GEOLOGY - (Cont'd)

The coal and coaly waste materials were dug and loaded by hydraulic excavator and trucks without difficulty except in the south side of the trench, where the excavation rate has been low due to tougher digging. The large block of hard clinker in the burn zone was bored with an air-trac drill, blasted and removed by scraping and dozing.

The overall pit walls (60°) in Trench A, that crosscut the bedding structure, maintained their stability during excavation. But the pit walls on the west side failed during the winter season of 1978.

Stumps of petrified wood were uncovered throughout the excavation. They range in diameter from 1 to 1.5 m and are discreetly separated from the coal. More than 12 claystone and ash beds were contained in the coal zone of the north and south walls, but most of them were less than 0.3 m in true thickness and were included in the coal pile without separation. However, one claystone bed near the contact with the C1 rock zone in the west slide measured 1.5 to 2 m in true thickness. This claystone bed was separated for disposal to the waste dump without much difficulty.

A crushing system was installed to reduce the run-of-mine coal to -38 mm for shipment to Battle River.

Trench "B"

As the coal obtained from Trench A was not high enough to meet the average grade, a second trench, B, was cut in "D" Zone coal at the north edge of the deposit.

The excavation consisted of overburden removal and coal cut, terraced with two levels obtaining maximum dimensions of 90 m long, 48 m wide, and 9 m deep. The pit slopes in gravels and coal were 45° and 60° respectively.

3.5 <u>TRENCH GEOLOGY</u> - (Cont'd)

The section exposed in the trench was the contact of C-Zone with upper D-Zone. This was characterized by an abundance of petrified wood at the cessation of D-Zone and the initiation of C-Zone. A change in depositional environment conducive to the petrification and association with pyrite is also noted at the junction of C-Zone and B-Zone, as in the case of Trench A. In the study of sulphur distribution, samples from these areas are expected to be high in sulphur on account of the concentration of pyrite.

Unlike the Trench A excavation, digging with the hydraulic excavator in the D coal was more difficult due to a flat dip of the coal beds. However, D-Zone coal, being older in sequence of deposition, shows generally higher rank of metamorphism and is consequently harder than the other zone coals.

The Trench B excavation resulted in an excessive water inflow into the pit, which seeped mostly through an old drainage channel flowing to the north, parallel to the existing Hat Creek. Very little water seeped in from the creek side of the pit, even though the pit was significantly below the level of Hat Creek. The average rate of inflow was measured at 190 gal/min over a 16-day period from 18 July to 3 August 1977; the maximum flow experienced during the recorded period was approximately 240 gal/min over a 40-hour period on 18, 19 and 20 July. In addition to the continuous pumping operation, problems were encountered in keeping the water draining towards the sump and in operating the equipment in water. At present the pit is completely filled with water; the seasonal variation in water levels is within 2 to 3 m from the surface.

The fuel analyses of the combined coal sample from Trench A and B for the burn test at Battle River Powerplant is summarized:

3.5 TRENCH GEOLOGY - (Cont'd)

		Air Dried	Dry Basis	As Received
Proximate Analysis				
Moisture	_____%	5.8	-	21.9
Ash	_____%	38.2	40.5	31.7
Volatile matter	_____%	31.5	33.4	26.1
Fixed carbon	_____%	24.5	26.1	20.3
Heating Value				
kJ/kg	_____%	14 759	15 668	12 237

Trench "C"

Trench C was excavated to determine slope stability, material characteristics and handling quality in the bentonitic surficial materials of the inactive slide zone, about 400 m west of Trench A.

The trench consisted of three separate excavations in the adjacent area extending up to 20 m in depth.

The excavation revealed that a large mass of the Coldwater Formation with coaly lenses has slid over the glacial till.

Some glacial tills in the trench presented difficulties in digging due to the compact nature of the materials. Also, some excavation problems were encountered in the highly bentonitic soil in the clay-cut.

The failure of some of the faces indicates that material weakness is developed partly from water seepage. Equipment performance and capacity was also evaluated.

4.0 - APPLICATION OF DOWNHOLE GEOPHYSICS

4.1 INTRODUCTION

The contrast in physical properties between coals and waste rocks offers an accurate and convenient method of obtaining subsurface information of the coal measures: depth to the top of bedrock, lithologic identification, depth and thickness of individual coal seams, general heat value and ash contents of coals.

Since 1974, all drill holes, as a standard practice, have been geophysically logged except those which were abandoned due to severe squeezing or caving. The types of logs tested were gamma ray, bulk density, resistance, caliper, focused beam, spontaneous potential and acoustical. The two most suitable and useful logs were the natural gamma ray and bulk density, which could be applied through the drill stem. The other logs were of limited application because they could only be run in open holes, and most holes had to be cased while drilling.

Gamma Ray

This records the natural gamma radiation from the formations and is expressed in API (American Petroleum Institute) units. The radiation is related to formation content of potassium, uranium and thorium, which are mostly concentrated in claystone, siltstone and sandstone giving a value of 50-55 API.

In coal, the gamma ray reading rarely exceeds 35 API.

Bulk Density

The bulk density works on the principle that the more dense a material, the less gamma radiation will be transmitted through the material from a gamma ray source to a gamma ray detector. When the

4.1 INTRODUCTION - (Cont'd)

density tool is lowered down the hole, gamma rays are emitted from the source and penetrate beyond the wall of the drill hole. A proportion of these gamma rays are returned to the detector after passing through the rock material.

For coal, the bulk density is usually low, less than 1.6 g/cc.

A marked contrast between coals and waste materials on the gamma ray and bulk density logs leads to an accurate (depthwise), unbiased, graphic presentation of the coal measures. A preliminary statistical analysis of the API values from the geophysical logs versus analytical data indicate that the ash and thermal value of the various coal segments could be predicted.

4.2 APPLICATION OF DOWNHOLE GEOPHYSICS TO STRATIGRAPHIC CORRELATION

Based on the various API ranges from the gamma ray log, the rocks and coal within the formation were classified into the five different categories for stratigraphic correlation and structural interpretation. The formations were cross checked against bulk density values.

TABLE 7

API RANGES VERSUS ASH AND HEATING VALUES
(The five ranges tentatively correspond to the following ash-heating values)

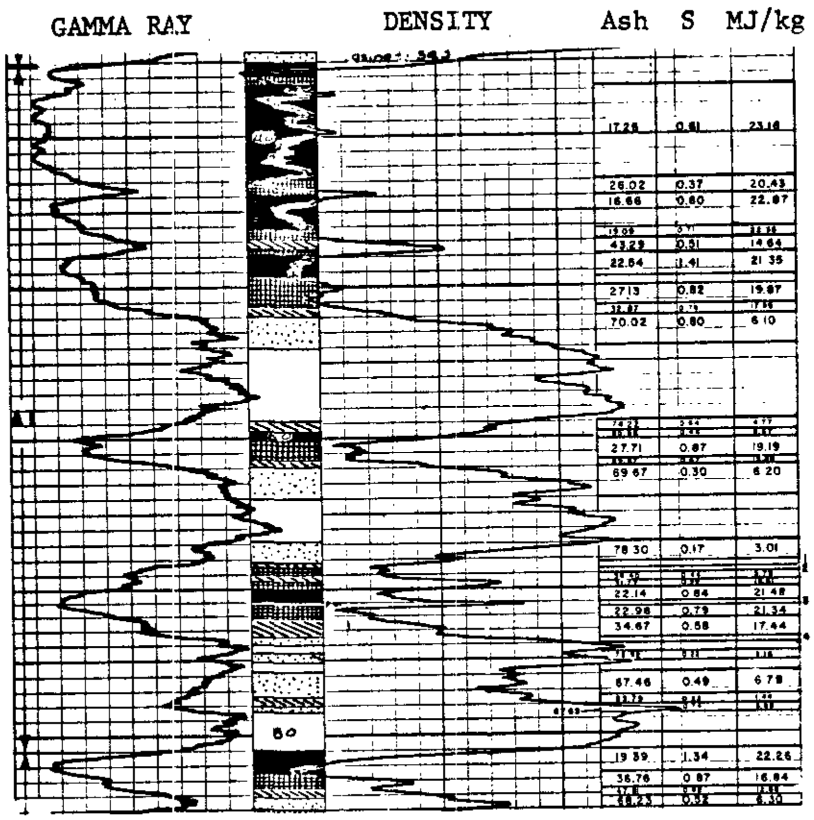
API	Description
0 - 15	Coal: (22% Ash, 22.0 kJ/kg db)
15 - 25	Coal: (22.0 - 40.0% Ash, 22.0 - 16.0 kJ/kg db)
25 - 35	Coal: (40 - 60.0% Ash, 16.0 - 9.5 kJ/kg db)
35 - 45	Coaly shale and/or carbonaceous shale.
+45	Claystone, silstone, conglomerate, shale, sandstone, marl, petrified wood.

4.3 APPLICATION OF DOWNHOLE GEOPHYSICS TO QUALITY AND RESERVE ESTIMATION

The sampling method adopted during the 1978 drilling program was to provide a base for correlating the gamma ray values to the ash content. The sample intervals for DH 78-269 to DH 78-292 were based on the geophysical values, corresponding to the five categories established in Table 7. A typical section showing the sampling method is shown in Fig. 2.

FIGURE 2

SAMPLING METHOD USING GEOPHYSICS



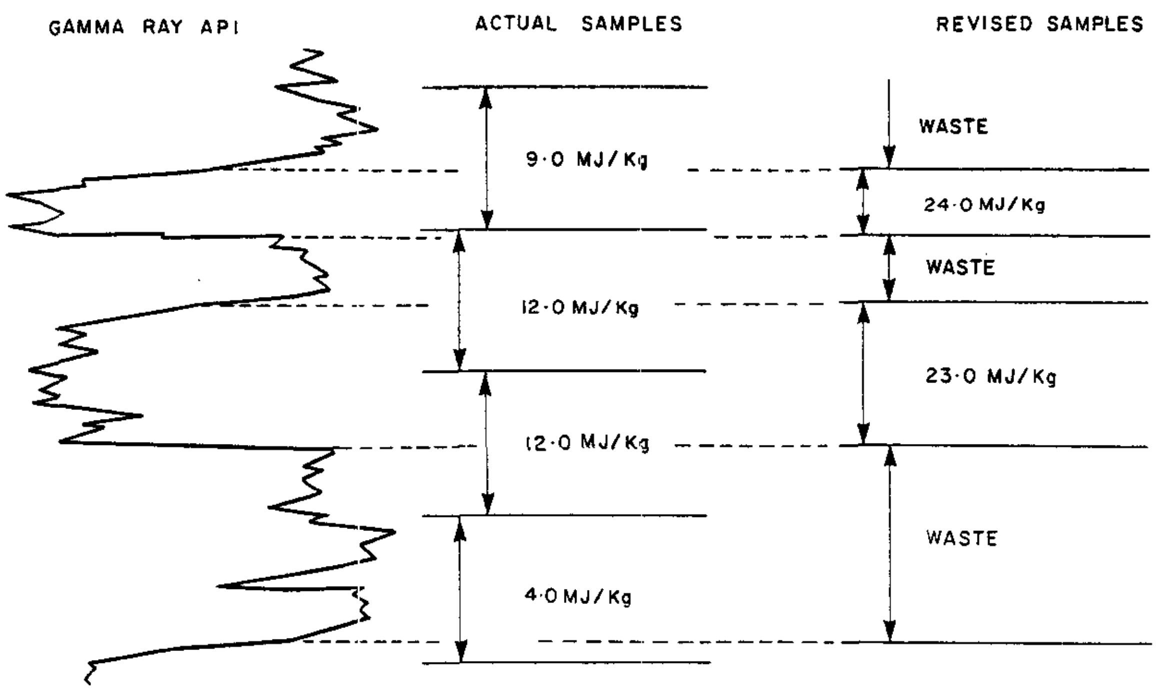
A preliminary statistical analysis of the geophysical values vs. analytical data showed that the ash and thermal values could be predicted, to some degree, directly from the magnitude of the gamma ray and bulk density curves. It was also noted that the character of the radiation levels (gamma ray magnitude in API units) is different in

D-Zone than in that of the other zones, (i.e. the gamma reads higher in D-Zone for the same ash and thermal value). With the proposed detailed statistical study of the samples from DH 78-269 to DH 78-292 it is possible to determine the accuracy of predicting ash and heat values directly from the geophysical logs.

The ability to predict the ash and thermal values from the geophysics has an application in re-evaluating the earlier geophysical logs and identifying all the intervals that are below the cut-off grade for selective mining. The analytical values could then be predicted for the intervals mined (Fig. 3).

FIGURE 3

GEOPHYSICALLY ADJUSTED SAMPLE DATA (THERMAL VALUE)



4.3 APPLICATION OF DOWNHOLE GEOPHYSICS TO QUALITY AND RESERVE ESTIMATION - (Cont'd)

In this manner previously unidentified intervals of material below the cut-off grade could be identified and the true grades and tonnages estimated. To illustrate and test the above method, three drill holes were selected, 75-106, 76-136 and 78-274. The results are shown in the following table.

TABLE 8

GEOPHYSICAL ADJUSTMENT OF SAMPLE DATA
FOR DDH 106, 136 AND 274

Drill Hole	Sampling Method	From Lab Samples using 9.3 MJ/kg cutoff		Samples Revised from the Geophysics using 9.3 MJ/kg cutoff		% Change due to Revised Samples	
		MJ/kg	Coal(m)	MJ/kg	Coal(m)	MJ/kg	Coal(m)
75-106	42 samples were taken without the aid of geophysics	17.05	374.9	19.03	322.2	+10.4%	-14.1%
76-136	270 samples were taken without the aid of geophysics	17.96	340.0	19.22	310.9	+6.5%	-8.6%
78-274	354 samples were taken from picks on the geophysical logs	19.19	375.8	19.19	375.8	0	0

The above table indicates that the proposed detailed evaluation of the earlier geophysical logs would upgrade the thermal value by more than 8 percent and reduce the tonnage by more than 12 percent.

5.0 - COAL QUALITY

5.1 INTRODUCTION

During the last 22 years the method of sampling and the emphasis on various tests have been constantly modified as our knowledge of the deposit improved. With the stratigraphic subdivision of the No. 1 deposit into smaller units, the quality correlation of various horizons has become useful in practical mining.

In some of the 1957 core samples, the sample was split at 100-foot increments. All partings less than 3 m thick were included in the sample. By the time DDH 57-10 was sampled, smaller samples of 3 m to 6 m increments were analyzed. Sometimes, the lithological continuity was overlooked in determining the sampling interval. These initial analyses were done for proximate, thermal value determination and sulphur. Some 10 months after the drilling, the Fuels Division of the Department of Mines and Technical Surveys, Mines Branch, ran 23 samples for ash-mineral analyses, fusibility, grindability and the corresponding proximate, sulphur and thermal value determinations. These represented large aggregates of composited samples with possible elimination of waste bands.

The 1959 core samples were generally split by natural lithological boundaries, where the sample interval varied between 5-7 m to 18-30 m. The description of the sampled interval material had been well documented. Even though these analytical intervals were too large for quality projection into practical mining blocks, it may be possible to use the data in an overall quality estimate for that horizon.

The analytical work for the years 1974 to 1976 was regulated by various coal analysis schedules issued by Dolmage Campbell & Associates. In the later phase of the program, a 6 m maximum sampling

5.1 INTRODUCTION - (Cont'd)

interval was adopted for proximates, thermal values, etc., and 12 m to 18 m maximum for mineral-ash analyses, fusibility, grindability and other tests.

In all subsequent exploration programs (1977/78) with B.C. Hydro's more active involvement, two major recommendations were introduced:

1. the sampling intervals must correspond to the geophysical logs instead of visual lithological logs,

2. the sample lengths must not exceed 6 m - based on statistical studies by Dr. A.J. Sinclair of the University of British Columbia.

Since 1977, all the samples were run at B.C. Hydro's site laboratory at Hat Creek. Check samples were regularly sent out to commercial laboratories. One of the main advantages of the site laboratory was that the samples were analyzed or at least prepared and kept in sealed jars ready for analyses, almost immediately after sampling. Other advantages were higher reliability in analytical procedure and reduced cost.

5.2 ASH-HEATING VALUE RELATIONSHIP

The ash content of coal, especially in thick seams, is not always a true index of the normal coal because of the extraneous inert or waste partings so often associated with them. Caution has, therefore, to be exercised in the sample selection for Ash-Heating Value regression curve.

In order to establish the variation in quality and lithology for each of the zones in the entire section of the coal measures, Dolmage Campbell & Associates on the recommendation in Integ-Ebasco

5.2 ASH-HEATING VALUE RELATIONSHIP - (Cont'd)

drilled two holes, DDH 75-135 and 75-136 near the trough of the syncline. These holes were the most exhaustively sampled and their data were used to correlate DDH 78-274 (Plate 7). The ash-heating value regression curve for A, B and C zones was almost identical to the D Zone coal (Fig. 4 and 5) which indicates similar condition in coal deposition and metamorphism from D Zone to A Zone. It also justified adopting a common regression equation for ash and heating value (db) excluding samples below the cutoff grade (Fig. 6).

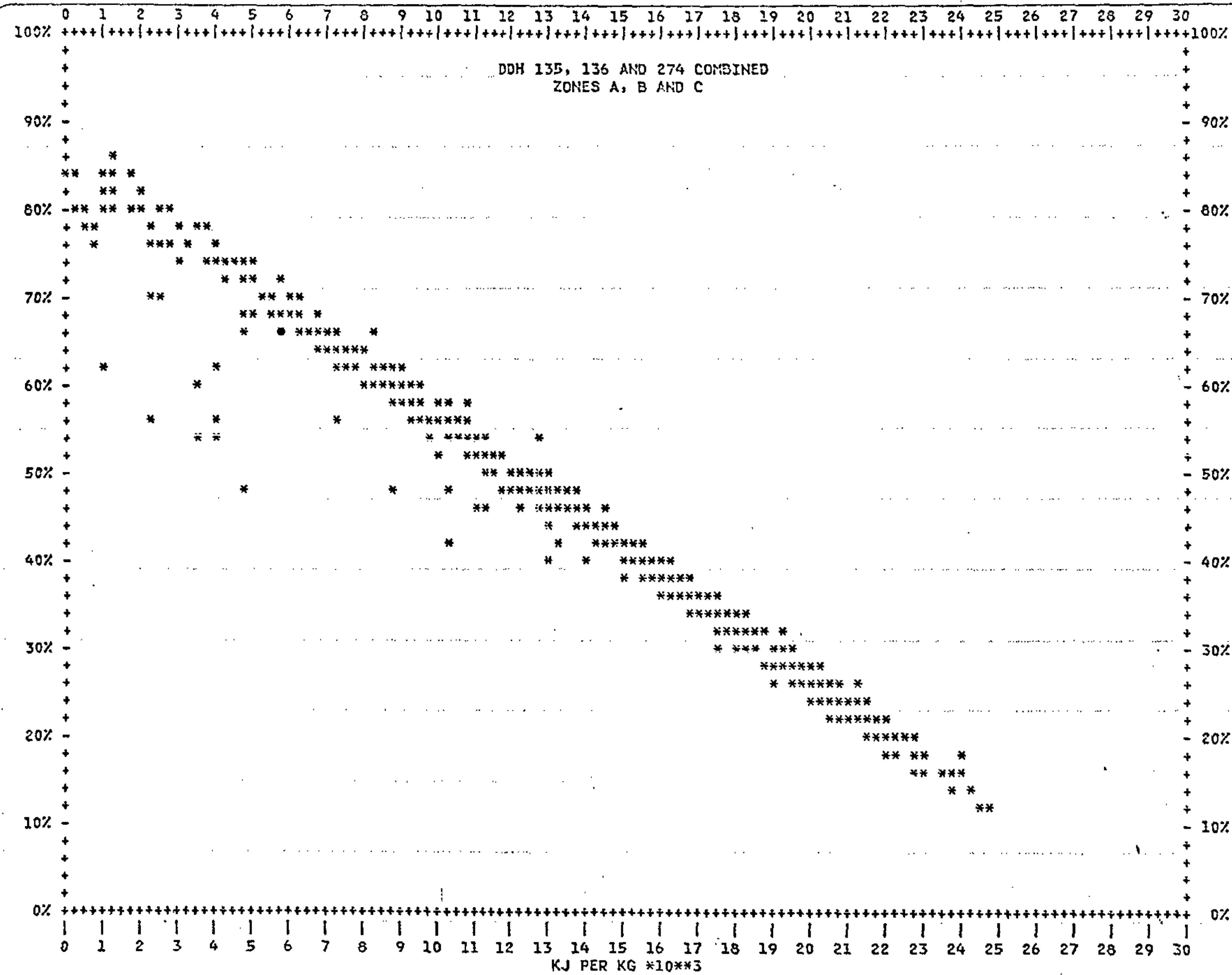
$$\text{Heating Value (db) (MJ/kg)} = 29.5688 - 0.34134\ Y$$
$$\text{Ash \% (db)} = 86.6254 - 0.00292962\ X$$
$$\text{Where } X = \text{Thermal Value MJ/kg (db)}$$
$$Y = \text{Ash \% (db)}$$

5.3 MOISTURE DETERMINATION

Moisture in coal is present in two forms - surface and interlattice or bonded. The surface moisture is easily lost when exposed to the atmosphere while the interlattice moisture is released at 110°C.

"In situ" moisture is the total moisture present in coal in its natural state. It is one of the most important parameters in coal mining.

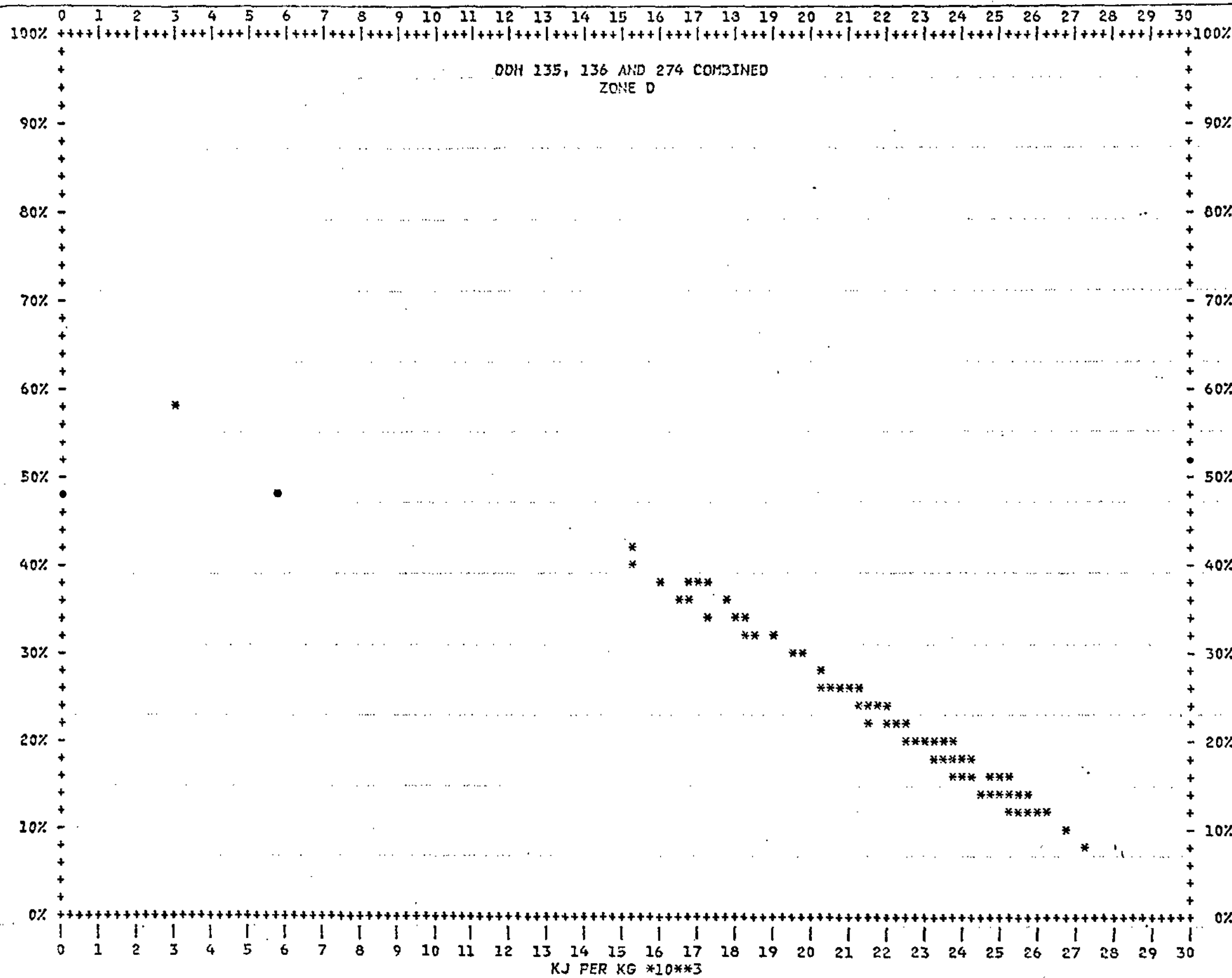
In the exploration stage, where heavy reliance is imposed on drill cores, it is not possible to get cores in their natural state because of the drilling water contamination. To augment this situation, "equilibrium moisture" as per ASTM (1412-56) was determined. This tended to be higher than true "in situ" moisture, as coal in nature is more compact and not always saturated to the optimum level the ASTM calls for. Table 9 summarizes all such tests run from 1957 to 1977.



Y SCALE = 2.0% DRY ASH
X SCALE = 250 KILOJOULES

Y INTERCEPT = +085.11
X INTERCEPT = +29856.30

Figure 4



Y SCALE = 2.0% DRY ASH
X SCALE = 250 KILOJOULES

Y INTERCEPT = +075.90
X INTERCEPT = +31895.45
Y INTERCEPT AT 30000 KJ = 4.51

Figure 5

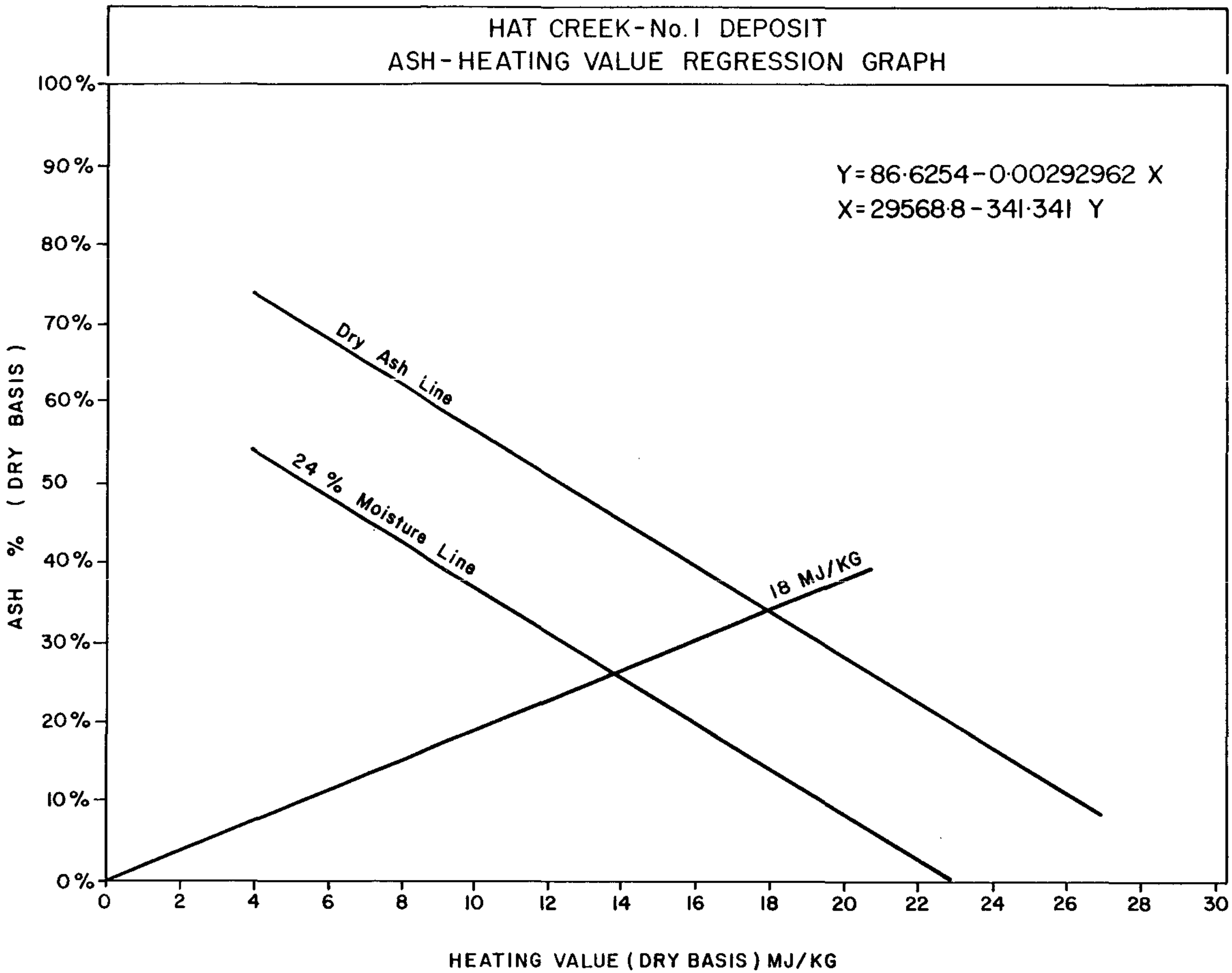

HAT CREEK-No.1 DEPOSIT
ASH-HEATING VALUE REGRESSION GRAPH
Y=86·6254-0·00292962 X
X=29568·8-341·341 Y
Dry Ash Line
24 % Moisture Line
18 MJ/KG
ASH % (DRY BASIS)
100%
90%
80%
70%
60%
50
40%
30%
20%
10%
0%
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
HEATING VALUE (DRY BASIS) MJ/KG

Figure 6.

5.3 MOISTURE DETERMINATION - (Cont'd)

TABLE 9

SUMMARY OF MOISTURE TESTING
1957 - 1977

Moisture Type	Date Source	No. of Samples	Moisture (%)		
			Mean	Minimum	Maximum
Equilb.	1957 - 1959	22	24.4	20.9	28.0
Equilb.	1974 - 1975	49	22.9	16.8	35.5
Equilb.	Integ-Ebasco	26	25.4	21.6	27.0
Equilb.	Trench A, DDHs - 1977	49	26.0[1]	12.6	38.6
Equilb.	Trench B, DDHs - 1977	13	24.1[1]	18.5	25.8

1 Near surface samples - weathered and oxidized.

The 1978 5A drilling program incorporated a careful moisture analysis program. The sampling technique involved the following steps:

1. Taking 10 cm samples every 15 m in coal.
2. Taking the sample immediately after it came out of the core barrel.
3. Wiping the surface moisture off with a rag.
4. Sealing the sample in plastic wrap and tape.
5. Resealing the sample in a plastic tube with the air squeezed out and the end heat-sealed.

5.3 MOISTURE DETERMINATION - (Cont'd)

This sampling was expected to produce the most accurate representation of the total in situ moisture content of the coal. The actual value of the moisture content may be somewhat lower than the measured value. This is due to the difficulty in completely removing the effects of the drilling water.

Results

A total of 121 samples showed an average total of in situ moisture of 21.86 percent average ash (db) 28.18 percent (and thermal value of 20 126 kJ/kg (db)) with a standard deviation of ±4.14, and standard error of the mean 0.38.

Residual moisture, which is the interlattice moisture, cannot be reduced without heating. Over 4000 samples analyzed for residual moisture indicate the arithematic mean to be 9.06 percent with standard deviation of ±4.75 and standard error of the mean 0.075.

Air dry moisture is the amount of moisture lost in bringing the coal from "as received" or "total in situ" state to equilibrium-with-laboratory-atmosphere.

The 2605 samples statistically tested show a mean value of 12.97 percent, with a standard deviation of ±5.73, and standard error of the mean 0.11.

The term "Pseudo" equilibrium moisture appearing in the analytical file should not be misconstrued as equilibrium moisture. "Pseudo" equilibrium moisture does not relate to the "equilibrium moisture" but to moisture of stauration.

In specific gravity determinations on 3-inch lengths of core, the samples were presoaked in water to bring them to a common "standard" before specific gravity could be determined. Therefore, all

5.3 MOISTURE DETERMINATION - (Cont'd)

such moisture determination, termed as "pseudo equilibrium moisture" should not be considered in the context of normal moisture values. The corresponding "ash" content should also be treated independently (see L.T. Jory's letter to C.B. Guelke of 27 October 1976).

The average "total moisture" for the run-of-mine coal, which may include weathered and oxidized coal, is 24.0 percent.

5.4 SULPHUR DISTRIBUTION

Initial studies on sulphur distribution in the No. 1 deposit showed an average value of 0.51 percent, of which approximately 71 percent is organic, 25 percent pyritic and 4 percent sulphate.

The organic sulphur of the D-Zone is in the 0.28 percent (db) range, but in B-Zone it is 0.5 percent. This difference can be explained by: 1) difference in vegetation, and 2) difference in the physico-chemical environment, especially pH and Eh condition of the water in the basin.

The sulphur form distribution in the zones is summarized in Table 10.

TABLE 10

SULPHUR FORMS - NO.1 DEPOSIT

	Zone A	Zone B	Zone C	Zone D	Deposit Total
Pyritic sulphur (%)	0.22	0.20	0.11	0.04	0.13
Organic sulphur (%)	0.50	0.44	0.31	0.24	0.36
Sulphur as sulphates (%)	0.02	0.03	0.01	0.02	0.02
TOTAL	0.74	0.67	0.43	0.30	0.51

5.4 SULPHUR DISTRIBUTION - (Cont'd)

Table 11 shows the statistical summary of total sulphur distribution in the subzones of No. 1 deposit, based on the subzone composite samples.

TABLE 11

TOTAL SULPHUR DISTRIBUTION IN SUBZONES OF NO.1 DEPOSIT

Subzone	Number of Intersections	Mean Sulphur (%)	Standard Deviation	Standard Error of the Mean
A1	32	0.723	0.193	0.034
A2	38	0.804	0.174	0.028
A3	42	0.634	0.137	0.021
A4	48	0.624	0.165	0.024
A5	54	0.739	0.187	0.025
A6[1]	-	0.540	0.169	0.027
B1	53	0.640	0.210	0.029
B2	57	0.664	0.174	0.023
C1[1]	-	0.450	0.300	0.051
C2[1]	55	0.486	0.209	0.028
C3[1]	56	0.356	0.213	0.028
C4[1]	67	0.369	0.266	0.032
D1	74	0.323	0.192	0.022
D2	77	0.260	0.096	0.011
D3[1]	84	0.298	0.0987	0.011
D4	86	0.388	0.102	0.011

---

1 These subzones exhibit random distribution in the variograms.

5.4 SULPHUR DISTRIBUTION - (Cont'd)

Recent studies indicate that the sulphur occurrence in the deposit is not as erratic as envisaged earlier. In many sections within the subzones, continuity in sulphur distribution is observed. There are distinct bands in the subzones that contain a high sulphur concentration. High sulphur concentration has been identified in the top 3 m of A1 subzone coal and bottom of B2 zone.

The identification of such sections over the subzones will have direct impact in controlling the sulphur content of the run-of-mine coal.

Some of the broad conclusions are:

1. The western sector of the deposit shows higher sulphur than the eastern sector.

2. A-Zone contains the highest average total sulphur, while B-Zone contains the highest local concentration.

5.5 MINERAL ANALYSIS OF ASH, ASH FUSIBILITY AND GRINDABILITY

The major constituents of the coal-ash average 52.4 percent SiO_2 and 27.5 percent Al_2O_3 excluding samples with ash greater than 70 percent. Such high content of Al_2O_3 may be of interest for alumina extraction. The analyses of ash from the four zones show no appreciable difference, indicating the source material for the ash remained unchanged throughout the coal deposition.

The statistical summary of the mineral analysis is presented in Table 12.

The ash deformation temperature is indicative of its physical behaviour at combustion temperatures. The range from initial deformation to fluid temperature suggests the fouling conditions of the boiler.

TABLE 12

STATISTICAL SUMMARY OF ASH ANALYSES
(Combined Drill Holes-No.1 Deposit)

EXCLUDING SAMPLES WITH HHV < 9304 KJ/KG & ASH > 70.00%

MINERAL SUMMARY - %DRY ASH

	% SIO2	% AL2O3	% TIO2	% FE2O3	% CAO	% MGO	% NA2O	% K2O	% MN3O4	% V2O5	% P2O5	% SO3	% UNDET +ERR
MAXIMUM	77.16	40.19	1.85	56.00	47.08	8.07	5.42	1.80	1.94	.49	6.14	7.64	7.57
MINIMUM	17.06	9.26	.04	.10	.33	.00	.17	.00	.00	.00	.00	.04	-1.56
RANGE	60.10	30.93	1.81	55.90	46.75	8.07	5.25	1.80	1.94	.49	6.14	7.60	9.13
WEIGHTED MEAN	52.39	27.53	.94	8.40	3.55	1.57	1.40	.49	.17	.06	.42	2.08	.99
SAMPLE COUNTS	913	913	913	913	913	913	951	951	913	913	913	913	913
SAMPLE CORE LENGTHS	4159	4159	4159	4159	4159	4159	4418	4418	4159	4159	4159	4159	4159
ARITHMETIC MEAN	52.29	27.96	.91	8.34	3.46	1.57	1.35	.51	.16	.05	.38	1.98	.96
SAMPLE COUNTS	913	913	913	913	913	913	951	951	913	913	913	913	913
SAMPLE CORE LENGTHS	4159	4159	4159	4159	4159	4159	4418	4418	4159	4159	4159	4159	4159
STANDARD DEVIATION	7.29	5.10	.28	6.35	3.72	.76	.79	.30	.22	.04	.61	1.22	1.04
COEFF. OF VARIATION %	13.95	18.25	31.49	76.15	7.43	48.52	59.04	58.42	35.18	71.02	58.68	61.72	7.91

MINERAL SUMMARY - MOLE%

	% SIO2	% AL2O3	% TIO2	% FE2O3	% CAO	% MGO	% NA2O	% K2O	% MN3O4	% V2O5	% P2O5	% SO3
MAXIMUM	85.69	28.83	1.72	36.81	55.80	14.37	6.08	1.38	.77	.19	3.08	7.36
MINIMUM	23.38	6.04	.04	.04	.42	.00	.20	.00	.00	.00	.00	.04
RANGE	62.31	22.79	1.68	36.77	55.38	14.37	5.88	1.38	.77	.19	3.08	7.32
WEIGHTED MEAN	63.61	19.80	.86	3.97	4.62	2.87	1.67	.38	.06	.02	.22	1.91
SAMPLE COUNTS	913	913	913	913	913	913	913	913	913	913	913	913
SAMPLE CORE LENGTHS	4159	4159	4159	4159	4159	4159	4159	4159	4159	4159	4159	4159
ARITHMETIC MEAN	63.56	20.12	.83	3.95	4.51	2.89	1.60	.40	.05	.02	.20	1.82
SAMPLE COUNTS	913	913	913	913	913	913	913	913	913	913	913	913
SAMPLE CORE LENGTHS	4159	4159	4159	4159	4159	4159	4159	4159	4159	4159	4159	4159
STANDARD DEVIATION	6.96	3.74	.25	3.37	4.57	1.45	.91	.23	.07	.01	.31	1.14
COEFF. OF VARIATION %	10.95	18.58	30.98	85.31	1.37	50.43	56.89	57.95	45.83	70.75	56.63	62.68

5.5 MINERAL ANALYSIS OF ASH, ASH FUSIBILITY AND GRINDABILITY - (Cont'd)

The average initial deformation temperature, taken over the entire deposit, is in excess of ±1400°C, the limit of most of the laboratory furnaces.

Table 13 shows the temperatures of the four stages of deformation in both reducing and oxidizing atmospheres.

The Hardgrove Grindability Index for D-Zone coal is lower than the A, B and C-Zone coal. This is summarized in Fig. 7. The normal range of fuel coal HG index falls between 38 and 45.

5.6 SPECIFIC GRAVITY

Coal

Specific gravity was determined on small pieces of coal cores by the water displacement method after the sample had been fully saturated with water. As there was no significant difference between the specific gravities of coal from different zones for a given ash value, one common regression curve was developed:

Specific Gravity = 1.21104 + 0.00738 x Ash %

Waste and Burn Zone Material

The average of 1584 waste samples gave the specific gravity of 1.93. For calculation purposes a specific gravity of 2.00 was considered as more conservative.

The burn zone material average 2.16.

These values were used in reserve estimation.

TABLE 13
COMPUTER SUMMARY OF ASH FUSION TEMPERATURE

EXCLUDING SAMPLES WITH HHV < 9304 KJ/KG & ASH > 70.00%

FUSION SUMMARY - CELSIUS

	REDUCING				OXIDIZING			
	INIT. DEFORM	H=W	H=.5W	FLUID	INIT. DEFORM	H=W	H=.5W	FLUID
MAXIMUM	1482	1482	1482	1482	1482	1482	1482	1482
MINIMUM	1037	1054	1073	1096	1165	1182	1187	1193
RANGE	445	428	409	386	317	300	295	289
WEIGHTED MEAN	1396	1412	1422	1431	1444	1449	1454	1458
SAMPLE COUNTS	1465	1465	1465	1465	252	252	252	252
SAMPLE CORE LENGTHS	7050	7050	7050	7050	630	630	630	630
ARITHMETIC MEAN	1398	1413	1423	1432	1444	1450	1454	1458
SAMPLE COUNTS	1465	1465	1465	1465	252	252	252	252
SAMPLE CORE LENGTHS	7050	7050	7050	7050	630	630	630	630
STANDARD DEVIATION	108	95	85	74	76	69	62	57
COEFF. OF VARIATION %	7.72	6.72	5.99	5.23	5.26	4.76	4.31	3.96
SAMPLE COUNTS OF + DATA								
SAMPLE CORE LENGTHS OF + DATA								

HARDGROVE GRINDABILITY INDEX
(14-16 % MOISTURE)

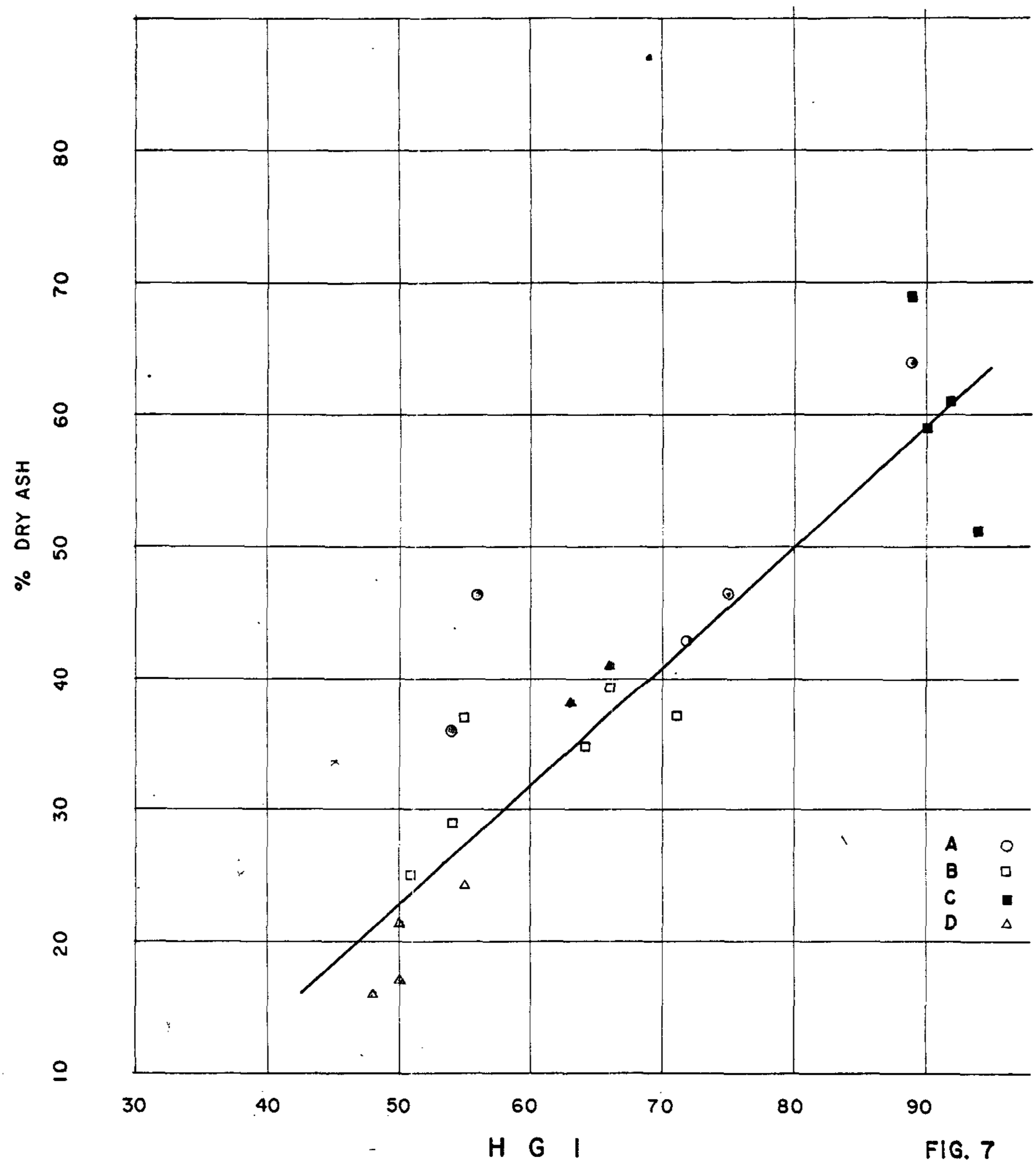


FIG. 7

5.7 PROXIMATE AND ULTIMATE ANALYSES

Proximate Analyses

Proximate analyses were conducted on all the core samples. As the variation in volatile matter values was not very critical, its determination in 1977 exploration program was not considered essential.

Ultimate analyses

In coal combustion a "net" heating value and pollution level determination of the constituents of the "heat giving" material is important.

The average value for Hat Creek coal is as follows:

C = 47.28%
H = 4.03%
O = 15.96%
N = 0.90%
Cl = 0.02%
S = 0.57%

The attached statistical summaries for proximate and ultimate analyses are based on data in B.C. Hydro's computer file (Tables 14 to 18).

Over 4028 samples were analysed for ash and the related heating and sulphur values: of these only 1375 samples were tested for volatile matter.

5.8 COAL BENEFICIATION

Coal beneficiation is a broad term that encompasses any process that improves the quality of coal. In dealing with boiler fuels this generally implies raising the heating value and reducing the ash content of the coal, but it can also contribute to reduction of the

TABLE 14

STATISTICAL SUMMARY OF PROXIMATE AND ULTIMATE ANALYSES
(Combined Drill Holes-No.1 Deposit)

EXCLUDING SAMPLES WITH HHV < 9304 KJ/KG & ASH > 70.00%

PROXIMATE, MOISTURE AND OTHER SUMMARY

	HHV (KJ/KG)	% ASH	% F.C.	% V.M.	% S	% MOISTURES AS RECVD.	AIR DRY	RES-IDUAL	EQUIL.	% CO2	%ALK. AS NA2O	WATER SOLUBLE % NA2O	WATER SOLUBLE % K2O
MAXIMUM	27398	62.18	72.83	46.61	5.54	36.92	31.56	22.35	35.60	15.60	1.57	.35	.60
MINIMUM	9317	7.96	7.56	.63	.03	2.26	.44	.22	16.76	.02	.08	.15	.01
RANGE	18081	54.22	65.27	45.98	5.51	34.66	31.12	22.13	18.84	15.58	1.49	.20	.59
WEIGHTED MEAN	18443	32.56	33.96	34.37	.55	22.54	12.93	8.90	23.83	1.42	.51	.26	.07
SAMPLE COUNTS	4028	4028	1375	1375	4026	1793	1792	4027	34	1445	951	18	19
SAMPLE CORE LENGTHS	15384	15384	7101	7101	15374	9276	9275	15383	239	6935	4418	54	58
ARITHMETIC MEAN	18037	33.76	33.54	33.90	.57	22.44	12.96	7.94	23.82	1.48	.51	.25	.05
SAMPLE COUNTS	4028	4028	1375	1375	4026	1793	1792	4027	34	1445	951	18	19
SAMPLE CORE LENGTHS	15384	15384	7101	7101	15374	9276	9275	15383	239	6935	4418	54	58
STANDARD DEVIATION	4456	12.94	8.79	5.35	.37	4.51	5.33	4.15	4.70	2.00	.24	.05	.13
COEFF. OF VARIATION %	24.70	38.32	26.21	15.79	66.21	20.12	41.18	52.28	19.74	35.12	47.95	21.87	25.75

ULTIMATE SUMMARY

	% C	% H	% N	% CL	% S	% ASH	% OXY	% UNDET +ERR	% OXY (DIFF)
MAXIMUM	68.99	6.62	2.07	.93	5.54	62.02	22.86	3.52	22.65
MINIMUM	23.32	1.60	.06	.00	.14	8.13	10.62	-7.42	6.81
RANGE	45.67	5.02	2.01	.93	5.40	53.09	12.24	10.94	15.84
WEIGHTED MEAN	48.18	4.11	.89	.03	.55	31.06	16.02	-1.35	15.18
SAMPLE COUNTS	938	938	911	911	938	938	253	253	911
SAMPLE CORE LENGTHS	4305	4305	4152	4152	4305	4305	633	633	4152
ARITHMETIC MEAN	47.28	4.03	.90	.02	.57	32.17	15.96	-1.32	15.00
SAMPLE COUNTS	938	938	911	911	938	938	253	253	911
SAMPLE CORE LENGTHS	4305	4305	4152	4152	4305	4305	633	633	4152
STANDARD DEVIATION	10.70	.90	.22	.04	.38	12.81	1.77	1.25	1.94
COEFF. OF VARIATION %	22.63	22.48	24.52	62.32	67.40	39.82	11.13	-95.06	12.95

TABLE 15

SUMMARY OF PROXIMATE AND ULTIMATE ANALYSES-ASH≤60%
A Zone

SAMPLES EXCLUDED: 1. GENERAL TESTING
2. ASSIGNED VALUES
3. ASH > 25% & MAF KJ > 29000
4. ZONES A6, C1 & C2

PROXIMATE, MOISTURE AND OTHER SUMMARY

	HHV (KJ/KG) DRY	HHV (KJ/KG) ASH FREE	% ASH	% F.C.	% V.M.	% S	% MOISTURES AS RECVD.	% MOISTURES AIR DRY	% MOISTURES RES-IDUAL	% MOISTURES EQUIL.	% CO2	%ALK. AS NA2O	WATER SOLUBLE % NA2O	WATER SOLUBLE % K2O
MAXIMUM	26828	29605	60.00	47.46	44.44	4.95	33.82	25.83	20.87	35.60	29.22	1.46	.31	.12
MINIMUM	3526	8072	7.96	.01	21.80	.03	2.26	.97	.43	16.76	.06	.15	.18	.02
RANGE	23302	21533	52.04	47.45	22.64	4.92	31.56	24.86	20.44	18.84	29.16	1.31	.13	.10
WEIGHTED MEAN	16396	26219	39.09	28.35	31.86	.76	22.56	12.61	7.78	22.72	1.73	.61	.22	.05
SAMPLE COUNTS	1368	1368	1368	338	338	1366	351	351	1368	8	245	236	4	4
SAMPLE CORE LENGTHS	4472	4472	4472	1550	1550	4462	1630	1630	4472	49	1029	934	11	11
WGTD. STANDARD DEVIATION	3956	1827	11.64	7.29	4.63	.32	4.29	4.86	3.91	4.28	2.29	.25	.04	.03
WGTD. COEFF. OF VARIATION %	24.13	6.97	30.56	25.70	14.54	42.26	19.03	38.51	50.32	18.84	32.14	41.13	18.05	68.56

ULTIMATE SUMMARY

	% C	% H	% N	% CL	% S	% ASH	% OXY	% UNDET +ERR	% OXY (DIFF)
MAXIMUM	61.45	5.63	2.07	.93	3.10	60.00	22.86	3.52	20.31
MINIMUM	17.78	.79	.06	.00	.23	13.21	11.55	-3.75	8.56
RANGE	43.67	4.84	2.01	.93	2.87	46.79	11.31	7.27	11.75
WEIGHTED MEAN	41.06	3.42	.90	.04	.71	39.15	15.99	-.90	14.72
SAMPLE COUNTS	226	226	226	226	226	226	98	98	226
SAMPLE CORE LENGTHS	928	928	928	928	928	928	264	264	928
WGTD. STANDARD DEVIATION	8.72	.56	.25	.06	.27	10.76	1.96	1.33	1.66
WGTD. COEFF. OF VARIATION %	21.25	16.43	28.20	50.98	37.90	27.48	12.31	-47.42	11.34

TABLE 16

SUMMARY OF PROXIMATE AND ULTIMATE ANALYSES-ASH≤60%

B Zone

PROXIMATE, MOISTURE AND OTHER SUMMARY

	HHV (KJ/KG) DRY	HHV (KJ/KG) ASH FREE	% ASH	% F.C.	% V.M.	% S	% MOISTURES AS RECVD.	% MOISTURES AIR DRY	% MOISTURES RES-IDUAL	% MOISTURES EQUIL.	% CO2	%ALK. AS NA2O	WATER SOLUBLE % NA2O	WATER SOLUBLE % K2O
MAXIMUM	25274	29445	59.38	46.18	43.46	5.54	32.91	24.14	22.35	24.72	14.66	1.56	.32	.60
MINIMUM	1365	3283	11.29	14.82	21.22	.03	2.79	1.69	.74	16.85	.04	.13	.21	.02
RANGE	23909	26162	48.09	31.36	22.24	5.51	30.12	22.45	21.61	7.87	14.62	1.43	.11	.58
WEIGHTED MEAN	17692	26793	34.47	31.11	33.38	.67	23.28	13.91	8.34	22.03	1.73	.56	.27	.13
SAMPLE COUNTS	607	607	607	187	187	607	223	223	607	7	173	136	6	7
SAMPLE CORE LENGTHS	2126	2126	2126	847	847	2126	1051	1051	2126	50	738	539	18	22
WGTD. STANDARD DEVIATION	3683	1609	10.82	6.85	5.03	.33	3.81	4.52	4.05	2.56	2.42	.25	.02	.22
WGTD. COEFF. OF VARIATION %	20.82	6.00	31.40	22.04	15.08	49.16	16.39	32.52	48.65	11.64	40.11	44.80	8.36	62.34

ULTIMATE SUMMARY

	% C	% H	% N	% CL	% S	% ASH	% OXY	% UNDET +ERR	% OXY (DIFF)
MAXIMUM	58.96	4.51	1.51	.08	5.54	58.78	19.06	1.22	19.31
MINIMUM	26.11	2.41	.09	.00	.30	17.60	11.52	-4.01	10.79
RANGE	32.85	2.10	1.42	.08	5.24	41.18	7.54	5.23	8.52
WEIGHTED MEAN	44.00	3.53	.86	.02	.80	35.84	16.05	-1.60	14.95
SAMPLE COUNTS	127	127	127	127	127	127	61	61	127
SAMPLE CORE LENGTHS	486	486	486	486	486	486	139	139	486
WGTD. STANDARD DEVIATION	8.93	.52	.22	.01	.47	11.04	1.44	.93	1.89
WGTD. COEFF. OF VARIATION %	20.30	14.92	26.48	86.83	59.07	30.81	8.98	-58.49	12.69

TABLE 17

SUMMARY OF PROXIMATE AND ULTIMATE ANALYSES—ASH ≤60%
C ZONE

SAMPLES EXCLUDED: 1. GENERAL TESTING
2. ASSIGNED VALUES
3. ASH > 25% & MAF KJ > 29000
4. ZONE C1

PROXIMATE, MOISTURE AND OTHER SUMMARY

	HHV (KJ/KG) DRY	HHV (KJ/KG) ASH FREE	% ASH	% F.C.	% V.M.	% S	% MOISTURES AS RECVD.	% MOISTURES AIR DRY	% MOISTURES RES-IDUAL	% MOISTURES EQUIL.	% CO2	%ALK. AS NA2O	WATER SOLUBLE % NA2O	WATER SOLUBLE % K2O
MAXIMUM	26237	28937	59.96	39.73	43.44	4.21	29.92	23.29	18.62	22.65	15.60	1.57	.31	.04
MINIMUM	968	2373	9.33	7.48	20.34	.11	1.49	1.06	.43	20.79	.08	.18	.25	.03
RANGE	25269	26564	50.63	32.25	23.10	4.10	28.43	22.23	18.19	1.86	15.52	1.39	.06	.01
WEIGHTED MEAN	14103	25182	44.57	24.59	29.88	.47	22.14	14.31	7.25	21.50	2.74	.69	.28	.04
SAMPLE COUNTS	417	417	417	117	117	417	147	147	417	4	109	64	2	2
SAMPLE CORE LENGTHS	1273	1273	1273	568	568	1273	704	704	1273	28	462	286	6	6
WGTD. STANDARD DEVIATION	3410	2332	9.57	6.32	4.64	.36	3.94	4.99	3.92	.64	2.97	.27		
WGTD. COEFF. OF VARIATION %	24.17	9.26	21.47	25.69	15.53	77.22	17.81	34.87	54.10	2.97	8.12	39.19		

ULTIMATE SUMMARY

	% C	% H	% N	% CL	% S	% ASH	% OXY	% UNDET +ERR	% OXY (DIFF)
MAXIMUM	58.25	4.24	1.13	.08	1.09	59.96	20.83	.00	22.65
MINIMUM	23.32	1.42	.29	.00	.15	17.61	13.10	-7.42	10.50
RANGE	34.93	2.82	.84	.08	.94	42.35	7.73	7.42	12.15
WEIGHTED MEAN	33.83	2.78	.76	.01	.50	48.31	15.19	-2.44	13.81
SAMPLE COUNTS	60	60	60	60	60	60	24	24	60
SAMPLE CORE LENGTHS	257	257	257	257	257	257	70	70	257
WGTD. STANDARD DEVIATION	7.06	.53	.16	.01	.25	8.60	1.85	1.51	2.09
WGTD. COEFF. OF VARIATION %	20.89	19.23	21.57	75.15	51.94	17.81	12.21	-62.14	15.14

TABLE 18

SUMMARY OF PROXIMATE AND ULTIMATE ANALYSES–ASH $\leq$ 60%
D Zone

SAMPLES EXCLUDED: 1. GENERAL TESTING
2. ASSIGNED VALUES
3. ASH > 25% & MAF KJ > 29000
4. ZONES A6, C1 & C2

PROXIMATE, MOISTURE AND OTHER SUMMARY

	HHV (KJ/KG) DRY	HHV (KJ/KG) ASH FREE	% ASH	% F.C.	% V.M.	% S	% MOISTURES AS RECVD.	% MOISTURES AIR DRY	% MOISTURES RES-IDUAL	% MOISTURES EQUIL.	% CO2	%ALK. AS NA2O	WATER SOLUBLE % NA2O	WATER SOLUBLE % K2O
MAXIMUM	27398	31255	59.70	57.06	45.61	2.09	48.17	37.32	21.99	32.50	19.33	1.36	.35	.03
MINIMUM	3156	7831	7.96	7.40	23.06	.02	9.01	.44	.55	17.89	.05	.08	.15	.01
RANGE	24242	23424	51.74	49.66	22.55	2.07	39.16	36.88	21.44	14.61	19.28	1.28	.20	.02
WEIGHTED MEAN	21624	2[illegible]217	23.69	39.36	37.40	.31	24.51	14.05	10.21	25.73	.95	.46	.26	.02
SAMPLE COUNTS	1052	1052	1052	411	411	1052	551	551	1052	15	435	248	6	6
SAMPLE CORE LENGTHS	4635	4635	4635	2360	2360	4635	3149	3149	4635	111	2279	1241	18	18
WGTD. STANDARD DEVIATION	3191	1256	8.95	6.03	4.11	.16	3.98	5.06	5.05	4.84	1.32	.20	.04	
WGTD. COEFF. OF VARIATION %	14.75	4.45	37.80	15.33	10.98	53.09	16.27	36.03	49.42	18.82	39.14	44.41	18.71	

ULTIMATE SUMMARY

	% C	% H	% N	% CL	% S	% ASH	% OXY	% UNDET +ERR	% OXY (DIFF)
MAXIMUM	68.99	5.00	1.64	.41	.90	58.72	19.61	.14	19.33
MINIMUM	24.51	1.49	.12	.00	.15	8.13	13.40	-3.55	12.28
RANGE	44.48	3.51	1.52	.41	.75	50.59	6.21	3.69	7.05
WEIGHTED MEAN	55.99	4.09	.88	.02	.33	22.24	16.56	-1.47	16.44
SAMPLE COUNTS	234	234	234	234	234	234	65	65	234
SAMPLE CORE LENGTHS	1138	1138	1138	1138	1138	1138	152	152	1138
WGTD. STANDARD DEVIATION	7.08	.42	.14	.03	.13	8.27	1.04	.82	1.33
WGTD. COEFF. OF VARIATION %	12.65	10.28	16.95	36.66	40.31	37.17	6.30	-55.75	8.10

moisture or sulphur content. The majority of the proven beneficiation processes in use are wet, gravity separation processes. Dry processes have been used in the past and new dry processes are under development.

An extensive coal beneficiation program completed to date is outlined below.

Washability Tests

Sink and float tests using various size fractions of coal and liquids of different specific gravities in the range 1.30 to 1.90 helps to develop washability curves. These curves reflect the efficiency of separation and the corresponding thermal value improvement in coal. Larger samples of the coal are then processed through pilot-scale benefication plants to validate the predictions made from the sink-float tests and develop design criteria for various systems.

Testing Programs

Bucket-Auger Sampling

In 1973 three bulk samples of Hat Creek coal were obtained by drilling a series of 36-inch diameter bucket-auger holes shown on Plate 4 (refer to borehole location plan in geology section). These three samples represented coals of different quality: 13.2, 18.1 and 20.2 MJ/kg equivalent to 5700, 7800 and 8700 Btu/lb (db). Representative samples from these three were subjected to screen analysis and sink-float tests.

The clay content of the sample, especially the finer fractions, tend to affect the density of the solution, resulting in a separation at higher level and imbalance in float and sink weights. To augment this situation the normal procedure of using the same sample through a series of liquids of varying specific gravity was modified to produce nine splits from one sample, one for each specific gravity test.

The remainder of the three bulk samples was crushed to -20 mm (3/4 in). The (3/4 in x 28 mesh) fractions were cleaned using heavy media cyclones and the minus (28 mesh) fractions using water-only cyclones. In the heavy media process the clay coated the media creating density control problems and high magnetite loss. Part of the raw and washed coal samples were shipped to Canadian Combustion Research Laboratory, Ottawa for pilot-scale burn tests.

The tests showed poor washability characteristics due to the presence of high proportion of near gravity material. The ash distribution in the sink and float fractions for various size ranges does not show significant variation - thus no improvement in quality is to be expected by size reduction. In other words, ash in the transitional-zone-coal is not confined to the waste or clay bands but inherent in clay.

The pilot plant wash test further showed that the proportion of -28 mesh fraction was far greater than indicated from the laboratory dry screening. The clays in coal break down in the water circuits. To estimate the size degradation in this process wet attrition tests were performed on the samples sent to Warnock Hersey in 1977/78.

Higher yield values from the dense medium circuits, as compared to laboratory data, is attributed to the breakage of clay particles in the water, reporting to the -28 mesh fractions and thus reducing the ash content of the heavy medium cyclone feed.

The 3/4-inch trommel screen was completely blinded within 6 hours of the plant running, suggesting that clay in the feed is detrimental for effective separation. Yet dry screening is inefficient and impractical for clay removal.

There would be some reduction in the inorganic sulphur content of the coal through washing, with resulting lower powerplant sulphur emissions. Since 70 to 80 percent of the sulphur in this coal is organic nature, no direct reduction is anticipated by washing.

Trench Sampling (Bulk Sample Program)

In 1977 three samples were obtained during the bulk sample program: two from Trench A (Zone B/A coal) and one from Trench B (Zone D coal).

Sink and float tests, including wet attrition test for evaluating the size degradation, were carried out at Warnock Hersey Professional Services Laboratory in Calgary.

A 82-ton sample for EMR Canment Pilot Plant, Edmonton, was taken from two sections in Trench A, parallel to the pits from which laboratory samples were taken. This has permitted direct correlation between the washability and size consist data from the laboratory and the wash test results from the pilot plant. A second objective of this program was to evaluate the production and treatment of the liquid tailing effluent.

Conclusion Drawn from Test Results

1. Hat Creek coal is subject to severe breakdown in water especially where there is attrition. The clay particles from the coal form a suspension which can interfere with gravity separation processes. This problem is particularly severe in

the heavy-medium cyclone process, which has been eliminated from further consideration.

2. Washability data shows that the degree of beneficiation achieved would be relatively low for the effort expended.

3. The removal of high ash fines by dry screening would be limited to the treatment of low grade coal because of the difficulty of dry screening at the finer sizes necessary to obtain satisfactory recovery.

4. The better quality (D Zone) coal would not require washing because the small improvement in quality would not offset process losses.

5. The tailings produced by any process washing Hat Creek coal would be largely a clay-water suspension, which would be extremely difficult and costly to dewater. The quantity of tailings produced by any process would be dependent on the feed size of the material and the duration of contact between the coal and water.

6. There would be some reduction in the sulphur content per million Btu of the coal through washing, with resulting lower powerplant sulphur emissions.

Dry Processes

Screening and blending of the overflow material with the product is the simplest form of dry process.

Normally, the practical range of material that could be effectively screened is above 13 mm. The earlier screen analyses were confined to low ash material. In 1979, two new samples were taken from Trench A to test the low grade material below 9.3 MJ/kg (db). It was difficult to find any homogeneous coaly material within the specified grade (between 6.9 and 9.3 MJ/kg) in the B Zone exposed Trench A. Of several sections analyzed, the one closest to cutoff grade had 61.5 percent ash (db). The screen analysis data when plotted for cum. % wt. vs cum. % ash showed a reversal of general trend on which percentage ash increased with decreasing size.

This new data plot, in comparison to the seven earlier ones, led to the conclusion that for high ash material, the trend of increasing ash with decreasing size diminishes and eventually reverses. This implies that there exists at some undetermined ash level, a coal of constant ash independent of particle size. As mining advances, better understanding of the nature of material, its distribution and ash-size relationship will be developed.

However, the relatively difficult-to-determine nature of the narrow range of "low grade material", their very limited quantitative distribution in the total deposit and the problems associated with fine screening of clay related ash vis-à-vis corresponding cost benefit studies will be considered before final incorporation of this scheme.

Alternative Beneficiation Processes Considered

A wide range of possible beneficiation processes were reviewed in the light of the results of the test programs and the process characteristics. The processes were evaluated on the basis that only coal from the A, B and C-zones would be washed, while the better quality D-Zone coal would be blended with the wash plant product. The plant feed would be divided into coarse and fine fractions by screening at a nominal 13 mm. Six practical plant schemes were selected for evaluation:

5.8 COAL BENEFICIATION - (Cont'd)

1. Heavy-media bath (coarse coal) and water-only cyclone (fine).

2. Heavy-media bath (coarse) with untreated fines.

3. Baum jig (coarse) with untreated fines.

4. Untreated coarse with dried and classified fines.

5. Water-only cyclones for coarse and fine coal which would require crushing coarse coal to -40 mm. This scheme would be similar to the EMR pilot process.

6. Heavy-media bath (coarse) with dried and classified fines.

For each scheme a preliminary modular plant design was prepared and capital and operating cost estimates made. Predictions of plant performance were made based on the available test data.

Tailings Disposal

The disposal of tailings from a beneficiation plant received very close attention, because of the known difficulty experienced elsewhere by the tarsand, phosphate, diamond and china clay operations.

The concentration of clay particles would build up in the plant-process-water to a level that is unsuitable for use. Under lagoon storage conditions, it is anticipated that over a period of years natural sedimentation would produce a sludge with 40 percent solids. Any further improvement beyond this level would be extremely slow, requiring many years. The settling can be accelerated by the use of flocculants, which will produce a layer of relatively clear water for reuse in the process and a settled layer with a solids content of up to 40 percent. However, there are indications that the use of flocculants limits the long-term compaction.

5.8 COAL BENEFICIATION - (Cont'd)

The only possible alternative to lagoon sedimentation and storage is mechanical dewatering by the application of solid-bowl centrifuges. Laboratory work on Hat Creek tailings conducted at EMR, Edmonton, indicated that a cake of 75 percent solids material is possible. Operating plant experience suggests that a 45 percent solids product is a more realistic estimate. For the total beneficiation schemes evaluated, approximately 50 Mm^3 of 45 percent solids sludge will be produced over 35 years.

For phycial handling and disposal of the tailings two alternatives have been considered:

1. To convey the sludge with the wash-plant solid discard material to the Houth Meadows waste disposal area, a distance of approximately 2 km. Testing would be required to ensure that the sludge-solid discard mixture can be conveyed up 10 percent gradients in subzero temperatures.

2. To store the sludge in a lagoon, similar to that provided for the sedimentation process though smaller in dimension.

Of the two alternative methods for sludge disposal, only the lagoon sedimentation and storage approach can be considered proven and practical. There are some serious drawbacks to using this method: lack of a suitable storage space, the cost of building retaining structures for ther lagoons, and the possible permanent alienation of the land in the storage area should it prove impossible to reclaim.

The mechanical dewatering process would require further research and testing, particularly on the performance of centrifuge equipment and the handling and disposal of sludge, before it could be proposed with any confidence. Should dry disposal of the sludge prove impractical, the mechanical dewatering process could have the same disadvantages as their storage and sedimentation approach and be more expensive to operate.

5.8 COAL BENEFICIATION - (Cont'd)

Conclusions

An evaluation of the costs and benefits was conducted based upon the estimated capital and operating costs and the predicted plant performance of the selected schemes. The principal conclusions were:

1. Hat Creek coal can be beneficiated to produce a fuel averaging 21.0 MJ/kg, compared to 18.0 MJ/kg for run-of-mine coal.

2. Sulphur emissions could be reduced by approximately 20 to 25 percent using beneficiated fuel.

3. The disposal of clay tailings remains a major technical and economic problem, with potentially severe environmental impacts.

4. Resource utilization would be reduced by 5 to 8 percent because of process losses to tailings. This is partially offset by improved boiler efficiency, but the remaining losses must be made up by mining additional tonnages of coal at higher marginal stripping ratios.

5. The estimated capital and operating costs of the beneficiation plant exceed the anticipated savings in the powerplant.

Based upon these conclusions, it was decided to eliminate beneficiation from further consideration in the base plan.

5.9 BOILER FUEL SPECIFICATION DEVELOPMENT

Introduction

Various revisions of the fuel specifications were made as more data became available and new target specifications were set on coal quality. Each revision adopted a new methodology directed at removal of inconsistencies in the previous set of specifications and thereby improving the estimates obtained. Of particular concern was the derivation of reliable estimates of individual parameters; the average value was determined from such a large body of data that any averaging process using any reasonable weighting system yields basically the same average as all the others.

The first set of fuel specifications was developed by B.C. Hydro on 29 June 1978:

1. The means and standard deviations for proximate, ultimate and ash analysis were developed for each of the four zones (A, B, C and D).

2. The boiler fuel specification was developed by weighting each zone in the proportions to be mined in the 35-year pit.

3. The results obtained in 1 and 2 above were checked against samples selected from limited heating value ranges for each zone in the whole deposit. There is no significant difference between the parameters of an individual fuel of a given heating value and a blended fuel of the same heating value.

4. The values presented in the fuel specification were weighted mean values with the ranges of ±1 standard deviation.

The two prerequisite assumptions to this study were:

1. that the distribution of the analytical data be unbiased,

2. that analyses by various laboratories be within statistical limits set by ASTM.

5.9 BOILER FUEL SPECIFICATION DEVELOPMENT - (Cont'd)

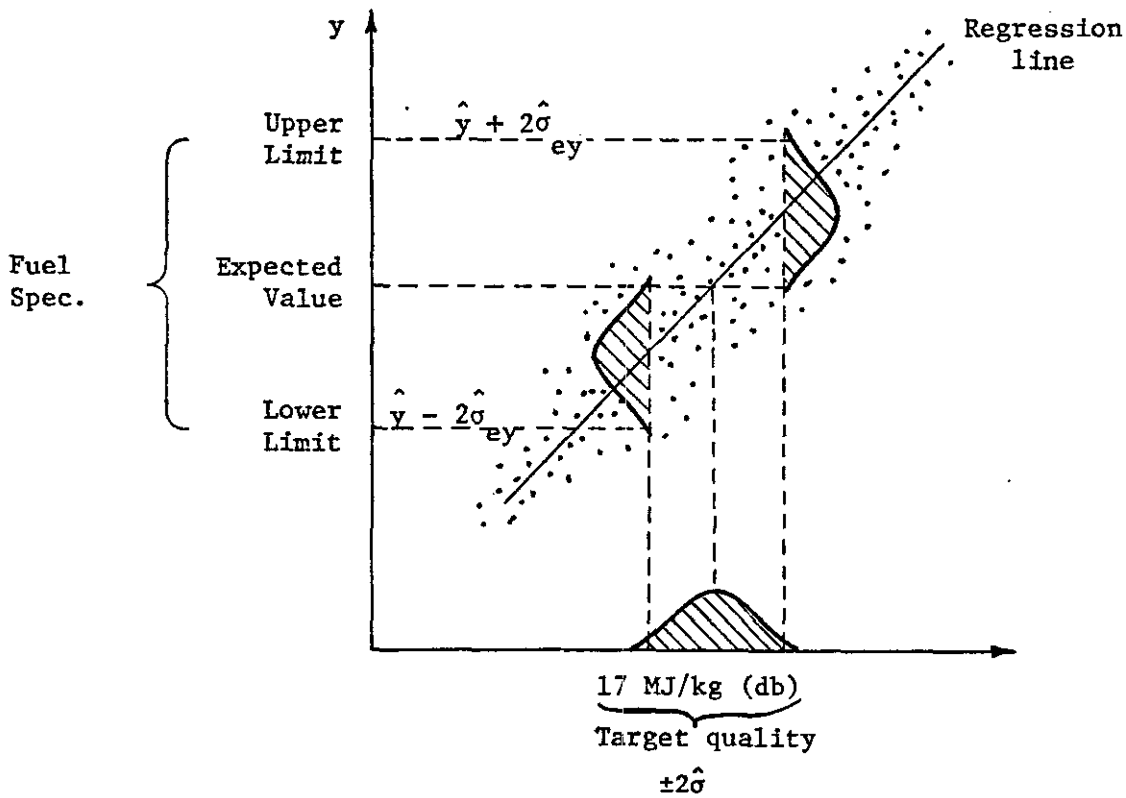
As the fuel consists of blended coals from different blocks, it was assumed that the standard deviation in the blended coal is about one third the standard deviation of the drill cores for all parameters.

Another important consideration in developing these fuel specs is the degree of dependence between each individual parameter and coal quality. If the boiler fuel meets the target specification, the range of variability of any fully dependent parameter is strictly determined by this target specification. To make an example, the ash content has an almost perfect negative linear dependence with coal quality ($r = -0.99$). By substituting the end members of the heating value range in the regression equation, the exact values of the end members of the ash content range are obtained. On the other hand, if we take a variable which is independent of coal quality, such as the silica content of the ash ($r = 0.05$), the best estimates of all analyses of the parameter's specs are given by the mean and standard deviation for all the analyses.

For variables with intermediate or partial dependence on coal quality, the relationship is linear in nature. Simple regression analysis can then be used to place confidence intervals on the range of variability of these parameters as the coal quality varies around its target. The target fuel, as proposed by mining group, was 17.0 MJ/kg (db) with a standard deviation of 0.5 MJ/kg, at +99 percent confidence level. In formulating the fuel specs, 95 percent confidence limits (two standard errors) have been constructed at 16.5 MJ/kg and 17.5 MJ/kg (two estimated standard errors). The highest and lowest values of these limits were conservatively taken as the 95 percent confidence interval for the fuel specs. The mechanics and logic of this computational scheme are graphically shown on the accompanying diagram (Fig. 8) for positive partial dependence, e.g. fixed carbon. For parameters with negative partial dependence, the diagram is the same but the regression line has negative slope.

Figure 8

FUEL SPECIFICATION PARAMETERS VS HEATING VALUE



5.9 BOILER FUEL SPECIFICATION DEVELOPMENT - (Cont'd)

Since none of the variables have either perfect dependence or independence, this scheme was applied in practice to all variables.

This methodology is perfectly consistent with regression theory. As the dependence increases the standard error of the estimate decreases and the confidence interval gets narrower. As the dependence decreases, the regression line approaches the mean of y line and the standard error of the estimate approaches the standard deviation of the y values.

Algebraically, $S_{ey}^2 = S_y^2(1 - r)^2$ where S_{ey} = standard error of the estimate of y

S_y = standard deviation of y

r = coefficient of correlation

Approaching dependence As r ±1, S_{ey}^2 0

Approaching independence As r 0, S_{ey}^2 S_y^2

This regression methodology for estimating the fuel specifications contains the necessary assumption that blended fuels in the target range have essentially the same values in all parameters as individual coals falling in the target range. Several independent studies have demonstrated the validity of this remarkable assumption.

Analystical Data Evaluation

In 1979, Paul Weir Company (WEIRCO), were retained as consultants to review the quantity and quality of analystical data available and the conclusions drawn from them to establish the fuel specification. They were also required to recommend a performance fuel specification in light of the selective mining scheme to upgrade the initial fuel specification.

For the inter-laboratory comparison they selected the main parameters. The distributaion of the core samples to the various laboratories was not concentrated in any one zone in section, thus the overall effect of eliminating one or more laboratory was minimal. Weirco believe that such exclusions do not affect the overall conclusions.

A series of regression studies were performed to establish certain relationships that are typical of western coals.

CO_2 - % = 0.058 x % Ash - 0.269
(This equation is used to adjust the volatile matter content for CO_2.)
Adjusted volatile matter - % = 48.90 - 0.475 x % Ash
Equilibrium moisture - % = 25.145 - 0.0617 x % Ash
As received moisture - % = 28.439 - 0.1566 x % Ash

A series of the Hardgrove Grindability Index (HGI) determinations at approximately 10 percent moisture were made on coal samples with varying ash content. Weirco calculated the following exponential curve as the best fit for the data:

$$HGI = 24.40\ e^{0.02 \times \%\ Ash}$$

Because of Weirco's previous experience with the under-reporting of the alkali content of western coals, a number of samples from each subzone were analyzed by two methods: the standard and a modified method. On an overall average basis, Na_2O was under-reported by 36.4 percent and K_2O by 17.0 percent. Based on these results, the alkali-content data was adjusted. These adjustments eliminated most of the undetermined error from the analytical data file.

Data summaries for the four zones were prepared for determining the final boiler fuel specification (Table 19). These summaries were prepared initially on a zone-by-zone basis and then on a

TABLE 19

HAT CREEK SUMMARY - ZONE ANALYSES
SELECTIVE MINING
(Ash, % ≤ 60)

	Zone A		Zone B		Zone C		Zone D	
	Mean	±S	Mean	±S	Mean	±S	Mean	±S
Moisture, %								
Equilibrium	22.7	4.3	23.1	2.6	22.4	0.6	23.6	4.8
As received	22.2	4.3	23.2	3.8	21.4	3.9	24.6	4.0
Proximate Analysis, % (dcb)[1]								
Ash	39.9	11.6	33.5	10.8	45.0	9.6	24.6	9.0
Volatile matter[2]	29.9	5.5	33.0	5.1	27.5	4.6	37.2	4.2
Fixed carbon	30.2	6.1	33.5	5.7	27.5	4.9	38.2	4.7
Ultimate Analysis, % (dcb)[1]								
Carbon	40.6	8.7	45.6	8.9	36.0	7.1	54.3	7.1
Hydrogen	3.4	0.6	3.6	0.5	3.0	0.5	4.0	0.4
Nitrogen	0.9	0.3	0.9	0.2	0.8	0.2	0.8	0.1
Chlorine	0.04	0.06	0.02	0.01	0.01	0.01	0.02	0.03
Oxygen (Difference)	14.5	-	15.7	-	14.8	-	16.0	-
Sulphur Forms, % (dcb)[1]								
Pyritic	0.22	0.16	0.20	0.35	0.11	0.12	0.04	0.09
Sulphate	0.02	0.02	0.03	0.02	0.01	-	0.02	0.03
Organic	0.50	0.20	0.44	0.20	0.31	0.17	0.24	0.10
TOTAL	0.74	0.27	0.67	0.47	0.43	0.25	0.30	0.13
High Heat Value, MJ/kg								
Equilibrium moisture basis	12.2	3.9	13.8	3.3	11.0	3.3	16.1	3.6
Dry coal basis	15.8	4.0	18.0	3.7	14.0	3.4	21.3	3.2
MAF basis	26.3	1.8	27.0	1.6	25.4	2.3	28.3	1.3
HGI @ 10% Moisture	51	-	45	-	56	-	38	-
Mineral Analysis of Ash, %								
SiO_2 (Acid)	51.8	6.3	52.3	6.4	52.1	7.3	54.1	7.7
Al_2O_3 (Acid)	28.9	4.3	28.8	5.0	27.8	4.5	27.5	5.6
TiO_2 (Acid)	1.0	0.3	1.0	0.3	1.0	0.3	1.0	0.3
Fe_2O_3 (Base)	8.6	5.6	8.6	6.6	10.0	7.7	7.2	5.9
CaO (Base)	3.1	4.1	3.2	4.2	3.2	4.2	3.9	2.6
MgO (Base)	1.7	0.6	1.6	0.7	1.7	0.7	1.2	0.5
K_2O (Base)	0.8	0.3	0.8	0.3	0.8	0.3	0.4	0.2
Na_2O (Base)	1.8	1.0	1.8	0.6	1.8	0.7	2.9	1.3
P_2O_3	0.3	0.3	0.2	0.3	0.2	0.2	0.1	0.1
SO_3	1.9	1.3	1.8	1.2	1.3	0.8	2.0	1.0
Mn_3O_4	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2
V_2O_5	0.1	0.1	0.1	<0.1	0.1	<0.1	0.1	0.1
Water Soluble Alkaline, % (dcb)[1]								
Na_2O	0.412	0.044	0.605	0.022	0.360	-	0.640	0.041
K_2O	0.067	0.033	0.164	0.242	0.028	-	0.026	-
CO_2, % (dcb)[3]	1.8	2.3	1.7	2.4	2.7	3.0	1.2	1.3

[1] dcb - dry coal basis.

[2] Adjusted for CO_2 (from regression equation for linear fit).

[3] From regression equation for exponential fit.

composite basis, where each zone was weighted in proportion to its contribution to the designed pit. In developing the data summaries, the regression equations were used to adjust the volatile matter, the HGI, and ultimate analyses except chlorine, sulphur and ash.

Concurrently, Weirco also examined the mining plan to evaluate its impact on coal quality. The principal conclusions drawn were as follows:

1. Core examination indicates that the run-of-mine coal quality can be upgraded by selective mining practices. Material exceeding 60 percent ash content should be excluded to the maximum practical extent.

2. No further allowance should be made for dilution, because the sampling procedures have included significant quantities of waste material within the good quality coal. This included waste interval could not be eliminated in the evaluation of selective mining.

3. The short-term fluctuations are the daily or weekly swings in quality which are a function of where the coal is being mined from a given bench or series of benches. On a weekly basis, the dry-ash content can probably be controlled to approximately ±1.5 percentage points, which equates to a heating value range of 0.6 MJ/kg. The daily fluctuations would be approximately double the weekly range.

Testing Programs

To establish the feasibility of burning various qualities of Hat Creek coal and to develop design parameters for full-size boilers and their associated equipment, two test programs were undertaken. The initial program was on a pilot-scale research boiler, followed by a burn test in a small commercial unit.

5.9 BOILER FUEL SPECIFICATION DEVELOPMENT - (Cont'd)

Pilot-scale Testing

Pilot-scale testing was conducted in the research boiler at the Canadian Combustion Research Laboratory (CCRL) in Ottawa.

Six samples of Hat Creek coal were tested along with a coal of known performance from Sundance, Alberta. The Hat Creek samples were obtained from the bucket-auger drilling program and consisted of three raw samples and three washed samples obtained from the test-washing program conducted by Birtley Engineering.

The principal conclusions and comments reported were:

1. Hat Creek coals having a heating value of 13.9 MJ/kg or more on an equilibrium-moisture basis can be successfully burned using conventional pulverized-fired technology. This heating value is equivalent to approximately 18.1 MJ/kg on a dry-coal basis. However, in the design of steam generators for this coal, it is imperative that reliable facilities be provided for removing the large quantities of ash that would be produced.

2. All three samples of raw Hat Creek coal burned during the program produced stable flames without support fuel.

3. The three samples of washed Hat Creek coals generally produced hotter, more stable flames than the raw coals. The removal of much of the extraneous clay by washing facilitiated handling and drying noticeably. Reactivity was also improved.

4. High clay and moisture content in the Hat Creek coal makes handling difficult. This problem could be minimized by drying the coal to less than equilibrium moisture.

The results of the CCRL pilot-scale tests were considered in the planning of the bulk burn test at Battle River.

Bulk Burn Testing

The principal objective of the burn test was to monitor the behaviour of Hat Creek coal of a quality at or near the anticipated minimum acceptable level in a commercial scale powerplant, and to obtain data needed for steam generator and ancillary equipment design. Key parameters observed included:

- coal-handling,
- pulverizer performance,
- combustion characteristics (flame stability and ignitability),
- slagging and fouling characteristics,
- ash-handling,
- precipitator performance.

The burn tests were conducted in Unit No. 2, a 32 MW (nominal capacity) unit at the Alberta Power Ltd. (APL), Battle River Station near Forestburg, Alberta, during August 1977.

In order to establish with confidence a lower limit for the practical burning of Hat Creek coal, the fuel selected for the test burn was below the minimum recommended by CCRL. The coal used in the test averaged 15.2 MJ/kg on a dry-coal basis, with individual tests being successfully run on samples as low as 13.0 MJ/kg. The "as received" moisture content was 21.8 percent.

The bulk burn test provided important practical data to establish the reasonable minimum quality of Hat Creek coal to be used as powerplant fuel.

Comparison with Other Plants

In assessing the suitablity of Hat Creek coal as a boiler fuel, it is useful to examine the design fuels for other powerplants. The Brazos Plant, San Miguel, Texas, has a 400 MW (net) unit scheduled for commercial service in early 1980, fuelled by raw lignite.

Table 20 compares some of the principal characteristics of the San Miguel fuel with Hat Creek performance coal and the fuel tested at Battle River.

Considering the results of the burn test and the San Miguel design fuel, the proposed Hat Creek performance coal (Table 21) appears to be well within the range of boiler technology and provides a reasonable basis for design.

Fuel Quality Control

To feed the powerplant with a fuel within the tolerance limits, especially HHV, ash content and sulphur, it is necessary to make long and short term forecasts based on reserves, corresponding quality, zonal distribution (based on variograms and kriging). The validity of these forecasts will be verified as mining progresses, and modifications made in further forecasts.

A three-stage quality control by coal sampling is envisaged.

Stage I - Preproduction Quality Control

This is probably the most critical stage in the quality control. Its main aim is to provide for long term and short term mine planning:

1. inventory of reserves,
2. quality distribution.

TABLE 20

COMPARISON OF HAT CREEK AND
SAN MIGUEL FUEL CHARACTERISTICS

Parameter	San Miguel Design Fuel	Hat Creek Battle River Test Average	Hat Creek Performance Coal
Heating value - as received MJ/kg	11.6	11.9	13.7
- dry basis MJ/kg	16.6	15.2	18.0
Moisture content (%)	30.0	21.8	24.0
Ash content - as received (%)	28.4	33.6	25.4
Weight of ash/heat input kg/GJ	24.4	28.3	18.5
Weight of water/heat input kg/GJ	25.8	18.4	17.5
Weight of coal/heat input - as received kg/GJ	86.0	84.3	73.0
HGI	92	44	45

TABLE 21

BOILER FUEL SPECIFICATION

	Performance Coal		Low-sulphur Coal	
	Dry-coal Basis	As Received	Dry-coal Basis	As Received
Moisture %				
Equilibrium	-	23.1	-	23.6
As Received	-	23.5	-	24.5
Proximate Analysis %				
Ash	33.5	25.6	24.6	18.6
Volatile Matter	33.0	25.3	37.2	28.1
Fixed Carbon	33.5	25.6	38.2	28.8
Ultimate Analysis %				
Carbon	46.2	35.3	54.3	41.0
Hydrogen	3.6	2.8	4.0	3.0
Nitrogen	0.9	0.7	0.8	0.6
Chlorine	0.03	0.02	0.02	0.02
Oxygen (by difference)	15.4	11.8	16.0	12.1
Sulphur Forms %				
Pyritic	0.13	0.10	0.04	0.03
Sulphate	0.02	0.01	0.02	0.02
Organic	0.36	0.28	0.24	0.18
Total	0.51	0.39	0.30	0.23
Higher Heating Value - MJ/kg	18.1	13.85	21.3	16.08
MAF Basis	27.2	-	28.3	-
Hardgrove Grindability Index (at 10% moisture)	45.0	-	38.0	-

TABLE 21 - (Cont'd)

	Performance Coal	Low-sulphur Coal
Mineral Analysis of Ash %		
SiO_2 (Acid)	52.6	54.1
Al_2O_3 (Acid)	28.3	27.5
TiO_2 (Acid)	1.0	1.0
Fe_2O_3 (Base)	8.5	7.2
CaO (Base)	3.4	3.9
MgO (Base)	1.5	1.2
K_2O (Base)	0.7	0.4
Na_2O (Base)	2.1	2.9
P_2O_5	0.2	0.1
SO_3	1.8	2.0
Mn_3O_4	0.2	0.2
V_2O_5	0.1	0.1
Base Acid Ratio	0.197	0.189
T_{250} °C	1500	1510
Water Soluble Alkalies %(dcb)		
Na_2O	0.51	0.64
K_2O	0.069	0.026
CO_2 % (dcb)	1.8	1.2
Fusibility of Ash °C (Range)		
Reducing - Initial Deformation	1170-1500+	1160-1500+
Softening	1210-1500+	1200-1500+
Hemispherical	1250-1500+	1230-1500+
Fluid	1290-1500+	1270-1500+
Oxidizing - Initial Deformation	1310-1500+	1330-1500+
Softening	1330-1500+	1340-1500+
Hemispherical	1340-1500+	1350-1500+
Fluid	1360-1500+	1360-1500+

Because of the time lag between preproduction stripping and actual mining, a detailed sampling and testing is suggested, especially in the area of combustion characteristics, environmental pollutants, etc.

Depending on mine planning and rate of production, a volume of coal is to be exposed ahead of production. Auger holes are drilled from the exposed benches on a 10 m x 10 m grid.

All standard and special analyses are conducted, and the data computerized, and quality projections made.

Stage II - Production Quality Control

The data from Stage I is confirmed by channel samples taken at regular intervals from the exposed bench faces. A detailed geological bench-face mapping at scale 1:100/200 showing the coal beds and waste partings and projecting them along their strike and dip helps update the block-quality.

The high ash material, thus identified in the bench faces will be spray painted for ease of recognition by shovel operators.

Conveyor Belt Quality Control

As production from several benches is blended together, crushed and loaded onto the conveyor belt, it is of paramount importance that the ash content be measured accurately and as near instantaneously as possible. The reason why "ash" parameter alone is selected is due to near linear relationship between ash and thermal value. Unfortunately, true ash determination by conventional pyrolysis methods, involving drying, crushing and subdividing of a sample prior to the actual laboratory determination is a lengthy process that cannot be effectively used in this region of high volume of material handling.

Ash monitors have been developed and used in Great Britain and other European countries for the past few years. These bulk density/ash meters in their earlier stages of development were elementary and the accuracy of the determination was affected by many factors such as material top size, percentage size variation, moisture content and packing density. The X-ray monitoring head required that the coal for analysis be crushed to -48 Tyler sieve mesh to present a minimum and consistent voidage.

The new bulk density meters are fed with constant volume and the corresponding bulk density are derived by monitoring weight only. Integrating bulk density-ash meter signals with an integrating unit gives the average ash content for that quantity over the given period of time. It is capable of providing a continuous integrated signal while the bulk density meter is running, and for different selected time periods up to full shift duration. The relationship between bulk density and ash has been established, therefore any wild ash changes will be minimized by integration.

Stage III - Blend Quality Control (from Stockpiles)

As coal is being loaded out from stockpiles, its quality should be within the acceptable limits. The strict quality control of the material going into the stockpile, undoubtedly smooths out any variation that might have existed before.

Provisions are made to sample the stockpile material in the quantities representative of a day's feed. The normal dimension of the stockpile being 570 m x 50 m x 17 m, a day's feed will represent 80 m x 50 m x 17 m, equivalent to 40 000 t.

Automatic samplers will monitor the ash level of the material as the material is loaded out. Should any serious fluctuation be noted, both the powerplant operators and the quality control group will be alerted. At this point high-grade material will be diverted immediately to the powerplant and to the stockpile. Such occurrences would be rare.

6.0 - COAL RESERVES

Coal reserve estimation is a function of the normal thickness of a seam or aggregate thickness of seams, the area underlain by the seams and the density of the material.

The quantity of coal in each "Block" is calculated as follows:

$T = Shd$

Where T = reserve in tonnes t

S = area underlain by coal m^2

h = normal thickness of seam(s) m

d = density of material tonnes per m^3

Some of the factors affecting the reserve estimation in the Hat Creek deposit are:

1. lack of sharp and regular contact between the seams or zones,
2. the varying ratio of coal and waste in blocks,
3. variation in coal quality within the block,
4. local structural complexity.

6.1 COMPUTER MODELLING

The structural complexity and quality variation of the Hat Creek deposit requires a methodology which is sensitive to the variability of main parameters, capable of accepting changes in the interpretation of geological structure, especially zone geometry and the interrelationship between zones.

With these requirements in view, a cross sectional computer model was constructed using the Variable Block Model (VBM) method

6.1 COMPUTER MODELLING - (Cont'd)

developed by Mintec Inc. The accuracy with which this model incorporated the structural geometry and the division into coal-waste fractions applying selective mining criteria in a block makes it more reliable for detailed planning in the early production years in the areas of steeply dipping zones and faulting than other models.

6.2 DEVELOPMENT OF VARIABLE BLOCK MODEL

Digitizing of Geologic Zones and Structure

The eighteen geological cross sections were digitized using an electronic digitizer. The co-ordinates of the top and bottom of the zones, including the borehole intersections, the faults and other features were entered into the computer.

On each cross section, the subzones were divided by faults and further divided into smaller blocks less than 200 m in horizontal length.

The upper and lower limits of each block coincide with the subzone boundaries, which produces a block of variable thickness conforming to the geological interpretation. Each block is projected halfway to the adjoining cross sections: 76.2 m north and south.

When the block definition process is completed the data is stored in the "geometry file".

Quality Assignment to Blocks

Composite sample values were calculated for each subzone in each drill hole. The individual samples were weighted by their length and specific gravity. The composite values were computed in two different ways. The first method combines all the samples, both coal and waste, for a given subzone and drill hole, which effectively assigns the whole intersection to either coal or waste at a given

6.2 DEVELOPMENT OF VARIABLE BLOCK MODEL - (Cont'd)

cut-off grade. This method represents non-selective mining. In the second method, the coal and waste samples were accumulated separately provided that they formed part of a band greater than 2 m in thickness, which reflects selective mining capability. Bands less than 2 m thick were combined with the adjacent samples. The split between coal and waste was defined by an assigned cut-off grade. Using the second method generated additional data for storage: coal thickness, waste thickness and the number of coal/waste contacts.

Quality values were calculated for each block using the inverse square of the distance method applied to the distance between the block centre and the mid-point of the composite sample used. The search distance used was 175 m north-south and 500 m east-west. If the closest composite contained no coal, then none was assumed to exist within the block. In the interpolation of blocks using the selective mining method the volumes of coal and waste in the block was estimated in proportion to the ratio of coal to waste thickness.

Blocks outside the search distance were classified as "undefined" and no quality values were assigned. Undefined materials were assumed to be waste in the A6 and C1 subzones and to be coal in the remaining subzones. The undefined coal is considered to be in the category of "Possible Reserves".

The specific gravity of coal was calculated from the formula:

$$S.G. = 1.221 + 0.00738 \text{ (\% dry ash)}$$

Burn zone material was assigned a specific gravity of 2.16, and other waste 2.00.

These factors were used in developing the composite sample values and in reserve calculations. In the "undefined" coal blocks calculations were based on the average specific gravity for the subzone.

Block values can be calculated for either the selective or non-selective mining cases and for different cut-off grades. Each set of block values is stored in its own "Quality File". In this study, four "Quality Files" were prepared: for both mining cases each at two different cut-off grades - 9.3 MJ/kg and 6.98 MJ/kg.

Application of the Variable Block Model

The "Geometry" and "Quality" files can then be used for calculating the reserves within a designed pit or for the total deposit.

6.3 RESERVES

1. Selective Mining - The proven and probable coal reserves with 2 m cut-off of the Hat Creek No. 1 depsoit have been computed to be 740 Mt with a heating value of 17.71 MJ/kg (dcb), ash content 34.82 percent and sulphur content of 0.51 percent. The possible reserves are an additional 45 Mt.

   These figures are for the proposed mining plan of selective mining with removal of 2 m partings and a cut-off value of 9.3 MJ/kg. Tables 22 and 23 show the distribution of the reserves by subzones and by 100 m bench elevations.

2. Non-selective Mining - If no parting removal as waste is considered then the reserves of the No. 1 deposit based on a cut-off value of 9.3 MJ/kg will be (as shown in Table 24) 746 Mt coal at 16.72 MJ/kg (dcb), 37.73 percent ash and 0.46 percent sulphur.

6.3 RESERVES - (Cont'd)

The coal reserves at the cut-off value lowered to 6.98 MJ/kg is 857 Mt (Table 25).

TABLE 22

COAL RESERVES BY SUBZONES AT 9.30 MJ/kg CUT-OFF
(Selective Mining – 2 Metres Minimum Thickness)

* HHV CUT-OFF 9.30 * NO DILUTION * 2-METRE MIN. THICKNESS *

DATE : 27-Mar-79

ZONE	COAL TONNES	ASH%	HHV MJ/KG	SUL%	TOTAL VOLUME	COAL VOLUME	WASTE TONNES	UNDEF TONNES COAL	UNDEF TONNES WASTE	UNDEF VOLUME COAL	UNDEF VOLUME WASTE
BURN	0.	0.00	0.00	0.00	6769.	0.	14620.	0.	0.	0.	0.
A1	27223.	31.18	10.74	0.75	28365.	18905.	18921.	0.	0.	0.	0.
A2	41408.	37.60	15.88	0.77	40524.	27566.	25915.	0.	0.	0.	0.
A3	35944.	45.50	13.76	0.65	41833.	23244.	37178.	0.	0.	0.	0.
A4	49558.	40.75	15.58	0.66	57099.	32794.	48611.	0.	0.	0.	0.
A5	50665.	44.42	14.47	0.74	56168.	38139.	36056.	0.	0.	0.	0.
A6	7041.	50.48	12.32	0.63	65940.	4450.	122745.	0.	235.	0.	117.
B1	72681.	38.06	16.55	0.65	56301.	48816.	14317.	488.	0.	327.	0.
B2	60561.	37.78	16.66	0.71	63751.	46075.	33836.	1129.	0.	758.	0.
C1	10245.	48.83	12.89	0.54	160095.	6527.	286629.	0.	20507.	0.	10253.
C2	19842.	47.06	13.37	0.51	24326.	12740.	22515.	512.	0.	328.	0.
C3	20058.	46.09	13.77	0.36	23116.	12940.	17272.	2388.	0.	1540.	0.
C4	32405.	45.01	13.90	0.35	31660.	21013.	18457.	2188.	0.	1418.	0.
D1	70005.	31.35	18.82	0.29	56075.	48594.	4150.	7799.	0.	5407.	0.
D2	89306.	25.18	21.09	0.27	70072.	64010.	0.	9585.	0.	6862.	0.
D3	70476.	19.70	23.08	0.29	59822.	51984.	389.	10367.	0.	7643.	0.
D4	66106.	24.84	21.50	0.38	55313.	47436.	668.	10518.	0.	7543.	0.
TOTAL	739523.	34.82	17.71	0.51	898027.	505233.	702279.	44973.	20742.	31825.	10371.

NOTE: 1. TONNAGES ARE THOUSANDS OF METRIC TONNES
2. VOLUMES ARE THOUSANDS OF CUBIC METRES

TABLE 23

COAL RESERVES BY BENCHES AT 9.30 MJ/kg CUT-OFF
(Selective Mining - 2 Metres Minimum Thickness)

* HHV CUT-OFF 9.30 * NO DILUTION * 2-METRE MIN. THICKNESS *

DATE : 27-Mar-79

SUMMARY FOR ALL BENCHES :

	BENCH	COAL TONNES	ASH%	HHV MJ/KG	SUL%	TOTAL VOLUME	COAL VOLUME	WASTE TONNES	UNDEF TONNES COAL	UNDEF TONNES WASTE	UNDEF VOLUME COAL	UNDEF VOLUME WASTE
1 (	1200)	0.	0.00	0.00	0.00	0.	0.	0.	0.	0.	0.	0.
2 (	1100)	235.	35.08	17.80	0.42	1487.	161.	2657.	0.	0.	0.	0.
3 (	1000)	40344.	40.41	15.64	0.56	79369.	26791.	105050.	341.	0.	244.	0.
4 (	900)	183099.	34.81	17.56	0.54	194776.	125031.	135066.	3476.	227.	2443.	114.
5 (	800)	209334.	33.47	18.15	0.51	206531.	143973.	122767.	1632.	8.	1177.	4.
6 (	700)	139151.	34.87	17.76	0.53	156375.	95061.	120642.	1373.	0.	994.	0.
7 (	600)	90910.	35.82	17.50	0.50	118810.	61814.	110798.	2116.	134.	1520.	67.
8 (	500)	53480.	35.75	17.57	0.41	80907.	36400.	77968.	5791.	2821.	4113.	1410.
9 (	400)	21455.	30.64	19.52	0.33	44104.	14982.	26946.	12713.	13578.	8859.	6789.
10(	300)	1514.	37.50	17.16	0.34	15666.	1019.	386.	17530.	3974.	12467.	1987.
11(	200)	0.	0.00	0.00	0.00	0.	0.	0.	0.	0.	0.	0.
	TOTAL	739523.	34.82	17.71	0.51	898027.	505233.	702279.	44973.	20742.	31825.	10371.

TABLE 24

COAL RESERVES BY SUBZONES AT 9.30 MJ/kg CUT-OFF
(Non-Selective Mining)

* HHV CUT-OFF 9.30 * NO DILUTION * NO MINIMUM THICKNESS *

DATE : 30-Mar-79

ZONE	COAL TONNES	ASH%	HHV MJ/KG	SUL%	TOTAL VOLUME	COAL VOLUME	WASTE TONNES	UNDEF TONNES COAL	UNDEF TONNES WASTE	UNDEF VOLUME COAL	UNDEF VOLUME WASTE
BURN	0.	0.00	0.00	0.00	6769.	0.	14620.	0.	0.	0.	0.
A1	43219.	48.17	13.04	0.53	28365.	27637.	1455.	0.	0.	0.	0.
A2	38078.	46.08	13.78	0.63	40524.	24600.	31848.	0.	0.	0.	0.
A3	32392.	54.60	10.94	0.53	41833.	20076.	43515.	0.	0.	0.	0.
A4	46830.	49.40	12.85	0.54	57099.	29744.	54710.	0.	0.	0.	0.
A5	60364.	49.93	12.68	0.64	56168.	38239.	35058.	0.	0.	0.	0.
A6	1839.	50.21	12.46	0.44	65940.	1164.	129317.	0.	235.	0.	117.
B1	69475.	36.91	16.83	0.64	56301.	46917.	18116.	485.	0.	327.	0.
B2	66861.	38.09	16.25	0.67	63751.	44716.	36553.	1135.	0.	758.	0.
C1	9043.	51.45	12.33	0.49	160095.	5672.	288300.	0.	20507.	0.	10253.
C2	23876.	49.10	12.65	0.52	24326.	15185.	17624.	517.	0.	328.	0.
C3	20766.	48.58	12.75	0.34	23116.	13244.	16665.	2416.	0.	1540.	0.
C4	32922.	46.72	13.24	0.34	31660.	21182.	18120.	2206.	0.	1418.	0.
D1	73542.	32.99	18.27	0.28	56075.	50669.	0.	7864.	0.	5407.	0.
D2	89306.	25.18	21.09	0.27	70872.	64010.	0.	9585.	0.	6862.	0.
D3	70052.	20.02	22.92	0.29	59022.	52179.	0.	10305.	0.	7643.	0.
D4	66693.	25.20	21.35	0.38	55313.	47769.	0.	10537.	0.	7543.	0.
TOTAL	746058.	37.73	16.72	0.46	898027.	503022.	706701.	45130.	20742.	31825.	10371.

NOTE: 1. TONNAGES ARE THOUSANDS OF METRIC TONNES
2. VOLUMES ARE THOUSANDS OF CUBIC METRES

TABLE 25

COAL RESERVES BY SUBZONES AT 6.98 MJ/kg CUT-OFF
(Non-Selective Mining)

* HHV CUT-OFF 6.98(3000BTUS) * NO DILUTION * NO MINIMUM THICKNESS *

DATE : 30-Mar-79

ZONE	COAL TONNES	ASH%	HHV MJ/KG	SUL%	TOTAL VOLUME	COAL VOLUME	WASTE TONNES	UNDEF TONNES COAL	UNDEF TONNES WASTE	UNDEF VOLUME COAL	UNDEF VOLUME WASTE
BURN	0.	0.00	0.00	0.00	6769.	0.	14620.	0.	0.	0.	0.
A1	44284.	47.83	12.94	0.53	28365.	28365.	0.	0.	0.	0.	0.
A2	46623.	49.60	12.68	0.59	40524.	29638.	21772.	0.	0.	0.	0.
A3	51223.	57.51	9.98	0.48	41833.	31339.	20980.	0.	0.	0.	0.
A4	52286.	53.28	11.63	0.49	57099.	38885.	36429.	0.	0.	0.	0.
A5	74965.	52.68	11.79	0.60	56168.	46911.	18513.	0.	0.	0.	0.
A6	3060.	58.15	10.65	0.36	65940.	1870.	127903.	0.	235.	0.	117.
B1	82809.	41.13	15.48	0.60	56301.	54868.	2212.	495.	0.	327.	0.
B2	76557.	42.01	15.24	0.66	63751.	50489.	25007.	1153.	0.	758.	0.
C1	14528.	55.61	10.80	0.52	160095.	8972.	281740.	0.	20507.	0.	10253.
C2	31374.	52.45	11.56	0.48	24326.	19658.	8679.	525.	0.	320.	0.
C3	28250.	52.04	11.63	0.32	23116.	17737.	7679.	2456.	0.	1540.	0.
C4	40550.	49.54	12.31	0.32	31660.	25765.	8953.	2236.	0.	1418.	0.
D1	73542.	32.99	18.27	0.28	56075.	50669.	0.	7864.	0.	5407.	0.
D2	89306.	25.18	21.09	0.27	70872.	64010.	0.	9585.	0.	6862.	0.
D3	70852.	20.02	22.92	0.29	59022.	52179.	0.	10385.	0.	7643.	0.
D4	66693.	25.20	21.35	0.38	55313.	47769.	0.	10537.	0.	7543.	0.
TOTAL	856909.	41.03	15.62	0.45	898027.	569124.	574497.	45235.	20742.	31825.	10371.

NOTE: 1. TONNAGES ARE THOUSANDS OF METRIC TONNES
2. VOLUMES ARE THOUSANDS OF CUBIC METRES

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