

HC Hat Creek 7509A

B.C. Hydro & Power Authority

Hot Creek Coal Project

ASSESSMENT OF ROTARY DRILLING
TRIAL PROGRAM

Hot Creek, British Columbia

GEOLOGICAL BRANCH
ASSESSMENT REPORT

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January 28, 1975

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VANCOUVER, CANADA



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SUMMARY AND CONCLUSIONS

A test rotary drill program consisting of four vertical holes totalling 4,693 feet has been completed, (December 2, 1974 - January 20, 1975), at Hat Creek. The holes were drilled into typical coal measure rocks in the vicinity of the No. 1 Openpit coal deposit.

The performance of the rotary drill is severely hampered at Hat Creek by the nature of the non-coal sedimentary rocks that comprise the coal-bearing strata. Because of their softness and clayey character these rocks tend to cave and squeeze the drill holes and ball-up the rotary bit, necessitating costly delays in reaming holes and cleaning bits, etc.

The test program has indicated that the rotary drilling's best average performance is no faster than diamond drilling and is not markedly less costly. The comparative total costs per foot are:

Rotary drilling \$15.53/ft.
Diamond drilling \$15.91 - \$17.43/ft. (Max. = winter conditions)

The major disadvantages in rotary drilling in the present exploration stage at Hat Creek are:

1. Lack of geological (stratigraphic and structural) data obtainable from core drilling.
- and 2. Lack of flexibility in drilling off existing roads.

It is concluded from the results of the test rotary drill program that there is no distinct advantage for B.C. Hydro & Power Authority to conduct any more of the exploratory (Stage 2) drilling with a rotary rig.

However, it is suggested that the rotary rig could possibly have speed and cost advantages over diamond drilling in some stage of development drilling of a defined openpit coal deposit. For this reason, the future use of this type of drilling should be again considered in the Hat Creek project when the conditions are more favourable for its particular characteristics.

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INTRODUCTION

Following extensive diamond drill exploration of the Hat Creek coal deposit in the summer of 1974, it was decided by B.C. Hydro & Power Authority to conduct a test program on the deposit using rotary drilling. The purpose of this test program, which consisted of four 1500-foot vertical holes, was to determine the suitability of rotary drilling, versus diamond drilling, in the exploration and/or development of this particular deposit.

LOCATION: (50° 45'N, 121° 35'W)

The Hat Creek coal deposit is located 120 miles northeast of Vancouver, B.C., midway between the towns of Lillooet and Ashcroft. Rail-heads are at Pavillion, on the B.C. Railroad, 15 miles to the northwest, and at Ashcroft, on the C.P. and C.N. Railroads, 23 road miles to the east. Easiest access to the property is from the Trans Canada Highway at Cache Creek 13 miles to the east, via the paved secondary highway between Cache Creek and Pavillion. The closest regularly serviced airport is at Kamloops, 60 miles to the east.

A well graded gravel road traverses the length of the Upper Hat Creek valley south from the Cache Creek-Pavillion highway.

PHYSIOGRAPHY:

The explored portion of the Hat Creek coal deposit underlies about one square mile of the north end of the broad, north-trending, grassland valley, about 16 miles in length, through which flows the upstream portion of Hat Creek. From the north end of this valley Hat Creek flows northeastward through a very narrow valley into the Bonaparte River, which flows south to join the Thompson River at Ashcroft.

The Upper Hat Creek valley lies within the Interior Dry Belt of British Columbia at a mean elevation of about 3500 feet. The coal deposit is located at an elevation of about 3000 feet. The valley is flanked by somewhat subdued mountains that rise to elevations of 6000-7000 feet four miles west of Hat Creek and to elevations of 5000-6000 feet six miles to the east. The uplands are covered with thin forest of fir and poplar and the valleys are open ranges of grass and sage with local, thin forests of pine.

Rock outcrops are sparse in the floor of the Upper Hat Creek valley. The overburden generally consists of loosely compacted sand and gravel that ranges in depth from 10 to 300 feet in the vicinity of the explored portion of the coal deposit. Some of the overburden is of volcanic (clastic) origin, not related to the sand and gravel in origin. Glacial till is also locally in evidence.

TEST ROTARY PROGRAM:

The specific purpose of testing rotary drilling at Hat Creek was to determine if the exploration for coal and the sampling of that coal could be accomplished more rapidly and economically, with no loss of effectiveness, by rotary drilling than by diamond drilling.

The work was performed by the Big Indian Drilling Division of Kenting Petrolia Drilling, Ltd., Calgary, with the use of a table-drive rig. Kenting was the sole bidder of six companies solicited for this contract. The rig had the design capability of drilling to a depth of about 1200 feet with dual-wall, reverse circulation equipment and to a depth of about 2000 feet with standard circulation equipment. The rig arrived on the site on December 1st, 1974. Drilling was carried out on a two, 12-hour shift basis during the periods from December 2nd to 19th and from January 3rd to 20th, 1975.

In this report, all of the pertinent data on the trial rotary program are presented and aspects of the trial rotary drilling program pertinent to the assessment of the rotary drill as a tool for the rapid and economical exploration of coal deposits in the Hat Creek valley are discussed.

GEOLOGICAL CONDITIONS

The valley of Upper Hat Creek is largely underlain by Tertiary volcanic and sedimentary strata that form a basin-like structure whose boundaries conform to the valley walls, at elevations of 1000 feet or more above the valley floor. The Upper Hat Creek "basin" of Tertiary formations lies north-south along the valley of upper Hat Creek for a length of about 16 miles and an average width of about 3 miles. It is entirely within the confines of the mountains to the east and to the west. The Tertiary formations occur beneath the valley floor and along its lower sides. The Tertiary sequence consists primarily of a thick sequence of sedimentary rocks, termed the Coldwater Formation, that is possibly underlain by a basal volcanic formation and that is unconformably overlain by an eroded cap of flat-lying volcanic rocks.

Most of the bedrock in the Hat Creek valley is covered by deposits of overburden ranging up to 400 feet in depth. The higher elevations of the valley sides are underlain by terraces of volcanic rocks that apparently represent erosional remnants of volcanic deposits that once covered the valley.

The bedrock geology of the Hat Creek graben is known only from scattered surface outcrops and, in the north end only, from the diamond drill cores. Since the drilling of the coal deposit is very limited in scope, the interpretation of the stratigraphy and structure of the Tertiary formations is subject to considerable variation of interpretation; however, the following basic features are established by the available drill core data:

1. The Coldwater sedimentary strata, of which the coal measure is a major portion at the north end of the valley, directly underlies the overburden in a strip that apparently extends the full length of Upper Hat Creek valley. At the north end of the valley this "window" of sedimentary bedrock is approximately 3 miles in width; four miles south, at McCormak Creek, it is about $1\frac{1}{2}$ miles in width; at the south end of the valley, at Blue Earth Creek, it appears to be only about $\frac{1}{2}$ mile in width. (The presence of overlying volcanic rocks along the flanks of the valley has been determined from outcrops and from a magnetometer survey.)
2. The Hat Creek Tertiary formations appear to be terminated along the entire western side of the valley by a north-trending, near-vertical block fault.

The occurrence of a similar fault along the east side of the southern half of the valley has been inferred from outcrop and air photo evidence as well.

3. The Tertiary formations at the north end of the valley are dislocated by one, and possibly three, eastnortheast-trending, near-vertical faults. One of these, the Medicine Creek Fault, is well located by outcrop evidence along Medicine Creek.

Diamond drilling and magnetometer surveys within the area of the coal measure north of the Finney Fault have established the presence of at least one, and probably three, northward-trending, steeply east-dipping faults that have an apparent displacement down to the east of more than 1000 feet.

4. The Tertiary Coldwater strata underlying the valley of Upper Hat Creek have been moderately deformed into north-northwest-trending broad folds. These strata are comprised in the drilled area at the north end of the valley, of at least 5000 stratigraphic feet of siltstone, shale, conglomerate and coal. The coal occurs in at least two layers or "seams", one 1600-1800 feet in thickness and the other 300-400 feet in thickness.

The thicker sequence of coal consists of three basic parts: the upper third is abundantly interbedded with siltstone, the middle third is interrupted by a few siltstone beds near its base, and the bottom third is essentially clean coal. This entire sequence of coal has now been designated as the No. 2 Seam. This main coal sequence is underlain by at least 800 feet of interbedded shale, sandstone and siltstone.

The trace of the hangingwall contact (top) of No. 2 Seam, which dips steeply west, lies about 1600 feet west of Hat Creek and strikes N 20° W for a distance of 4800 feet. It is truncated at the north and south ends by inferred faults.

5. The coal measure rocks at Hat Creek are, with minor exceptions, markedly poorly indurated. The non-coal rocks in particular are soft and very incompetent, with negligible shear or compressive strengths. They core well in diamond drilling, with recoveries generally in excess of 95 percent, but much of the rock breaks down readily when soaked in water and most of the core, (NQ), can be broken by hand. The pebbles in the conglomerates are hard volcanic rocks, but the cement is extremely weak. This feature applies to most of the sandstones and siltstones as well; however, there are numerous sandstone beds that are well cemented and are thus hard, competent rocks.

The coal is soft but it is compact and it generally cores well.

ROTARY TEST PROGRAM

GENERAL PROCEDURES:

As the 1974 diamond drilling progressed, it became apparent that the capability of rotary drilling should be assessed, particularly from the following three points of view:

1. As a general exploration tool in a "known" coal area, capable of penetrating rock rapidly and of returning good quality, reverse circulation coal samples at whatever depth coal is encountered. The key here is that the location of the coal may be known in advance only in a general way and that it may constitute either a major or minor portion of the drilled depth.

2. As a rapid, reconnaissance exploration tool using standard circulation equipment and capable of showing the presence or absence of coal but not necessarily of obtaining good quality coal samples.

and 3. As a tool for the detailed, development sampling of coal using reverse circulation equipment and confined to use in areas where thicknesses of rock overlying the coal are not large and where the bottom of the coal to be sampled is within the depth capability of the rig.

A fourth consideration, not pertinent to the present study, is the use of the rotary rig for obtaining engineering samples of overburden.

The above considerations formed the principal objectives of the four-hole rotary test program and therefore the discussions in this report concentrate on these features.

DRILLING:

Reverse circulation rotary equipment produces virtually uncontaminated samples which rise up the centre of a double-walled pipe under lift from air or a fluid forced down an annulus between the two pipes. Standard circulation equipment uses a fluid forced down the centre of a single-walled pipe to raise drill cuttings to surface between the pipe and the hole wall. These samples may be highly contaminated.

The initial intent of the Hat Creek test was to drill all four holes to a depth of 1500 feet with reverse circulation equipment using air as the circulating medium. It was anticipated that the injection of water into the air stream would be required to aid in the removal of sticky cuttings from clay-rich strata.

However; by the time the fourth hole was completed, almost every conceivable rotary drilling technique had been tried. These included the following:

- (i) Air
- (ii) Air with water injection
- (iii) Water
- (iv) Drilling mud
- (v) Standard circulation but using reverse circulation pipe
- (vi) Standard circulation using standard, single-wall pipe.

Tannins to thin the mud were considered but not used. Innovations also included the use of drag, tricone and modified tricone bits. The modified tricone bits, which proved reasonably successful, were altered by cutting away the tip of the long cone and bevelling the bottom ring of teeth on the smaller cones.

The drill rig was equipped with a table drive rather than an overhead drive, which meant that the bit had to be raised 15 feet off the bottom of the hole every time a new pipe was added. As a result, the possibility of plugging the bit before it returned to the bottom was always present. Hole sizes drilled were 4-7/8 inches for standard pipe and 5-1/8 inches for reverse circulation pipe.

Six-inch diameter casing was set by first advancing the hole with tricone bits ranging in diameter from 6-3/4 inches to 8-3/4 inches. After triconing, the drill pipe was removed and the casing was lowered to the bottom of the hole. Because there was no reaming shoe on the bottom of the casing, it could not be advanced to a greater depth without removing the existing casing and advancing the hole with the tricone. In caving ground, such as at Hat Creek, this is not a desirable procedure because there is no guarantee that the hole will not cave and prevent the casing from reaching the new bottom.

SAMPLING:

In the first two holes drilled, RH 74-1 and RH 74-2, bulk overburden samples were collected from 20 to 55 feet and 25 to 107 feet, respectively. They were recovered in five-foot lengths in a cyclone with reverse circulating air and were of suitable quality for sieve analyses. In the overburden sections of RH 75-3 and RH 75-4, drilling mud, which introduced contamination to the samples, was used; therefore, only small samples for geological examination were collected from the shale shaker.

Coal was encountered only in RH 75-4. The hole was drilled with standard circulation equipment making the samples subject to contamination from the hole wall. In this hole, however, the casing was set into the top of the coal,

and water instead of drilling mud was used as the drill fluid while sampling the coal. Contamination of coal samples, therefore, was only by coal or shale partings in the coal higher up the hole than the location being sampled. That same breakdown of the coal wall did occur was demonstrated by the presence of coal fragments in drill cuttings derived from below the coal, all the way to the bottom of the hole.

The coal samples from RH 75-4 were collected on the shale shaker. Some fines were undoubtedly lost.

Chip (geological) samples were collected in bedrock at five-foot intervals, washed, dried and examined with a binocular microscope to determine the stratigraphy in each of the four holes.

GEOPHYSICAL LOGGING

The standard geophysical logs being obtained in the Hat Creek drill holes are density, gamma ray, resistance, and caliper. The last two can be obtained only in open holes. The first two can be obtained in the open hole, through casing, and through double-wall reverse circulation drill pipe but not, because of size restrictions, through single-wall rotary drill pipe. However, it was shown during the rotary program that whereas gamma ray logs obtained through double-wall pipe provide useful information, density logs obtained under the same conditions are of little value. The density signal is too attenuated by the double-thickness of steel and the thick pipe joints mask rock signals. And, of course, any density log, even from an open hole, obtained without an accompanying caliper log is of limited value for purposes of correlating stratigraphy and is of questionable value for estimating the ash content of coal.

In the first two rotary drill holes, density and gamma ray logs were obtained through the double-wall pipe as insurance should the holes cave and not be loggable after removal of the pipe. This proved to be the case in RH 74-1. Open hole logs were obtained to a depth of only 230 feet in that hole.

Both RH 75-3 and -4 were judged to be in good enough condition to stand open for logging and this proved to be the case except for the bottom 190 feet of RH 75-4 which caved. (RH 75-4, of course, was drilled with standard circulation pipe and could not be logged through the pipe anyway.) Thus, essentially complete open hole logs were obtained in these holes except for a caliper log in RH 75-3 which could not be obtained because of an equipment malfunction.

DRILLING DETAILS

Abbreviated geological logs of the drill holes are given in Table I.

The first three rotary holes were drilled with reverse circulation equipment but encountered no coal. It was decided to drill the fourth hole with standard circulation equipment because by that time it was more important to establish the performance of the drill as a reconnaissance exploration tool than as a quality coal sampling tool. (See the three applications considered for the drill under "General Procedures", above.) It is reasonable to assume from experience elsewhere that reverse circulation equipment will return good quality samples from the Hat Creek coal deposit.

The overall drilling time was approximately the same for the rotary rig as for the diamond drill rig.

The drilling techniques used in each hole are discussed below with particular reference to problems encountered. The total length of the four holes drilled was 4643 feet.

RH 74-1 (7000 N, 5500 E; 960 feet T.D.)

0 to 54 feet - Reverse circulation with air to bottom of overburden where a water inflow prevented further advance.

54 to 116 feet - Reverse circulation with water injection in air not successful; advanced with difficulty with reverse circulating mud; considerable difficulty in getting the casing set to 101 feet in hole drilled to 116 feet.

116 to 960 feet - Reverse circulation with experimentation with air, air with water, water, and drilling mud; a water inflow at 118 feet caused caving and complicated the problems; the bits plugged frequently and when returning it to the bottom of the hole after it was cleaned it was necessary at times to ream for 100 feet or more; 40% of the time was consumed in pulling pipe, cleaning the bit and reaming back to the bottom of the hole.

In hind sight, it was generally agreed that the water inflow past the end of the casing and the use of air after the initial hole-wall damage set up a chain of events which resulted in more and more damage to the hole wall. Every time the pipe had to be pulled out, the situation was further aggravated. Also, because it was the first hole, the drill crews were unfamiliar with the characteristics of the rocks.

TABLE 1SUMMARY STRATIGRAPHY

Hat Creek Trial Rotary Drill Holes

RH 74-1

- 0 - 54 : Overburden; dirty sandy gravel
- 54 - 130 : Vesicular basaltic lava
- 130 - 174.5: Crystal tuff
- 174.5- 960 : Siltstones, claystones, sandstones and conglomerate with minor coal seams from 407 to 420 feet.

RH 74-2

- 0 - 107 : Overburden; dirty sandy gravel
- 107 - 804 : Claystones, siltstones and sandstones
- 804 - 880 : Cherty shale
- 880 - 905 : Mixed cherty shale and grey claystone
- 905 - 925 : Cherty shale
- 925 - 965 : Mixed cherty shale and claystone
- 965 - 990 : Mixed basaltic lava and claystone
- 990 -1055 : Very fine-grained basaltic lava

RH 75-3

- 0 - 94 : Overburden; sandy gravel, silty sand at 55' - 85'.
- 94 - 595 : Grey brown, silty claystone
- 595 -1168 : Brown clayey siltstone

RH 75-4

- 0 - 45 : Overburden; sandy gravel.
- 35 - 125 : Carbonaceous siltstone with some coal
- 125 - 135 : Silty coal
- 135 - 538 : Good coal
- 538 - 900 : Soft grey-brown siltstone, locally sandy
- 900 -1460 : Similar to above; locally conglomeratic

RH 74-2 (4000 N, 5000 E; 1055 feet T.D.)

0 to 107 feet - Reverse circulation with air in overburden; performance generally good.

107 to 149 feet - Reamed and advanced to 149 feet with mud and casing set.

149 to 807 feet - Reverse circulation with mud using modified tricone bits.

807 to 1055 feet - Reverse circulation with mud in harder ground and using unmodified tricone bits.

The better performance in this hole than in RH 74-1 can be attributed to the following:

1. Setting the casing deeper, thus sealing off a water inflow at 104 feet;
2. The use of drilling mud throughout in bedrock;
3. The use of modified tricone bits; and
4. The increased experience of the drill crews.

RH 75-3 (8000 N, 12000 E; 1168 feet T.D.)

0 to 94 feet - Reverse circulation with mud in overburden; only 50% mud return; minor caving at 94 feet.

94 to 1168 feet - Reverse circulation with mud; soft to moderately hard siltstones and claystones; drill-cuttings not as sticky when wet as those from previous holes; modified tricone bits were used in some places; casing set at 94 feet.

Because of the more easily drilled formations, the progress in this hole was much improved. In one 24-hour period, 416 feet were drilled. When the hole was stopped, the rig was near its maximum depth capacity with reverse circulation equipment.

RH 75-4 (10000 N, 10850 E; 1460 feet T.D.)

0 to 45 feet - Standard circulation with mud in overburden.

45 to 135 feet - Standard circulation with mud; casing set to 118 feet in depth.

135 to 538 feet - Standard circulation sampling of coal using water as the drilling fluid; some problems with cuttings rising up the outside of the casing instead of between the casing and the drill pipe; attempts made to cement around the casing at surface.

538 to 1460 feet - Standard circulation with mud; further problems with cuttings coming up on outside of casing; progress slowed in last few hundred feet by difficulty in raising cuttings from the hole. The hole was stopped short of 1500 feet because of the slow progress.

Thus, the major problem in RH 75-4, the only hole drilled with standard drill pipe, was in getting the cuttings out of the hole. A major factor in this regard may have been the fact that the drill kelly was an oversized one designed for use with the larger reverse circulation pipe. Thus, the clearance between the kelly and the drill pipe was restricted and this impeded passage of the cuttings.

The use of drilling mud instead of air in bedrock in holes R-2, -3, and -4 improved the performance but the clean samples initially hoped for were not obtained.

COSTS

Approximate costs for the drilling are given below. The costs are subject to small adjustments after all invoices for the work have been received. Costs for the following items are not included:

1. Extra mobilization charge for standard circulation pipe used in RH 75-4;
2. Casing left in the hole;
3. Site access and preparation; and
4. Sample bags.

<u>Cost Item</u>	<u>RH 74-1</u>	<u>RH 74-2</u>	<u>RH 75-3, -4</u>
Drilling (footage plus hourly rates)	\$12.70	\$ 9.50	\$10.81
Casing, reaming, moving, rig repair, bits, mud	5.65	2.98	2.30
Standby for geophysical logging	0.55	0.90	0.41
Board and lodging	1.10	0.70	0.93
Sub Total	<u>\$20.00</u>	<u>\$14.08</u>	<u>\$14.45</u>
Mobilization and demobilization	<u>1.08</u>	<u>1.08</u>	<u>1.08</u>
<u>Total</u>	<u>\$21.08</u>	<u>\$15.16</u>	<u>\$15.53</u>
Feet drilled	960	1055	2628

The higher unit costs for the first drill hole can be attributed partly to the presence of a large percentage of soft, sticky claystones in the drill hole and partly to the unfamiliarity of the drill crew with the characteristics of the Hat Creek sedimentary rocks. A drill crew thoroughly familiar with the area and using a top drive instead of a table drive rig could probably reduce the unit costs somewhat under those obtained in the last three holes.

The best drilling performances in 24-hour periods were 416 feet in one day in RH-75-3 and 330 feet in one day in RH 75-4. Average performances are shown below:---

	<u>Average Feet Per Hour</u>	<u>Average Feet Per Day</u>
Feet \div drilling hours only	7.25	174
Feet \div total hours (drilling, casing, moving, etc., but excluding standby)	5.92	142

COMPARATIVE COSTS: Rotary and diamond drilling.

If it is assumed that the rotary drill performance on holes RH 75-3 and -4 represents a near-average of what would be obtained in a full-scale program, the total cost per foot for rotary drilling at Hat Creek is approximately \$15.53 per foot. Comparison with the equivalent costs for diamond drilling of comparable holes at Hat Creek is as follows:

	<u>Total Cost/Ft.</u>	
Rotary drilling	\$15.53	(RH 75-3, -4)
Diamond drilling (Nov.-Dec.)	<u>\$17.43</u>	(Winter Conditions)(9,033')
Diamond drilling (July-Dec.)	<u>\$15.91</u>	(1974 Average) (35,446')

If the rotary drill is required to move off existing roads, an increase in total cost per foot of about \$0.50 to perhaps \$1.00 will occur.

COMPARISON OF ROTARY AND DIAMOND DRILLING

It is generally considered that rotary drilling offers distinct advantages in drilling rate and unit costs over diamond drilling. These advantages can then be offset against the disadvantages inherent in the rotary drilling. However, at Hat Creek the abundance of soft, sticky, clay-bearing rocks adversely affects rotary drilling rates and greatly increases unit costs, thereby decreasing the advantages the rotary rig normally has and making other considerations more important.

The relevant aspects of the two drilling techniques are compared below, emphasizing their specific relation to the Hat Creek conditions. Many of the features refer particularly to the conditions in the Hat Creek valley and encompass such considerations as the complexity of the geology and the importance of obtaining information on bedrock stratigraphy and structure. Some of the points refer to the particular rotary rig used, i.e., a table-drive rig with a depth capability less than that required for complete exploration of even the known Hat Creek coal deposits. A rotary drill with a greater depth capacity could be used but there are not many such rigs available and the unit costs would probably be higher.

DIAMOND DRILL ADVANTAGES (HAT CREEK):

1. Information on Bedrock Structure and Stratigraphy

Structures revealed in drill cores are not available from rotary cuttings. Dip meters can provide some structural information from rotary holes but the surveys are expensive (possibly as much as \$10 per foot) and holes $6\frac{1}{4}$ inches or more in diameter must be drilled.

Better stratigraphic information is obtained from drill cores.

2. Mobility; Site Access and Preparation Costs

Normally, the truck-mounted rotary rig should have the advantage in moving costs. At Hat Creek, the strength of the wooden bridges and their ability to accommodate the heavier rotary rig is important.

The rotary drill requires better new access roads and larger prepared sites. This increases both costs and land disturbance. The four holes drilled for the trial program were all purposely located near existing roads.

3. Depth Capacity

In non-squeezing ground, the diamond drill has a depth capacity in excess of 2000 feet for both exploration and coal sampling.

In any ground the rotary drill has a maximum depth capacity of about 1200 feet for sampling (reverse circulation) and of upwards to 2000 feet for exploration (standard circulation).

4. Standby Charges for Geophysical Logging

Hourly standby rates are lower for the diamond drill.

5. Setting Casing

With the rotary rig used for this program, casing once set could not be installed to a lower level without removing it and deepening the hole with a tricone. In badly caving ground, this is a marked disadvantage.

ROTARY DRILL ADVANTAGES:

1. Unit Costs

Under winter conditions, and provided the rotary rig drills only from existing roads, the rotary drilling can probably be done for a saving of about \$2.00 per foot. Since winter conditions have more effect on the diamond drilling, (hauling water, etc.), it should be appreciated that under non-winter conditions the cost advantage of the rotary drilling at Hat Creek may become less than \$1.00 per foot.

2. Geophysical Logging

A better mud cake is built up on the wall of the rotary hole; therefore, the probability of obtaining complete open-hole logs is higher.

However, reasonable quality gamma ray and density logs can always be obtained through the diamond drill rods. No geophysical logs can be obtained through standard circulation pipe; if the standard hole caves, the only information obtained is the general stratigraphy from the contaminated drill cuttings. The situation is similar for a reverse circulation rotary hole except that an inferior quality gamma ray log can be obtained through the pipe before removal if the possibility of caving is suspected.

3. Coal Sampling

(The depth restriction of the rotary rig for coal sampling has been noted above.)

Rotary coal samples are larger and could provide more material for special tests.

Coal recovery by diamond drilling at Hat Creek has been excellent

but reverse circulation rotary samples using air could be of equal or better quality. If it is necessary to use drilling mud for rotary drilling, very inferior coal samples will be obtained.

4. Overburden Sampling

The rotary rig can obtain large, representative but disturbed samples of overburden in which finer sizes predominate.

The diamond drill can obtain undisturbed samples and possibly more representative samples in coarser overburden.

SUMMARY:

Considering the preceding comparative advantages and disadvantages of the two types of rigs, the most important one for Hat Creek is the availability of detailed structural and stratigraphic information from the diamond drill cores. At this stage of development of the deposit, it is our opinion that this advantage more than offsets the apparent potential cost saving to be gained by using the rotary rig for either reconnaissance or general exploration purposes. However, a rotary rig, particularly one with a top drive and greater depth capability, could still offer advantages for development sampling of known coal after the major geological structures have been deciphered. Alternatively, during the development drilling of coal, a rotary rig could be used to drill and sample the overburden portion of a hole and a diamond drill could be used to drill and sample the coal and bedrock portions.

CONCLUSIONS

The original premise has been that rotary drilling of the Hat Creek valley would provide a means of exploring for and sampling coal which, when used in conjunction with geophysical logging, would be considerably cheaper and faster than the diamond drilling. The four-hole test program has admittedly been limited in scope, nevertheless there has been no indication from it that the rotary drilling, under Hat Creek conditions, will be appreciably cheaper than the diamond drilling nor any faster. The fundamental hindrance to the rotary drill performance at Hat Creek is simply the nature of the rocks that comprise the Coldwater Formation; they are soft and clayey and persistently ball-up the rotary bit, as well as tighten on the casing and rods.

The absence of capability of the rotary drill to return the geological data obtainable from cores, as well as to drill as deep as the diamond drill and at the angles possible with the diamond drill, are critically important disadvantages to rotary drilling at Hat Creek at the present stage of exploration of the coal resource in the valley. These disadvantages would not be as critical however should the rotary drill be employed in the development of a defined openpit coal deposit.

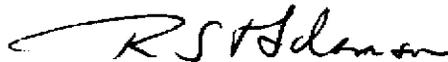
The results of the test rotary drill program at Hat Creek have not revealed any significant advantages to B.C. Hydro & Power Authority, under existing drilling conditions, to undertake any further exploratory work in the valley with a rotary rig at this time. Consideration for use of a rotary rig in development drilling of a known coal deposit should however be made again in the future.

Respectfully submitted,

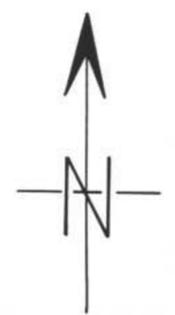
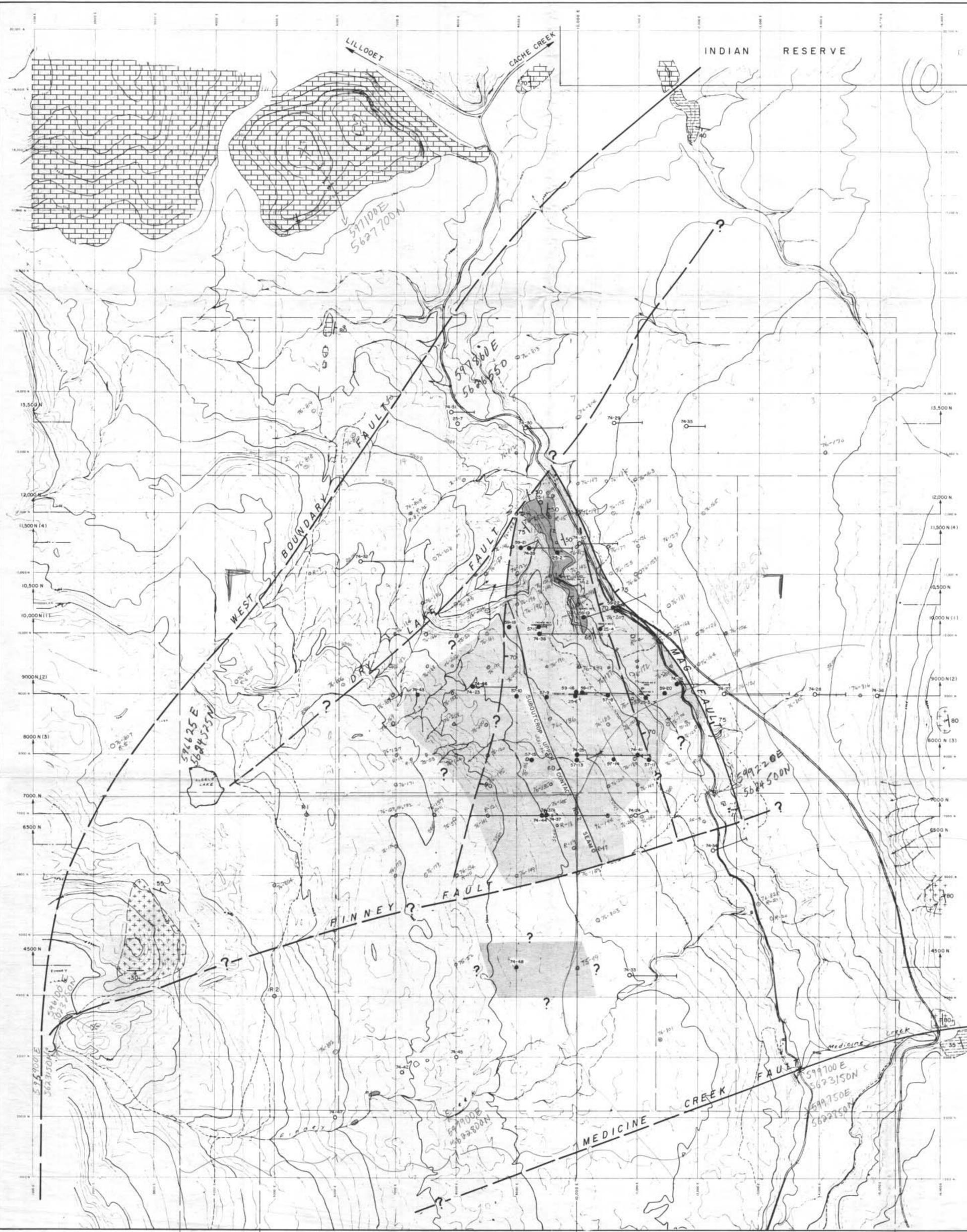
DOLMAGE CAMPBELL & ASSOCIATES LTD.



RW
L. T. Jory, P.Eng., Ph.D.



Douglas D. Campbell, P.Eng., Ph.D.



SCALE 1" = 800'
 0 800 1600 2400 FEET

LEGEND

- OVERBURDEN
- (TERTIARY ?) VOLCANIC ROCKS
- TERTIARY SEDIMENTARY ROCKS (Coldwater Fm)
- COAL
- AREA UNDERLAIN BY STRIPPABLE COAL
- PRE-TERTIARY
 - CACHE CREEK GROUP (Marble Canyon Limestone)
- 80 / BEDDING ATTITUDE
- FAULT (Known)
- FAULT (Inferred)
- DRILLING
 - DIAMOND DRILL HOLE IN COAL (Mineable from surface)
 - DIAMOND DRILL HOLE (No surface mineable coal)
 - 57-12 YEAR DRILLED - HOLE NUMBER
 - OR 2 ROTARY DRILL HOLE (1974 - 1975)

HC 75(0)A

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DOLMAGE CAMPBELL & ASSOCIATES LTD, CONSULTANTS VANCOUVER, CANADA		
B.C. HYDRO & POWER AUTHORITY VANCOUVER, CANADA		
HAT CREEK COAL DEPOSIT		
NO. 1 OPENPIT DEPOSIT DRILL HOLE PLAN		
SCALE 1" = 800'	JAN. 1/1975	FIG 5