HYDROGEOLOGY

BLIZZARD RIDGE, BRITISH COLUMBIA

(and adjoining areas)

for

NORCEN ENERGY RESOURCES LIMITED

by

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78-089

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SELECTED REFERENCES

Arndt, R. H. and Kuroda, P. K.
1953: Radioactivity of Rivers and Lakes in Parts of Garland and Hot Spring Counties, Arkansas: Econ. Geol., V.48, pp 551-567.

Bayrock, L. A., Kuss, C. P. and Thomson, I. P.
1979: Surficial Geology Blizzard Property, British Columbia. (Not published).

Boyle, D. R.
1979: The Dispersion of Uranium in the Vicinity of Miocene "Basal Type" Uranium occurences in the Lassie Lake Area, South-Central British Columbia; in Current Research, Part A. Geol. Surv. Can., Paper 79-1A, p 340-356.

Cedergren, H. R.
1977: Seepage, Drainage, and Flow Nets; 2nd Edition, Wylie, p 75.

Cooper, H. H., Jr. and Jacob, C. E.
1946: A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History; Trans. Am. Geophys. Union, v 27, pp 526-534.

Envirocon Ltd.
1978: Norcen Energy Resources Limited Blizzard Uranium Project Environmental and Socio-economic Feasibility Report. (Not published).

Hardy R. M. & Associates Ltd.
1978: Geotechnical Investigation Blizzard Mine Project Beaverdell, B. C. (Not published).
1979: Additional Geotechnical Investigations Blizzard Mine Project Beaverdell, B. C. (Not published).

Hazel, C. P.
1973: Groundwater Hydraulics, Australian Water Resources Council, Queensland Irrigation and Water Supply Commission.

Little, H. W.
1957: Geology of the Kettle River (East Half) Area, British Columbia; Geol. Surv. Can. Map 6-1957.
1961: Geology of the Kettle River (West Half) Area, British Columbia; Geol. Surv. Can. Map 15-196.

SELECTED REFERENCES

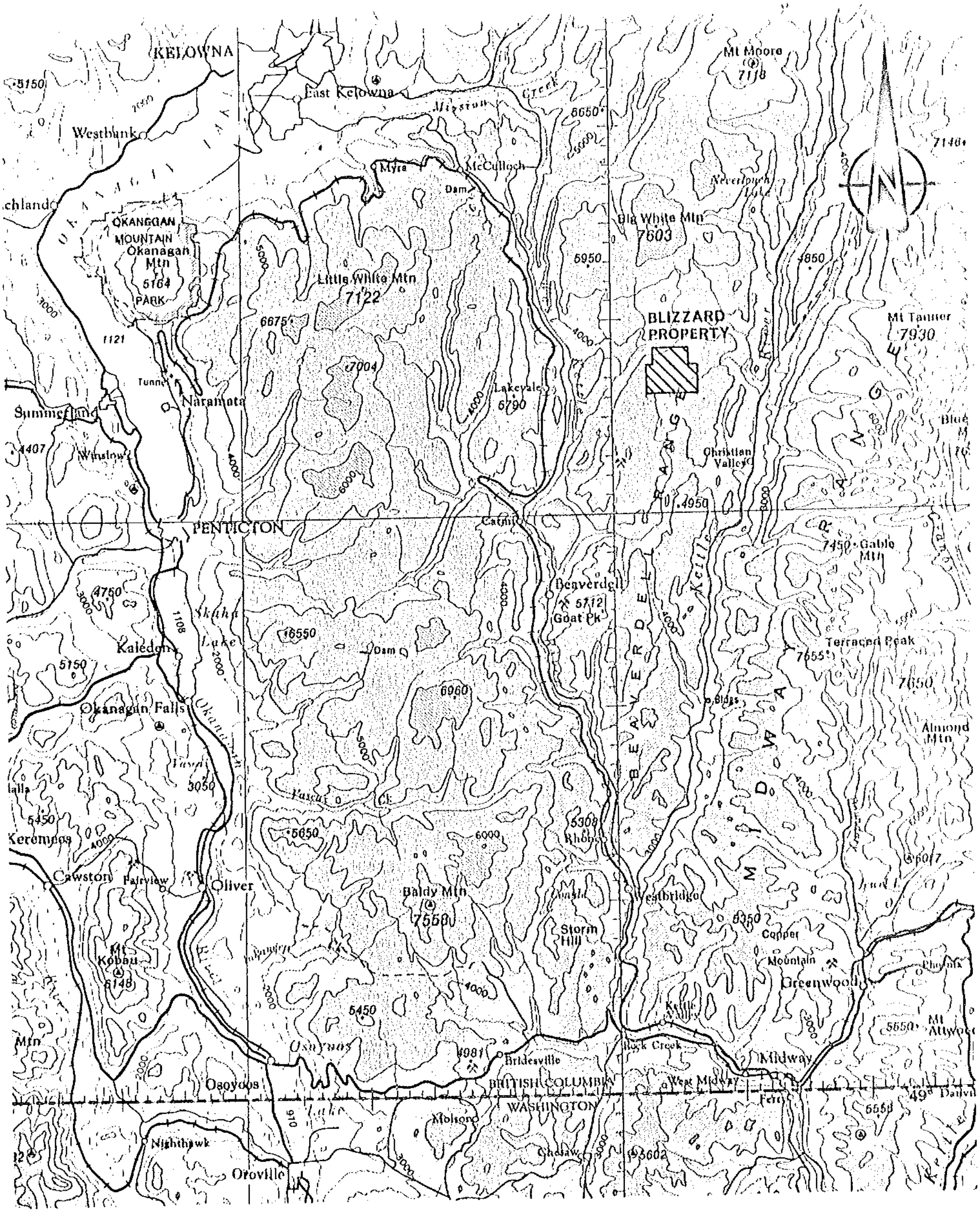
Continued...

McKee, J. E. and Wolf, H. W.
1963: Water Quality Criteria, Pub. No. 3-A, California State Water Resources Control Board, Reprint Dec. 1971.

McWilliams, G. H., Barclay, J. E., Sawyer, D. A. and Turner, A. J.
1978: Yearend Geological Report 1978 Drilling and Exploration Program Blizzard Property British Columbia N.T.S. 82-E-10W; 3 vols and 3 boxes. (Not published).

The Joint Committee on Drinking Water Standards
1968: Canadian Drinking Water Standards and Objective 1968, Dept. Health and Welfare Canada, Reprint 1972.

Theis, C. V.
1935: The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage; Trans. Am. Geophys. Union, vol 16, pt 2, pp 519-524.
1952: Reissue of Theis, 1935; U. S. Geol. Surv. Notes No. 5, Hydraulics, August.



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LOCATION PLAN
BLIZZARD URANIUM PROJECT

DWG. 1

1.0 EXECUTIVE ABSTRACT

The hydrogeology of Blizzard Property and its environs have been studied by:

1. The drilling, logging and testing of three specifically designed groundwater test wells screened in the ore body sandstones.

2. The drilling, logging and testing of 42 piezometers located in and around the containment area and on the slopes of Blizzard Ridge.

3. The compilation of geologic data from published and unpublished reports.

4. The examination of air photos.

5. The examination of the site on the ground and from a helicopter.

6. The inventory of groundwater use in the valleys of the Kettle and West Kettle Rivers and their tributaries.

The largest and most reputable water well drilling contractor in British Columbia constructed the water wells and piezometers under the constant supervision of a Hydrogeologist registered to practise engineering in the Province of British Columbia.

No unusual hydrogeologic conditions exist on or around Blizzard Ridge. The water table-piezometric surface is sub-parallel to the topographic surface. Hills and ridges are recharge areas and some valleys and depressions are discharge areas. The discharge areas are of limited areal extent. The deeply incised valleys of Trapping, Copper Kettle and Beaverdell Creeks and of the Kettle and West Kettle Rivers effectively separates the Blizzard Ridge groundwater flow system from areas beyond these valleys.

1.0 EXECUTIVE ABSTRACT continued

Uplift and glacial erosion has taken the Blizzard ore body out of the hydraulic groundwater discharge regime under which it formed into a hydraulic recharge regime under which the ore body is presently being wasted or leached. Springs and seeps (intermittent springs) are present on the slopes of Blizzard Ridge.

The mean contents of uranium in waters and sediments in the region around Blizzard Ridge is 0.49 parts per billion and 12 parts per million respectively. This compares with an Okanagan Plateau regional mean of uranium content of 0.29 ppb for waters and 6.8 ppm for sediments. The uranium content in waters and sediments in the region around Blizzard Ridge ranges from 0.07 to 74 ppb and 0.80 to 178 ppm respectively. The uranium content for waters and sediments on and around Blizzard Ridge range from 0.2 to 18.0 ppb and 4.5 to 178 ppm respectively.

are

The representative effective permeabilities used in calculation of groundwater flows are as follows:

Basement Rocks	10^{-7} cm/sec
Surficial Sediments	10^{-5} cm/sec
Ore-bearing Sedimentary Rocks	10^{-3} cm/sec.

Sandstones

Using these permeability figures it is calculated that a particle of water will take over 3200 years to move through the basement rocks from the northwest end of the ore body to the closest part of Trapping Creek valley. A particle of water will take over 320 years to move through the glacial debris over the same distance.

The groundwater flow through the basement rocks is so small and so slow that for all practical purposes it can be ignored. The relatively high permeability

1.0 EXECUTIVE ABSTRACT continued

ore-bearing sedimentary rocks allow the groundwater to flow longitudinally along the sinusoidal bedrock channel containing these sediments and to discharge as springs and seeps at either end of the deposit.

Groundwater is not used by humans on the plateau surrounding Blizzard Ridge (except for the Norcen camp) nor in the valleys of Trapping or Copper Kettle Creeks. Surface water is generally used in the valleys of the Kettle and West Kettle Rivers. A few dug wells produce domestic and irrigation water for farms.

Groundwater is used for domestic purposes at the communities of Beaverdell, Carmi and Westbridge where approximately 50 wells have been drilled. The wells range in depth from 14 to 17 meters (45 to 55 feet) and obtain water from sands and gravels that are capped by silty gravels. Carmi and Beaverdell lie 20 and 25 kilometers (12 and 15 miles) respectively to the southwest of the ore body and Westbridge lies 50 kilometers (30 miles) to the south of the ore body.

2.0 INTRODUCTION

2.1 General Statement

Envirocon Ltd. was retained by Norcen Energy Resources Limited (Norcen) to conduct an environmental base line study on a potential mine near Beaverdell, B. C. Crippen Engineering Ltd. was retained by Envirocon to study the hydrology of the area and in turn retained Brown, Erdman & Associates Ltd. as their specialist consultants in the field of hydrogeology (groundwater geology and hydrology).

Norcen retained Kilborn Engineering (B. C.) Limited to conduct certain engineering studies and designs for the project. Kilborn in turn retained Hardy Associates (1978) Ltd. to conduct the geotechnical aspects of the project.

2.2 Location and Physiography

Blizzard Ridge which contains the Blizzard Property is located in the Lassie Lake area of south-central British Columbia approximately 400 kilometers (250 miles) east of Vancouver and west of Calgary in the Okanagan Highlands Physiographic Province. The Okanagan Highlands is an area of subdued or moderate relief with marked incised river valleys. The plateau areas have an average elevation of 1220 meters (4000 feet) with small hills and ridges, such as Blizzard Ridge, that rise to a general elevation of 1400 meters (4600 feet). The main valleys of the Kettle and West Kettle Rivers to the east and west of Blizzard Ridge respectively occur at a general elevation of 920 meters (3000 feet) and are typical glaciated valleys with a generally flat floor of little topographic relief. The location and regional setting is illustrated on Drawing 1.

2.3 Rationale

2.3.1 General Statement - The groundwater geology and hydrology (hydrogeology) of the potential Blizzard Mine-Mill complex and surrounding areas must be known in sufficient detail to allow groundwater flow rates and directions to be predicted with a reasonable degree of accuracy. Water can transport contaminants and of the two types of water, namely surface water and groundwater, the latter is generally hidden from easy inspection. The programs described in this report were conducted to establish the natural characteristics of the regional and local hydrogeology and to ensure that the proposed mine-mill-containment activities would not alter the groundwater regime to the extent that contamination and slope stability problems would arise.

2.3.2 Regional Study - A general survey of the use and occurrence of groundwater in the valleys of the Kettle and West Kettle Rivers was conducted and the general hydrogeology described. These studies are necessary to establish the existing groundwater features of the region where the Blizzard complex would be located. Such a study will establish the relationship of regional groundwater flow to the local conditions.

2.3.3 Local Study - The groundwater conditions in the ore-bearing sediments have been studied by the drilling and aquifer testing of three specially designed and constructed exploration water wells. Conditions in the complex area have been studied using 42 piezometers. Please refer to Local Location Map Drawing No. 2.

2.3 Rationale, continued

2.3.3 Local Study - continued

These studies are required to establish the groundwater flow rates and directions that exist under natural conditions in the Mine, Mill and Containment areas prior to operation.

2.4 Timing

The groundwater investigations were conducted on the following schedule:

Date	Activity
April 18/78	Site inspection.
April 20/78	Groundwater program designed and recommended.
May 31/78	Groundwater program authorized.
June 20/78	Bids for groundwater program requested.
July 10/78	Phase I groundwater drilling program for the ore-bearing sediments started.
Sept 10/78	Phase I groundwater drilling program finished.
Oct 3 to 6/78	Survey of Kettle and West Kettle River Valleys.
Nov 20/78	Preliminary report presented.
Dec 5/78	Phase II groundwater program for containment area started.
Jan 8/79	Phase II groundwater program finished.

2.4 Timing, continued

Date	Activity
July 24/79	Phase III groundwater program for local area started.
Aug 15/79	Phase III groundwater program finished.
Sept 7/79	Revisions and final report finished.

3.0 METHODS

3.1 Available Data

The logs of 327 exploration holes, drilled by Norcen to evaluate the ore body, were reviewed and data from these logs were used to delineate the aquifers within the ore body. During aquifer testing many of these exploration holes were used as observation wells to measure aquifer response to pumping. These exploration holes were subsequently cemented.

Norcen personnel mapped the geology of Blizzard Ridge and the surrounding plateau areas by means of ground traverses, air photo studies and compilation of published maps and reports. This mapping described the stratigraphy (rock successions) and the structure (bedding, faulting and fracturing) of the area. This geological mapping forms the basis for portions of Section 4.0 of this report.

Bayrock Surficial Geology Ltd. as well as Brown, Erdman & Associates Ltd. completed the surficial geological mapping of the area.

3.2 Regional Hydrogeology

The regional groundwater studies of the valleys of the Kettle and West Kettle Rivers were completed. In order to supplement this data, an inventory of existing water wells in the area was completed. Air photo studies and ground traverses were conducted in order to establish regional hydrogeological features. Unfortunately due to the paucity of data only qualitative evaluations are possible.

3.3 Local Hydrogeology

3.3.1 Surficial Sediments - In order to describe the basic hydrogeological relationships between the surficial

3.3 Local Hydrogeology, continued

3.3.1 Surficial Sediments - continued

sediments and the bedrock, piezometers were installed in both. Beginning with piezometer nest WP8 (Drawing No. 20) at least one and sometimes two piezometers in each group were completed in surficial sediments. Completion procedures for these piezometers are fully described in Section 3.3.3 and Drawing No. 2 shows their location. Upon completion, falling head permeability tests were conducted in these piezometers and the data analyzed as described in Section 3.3.3.

3.3.2 Ore-bearing Sediments - Three groundwater exploration wells were drilled and cased using an air rotary rig equipped with a down-the-hole hammer bit and casing drive hammer. Rock units intersected by these wells were described and aquifer zones were noted.

A 200 millimeter (8-inch) diameter open (uncased) hole was drilled through the basalt cap. When the ore-bearing sediments were encountered 150 millimeter (6-inch) diameter casing was installed and drilling and casing proceeded to the basement granodioritic rocks. Sandstones within the ore zone were friable and soft and had to be cased in order to maintain hole stability. An uncased, 150 millimeter (6-inch) diameter hole was drilled into the basement rocks at least 5 meters (16 feet) to ensure proper location of the basement-sediment contact and to test for the presence of aquifer zones.

3.3 Local Hydrogeology, continued

3.3.2 Ore-bearing Sediments - continued

Stainless steel, telescopic, 150 millimeter (6-inch) diameter well screens with a 1.3 millimeter (50/1000-inch) slot opening were installed opposite the most productive sandstones in each well and the 150 millimeter (6-inch) casing was withdrawn to expose the screen to this unit. After development, 10,000 minute constant rate aquifer tests were completed in each well and results analyzed.

Aquifer tests were analyzed using the non-equilibrium type curve method of Theis (1935) and modified non-equilibrium straight line method of Cooper and Jacob (1946). These methods utilize time-drawdown data plotted either on full logarithmic paper or semi-logarithmic paper and allow the aquifer parameters of transmissivity, storativity, and permeability to be calculated. Transmissivity is the product of the average permeability and the thickness of the aquifer. Therefore transmissivity is the rate of flow under a hydraulic gradient of unity through a cross section of unit width over the whole thickness of the aquifer. Transmissivity is commonly expressed in units of cubic meters per day per meter ($m^3/d/m$) or gallons per day per foot (gpd/ft). Storativity is the volume of water released or stored per unit surface area of the aquifer per unit change in head and is dimensionless. Permeability (or hydraulic conductivity) is the rate of flow under a hydraulic gradient of unity through a unit area of the aquifer.

3.3 Local Hydrogeology, continued

3.3.2 Ore-bearing Sediments, continued

Permeability is commonly expressed in units of meters per day (m/day), centimeters per second (cm/sec) or gallons per day per square foot (gpd/ft^2).

The Theis equation, stated in non-dimensional form, is

$$s = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-x}}{x}\,dx \qquad (1)$$

where s = drawdown at any point of observation in the vicinity of the discharging well, feet or meters.

Q = discharge rate of well in ft^3/day or m^3/day.

T = transmissivity in ft^2/day or m^2/day.

r = distance from pumping well to point of observation in meters or feet.

S = storativity, dimensionless.

t = time of discharge and observation, in days.

$$u = \frac{r^2 S}{4Tt} \text{ or } \frac{r^2}{t} = \frac{4Tu}{S} \text{ or } S = \frac{4Tut}{r^2} \qquad (2)$$

The integral expression in this formula cannot be solved directly, but is approximated by the expression

$$\int_u^\infty \frac{e^{-x}}{x}\,dx = (-0.577216 - \log_e u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} - \dots)$$

3.3 Local Hydrogeology, continued

3.3.2 Ore-bearing Sediments - continued

this series is commonly expressed as W(u) and is called "the well function of u" and the Theis equation then reduces to

$$s = \frac{Q}{4\pi T} W(u) \qquad (3)$$

Examining equations (2) and (3) and taking logarithms, it can be seen that the two terms involving T are constants and that drawdown (s) is related to t/r^2 in the same way that 1/u is related to W(u).

A log-log plot of W(u) versus u will therefore be a theoretical plot (called a type curve) of well response to pumping and a log-log plot of t/r^2 and s will be an actual field plot of data for an individual aquifer. These two plots will be offset by an amount equal to these constants and transmissivity and storativity can be calculated.

In gallon notation, the Theis formula becomes

$$s = \frac{114.6\ Q}{T} W(u) \qquad (4)$$

and $$S = \frac{Tut}{2246\ r^2} \qquad (5)$$

where T is in gallons per day per foot.

t is in minutes.

Q is in gallons per minute.

3.3 Local Hydrogeology, continued

3.3.2 Ore-bearing Sediments - continued

The method of Cooper and Jacob or the straight line method utilizes the fact that in the series representing the well function the sum of the terms beyond $\log_e u$ is not significant when u becomes small. The value of u decreases as time increases and as radial distance decreases. Therefore for large values of time and small radial distance these terms can be neglected.

The modified non-equilibrium formula, (Jacob formula), in non-dimensional form is therefore

$$s = \frac{Q}{4\pi T}\left(\log_e \frac{4Tt}{r^2 s} - 0.5772\right) \qquad (6)$$

or

$$s = \frac{2.3Q}{4\pi T} \log \frac{2.25\,Tt}{r^2 s} \qquad (7)$$

All symbols previously defined for non-dimensional form i.e. foot or meter, and ft^3/day or m^3/day.

Equation (7) can be rearranged to form the equation of a straight line and considering a particular observation well the distance r will be constant. if s_1, s_2, are the drawdown at t_1 and t_2, terms can be eliminated giving

$$s_2 - s_1 = \frac{2.3Q}{4\pi T}\left(\log \frac{t_2}{t_1}\right) \qquad (8)$$

The most convenient way to apply this formula is to plot the field data on semi-log paper (drawdown on the vertical arithmetic scale and time in the horizontal log scale). After the value of

3.3 Local Hydrogeology, continued

3.3.2 Ore-bearing Sediments - continued

u becomes small (generally less than 0.01) and time becomes large, the observed data should fall on a straight line. From this straight line an arbitrary choice of t_1 and t_2 is made and corresponding values of s_1 and s_2 are made.

If t_1 and t_2 are chosen to be one log cycle apart the term log t_2/t_1 is eliminated and the equation (in non-dimensional form) reduces to

$$T = \frac{2.3Q}{4\pi\Delta s} \tag{9}$$

where Δs = change in drawdown over one log cycle of time - dimensionless.

In gallon notation this equation is

$$T = \frac{264Q}{\Delta s} \tag{10}$$

where Q is in gallons per minute.

T is in gallons per day per foot.

Storativity can also be determined. If drawdown is zero in equation (7) then in non-dimensional form

$$S = \frac{2.25\ Tt_0}{r^2} \tag{11}$$

or in gallon notation

$$S = \frac{0.36\ Tt_0}{r^2} \tag{12}$$

where t_0 = time intercept at zero drawdown in days.

3.3 Local Hydrogeology, continued

3.3.2 Ore-bearing Sediments - continued

The Jacob or straight line method can also be used for distance drawdown data. When drawdowns from different observation wells are measured simultaneously drawdown (arithmetic scale) versus distance from pumping well (log scale) are plotted on semi-log paper and aquifer parameters can be calculated by drawing a straight line through this data. At Blizzard Ridge, analysis of distance drawdown data obtained during aquifer tests was attempted. This analysis proved unsatisfactory because of the elongate anisotropic nature of the ore-bearing sediments.

3.3.3 Basement Rocks - Twenty-two nests of piezometers were drilled in the basement rocks and surficial sediments occurring in the environs of Blizzard Ridge. Many of these were completed near and down slope of the proposed containment area and many piezometers were drilled in nests of two or three holes in order to establish vertical groundwater gradients and recharge-discharge conditions.

The piezometers were drilled by the air rotary method using a 150 millimeter (6-inch) diameter hammer bit. Stainless steel well points, attached to 44 millimeter (1.75-inch) P.V.C. pipe, were installed in the 150 millimeter (6-inch) hole. The well points were 1.22 meters (4 feet) long with 0.91 meter (3 feet) of open area which had number 80 gauge (.175 millimeter or 0.0069-inch) openings. Approximately two meters (6.5 feet) of Monterey f16

3.3 Local Hydrogeology, continued

3.3.3 Basement Rocks - continued

silica sand were placed in the annular space between the hole and the well point. A one meter (three foot) thick layer of bentonite pellets was placed on top of the sand and the remainder of the annular space was back-filled with a mixture consisting of 10 percent of bentonite pellets by weight in 150 pounds of cement. The bentonite prevents shrinkage of the cement during setting.

In order to emplace a piezometer in one of the upland bogs WP8-3 and WP9-3 were drilled with a tripod rig. P.V.C. 10 centimeter (4-inch) diameter casing was set through the bog organics and a well point was driven into the underlying till.

After the piezometers were completed and developed (to ensure reasonable hydraulic response) all water was removed by airlifting and two to three weeks were allowed for stabilization of groundwater levels in Phase II. After this period, falling head permeability tests were completed by Hardy Associates (1978) Ltd. Permeabilities were calculated from both falling and rising head data using the appropriate Hvorslev formula (Cedergren 1977)

$$K = \frac{r_s^2 \ \ln \frac{1}{r_h} \ \ln \frac{h_s}{h_o}}{2lr}$$

where

3.3 Local Hydrogeology, continued

3.3.3 Basement Rocks - continued

K = permeability, cm/sec.

r_s = radius of standpipe, cm.

r_h = radius of hole, cm.

h_s = head at start of test, cm.

h_o = head at end of test, cm.

l = length of open hole (length of sand packed hole), cm.

t = time to rise or fall, second.

$\ln$ = natural logarithm to base "e".

Only falling head tests were conducted in Phase III.

4.0 GEOLOGY

4.1 General Geology

Plutonic (granitic), sedimentary (sandstones, mudstones and conglomerates) and volcanic (basalt) rock types are found on Blizzard Ridge and adjacent areas.

The plutonic rocks are the oldest and most abundant rock type present in the area. They underlie the ore-bearing sediments and are referred to as the Basement Rocks in this report.

The sedimentary series of loosely consolidated sandstones, mudstones and conglomerates are the uranium-bearing rocks of Blizzard Ridge. These sediments were deposited by streams into ancient valley or channel-like depressions in the basement rocks.

Volcanic rocks (basalts) cap Blizzard Ridge and have protected the loosely consolidated sediments from erosion, particularly from erosion by the Pleistocene ice sheets. The basalts and sediments are essentially flat lying while some of the plutonic granitic rocks have been foliated. Numerous joints cut through the basement rocks. The joints are primarily oriented to the north and north-northeast and are steeply (70^{o} to 90^{o}) dipping. Dykes with the same general orientation are to be found to the east and west of the Ridge. A volcanic vent (diatreme) is present beneath the apex of Blizzard Ridge. It has caused intense jointing in the surrounding basalt cap.

4.2 Regional Geology

4.2.1 General Statement - Little (1957, 1961) mapped the Okanagan-Kettle River area on a scale of four miles to the inch (1:253,440). His work has been modified to produce the regional geologic map Drawing 33 and the attached Geologic Column. The rock units frequently

GEOLOGIC COLUMN

Modified from G.S.C. Map 6 - 1957 by H. W. Little

CENOZOIC		PLEISTOCENE		clay, sand, gravel, till
	TERTIARY	MIOCENE (?) *	(9)	Olivine Basalts - columnar, vesicular
			(8)	Sedimentary Rocks - mudstone, sandstone, (conglomerate)
		OLIGOCENE (?)	(7)	Coryell syenite
			(6)	Phoenix Group - biotite andesite
		EOCENE (?)	(5)	Kettle River Group - dacite flows, conglomerate, sandstone
MESOZOIC		CRETACEOUS (?)	(4)	Nelson hornblende granodiorite
			(3)	Valhalla biotite granodiorite
PALEOZOIC		PERMIAN (?)	(2)	Anarchist Group - greenstone, greywacke
PRECAMBRIAN		PROTEROZOIC (?)	(1)	Monashee Group - Biotite gneiss

* Note - (?) indicates uncertain geologic ages of rock groups.

4.2 Regional Geology, continued

4.2.1 General Statement - continued

encountered in the area are described below.

4.2.2 Monashee Group (1) - These are the oldest rocks observed and are present to the north of Blizzard Ridge in the Hydraulic-Haynes Lake area. They consist mainly of layered gneiss.

4.2.3 Anarchist Group (2) - These rocks consist of volcanic and sedimentary rocks that have been metamorphosed to greenstones, quartzites, and argillites. They are present south of Blizzard Ridge in the area of Beaverdell Creek.

4.2.4 Valhalla Biotite Granodiorite (3) - These are the most areally extensive rocks in the area. They form the basement rocks of the Blizzard Ridge ore body and are believed to be the source of the uranium found in the ore body. In many places the Valhalla complex contains very coarse grained leucocratic pegmatite dykes of the same minerology as the main intrusive mass.

4.2.5 Nelson Intrusions (4) - The Nelson rocks consist of large blocks of granodiorite and diorite to the south of the ore body.

4.2.6 Kettle River Group (5) - This Group consists of poorly sorted and well lithified conglomerates and sandstones that are exposed to the southeast of the Property.

4.2.7 Pheonix Group (6) - The Pheonix Group biotite andesite caps the Kettle River Group of sediments.

4.2 Regional Geology, continued

4.2.8 Coryell Syenites (7) - The Coryell Syenites which are present as both masses and dykes are intrusive into all rocks except the Plateau Basalts and the Miocene sediments. Numerous dyke equivalents of the Coryell are present with a predominant northeast trend. With the exception of the mineralized Miocene sediments the Coryell has the highest total radiometric count of all rock units in the Lassie Lake area. Coryell dykes are present to the south and east of Blizzard Ridge.

4.2.9 Sedimentary Rocks (8) - These are stream bed deposits of mudstones, sandstones and conglomerates. Cobbles within the conglomerates have a predominantly granitic composition. Organic carbonaceous material is abundant through the sedimentary sequence. The beds are flat lying although stream bed channel structures are present.

4.2.10 Olivine Basalts (9) - These Plateau Basalts are flat lying. They consist of vesicular and columnar basalt flows with occasional interformational fluvial sediments. The basalt cappings form distinct topographic hills which trend to the northeast or to the northwest.

4.3 Local Geology (Please see Geologic Map Drawing 34.)

4.3.1 General Statement - Blizzard Ridge and its environs are composed of the Valhalla granodiorite (Basement Rocks) overlain by Miocene Fluvial Sediments which in turn are overlain by Plateau

4.3 Local Geology, continued

4.3.1 General Statement - continued

Olivine basalts. The sediments and basalt flows are both flat lying. The Valhalla has foliations that trend to the northeast and northwest.

4.3.2 Valhalla (4) - The Valhalla plutonic granodiorites are intruded to the east of Blizzard Ridge by Coryell syenitic dykes and to the west of Blizzard Ridge by dacite dykes. The Coryell dykes trend north while the dacite dykes trend to the northeast. Several northeast and northwest trending faults are observable on air photos and on the ground to be cutting across the dykes.

4.3.3 Sedimentary Rocks (8) - These unconsolidated to moderately consolidated sediments should be referred to as clays, sands and gravels. For simplicity they have been referred to by others as mudstones, sandstones and conglomerates to clearly distinguish them from the surficial Pleistocene debris.

This sequence of stream lain sediments occupies a sinusoidal paleochannel. It unconformably overlies the Valhalla plutonic rocks and in turn is overlain throughout most of its length by a basalt cap. The axis of the trough is oriented northwest-southeast and plunges to the southeast on a 2.6 percent grade (1.5 degrees). The length of the channel is 1600 meters (5250 feet) and the width ranges from 200 meters (660 feet) to 450 meters (1475 feet). The paleotopographic surface on which the sediments accumulated contains considerable relief caused by local faulting (please refer to Paleotopography Map Drawing 32).

4.3 Local Geology, continued

4.3.3 Sedimentary Rocks (8) - continued

The sedimentary rocks consist of a basal conglomerate underlying a sequence of interbedded mudstones and sandstones. The basal conglomerate occurs between the basement plutonic rocks and the loosely consolidated sedimentary rocks. The thickness of this unit ranges from 0 to 25 meters (82 feet) with the thickest sections occurring in the depressions of the basement rocks. In areas of steep relief of the basement rocks the conglomerate resembles a buried talus while in other areas the pebbles are rounded and water worn. All characteristics of the conglomerate indicate that it was very rapidly deposited from local granodiorite and dyke sources. Limonite and possibly hematite are prominant in the lower part of the conglomerate and along the basement contact. No iron sulphides are present. Where the clay matrix content exceeds 40 percent the conglomerate is moderately to well consolidated. It is not generally cemented except locally where limonite is abundant and forms a cement. Uranium mineralization is not common in the conglomerate. Where uranium is present, flakes of autunite coat pebbles and sand grains near the upper contact with the mudstone-sandstone sequence. The conglomerate does not contain plant fragments or organic debric. It generally has a low permeability.

debris

The interbedded mudstone-sandstone sequence ranges from 0 to 34 meters (111 feet) in thickness (see Drawing

4.3 Local Geology, continued

4.3.3 Sedimentary Rocks (8) - continued

No. 30). It contains several lithofacies which consist of clean sandstones, carbonaceous sandstones, sandstone-mudstone, and carbonaceous mudstone. These lithologic units occupy varying positions within the mudstone-sandstone sequence with regard to both vertical and lateral occurrence. It is impossible to correlate the logs of holes with any degree of assurance.

The clean sandstones consist primarily of arkosic sandstones containing less than 10 percent clay. The sandstones are unconsolidated to poorly consolidated, friable, essentially uncemented, medium to coarse grained and subrounded to subangular. Organic material and plant fragments are rare. The highest grade mineralization occurs in the clean sandstones. Autunite and saleeite are present in the form of rectangular crystals, crystal aggregates and a surface coating on limonite concretions. The groundwater test wells WW1, WW2 and WW3 tested the clean sandstones which are the aquifers of the ore-bearing sediments.

The carbonaceous sandstones contain sooty carbonaceous matter, are fine to medium grained, poorly sorted, and poorly consolidated. Thin mudstone and carbonaceous laminations commonly occur. Plant fragments and woody material are present in various states of decay.

The sandstone-mudstone lithofacies consists of fine to medium sandstone beds interbedded with siltstone, mudstone and claystone. Contacts are

4.3 Local Geology, continued

4.3.3 Sedimentary Rocks (8) - continued

sharp to gradational. Because this lithofacies has a low permeability caused by the abundance of silt and clay it contains only minor amounts of uranium.

Carbonaceous mudstone is a moderate to well consolidated rock with plant remains forming its major constituent. It is primarily composed of silt sized particles and occurs in beds that range from a few centimeters to beds four meters (13 feet) thick.

4.3.4 Olivine Basalts (9) - The basalt cap on Blizzard Ridge forms an ellipsoidal or drumlin shaped hill with its major axis trending northwest. Approximately 98 percent of the hill is covered by glacial debris. The basalt cap extends over an area that is 1200 meters (3936 feet) long and 510 meters (1673 feet) wide and covers approximately 5.2 hectares (12.8 acres). The thickness of basalt on Blizzard Ridge ranges from 0 to 74 meters (243 feet).

The rocks which form the basalt cap are categorized as massive basalt, vesicular basalt, breccia, and interflow sediments.

The massive olivine basalt forms a thick, up to 70 meters (230 feet), upper layer. Where weathered the colour is grey and where unweathered the colour is dark grey to dark green. Horizontal jointing commonly occurs within the upper 10 meters (33 feet) of the basalt section. These are primary joints formed as the basalt cooled. Local fracture zones within the massive basalt are frequently lined with limonite and chlorite.

4.3 Local Geology, continued

4.3.4 Olivine Basalts (9) - continued

The vesicular basalt commonly underlies the massive basalt. The vesicles (bubbles) range in size from several millimeters to six centimeters (2.5 inches) and in shape from tubular to ellipsoidal. They decrease in size and abundance upwards. The percentage of vesicles ranges from less than one to 25 percent with the most common range being from two to 10 percent. The vesicles are usually open but limonite and zeolites do occur lining or filling the vesicles. Zeolites are well known for their base exchange ability to soften water by replacing calcium, magnesium, and potassium with sodium. Where moderately fractured, chlorite has replaced the mafic minerals and limonite coats the fracture surfaces. Where highly fractured the mafic minerals are completely replaced by chlorite and the plagioclase by clay minerals. Near the breccia pipe fracturing appears to have been caused by degassing along zones of structural weakness.

Uranium mineralization in the vesicular basalt is restricted to highly altered zones.

The breccia composed of a heterogeneous collection of rock fragments in a claystone, siltstone, sandstone and tuff (ash) matrix was formed in a volcanic pipe. This pipe (diatreme) is located in the northwest corner of the deposit and intrudes the basement rocks, the ore-bearing sediments and part of the basalt cover. The basalt restricted

4.3 Local Geology, continued

4.3.4 Olivine Basalts (9) - continued

the diatreme and forced it to spread laterally creating a mushroom shaped breccia zone at the top of the pipe. This zone underlies an area that is 60 to 90 meters (200 to 295 feet) across. The rocks within the diatreme consist of an assortment of host rock fragments, clasts from surrounding rock units, and volcaniclasts derived from depth. The basalt adjacent to and overlying the breccia filled pipe is highly altered and intensely fractured. Chlorite slickensides on fracture surfaces attest to local movement and displacement. The vertical thickness of the altered and highly fractured zone ranges from a few meters to over 16 meters (50 feet) in drill hole 83 where the zone extends to the base of the surficial deposits. In the altered zone the primary mineralogy and texture of the basalt has been destroyed by the development of clay minerals, chlorite, and limonite which commonly produces a friable, mottled rock.

Interformational breccia occurs between lava flows and consists of angular blocks of unaltered to altered basalt in a silty clay matrix. Silty clay and sand beds or lenses varying in thickness from a few centimeters (inches) to several meters (feet) are also present in the basalt sequence.

Uranium mineralization is present in the breccia pipe as calcium and magnesium uranyl phosphates, autunite, saleeite, and possibly pitchblende.

4.3 Local Geology, continued

4.3.5 Surficial Sediments - The surficial sediments were mapped and described by personnel of Bayrock Surficial Geology Ltd (Bayrock et al 1979). These sediments consist of ground moraine (basal glacial till), overlain by small pockets of outwash sands and gravels, and lake and swamp lain sandy clay and organics. Please refer to the Local Bedrock and Surficial Geology Map Drawing No. 35 for the distribution of the lithologic units that will be described below.

Ground moraine or glacial till deposited from the sole of an ice sheet overlies bedrock and is at ground surface or underlies a thin soil mantle over 75 percent of the Blizzard Property. The soil A and B horizons developed on the ground moraine range in thickness from zero to 62 centimeters (2 feet).

The deposits of outwash sands and gravels overlie the ground moraine in nine small and widely scattered areas. The deposits consist of coarse sand containing pebbles with a noticeable absence of silt or clay sized particles. The lake or swamp lain sediments consist of up to 8 centimeters (3 inches) of clay overlain by one meter (3.28 feet) of organic bog material. The organic deposits are usually one meter (3.28 feet) thick and are underlain by glacial till or clay. These deposits are present beneath the swamps of the Blizzard Property.

5.0 GROUNDWATER EXPLORATION AND TESTING PROGRAMS

5.1 Ore Deposit

5.1.1 General Statement - Please refer to Drawing No. 2 for the location of the Groundwater Test Wells. All wells were drilled to intersect the ore-bearing sediments and thus test aquifer zones present. Groundwater Test Well No. 1 (WW1) was drilled at the northwestern end, Groundwater Test Well No. 2 (WW2) was drilled in the central portion and Groundwater Test Well No. 3 (WW3) was drilled in the southeastern end of the ore body.

The main aquifers present in the ore deposit are slightly consolidated sandstones associated with the mudstone-sandstone sequence which forms the main ore body. Not all sediments in the ore deposit have significant permeabilities and aquifer thicknesses and distributions are highly variable depending on the distribution of these slightly consolidated sandstones. During the exploratory water well drilling the most prospective and representative aquifer zones were screened and subsequently tested by means of constant rate aquifer tests with observation wells. Aquifer test analysis was complicated by the fact that aquifers in the ore body are limited in areal extent and have discontinuous, narrow, elongate configurations. Because of the confined nature of the aquifers, the cone of depression migrates extremely rapidly and thus encounters the aquifer boundaries (equivalent to hydraulic discharge boundaries) very quickly. This causes increased drawdown compared to theoretical response and an elliptical drawdown pattern. Aquifer transmissivities

5.1 Ore Deposit, continued

5.1.1 General Statement - continued

obtained from aquifer test analysis therefore are lower than theoretical values (i.e. those that would be obtained if the aquifer was infinite in areal extent) but are the correct values to describe the aquifer in its physical setting. Fortunately, both the aquifer configuration and characteristics are extremely advantageous for future dewatering requirements.

5.1.2 Groundwater Test Well No. 1

5.1.2.1 Construction and Testing -

Please refer to the log of Groundwater Test Well No. 1, Drawing No. 3, and Table 5.1. Reference to the log will show that this well was drilled to a depth of 57.93 meters (190 feet) and encountered the following rock types:

DEPTH		DESCRIPTION
Meters	Feet	
0 - 6.7	(0 - 22)	Till with basalt boulders.
6.7 - 32.0	(22 - 105)	Basalt with interbedded silty sand water-bearing zone from 22 to 29 meters (72 to 95 feet).
32.0 - 48.78	(105 - 160)	Interbedded mudstones and sandstones. Main groundwater-bearing zone from 40.55 to 43.29 meters (133 to 142 feet).
48.78 - 57.93	(160 - 190)	Granodiorite, fractured below 49.70 meters (163 feet) small amounts of groundwater.

TABLE 5.1

ORE DEPOSIT

PERTINENT DETAILS OF GROUNDWATER TEST WELLS AND AQUIFER PARAMETERS

Well	Surface Elevation (Meters)	Water-bearing Zones Depths (Meters)	Water-bearing Zones Elevation (Meters)	Screen Settings Depths (Meters)	Static Water Levels (Meters)
1	1389.30	40.55-43.29	1348.75-1346.01	42.06-43.33	12.47 (8/8/78)
2	1393.90	46.34-53.05	1347.56-1340.85	46.86-49.48	20.53 (18/8/78)
3	1357.28	19.82-26.22	1337.46-1331.06	24.78-26.08 21.35-22.65	3.90 (6/9/78)

AQUIFER PARAMETERS

STRAIGHT LINE METHOD - WW2 and WW3 Aquifer Tests

Well	Transmissivity $m^3/d/m$	Transmissivity gpd/ft	Assumed Thickness (m)	Permeability cm/sec	Remarks
1	4.0	268	2.74	1.7×10^{-3}	As observation well.
2	3.79	254	2.62	1.7×10^{-3}	Pumping well.
3	3.0	201	4.73	7.3×10^{-4}	Pumping well.

Storativity values, calculated from observation well data, ranged from 4.3×10^{-3} to 2.9×10^{-5} with an average value of 3×10^{-4}.

5.1 Ore Deposit, continued

5.1.2 Groundwater Test Well No. 1 - continued

A stainless steel well screen as described in Section 3.3.2 was installed between depths of 42.06 and 43.33 meters (138 to 142 feet) and the well developed by surge blocks and bailer.

Although Groundwater Test Well No. 1 was not pump tested, it was used as an observation well during the constant rate aquifer test completed in Groundwater Test Well No. 2.

5.1.2.2 Analysis and Results - Time drawdown data obtained in this well during testing in Groundwater Test Well No. 2 was analyzed using the previously described methods of Theis and Cooper and Jacob, and the results are shown in Tables 5.1 and 5.1.3.2. Analyses indicated average values for transmissivity and storativity of 3.75 $m^3/d/m$ (250 gpd/ft) and 3×10^{-5} respectively. Assuming a thickness of 2.74 meters (9 feet), the average permeability of the aquifer is about 1.4×10^{-3} cm/sec. Although hydraulic boundary effects are not obvious in the type curve plot of the data, these effects can probably not be detected.

5.1 Ore Deposit, continued

5.1.3 Groundwater Test Well No. 2

5.1.3.1 Construction and Testing - Please refer to the log of Groundwater Test Well No. 2, Drawing No. 4, and Table 5.1. Reference to the log will show that Groundwater Test Well No. 2 was drilled to a total depth of 67.68 meters (222 feet) and encountered the following rock types:

DEPTH Meters	Feet	DESCRIPTION
0 - 0.6	(0 - 2)	Gravelly soil.
0.6 - 39.63	(2 - 130)	Basalt.
39.63 - 55.49	(130 - 182)	Interbedded mudstones and sandstones. Sandstone water-bearing.
55.49 - 61.89	(182 - 203)	Conglomerates dry when drilled.
61.89 - 67.68	(203 - 222)	Granodiorite dry when drilled.

A stainless steel well screen as described in Section 3.3.2 was installed between depths 48 of 46.86 and 49.40 meters (154 and 162 feet) and developed by surge blocks and bailer.

The well was pumped at a constant rate of 1.89 l/sec (25 gpm) for a total of 10,000 minutes. Please refer to the straight line drawdown and recovery plots of pumping well data shown in Drawings Nos. 5 and 6.

TABLE 5.1.3.2

AQUIFER PARAMETERS - WW2 AQUIFER TEST
TYPE CURVE METHOD

Observation Well	Transmissivity		Storativity	Assumed Thickness	Permeability
Number	m^3/d/m	gpd/ft		(m)	cm/sec
WW1	3.47	233	3.6×10^{-5}	2.74	1.6×10^{-3}
DDH2	5.42	363	2.7×10^{-3}	6.25	1×10^{-3}
DDH4	4.82	323	3.35×10^{-3}	4.17	2.5×10^{-3}
DDH91	5.66	379	6.9×10^{-4}	5.32	1.2×10^{-3}
DDH104	3.57	239	1.4×10^{-3}	4.15	1×10^{-3}
DDH117	4.00	268	4.4×10^{-4}	4.45	1×10^{-3}
DDH124	4.57	306	5.7×10^{-4}	6.65	8×10^{-4}
DDH134	3.10	208	4.4×10^{-3}	4.2	9×10^{-4}

5.1 Ore Deposit, continued

5.1.3 Groundwater Test Well No. 2 - continued

In addition to measuring water levels in the pumping well, water levels were also recorded in nine observation wells which were either diamond drill holes or other groundwater test wells. Plots of time drawdown data for all observation wells is shown in Drawing No. 7.

The condition of that portion of the diamond drill holes through the aquifer zones was not known. Due to the loose, slightly consolidated nature of the sandstones caving may have occurred in this section of the holes. With any of the aquifer open to these holes, however, the partial penetration effect caused by caving would be eliminated at distances greater than twice the aquifer thickness away from the pumping well. Therefore the aquifer response obtained from these holes is equivalent to a specially constructed observation well.

5.1.3.2 Analysis and Results - Tables 5.1.3.2 and 5.1 summarize the aquifer parameters obtained from the type curve and straight line analysis of the test data. In addition Drawing Nos. 5 and 6 show the plots of the time-drawdown data. During

5.1 Ore Deposit, continued

5.1.3 Groundwater Test Well No. 2 - continued

pumping an elongate and distorted drawdown cone developed due to the aquifer's irregular and limited distribution. Drawing No. 13 indicates that this effect migrated along the ore-bearing channel to the northwest of WW1. Analysis of the aquifer test data indicated that the aquifer transmissivity varied from 3.10 to 5.66 $m^3/d/m$ (208 to 379 gpd/ft), which probably indicates variations of aquifer thickness, and has a mean value of 4.26 $m^3/d/m$ (286 gpd/ft) with a standard deviation of 0.90 $m^3/d/m$ (60 gpd/ft). Storativity values indicated confined aquifer conditions and varied from 1.4×10^{-3} to 3.6×10^{-5} with a mean value of 1.7×10^{-3} and a standard deviation of 1.5×10^{-3}. Using the assumed aquifer thicknesses as shown in Table 5.1.3.2 permeability values varied from 8×10^{-4} to 2.5×10^{-3} cm/sec and had a mean value of 1.25×10^{-3} cm/sec and standard deviation of 5.6×10^{-4}.

In summary, the above findings indicate that aquifers in the ore body are confined, have low to moderate transmissivities, and are limited in areal extent.

The limited areal extent of the aquifers will facilitate the dewatering of the ore-bearing sediments.

5.1 Ore Deposit, continued

5.1.3 Groundwater Test Well No. 2 - continued

For elucidation, a typical straight line method calculation is shown on Drawing No. 6 and outlined below. Modifying Equation (10) slightly and using the slope of the most representative straight line portion of the semi-log plot transmissivity of the aquifer around WW2 is calculated by

$$T = \frac{15.68\ (1.89)}{7.8} = 3.8\ m^3/d/m$$

or 254 gpd/ft

Assuming a thickness of 2.62 meters (8.6 feet), the aquifer permeability is calculated as 1.45 m/day, 29.5 gpd/ft^2, or 1.7×10^{-3} cm/sec.

Completing a similar calculation for Groundwater Test Well No. 1 and using Equation (12), storativity for the area between Groundwater Test Wells No. 1 and 2 can be calculated as

$$S = \frac{0.36 \times 268 \times 0.764}{1550 \times 1550} = 3.1 \times 10^{-5}$$

This storativity value is typical of a confined sandstone aquifer.

5.1.4 Groundwater Test Well No. 3

5.1.4.1 Construction and Testing - Please refer to the log of Groundwater Test Well No. 3, Drawing No. 9 and to Table 5.1.

5.1 Ore Deposit, continued

5.1.4 Groundwater Test Well No. 3 - continued

Reference to the log will show that Groundwater Test Well No. 3 was drilled to a total depth of 45.72 meters (140 feet), back-filled to the bottom of the screen at a depth of 26.08 meters (85.5 feet) and encountered the following rock types:

DEPTH Meters	Feet	DESCRIPTION
0 - 2.44	(0 - 8)	Glacial till.
2.44 - 12.20	(8 - 40)	Basalt.
12.20 - 32.62	(40 - 107)	Interbedded mudstone and sandstone water-bearing.
32.62 - 42.68	(107 - 150)	Granodiorite dry when drilled.

Stainless steel screens as described in Section 3.3.2 were installed between depths of 26.08 to 24.78 meters and 22.65 to 21.35 meters (85.5 to 81.3 and 74.3 to 70.0 feet). The screens were developed by surge blocks and bailer.

This well was pumped at a constant rate of 0.5 l/sec (6.25 gpm) for 500 minutes and the rate was then increased to 0.95 l/sec (12.5 gpm) for the remaining 5500 minutes of the test. Reference to the field data in Appendix I will show that diamond drilling in the vicinity of Groundwater Test Well No. 3 interfered with

5.1 Ore Deposit, continued

5.1.4 Groundwater Test Well No. 3 - continued

the latter part of the test. In addition to the pumping well, water level measurements were taken in eight observation wells, four of which produced useable data. Generally, the data from this test were not considered to be of the same quality as that for the Groundwater Test Well No. 2 test and hydraulic communication between the aquifer tested and some of the observation wells was not good.

5.1.4.2 Analysis and Results - As with the previous test, time-drawdown data was analyzed using the two quoted methods and results of these analyses are summarized in Tables 5.1 and 5.1.4.2. Once again, although the presence of hydraulic boundaries is not obvious in the type curve plot, Drawing No. 12, data was probably affected by the limited extent of the aquifer. The drawdown cone, Drawing No. 13, shows a similar elongated pattern as the previous test but is smaller in areal extent due to the shorter pumping time. Analysis of the pumping well data, Drawing Nos. 10 and 11 indicates aquifer transmissivities between 2.8 and 4.1 $m^3/d/m$ (187 to 275 gpd/ft) and a realistic average value of

TABLE 5.1.4.2

AQUIFER PARAMETERS - WW3 AQUIFER TEST

TYPE CURVE METHOD

Observation Well	Transmissivity		Storativity	Assumed Thickness	Permeability
Number	$m^3/d/m$	gpd/ft		(m)	cm/sec
DDH152	3.83	257	7.2×10^{-3}	2.0	2.2×10^{-3}
DDH153	13.56	909	3.1×10^{-3}	7.5	2.1×10^{-3}
DDH153	3.42	229	8.1×10^{-3}	7.5	5×10^{-4}
DDH154	1.00	67	4.6×10^{-3}	7.48	1.5×10^{-4}
DDH175	12.52	840	1.3×10^{-3}	12.40	1.2×10^{-3}

5.1 Ore Deposit, continued

5.1.4 Groundwater Test Well No. 3 - continued

about 3 m^3/d/m (200 gpd/ft). Analysis of the observation well data, Drawing No. 12 indicates a wider variation in transmissivities but the data from a number of the diamond drill holes is dubious. Using all results, however, indicates an aquifer transsivity between 1.00 and 13.56 m^3/d/m (67 and 909 gpd/ft) with a mean value of 6.87 m^3/d/m (460 gpd/ft) and a standard deviation of 5.75 m^3/d/m (386 gpd/ft). Storativity values for the aquifer range from 1.3×10^{-3} to 7.2×10^{-3} with a mean value of 4.9×10^{-3} and a standard deviation of 2.82×10^{-3}. Using the various assumed thicknesses shown, both analytical methods indicate a range in permeabilities of 1.5×10^{-4} cm/sec to 1.2×10^{-3} cm/sec with a mean value of 1.23×10^{-3} cm/sec and a standard deviation of 9.2×10^{-4} cm/sec.

5.2 Basement Rocks

5.2.1 Location and Construction - Please refer to the construction diagram and lithological log of each piezometer, Drawing Nos. 14 to 29 the piezometer location Map Drawing No. 2 and Table 5.2 which summarized the pertinent details for each piezometer.

There are 40 piezometer sites containing a total of 42 piezometer installations. Of the 42 piezometers, 31 were installed in basement rocks and 11 were installed in surficial deposits overlying bedrock. Generally, as is shown in Drawing No. 2, piezometers

5.2 Basement Rocks, continued

5.2.1 Location and Construction - continued

are located near the proposed tailings containment area and at various topographic positions around the proposed complex.

All piezometers were constructed as described in Section 3.3.3 and great care was taken to ensure that the sand or well point and sand packed section in each piezometer was properly sealed with bentonite and cement. At various locations the nests or sets of piezometers were drilled to different depths in the basement rocks to investigate the variation of the piezometric surface (static water level) with depth. Piezometer sites which have piezometers completed to different depths of basement rocks include WP1, WP2, WP6, WP9, WP10, WP12, and WP20. Other piezometers were completed to describe the regional variations in permeabilities and heads of the basement rocks and surficial deposits and thus attempt to establish hydraulic relationships between these two units.

In order to ensure the various structural types of basement rocks that are present in the environs of Blizzard Ridge were tested, piezometers were set into the rock types shown in Table 5.2. These generally include fractures, fissures, hard non-fractured rock and soft fault gouge materials.

When being drilled below the assumed static water level, all basement rock piezometers were dry except WP5, WP9-1, WP18-1, and WP21, which produced small but measurable amounts of groundwater.

5.2 Basement Rocks, continued

5.2.1 Location and Construction - continued

This general lack of groundwater indicated that most piezometers were set in fractured rock with a low permeability and porosity. These extremely low permeabilities resulted in very slow stabilization of water levels in many piezometers.

5.2.2 Analysis and Results - Permeabilities of the various basement rock types were determined using falling and/or rising head tests. For the initial sets of piezometers installed (up to and including Site WP7) the rise in water level over a three week period was recorded and the data analyzed as though this were a rising head test. These piezometers were then filled with a mixture of water and antifreeze to complete a falling head test. For the more recent sets of piezometers (Sites WP8 to WP22) only falling head tests were completed.

Please refer to Table 5.2 which summarizes the results of falling head tests and other pertinent details. The permeabilities were calculated using the Hvorslev formula described in Section 3.3.3.

When a large open fracture is encountered in a piezometer the effective area through which groundwater moves into or away from the piezometer becomes unknown. Therefore unless a falling head test is conducted for a long time the local permeability of the fracture rather than the gross permeability of the fractured rock will be obtained. This is similar

5.2 Basement Rocks, continued

5.2.2 Analysis and Results - continued

to, but the reverse of, pumping tests conducted on wells that obtain their water from fractured rock. These wells can be highly productive while stored water in open fractures supplies water to the well. When this stored water is depleted, however, the productivity of the well decreases markedly until discharge-recharge conditions are established by the regional transmissivity (permeability) of the fissured rock. In attempting to establish the most meaningful permeability of the basement rocks in the environs of Blizzard Ridge, i.e. that value which should be used in groundwater movement and velocity calculations, permeability values obtained from piezometers which encountered large open fractures or shattered zones were not considered accurate and were not included in averages. The data obtained from piezometers WP2-3, WP5, WP9-1b, WP13, and WP21 were therefore not used to calculate the mean value of regional permeability in the basement rocks, but this does not imply that their significance was ignored.

The resulting 25 values of permeabilities used indicate a mean permeability of the basement rocks of 8×10^{-7} cm/sec with a standard deviation of 1.4×10^{-6} cm/sec. This mean value is equivalent to clay. Of particular interest are permeability values of the basement rocks under the proposed tailings impoundment area. Using permeability values from piezometers WP1, WP11, WP12, and WP14, the mean value of permeability of the basement rocks under this area

BASEMENT ROCK PIEZOMETERS

PERMEABILITIES AND PERTINENT DETAILS

Piezometer Number	Total Depth (m)	Water Level Elevation Aug/79 (m)	Permeability Falling Head (cm/sec)	Basement Rock Type	Location
WP1-1	31.70	1351.11	2.1×10^{-7}	Soft, weathered	Tailings Area
WP1-2	19.20	1350.59	8.0×10^{-8}	Hard, no fractures	Tailings Area
WP1-3	13.41	1355.87	1.8×10^{-7}	Soft	Tailings Area
WP2-1	30.78	1340.58	5.0×10^{-8}	Hard, no fractures	Tailings Area
WP2-2	18.90	1346.12	1.0×10^{-9}	Hard, no fractures	Tailings Area
WP2-3	9.45	1345.40	8.8×10^{-6}	* Fractured zone, open	Tailings Area
WP3-1	19.81	1336.61	3.1×10^{-7}	Very soft	Tailings Area
WP3-2	18.29	1335.11	4.25×10^{-7}	Very soft	Tailings Area
WP3-3	19.81	1338.45	4.7×10^{-7}	Fractured zone, filled	Tailings Area
WP4	19.20	1383.69	2.2×10^{-7}	Hard, no fractures	Mill Site Area
WP5	19.51	1402.03	7.1×10^{-6}	* Fractured zone, open	Mill Site Area
WP6-1	39.60	1349.42	7.3×10^{-7}	Hard, no fractures	Tailings Area
WP6-2	25.00	1349.44	3.9×10^{-7}	Hard, no fractures	Tailings Area
WP6-3	15.00	1349.43	5.1×10^{-7}	Fractured zone, filled	Tailings Area
WP7	15.00	1369.57	3.3×10^{-7}	Hard, no fractures	Tailings Area
WP8-1	9.10	1325.82	1.0×10^{-6}	Fractured	West of Tailings Area
WP9-1a	19.50	1321.71	2.8×10^{-6}	Hard	Upland Bog
WP9-1b	11.30	1321.68	1.2×10^{-5}	* Weathered, water-bearing	Upland Bog
WP10-1	7.30	1326.62	3.1×10^{-8}	Fractured	West of Tailings Area
WP11	6.10	1338.72	6.0×10^{-7}	Fractured, weathered	Tailings Area
WP12	4.60	1332.58	4.9×10^{-8}	Hard	Tailings Area
WP13	4.60	1337.66	6.3×10^{-5}	* Shattered - dacite dyke	Tailings Area
WP14	6.10	1336.03	4.8×10^{-8}	Fractured	Tailings Area
WP15	6.10	1324.45	5.7×10^{-6}	Sheared, soft	Tailings Area
WP16-1	8.70	1343.73	3.7×10^{-7}	Sheared, soft	Tailings Area
WP17-1	14.40	1340.04	3.1×10^{-6}	Weathered	North of ore body
WP18-1	16.20	1360.68	1.4×10^{-7}	Sheared, soft, unweathered	North of ore body
WP19a	9.10	1306.87	7.3×10^{-8}	Weathered	East and south of ore body
WP20	7.40	1312.53	2.6×10^{-6}	Sheared	East and south of ore body
WP21	5.00	1366.25	5.4×10^{-5}	* Fractured	East and south of

5.2 Basement Rocks, continued

5.2.2 Analysis and Results - continued

felsic

is 2.3 x 10^{-7} cm/sec. The possible importance of the dacite dyke encountered in WP13 will be discussed in a later section.

5.3 Surficial Sediments

5.3.1 Location and Construction - Please refer to the construction diagram and lithological log of each piezometer, Drawing Nos. 20 to 29 the Piezometer Location Map, Drawing No. 2 and Table 5.3 which summarizes pertinent details for the surficial sediment piezometers.

In total, 11 piezometers were completed in surficial sediments. These piezometers were located at various points around the ore body and also in the tailings containment area as shown on the Piezometer Location Map.

All piezometers were constructed as outlined in Section 3.3.3 and construction procedures as outlined in that section were adhered to. At two locations, WP8 and WP9, piezometers were completed to different depths in the surficial sediments to determine variations in hydraulic heads of these sediments. Other surficial sediment piezometers were located in groups containing basement rock piezometers in order to study the hydraulic relationships between these rock types. During drilling, only one piezometer, WP19b, produced a measurable groundwater flow.

TABLE 5.3

SURFICIAL SEDIMENT PIEZOMETERS

PERMEABILITIES AND PERTINENT DETAILS

Piezometer Number	Total Depth (m)	Water Level Elevation Aug/79 (m)	Permeability Falling Head (cm/sec)	Surficial Sediment Type	Location
WP1-4	2.75	1355.90	1.4×10^{-5}	Silty sand and gravel	Tailings Area
WP8-2	4.40	1325.84	1.6×10^{-4}	Sub-stratified till	West of Tailings Area
WP8-3	8.40	1324.78	2.8×10^{-5}	Dense sand and gravel	West of Tailings Area
WP9-2	4.40	1321.72	4.0×10^{-6}	Dense stoney till	Tailings Area Upland bog
WP9-3	2.50	--	Not tested	Till	Upland Bog
WP10-2	3.20	1327.91	5.63×10^{-5}	Dense sandy till	West of Tailings Area
WP16-2	5.20	1343.85	1.7×10^{-4}	Sub-stratified till	Tailings Area
WP17-2	7.30	1339.94	8.9×10^{-6}	Silty sand and gravel	North of ore body
WP18-2	3.20	1360.01	4.3×10^{-5}	Sand and gravel	North of ore body
WP19b	5.70	1307.35	Not tested	Sand and gravel	East and south of ore body
WP22-2	6.30	1284.55	6.4×10^{-8}	Dense till	Southeast of ore body

5.3 Surficial Sediments, continued

5.3.2 Analysis and Results - Permeabilities of surficial sediments were calculated by means of falling head permeability tests. At two locations, WP9-3 and WP19b, falling head tests could not be completed because permeabilities were too high.

In order to determine the permeability of a number of sediment types, piezometers were located in the following units: dense till, dense stoney and sandy till, sub-stratified till, and sand and gravel. Results of falling head permeability tests, shown on Table 5.3, show the following values for these different units. Dense till, southeast of the ore body has a permeability of 6.4×10^{-8} cm/sec. The dense sandy or silty till, located in the tailings containment area, has a permeability range between 5.63×10^{-5} cm/sec and 4.0×10^{-6} cm/sec with a mean value of 3×10^{-5} cm/sec. The sub-stratified till, located in the tailings containment area, has a permeability range between 1.6×10^{-4} cm/sec and 1.7×10^{-4} cm/sec. Various sand and gravel lenses, located in the tailings containment area and north, east, and south of the ore body have permeability values of 8.9×10^{-6} cm/sec to 1.4×10^{-5} cm/sec with a mean value of 2.4×10^{-5} cm/sec and a standard deviation of 1.5×10^{-5} cm/sec. The permeability of the water-bearing sand and gravel encountered in WP19b was too large to be measured using the falling head technique.

6.0 HYDROGEOLOGY

6.1 General Statement

Groundwater occurs and moves in the pores of the unconsolidated glacial debris, in the pores of the ore-bearing sediments, and in the fractures and fissures of both the basalts and older basement rocks. The groundwater system is normal and predictable in that the water table-piezometric surface is subparallel to the topographic surface and groundwater recharge areas are present on the hills and ridges and groundwater discharge areas are present in the valleys. Regionally, groundwater movement is extremely slow because of low permeabilities.

The hydrogeology of the area is described both on a regional basis, which discusses the qualitative relationships between the plateau areas and the deeply incised river valleys, and on a local basis which discusses the detailed hydrogeology at and adjacent to Blizzard Ridge.

6.2 Regional Groundwater

6.2.1 General and Flow Systems - The reader should appreciate that statements concerning the regional hydrogeology of the area in which the Blizzard Property occurs must be qualitative because of a paucity of pertinent data. It is envisaged that the Blizzard Property is split by regional groundwater divides running parallel to and perpendicular to the Beaverdell Range. It is isolated from other regional groundwater flow systems by groundwater divides along the Kettle and West Kettle Rivers and Beaverdell, Trapping, and Copper Kettle Creeks (Drawing No. 1). This latter fact basically implies that groundwater recharging in the immediate area of

6.2 Regional Groundwater, continued

6.2.1 General and Flow Systems - continued

Blizzard Ridge cannot move across these topographic lows. As a result of uplift during the Pliocene and glacial erosion during the Pleistocene, the regional groundwater setting of the Blizzard Property has changed from one of regional discharge (which led to the formation of the deposit) to one of regional recharge due to its present topographic position. It is estimated that the presently acquired groundwater flow system has existed for three to four million years. The groundwater of the plateau areas is predominantly contained in the glacial debris overlying the basaltic and granodioritic rocks. The glacial debris consists of a gravelly soil overlying glacial till. Sand and gravel filled pods and lenses are present within the till sheet. These lenses are discontinuous and do not form areally extensive aquifers. Buried river channels do not exist in the plateau areas. Piezometers located around Blizzard Ridge indicate that the regional permeability of these deposits will probably be between 10^{-4} and 10^{-8} cm/sec. Because the sand and gravel lenses have higher permeability, groundwater movement will be comparatively rapid through them. Their small, discontinuous nature, however, ensures that this more rapid groundwater movement is short lived due to the low permeability of the till containing these deposits. Piezometer data also indicates that a groundwater flow system exists in the fractured, crystalline basement rocks of the area. The beginnings of these systems can be seen on Drawing No. 38. The extremely low permeabilities of these rocks, especially when compared to the overlying drift, means that the velocity of and amount of groundwater moving through these rocks is very small.

6.2 Regional Groundwater, continued

6.2.1 General and Flow Systems - continued

The groundwater flowing off the plateau areas is mainly contained in the surficial deposits and recharges the groundwater systems in the valleys which in turn flow into the main rivers. Groundwater does not flow naturally nor can it be reasonably forced to flow artificially from Blizzard Ridge towards the water shed of McCulloch Lake that is the source of water for part of Kelowna (please see Drawing 1). The groundwater flow through the basement rocks is so small and so slow that for all practical purposes it can be ignored.

The valleys of the Kettle and West Kettle Rivers are floored with highly permeable alluvial sands and gravels. No deep, drilled water wells are present in the valleys of these two rivers except in the vicinity of Beaverdell. Since surface water sources are normally used, less than a dozen shallow wells have been dug in the valleys.

Between 20 and 30 wells are present in Beaverdell. In general, the drilled wells obtain water in sands and gravels between depths of 14 to 17 meters (45 to 55 feet). These water-bearing sands and gravels are probably highly productive but only small domestic wells have been constructed to date and no reliable long-term productivity information is available. A sequence of silty gravels are reported to cap and confine the water-bearing zone.

By analogy with other glaciated valleys of interior British Columbia, where drill hole information does exist, the valleys

6.1 Regional Groundwater, continued

6.2.1 General and Flow Systems - continued

of the Kettle, West Kettle and Trapping Creek should contain three till sheets, two sections of glacial lake silts and clays, and three buried sand and gravel filled stream channels. These are capped by near surface sands and gravels overlain in places by flood plain silts and clays. Erosion which took place after each depositional period will have removed some or even all of each sedimentary type so that it will be unlikely that a full section of sediments would be encountered. The sands and gravels within the buried stream channels can be highly productive and have transmissivities ranging from 124 m^3pd/m to 1240 m^3pd/m (8000 to 83,000 gpd) and permeabilities from 2.5×10^{-2} to 2.5×10^{-1} cm/sec.

The main water-bearing sand and gravel filled stream channels are recharged from the plateau areas through the talus or scree boulder fans that are present along the valley walls. Recharge also comes from the high terrace areas in the upper reaches of the valleys and through erosion "windows" in the relatively impervious silt, clay and till sequences.

Since recharge comes from the higher areas of the valleys and from the plateau, artesian (confined) conditions can exist in the sand and gravel filled buried channels. This artesian pressure is normally equivalent to five meters (16 feet) of head above ground surface.

6.2 Regional Groundwater, continued

6.2.2 Environmental Considerations - From a regional groundwater aspect, the most important question is whether radionuclides can move from a source near Blizzard Ridge and eventually reach major drainages in the surrounding areas. Two concentrated sources of radionuclides are recognized; the tailings and the ore body itself. It has been stated that the portion of the Beaverdell Range in which the Blizzard Deposit occurs is isolated from other regional groundwater flow systems by groundwater divides corresponding with the major drainages in the area. Although this means that groundwater originating in the vicinity of Blizzard Ridge cannot move under these major drainages it does not imply that this groundwater cannot move into the surface waters contained in these drainages. In order to calculate groundwater velocity it is necessary to assume or know values of permeability, porosity (effective), and hydraulic gradient for the basement rocks and surficial sediments. From the existing piezometer data the weighted mean permeabilities of the basement rocks and surficial sediments are judged to be 10^{-7} cm/sec and 10^{-5} cm/sec respectively. Effective porosities have been assumed as one percent for the basement rocks and ten percent for the surficial sediments.

Considering the nearest major drainage to the ore body first, it can be seen that Trapping Creek is about 1750 meters (5740 feet) downslope and to the northeast of the ore body. In order to calculate the time required for groundwater to move from the ore body to

6.2 Regional Groundwater, continued

6.2.2 Environmental Considerations - continued

Trapping Creek, the following equation (Hazel, 1973) can be used:

$$V = - \frac{K}{\theta} \frac{dh}{dl} \qquad (13)$$

where

V = average water particle velocity.

θ = porosity, effective.

$\frac{dh}{dl}$ = hydraulic gradient.

If a length of flow path of 1750 meters (5740 feet) is assumed to occur over a vertical drop of 300 meters (1000 feet) the resulting (and very approximate) hydraulic gradient is 0.17. In the basement rocks, therefore, the groundwater velocity is

$$V = \frac{10^{-7} \text{ cm/sec}}{10^{-2}} \times 0.17 = 1.7 \times 10^{-6} \text{ cm/sec}$$
or about 54 cm/year.

At this velocity groundwater infiltrating near the northern end of the ore body will move the 1750 meters (5740 feet) to Trapping Creek in about 3200 years. In the surficial sediments, the groundwater will take 320 years to move this distance.

In considering the regional transport of radionuclides from the tailings containment area to major drainages it should be pointed out that the possible migration of these contaminants into Joan and Clarke Lakes is considered

6.2 Regional Groundwater, continued

6.2.2 Environmental Considerations - continued

in a later section on local hydrogeology. Although the surface water transport of radionuclides has not been considered here, it should be pointed out that Arndt and Kuroda (1953) reported that spring water in Arkansas lost 41 percent of its radon content after flowing only 1.2 meters (4 feet) as a surface stream. If the most natural southern flow of groundwater away from the tailings area is not considered here, the only other possible (though extremely remote because of flow system configuration) direction of migration is due west into Trapping Creek. Because of the intervening topography, all regional groundwater flow would have to be through the basement rocks. The appropriate distance is about 3500 meters (11,500 feet) over a vertical drop of 300 meters (1000 feet). Assuming the same permeability and porosity values for the basement rocks as before, groundwater will move this distance in about 6500 years.

In considering the above results it should be realized that the above time estimates are extremely pessimistic (i.e. less than expected) in that they do not take into account:

1. the true length of groundwater flow paths;
2. cation exchange capabilities;
3. radioactive decay, and
4. dispersion.

6.2 Regional Groundwater, continued

6.2.2 Environmental Considerations - continued

These factors would naturally decrease migration rates and attenuate concentrations of radionuclides.

6.3 Local Hydrogeology

6.3.1 General Statement - In describing the local hydrogeology, that area contained within the boundaries of the Blizzard Property, as shown on the Local Geology Map (Drawing No. 34), is of particular interest. More groundwater flows through the pore spaces of the surficial sediments, and the sandstones of the ore-bearing e shdimentary sequence than in the basement rocks. A groundwater flow system is also present in the fractured basement rocks and the fractured basalt cap rock. As has been described, the Blizzard Property, due to its topographic position is in a regional groundwater recharge configuration. On a local scale, however, variations in topography have formed numerous small groundwater flow systems which Could discharge within the boundaries of the area. Areas of local groundwater discharge are present as springs and seeps from the northwest and southeast ends of the ore body.

The swamps occupying topographic lows are fed by spring runoff and the discharge of groundwater from the surficial sediments.

6.3 Local Hydrogeology, continued

6.3.1 General Statement - continued

Of concern then is the definition of the parameters of these local flow systems in order that any effect on the groundwater regime or environment, by mining or tailings disposal, can be fully described.

6.3.2 Surficial Sediments - The surficial sediments which mantle the Blizzard Property can generally be classified into different types of glacial till. Isolated sand and gravel lenses, which are not areally extensive, are sporadically located along the western boundary of the property.

Piezometer data (Table 5.3) indicates that the permeabilities of the various tills range from 10^{-4} to 10^{-8} cm/sec. A reasonable mean permeability value for the surficial sediments is considered to be 10^{-5} cm/sec and this implies that the groundwater velocity in these sediments, considering the hydraulic gradients present, is about 500 to 600 cm/year. Because of a regional groundwater recharge configuration, groundwaters moving into the bedrock will pass through the surficial sediments.

Where the surficial sediments directly overlie the basement rocks, they will carry the bulk of the groundwater due to the lower permeability of the basement rocks. Where they overlie the

6.3 Local Hydrogeology, continued

6.3.2 Surficial Sediments - continued

ore body, however, the majority of the groundwater will be moving through the fractured basalt cap rock and into the slightly consolidated ore-bearing sediments. In either case the expression of groundwater movement through the surficial sediments will be the water table. The depth of the water table present in the surficial sediments varies from 0 to 3.5 meters (11.5 feet) below ground surface. Where they are thin, the surficial sediments are unsaturated and this is true for the topographically high portions of Blizzard Ridge. Although a water table contour map for the surficial sediments was not drawn per se, it would have groundwater elevations similar to, though slightly higher than, those of the uppermost portion of the basement rock (Drawing No. 31). The water table in the surficial sediments is therefore subparallel to the topography.

Piezometer data confirms the envisaged relationship between the surficial sediments and the underlying basement rocks. At six of the sites (WP1, WP8, WP9, WP10, WP16, and WP22) where piezometers were completed in both the surficial sediments and the basement rocks a downward vertical hydraulic gradient from surficial sediments into basement rocks is indicated. At three of these sites (WP1, WP9, and WP16) the vertical gradient is extremely small (10^{-2} to 10^{-3} m/m) indicating mainly lateral flow. Two sites (WP17 and WP18) indicated a vertical upward gradient of about 10^{-2} m/m from basement rocks

6.3 Local Hydrogeology, continued

6.3.2 Surficial Sediments - continued

into the surficial sediments. Qualitative directions of groundwater flow are shown on the Cross Section (Drawing No. 39).

Under the containment area, groundwater flow is downward from the surficial sediments into the basement rocks. Using the average hydraulic gradient between WP1 and WP8 of about 30 meter (100 foot) drop in head over 700 meters (2300 feet) or 0.04, a cross sectional area of flow of 800 meters (2625 feet), and an assumed average saturated thickness of two meters (6.6 feet) the quantity of groundwater moving under the proposed containment area in the surficial sediments can be calculated by:

$$Q = K\ i\ A$$

where K = permeability.

i = hydraulic gradient.

A = cross sectional area of flow.

and therefore

$$Q = \frac{10^{-6}\ \text{cm/sec}}{10^{2}\ \text{cm/m}} \times 0.04 \times 800\ \text{m} \times 2\ \text{m} \times 8.64 \times 10^{4}\ \text{sec/day}$$

$$= 5.5 \times 10^{-2}\ \text{m}^{3}\text{/day}$$

or 12 gallons per day.

6.3 Local Hydrogeology, continued

6.3.2 Surficial Sediments - continued

A similar calculation can be completed for the natural drainage between the proposed containment area and Joan Lake. The data from piezometers WP10 and WP8 show a hydraulic gradient of 2 m/100 m or 0.02. Piezometer WP8-3 shows that a sand and gravel unit is present under this drainage and if it is assumed that this is continuous from the containment area to Joan Lake the average permeability of the surficial sediments under this drainage is probably 10^{-5} cm/sec. With an average cross sectional area of 500 meter (1640 foot) width times an average saturated thickness of three meters (10 feet) the quantity of groundwater moving in the surficial sediments underlying the drainage is:

$$Q = \frac{10^{-5}\ \text{cm/sec}}{10^{2}\ \text{cm/m}} \times 0.02 \times 500\ \text{m} \times 3\ \text{m} \times 8.64 \times 10^{4}\ \text{sec/day}$$

$$= 2.6 \times 10^{-1}\ \text{m}^3/\text{day}$$

or about 60 gallons per day.

A final calculation of interest is the total volume of groundwater contained in the surficial deposits of the Blizzard Property. The approximate area of the property is 12 x 10^6 m^2 and if the surficial sediments are saturated over 85 percent of the area the total volume of groundwater contained in these sediments is:

$$\text{Volume} = \frac{85}{100} \times 12 \times 10^{6}\ \text{m}^2 \times .10\ \text{(effective porosity)}$$
$$\times\ 3\ \text{m (average saturated thickness)}$$

$$= 3.1 \times 10^{6}\ \text{m}^3$$

or about 6.5 x 10^{6} gallons.

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6.3 Local Hydrogeology, continued

6.3.3 Basalt - The position and thickness of the basalt cap rock are shown on Drawing Nos. 33 and 35. Although no quantitative hydrogeological evaluations of the basalt cap rock have been completed, a number of general statements concerning the general hydrogeology of this unit can be made. Groundwater present in the basalt is associated with fractures or sand interbeds. Although the primary effective porosity of the basalt is small the presence of secondary effective porosity, in the form of fractures, allows the basalt to transmit groundwater and thus permit regional and local groundwater recharge near the top of Blizzard Ridge. The fact that the piezometric surface contours in the ore-bearing sediments (Drawing No. 31) are distributed concentrically around the topographic high suggests that the basalt has a permeability that equals or is greater than the permeability of the surficial sediments. Groundwater within the ore-bearing sediments and basement rocks is therefore hydraulically connected to the groundwater in the basalt and groundwater levels in the basalt will coincide with the regional water table. Depth to groundwater in the basalt will generally be 5 to 15 meters (16 to 49 feet) below ground surface and have a downward hydraulic gradient consistent with groundwater recharge conditions. Qualitative groundwater flow directions in the basalt are shown in the Cross Section (Drawing No. 39).

6.3 Local Hydrogeology, continued

6.3.4 Ore-bearing Sediments - The Blizzard Deposit occurs in Miocene sediments deposited in a sinuous, undulating bedrock channel in the basement rocks (Drawing No. 32). Hydrogeologically, the ore body consists of a series of confined, slightly consolidated sandstone aquifers which occur within the mudstone-sandstone sequence forming the actual ore zone. The thickness of this sequence (without the basal conglomerate) is shown on Drawing No. 30 and varies between 0 and 35 meters (115 feet). The ore deposit was protected from glacial erosion by a basaltic cap rock and occurs slightly to the east of the topographic high forming Blizzard Ridge. Due to the physical distribution of the ore body, aquifers present are limited in areal extent. Based on aquifer tests, these slightly consolidated sandstone aquifers have mean transmissivity, storativity, and permeability of 4 $m^3/d/m$, 2 x 10^{-3}, and 1 x 10^{-3} cm/sec. The Local Groundwater Regime Map (Drawing No. 31 shows that these aquifers are recharged from the adjacent topographic high through the overlying surficial sediments and basalt cap rock. As groundwater enters the aquifers of the ore body, it is deflected along the strike of the deposit causing a marked change in direction of groundwater flow to the north and south. This effect is most noticeable over the central part of the ore body where the mudstone-sandstone sequence is extensive and relatively thick (Drawing Nos. 30 and 31). This feature shows that the general outward radial flow from the crest of the hill is modified by flow through the sandstones within the channel which have higher permeabilities than the surrounding cap and basement rocks.

6.3 Local Hydrogeology, continued

6.3.4 Ore-bearing Sediments - continued

When the groundwater, moving through these aquifers, reaches the northern and southern limits of the ore body it is forced to discharge through the overlying surficial sediments which act as confining beds. Where this confining layer of surficial sediments is breached, springs, seeps and flowing artesian conditions exist. These groundwater discharge conditions exist at the north and south ends of the ore body and along its northeastern flank (Drawing No. 31). Six exploration drill holes exhibited artesian flows and are close to the zone of groundwater discharge in the eastern end of the ore body. Thus the natural discharge of groundwater from the sandstones within the ore-bearing sediments is

1. to the northeast towards Trapping Creek,
2. towards the swamps around two unnamed lakes that drain northwards to Trapping Creek and
3. in a southeasterly direction towards the swamps in the upper part of Sandrift Creek.

Values of uranium in these discharging groundwaters confirm that the ore deposit is being "wasted" or leached by groundwater.

The containment area cross section, Drawing No. 39 indicates that groundwater recharging the ore body from Blizzard Ridge will move via short, local, groundwater flow systems developed in the ore-bearing sediments and basement rocks and be discharged

6.3 Local Hydrogeology, continued

6.3.4 Ore-bearing Sediments - continued

within the boundaries of the Blizzard Property. It should be noted here that the surface waters in lakes and swamps associated with groundwater discharge areas may be separated from this groundwater by a relatively impermeable layer of organic clays and silts.

The average groundwater velocity within the ore-bearing sediments can be calculated (using Equation 13)

$$V = \frac{10^{-3}\text{ cm/sec}}{0.20} \times 0.10 = 5 \times 10^{-4}\text{ cm/sec}$$

$$= 16,000\text{ cm/year}$$

$$\text{or } 160\text{ m/year.}$$

The average thickness of the ore-bearing sediments is estimated to be 15 meters (50 feet) over an average width of 150 meters (495 feet) and an average length (along the channel) of 1800 meters (6000 feet). The permeable sandstone beds represent an estimated 33 percent of the mudstone-sandstone sequence. Thus, the volume of the sandstone is estimated to be:

15 x 1/3 x 150 x 1800 = 1,350,000 cubic meters.

With an effective porosity of 20 percent, the amount of water in storage will be:

1,350,000 x 0.2 = 270,000 cubic meters, or approximately 60 million Imperial gallons.

The hydrograph of Groundwater Test Well No. 2, Drawing No. 8, shows the water level drop in response to the winter drought and also indicates the annual variation in the amount of water stored in these aquifers.

6.3 Local Hydrogeology, continued

6.3.4 Ore-bearing Sediments - continued

The immediate area of recharge of the sediments is approximately 500 meters (1640 feet) wide and 1500 meters (5000 feet) long, or an area of 750,000 square meters (8,200,000 square feet). The average annual precipitation is approximately 600 millimeters (24 inches). It is assumed that 10 percent of the annual precipitation recharges the ground-water-bearing zones in an average year. Thus the following amount of water recharges the water-bearing zones beneath Blizzard Ridge each year:

750,000 x 0.6 x 0.1 = 45,000 cubic meters, or approximately 10 million gallons.

If, for any reason, the sandstones within the ore-bearing sediments need to be dewatered, either before or concomitant with mining, the aquifer parameters obtained from pump testing can be used to calculate the well spacing. The sediments pinch out on the edges of the channel and depressions are present in the channel. Therefore, dewatering wells would presumably have to be placed within the open pits. Since recharge is expected to be minimal (1.4 litres per second or 19 gallons per minute), the sands could be dewatered ahead of mining.

Calculations show that wells on 200 meter (650 foot) spacing along the axis of the channel discharging at an average rate of one litre per second (13 gallons per minute) will dewater the sandstones in less than 100 days. Thus approximately nine wells will be required. These will initially discharge a total

6.3 Local Hydrogeology, continued

6.3.4 Ore-bearing Sediments - continued

of nine litres per second (119 gallons per minute). This discharge will reduce to the annual expected recharge of 1.4 litres per second (19 gallons per minute).

6.3.5 Basement Rocks and Containment Area -

Certain facts concerning the hydrogeology of the basement rocks have already been discussed. Groundwater moves in the basement rocks through fractures, fissures and shear zones from Blizzard Ridge to the major drainages surrounding the Blizzard Property. Based on piezometer data, the weighted mean permeability of these rocks is 10^{-7} cm/sec which indicates an average groundwater velocity of 55 cm/year.

At a more local scale, piezometer data indicate that groundwater recharging the basement rocks has moved through the surficial sediments and/or the ore-bearing sediments and that groundwater movement in the basement rocks is generally downward. The water table contour map for the basement rocks (Drawing No. 31), which is actually a representation of the piezometric surface of the uppermost portion of these rocks, confirms that groundwater movement in the basement rocks is generally downwards, radially away from Blizzard Ridge, and sub-parallel to the topography. Local, small areas of groundwater discharge from the basement rocks may occur into the topographic lows surrounding Blizzard Ridge. The ore body-containment area cross section (Drawing No. 39), however, indicates that any discharge into these topographic lows will come from very

6.3 Local Hydrogeology, continued

6.3.5 Basement Rocks and Containment Area - continued

local recharge, generally from the surficial sediments, on the lower slopes of Blizzard Ridge. Although it should be emphasized that the representation of groundwater flow on this cross section is approximate, the section does show that the majority of groundwater recharging near the top of Blizzard Ridge contributes to regional rather than local groundwater flow in the basement rocks. Even if this section is ignored and it is assumed that the basement rocks discharge groundwater into these lows, a permeability of 10^{-7} cm/sec limits the quantity of flow to the amounts shown below.

	Location	Area of Flow (m^2)	Gradient	Quantity of Flow (m^3/day)	(gpd)
1.	Lakes NE of WP19	12,000	0.1	1×10^{-1}	23
2.	Sandrift Meadow - Lassie Lake	45,000	0.1	4×10^{-1}	86
3.	Joan Lake Drainage	15,000	0.05	6.5×10^{-2}	14

Of these locations, only Nos. 1 and 2 would be affected by discharging groundwater that had travelled through the ore-bearing sediments. The above quantities suggest that groundwater flow from the basement rocks does not form a significant contribution to surface water bodies within the property area. Realistically, the flows shown above are probably occurring underneath the given locations.

6.3 Local Hydrogeology, continued

6.3.5 Basement Rocks and Containment Area - continued

The ore body-containment area cross section (Drawing No. 39) also indicates that groundwater flow in the basement rocks does not discharge in the containment area, but rather flows under it. Any groundwater flowing into the containment area would probably be from the surficial sediments mantling the lower western slopes of Blizzard Ridge. If this cross section is ignored and it is assumed that groundwater from the basement rocks does discharge into the containment area, the quantity of this discharge is calculated to be approximately 3×10^{-1} m^3/day (60 gpd). In our best judgment, however, this is the amount of groundwater moving under the containment area within the basement rocks.

Piezometer data (Table 5.2) indicate that a shattered dacite felsic dyke encountered in WP13 near the western edge of the containment area has a permeability of 6.3×10^{-5} cm/sec. Groundwater velocity in this dyke is calculated as

$$V = \frac{6.3 \times 10^{-5} \text{ cm/sec}}{.05} \times .03 = 3.78 \times 10^{-5} \text{ cm/sec}$$

or 12 m/year.

The quantity of groundwater flowing along strike in this dyke is estimated, assuming an effective thickness of 50 meters (190 feet), to be

$$Q = \frac{6.3 \times 10^{-5} \text{ cm/sec}}{10^{2} \text{ cm/m}} \times .03 \times 50 \text{ m} \times 50 \text{ m} \times 86{,}400 \text{ sec/day}$$

$$= 4 \text{ m}^3\text{/day or 880 gpd.}$$

6.4 Environmental Considerations

Mining will change the local groundwater regime of the Blizzard Ridge area. These changes are naturally associated with the removal of the ore body from its present buried position and the creation of a tailings containment area which will form a repository for milling waste products.

As has been discussed, the ore body is presently "wasting" or being leached by groundwater movement through it. Because of the relatively high permeability of the ore-bearing sediments (when compared to the surrounding rocks) the ore body presently forms a line sink for groundwater and groundwater movement through it is relatively quick. Due to the physical configuration of the bedrock channel, groundwater discharges at the ends and side of the ore body as seeps and springs. In moving through the ore-bearing sediments the groundwater is enriched in uranium content with the result that groundwater discharge associated with the ore body has formed a natural radioactive anomaly (halo) of soils and groundwater discharges around the slopes and base of Blizzard Ridge. Removal of the ore-bearing sediments will, of course, remove the most concentrated source of this anomaly and concentrations of uranium will gradually decrease with time in the present anomalous areas. It is understood that as mining is completed, the open pit will be filled with waste rock and covered by overburden which will probably be slightly more permeable than the ore-bearing sediments. This will have two effects on the local groundwater regime in the area of the ore body. The larger permeability will increase the discharge from the filled bedrock channel and thus increase the flow rate of springs and seeps. This may cause slope instability or erosion at the northwest end of the ore body. Filter blankets, drains, etc. could be used to control any adverse effect. It will also lower the piezometric surface in the area of the filled bedrock channel. An expected increase in effective porosity will create a larger amount of groundwater storage in the bedrock channel. None of these changes are considered significant in the long term as the natural concentrated source of the radioactivity will no longer exist and the present anomalous levels of radioactivity in the soils and groundwater on the north, east and south sides of Blizzard Ridge will gradually decrease.

During the predicted dewatering of the ore-bearing sediments, about 9 x 10^4 m^3 (20 x 10^6 gallons) of groundwater will be pumped to ground surface. It is understood that this groundwater will be used in process. as process water

Milling wastes will also be placed in the tailings containment area. Due to the less than 100 percent recovery of ore mineralization during milling and the extremely fine grained nature of these tailings, the containment area will be a source of radioactivity which would be capable of moving into the subsurface and migrating by means of groundwater flow. It is understood, however, that the containment area will be surrounded by interceptor ditches which will be excavated to the base of the surficial sediments and weathered bedrock. This will intercept surficial sediment groundwaters and surface waters moving into towards the containment area from the western slopes of Blizzard Ridge. ~~and~~ this water will be recycled through the mill. Interceptor ditches constructed between the containment area and Joan Lake drainage headwaters will intercept the flow

This water can be stored for use or diverted, 6.4 Environmental Considerations, continued

of any contaminated surface water or groundwaters in the surficial sediments and return these waters to the mill for recycling. Because of this construction method, the possible subsurface migration of radionuclides will be limited to the basement rocks in a southerly direction towards Joan Lake. The distance from the containment area to Joan Lake is 1600 meters (5250 feet) and to the swamp forming the headwaters of the Joan Lake drainage system is 650 meters (2132 feet). Assuming a groundwater flow velocity of 54 centimeters (21 inches) per year and a suitable flow system configuration, it would take 1200 years for radionuclides to migrate to the Joan Lake headwaters and 3000 years to migrate to Joan Lake. These calculated migration times are pessimistic (i.e. shorter than probable) as attenuation characteristics have not been considered and the actual distances of flow paths are not known.

process water

The presence of the higher permeability (6 x 10^{-5} cm/sec) felsic dyke along the northwestern portion of the containment area will modify groundwater flow velocities in the basement rocks in the immediate area of the dyke ~~underlying the containment area~~. With Assuming an effective porosity of five percent, ~~as~~ higher than assumed for other basement rocks, the groundwater velocity in this material would be about 12 m/year. At this velocity, ignoring attenuation and assuming a suitable flow system configuration, the underground movement of radionuclides would reach the headwaters of the Joan Lake drainage in 54 years and Joan Lake in 84 years. ~~The flow of groundwater in this dyke, however, could easily be controlled.~~ It should be noted, however, ~~the dyke only~~ that any potential ~~problem~~ environmental problems associated with the dyke ~~It slow~~ could be alleviated by (1) a slight change in the configuration of the containment area and ~~that~~ ~~groundwater~~ (2) water wells controlling g.w. flow ~~through~~ along the dykes ~~could easily be controlled~~ by ~~water wells~~

7.0 GROUNDWATER QUALITY

7.1 General Statement

The quality of the ground and surface waters contained in or on Blizzard Ridge and adjoining areas is the subject of a detailed report by Envirocon Ltd. The following sections describe the potability of the groundwater and the changes in groundwater chemistry caused by the hydrogeologic characteristics of the area.

The results of the chemical analyses conducted by Chemex Labs Ltd. on groundwater samples can be found in Appendix II, Tables A and B of this report. The acceptable levels of those ions set by the Canadian Drinking Standards and Objectives are shown on Table A for easy reference.

Table C shows the uranium content of waters and soil in the samples collected by the Geological Survey of Canada in 1977 in the environs of Blizzard Ridge.

The groundwater samples from WW2 and WW3 were collected during the later parts of pumping tests after large quantities of water had been flushed from these wells. The groundwater samples taken from WW1 and the piezometers are dip samples. As such these samples are subject to contamination by rock cuttings or rock flour.

7.2 Ore-bearing Sediments

Reference to Table A will show that the groundwater contained in the ore-bearing sediments meets the acceptable levels of the Canadian Drinking Water Standards for those elements tested except for:

7.2 Ore-bearing Sediments, continued

Iron
Manganese
Total Gross Radioactivity
Radium 226

7.2.1 Iron - The reported level of iron in the water from the water wells ranges from 14 to 7.4 mg/l. This is extremely high because water with 3 mg/l of iron will stain the ground where it falls. No staining occurred thus the high iron content reported is probably caused by the presence of rust scale or rock flour in the water so that the groundwater contains much less than reported. The level of iron in the Canadian Drinking Water Standards is set at 0.3 mg/l because higher levels cause staining to appliances and not because higher levels constitute a health hazard.

7.2.2 Manganese - The remarks concerning iron are applicable to manganese although the level beyond which staining occurs has been set at 0.05 mg/l.

7.2.3 Total Gross Radioactivity - The Canadian Drinking Water Standards set this level at 10 pc/l. The World Health Organization has set the safe level of alpha emitters at 1 pc/l and of beta emitters at 10 pc/l.

7.2.4 Radium 226 - While the Canadian Drinking Water Standards do not set a level for Radium 226 apparently many water supplies contain high levels. For example the average content in potable drinking water from drilled wells in Main and New Hampshire was found to be 66 and 6.9 pc/l respectively.

Maine

7.2 Ore-bearing Sediments, continued

The uranium content of the groundwater contained in the ore-bearing sediments shows an increase in uranium towards the southeastern end of the ore body. This is shown as follows:

Sample	Uranium (ppb)
Spring	19.5
WW1	29.0
WW2	34.0
WW3	52.0

The uranium content increases towards the southeast because the groundwater moves in this direction. It dissolves more and more uranium as it flows through the ore body.

7.3 Basement Rocks

The total amount of calcium, magnesium, and sodium was plotted against the depths from where the samples were collected and against distance from the top of Blizzard Ridge. These plots indicate that there is little or no relationship between the salt content and distance from Blizzard Ridge but that the salt content decreases with depth. Such a relationship has been noted in the Caribou Plateau area of British Columbia where water from shallow wells may not be potable because of the high salt content while waters encountered at depth are potable.

With a few exceptions the content or uranium in the groundwaters sampled from the piezometers increases with increased distance from the crest of Blizzard Ridge. There does not appear to be any relationship between depth and uranium content.

Reference to Table B, Appendix II will show that there is no significant difference in the total and dissolved content of calcium, magnesium and sodium in the groundwaters

7.3 Basement Rocks, continued

collected from the piezometers with the exception of the calcium content reported in piezometers 1-1 and 7. This is questionable. The marked difference between the iron and manganese total and dissolved contents indicates that the samples contained rock cuttings or flour from which the iron and manganese were dissolved ~~with acid.~~ The same explanation probably explains the low content of dissolved uranium compared with the total content reported. The exception is WP6-3 with a reported total and dissolved content of 60 micrograms per litre (ppb).

with acid during chemical analysis

~~were derived~~ ~~in flocculated~~ samples,

Examination of the piezometer data shows that there is no significant difference in the chemistry of the waters from different piezometers with the exception of the uranium content. The following indicates this exception:

Piezometer	(Depth (m)	Dissolved Uranium (pc/1)) ppb
2-2	18.90	less than 0.2
2-3	9.45	7.0
3-1	19.81	13.7
3-2	18.29	2.6
3-3	19.81	5.6
6-1	39.6	9.0
6-2	25.0	5.3
6-3	15.0	60.0

At the WP2 and WP6 nests the shallow water sample shows a marked increase in the uranium content over that of the deeper water.

At the WP3 nest, piezometer WP3-1 to the west or downhill side of the fracture zone has the highest uranium content of 60 micrograms per litre (ppb). Since both the total and dissolved content is the same this is the true content of the groundwater.

7.4 Regional Dispersion of Uranium

The paper by Boyle (1979) describes the dispersion of uranium around Blizzard Ridge in soils and waters. The locations of those sampling points in the area of Blizzard Ridge are shown on Drawing 2 and the uranium contents are shown in Appendix II. The samples were taken from streams, seeps, and springs. This work shows the following:

7.4.1 The regional mean of the uranium content in waters and sediments for the NTS map area 82E in central south British Columbia is 0.29 ppb and 6.8 ppm respectively (1546 samples).

7.4.2 The mean contents of waters and sediments in the Lassie Lake-Cup Lake area is 0.49 ppb and 12 ppm respectively.

7.4.3 The uranium content for waters and sediments varies from 0.07 to 74.0 ppb and 0.80 to 178 ppm respectively for the Lassie Lake-Cup Lake area whereas the uranium content on and around Blizzard Ridge ranges from 0.2 to 18.0 ppb and 4.5 to 178.0 ppm for waters and sediments respectively.

7.4.4 Anomalies of the uranium content are associated with the base-of-slope seeps and springs around the Blizzard Ridge ore body. They are also associated with fault and fracture zones cutting through alkaline intrusive and volcanic rocks.

7.4.5 Blizzard Ridge and its environs are an area of subdued relief with a limited integrated surface drainage system. The dispersion of anomalies is short in such an area. The uranium content in the waters and sediments drops from 0.93 ppb and 34.8 ppm respectively to 0.46 ppb and 10.9 ppm respectively in a distance of 2000 meters (6600 feet) off the northeast side of Blizzard Ridge.

7.4 Regional Dispersion of Uranium, continued

7.4.6 The uranium content of the water sample taken from WP6-3 is 60 ppb or almost three times the maximum content of the spring at the north-western end of the ore body.

Regionally, groundwater occurs + moves in the pores of the unconsolidated glacial debris, in the pores of the ore bearing seds., & in the fractures + fissures of both the basalts & older basement rocks.

8.0 CONCLUSIONS

8.1 The regional groundwater flows through the gravelly soils, the sand and gravel filled lenses and the tills of the plateau towards the main valleys of the Kettle and West Kettle Rivers.

8.2 Groundwater development in these valleys is limited because surface water is widely used. Wells obtain water from the river gravels at Beaverdell, Carmi and Westbridge.

8.3 Groundwater is present in the sandstones of the ore-bearing sediments which fill a channel in the granodiorite and are mainly capped by basalt.

8.4 The local groundwater generally flows radially outwards from Blizzard Ridge. This radial flow is interrupted in the central part of the ore body where a "sink" occurs and where the permeable sandstones are thick and extensive. The flow in this area is directed longitudinally down the channel.

8.5 The groundwater that flows naturally through the sandstones of the ore body discharges in an easterly and northeasterly direction into swamps which drain towards Trapping and Sandrift Creeks.

8.6 The groundwater table (piezometric surfaces) are sub-parallel to the surface topography.

8.7 Uplift and glacial erosion has taken the Blizzard ore body out of the hydraulic groundwater discharge regime under which it formed into a hydraulic groundwater recharge regime under which the ore body is being wasted or leached.

8.8 The uranium content of waters and sediments varies from 0.07 to 74.0 ppb and 0.80 to 178 ppm respectively for the Lassie Lake-Cup Lake area. The uranium contents range from 0.2 to 18.0 ppb and 4.5 to 178 ppm around Blizzard Ridge.

8.0 CONCLUSIONS, continued

8.9 The weighted effective permeabilities of the different rock and sedimentary types present beneath the Blizzard Property are relatively low with the permeability of the basement rocks being 10^{-7} cm/sec, that of the glacial debris being 10^{-5} cm/sec and that of the sandstones within the ore-bearing sedimentary rocks being 10^{-3} cm/sec.

8.10 The movement of groundwater through the basement rocks will be extremely slow so that for practical purposes they may be considered virtually impermeable.

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PAGE 1

WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY

WELL NO. WW2
JOB NO. 78-089

DRAWDOWN ☑
RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q US GPM		REMARKS
21-8-78	14:00	0	20.909			
		0.5	23.604	49		
		1	24.049			
		1.5	24.283			
		2	24.451			
		2.5	24.555			
		3	24.646			
		3.5	24.762			
		4	24.863			
		4.5	24.948	49		
	14:05	5	25.036	30		
		6	23.674			
		7	23.409			
		8	23.674			
		9	23.808			
	14:10	10	23.838			
		12	23.863			
		14	23.942			
		16	24.012			
		18	24.082			
	14:20	20	24.140			
	14:25	25	24.326			
	14:30	30	24.515			
	14:35	35	24.658			
	14:40	40	24.753			
	14:45	45	24.887			
	14:50	50	24.966			– WATER TEMPERATURE 7°C
	15:00	60	25.155			
	15:10	70	25.314			
	15:20	80	25.481			
	15:30	90	25.628			
	15:40	100	25.756	30		

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PAGE 2

WELL OWNER NORCEN RESOURCES
WELL NO. WW 2
DRAWDOWN ☑
LOCATION BLIZZARD PROPERTY
JOB NO. 78-089
RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q US GPM		REMARKS
21-8-78	16:30	150	26.301	30		
	17:20	200	26.950			
	18:10	250	27.423			
	19:00	300	27.776			
	19:50	350	28.136			
	20:40	400	28.505			
	21:30	450	28.874			
	22:20	500	29.145			
	23:10	550	29.401			
22-8-78	00:00	600	29.648			
	01:40	700	30.059			
	03:20	800	30.462			
	05:00	900	30.803			
	06:40	1000	31.190			
	08:20	1100	31.483			
	10:00	1200	31.733			
	11:40	1300	31.958			
	13:20	1400	32.169			
	15:00	1500	32.358			
	16:55	1615	32.531			
	18:20	1700	32.729			
	20:00	1800	32.894			
	21:40	1900	33.040			
	23:20	2000	33.193			
23-8-78	01:00	2100	33.342			
	02:40	2200	33.473	30.25		
	04:20	2300	33.808			
	06:00	2400	33.924			
	07:40	2500	34.089			
	09:20	2600	34.208			
	11:00	2700	34.342			
	12:40	2800	34.476	30.25		

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PAGE 3

WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO. WW2
JOB NO. 78·089
DRAWDOWN ☑
RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q US GPM		REMARKS
23-8-78	14:20	2900	34.610	30.25		
	16:00	3000	34.726			
	17:40	3100	34.781			
	19:20	3200	34.921			
	21:10	3310	35.034			
	22:40	3400	35.128			
24-8-78	00:20	3500	35.226			
	02:00	3600	35.329			
	03:40	3700	35.421			
	05:20	3800	35.500			
	07:00	3900	35.601			
	08:40	4000	35.677			
	10:00	4080	35.741			
	12:00	4200	35.835			
	13:40	4300	35.921			
	15:20	4400	36.012			
	17:00	4500	36.088			
	18:40	4600	36.158			
	20:20	4700	36.247			
	22:00	4800	36.265			
	23:40	4900	36.366			
25-8-78	01:20	5000	36.457			
	04:40	5200	36.594			
	08:00	5400	36.762	30.15		
	11:20	5600	36.881			
	14:40	5800	36.951			
	18:00	6000	37.115			
	21:20	6200	37.247			
26-8-78	00:40	6400	37.381			
	04:00	6600	37.490			
	07:20	6800	37.615	30.10		
	10:40	7000	37.698	30.10		

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WELL OWNER NORCEN RESOURCES WELL NO. WW2 DRAWDOWN ☑
LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☑

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q US GPM	T/T'	REMARKS
26-8-78	14:00	7200	37.786	30.10		
	17:20	7400	37.905			
	20:40	7600	37.975			
27-8-78	00:00	7800	38.054			
	03:20	8000	38.170			
	06:40	8200	38.249			
	10:00	8400	38.292			
	13:20	8600	38.371			
	16:40	8800	38.432			
	20:00	9000	38.521			
	23:20	9200	38.582			
28-8-78	02:40	9400	38.658			
	06:00	9600	38.704			
	09:20	9800	38.786			
	12:40	10000	38.859	30.0		
— END OF TEST PUMPING — BEGIN RECOVERY						
		0.5	—			
		1	36.820		10001	
		1.5	36.805		6668	
		2	36.774		5001	
		2.5	36.716		4001	
		3	36.661		3334	
		3.5	36.606		2858	
		4	36.549		2501	
		4.5	36.491		2223	
	12:45	5	36.439		2001	
		6	36.347		1668	
		7	36.256		1430	
		8	36.158		1251	
		9	36.100		1112	
	12:50	10	36.027		1001	

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WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO. WW2
JOB NO. 78-089
DRAWDOWN ☐
RECOVERY ☑

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q / GPM	T/T′	REMARKS
28-8-78	12:52	12	35.896		834	
		14	35.756		715	
		16	35.656		625	
		18	35.549		557	
	13:00	20	35.451		501	
	13:05	25	35.235		401	
	13:10	30	35.052		334	
	13:15	35	34.884		287	
	13:20	40	34.741		251	
	13:25	45	34.586		223	
	13:30	50	34.479		201	
	13:40	60	34.244		168	
	13:50	70	34.049		143	
	14:00	80	33.879		126	
	14:10	90	33.720		112	
	14:20	100	33.580		101	
	15:10	150	32.973		67.7	15:10 - 15:30 - PULLED PUMP
	16:30	230	32.205		44.5	— INSTALLED CHART RECORDER
	19:00	380	31.413		27.3	
	21:00	500	30.831		21.0	
	23:00	620	30.389		17.1	
29-8-78	01:00	740	30.008		14.5	
1-9-78	09:00	5540	24.777		2.81	
2-9-78	09:00	6980	24.219		2.43	
3-9-78	09:00	8420	23.848		2.19	
4-9-78	09:00	9860	23.537		2.01	
5-9-78	09:00	11300	23.275		1.88	
6-9-78	09:00	12740	23.046		1.78	— PUMPING WELL WW3
7-9-78	09:00	14180	22.866		1.71	″
8-9-78	09:00	15620	22.753		1.64	″
9-9-78	08:30	17030	22.705		1.59	″
10-9-78	08:15	18455	22.683		1.54	— END PUMPING WELL WW3

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WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO. WW2
JOB NO. 78-089
DRAWDOWN ☐
RECOVERY ☑

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q GPM	T/T'	REMARKS
17-9-78	16:40	29040	22.150		1.34	
24-9-78	12:45	38885	21.866		1.26	
25-9-78	17:50	40625	21.811		1.25	
29-9-78	17:50	46385	21.811		1.22	
2-10-78	07:00	50045	21.811		1.20	

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WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO. DDH 2
JOB NO. 78-089
DRAWDOWN ☑
RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q GPM		REMARKS
21-8-78	14:00	0	22.961			-PUMPING TEST WW2
	14:20	20	23.646			
	15:00	60	24.079			
	15:30	90	24.369			
	19:00	300	25.978			
	20:40	400	26.557			
	22:20	500	27.008			
22-8-78	01:40	700	27.676			
	03:20	800	27.971			
	05:00	900	28.206			
	06:40	1000	28.487			
	08:20	1100	28.715			
	10:00	1200	28.913			
	11:40	1300	29.087			
	13:20	1400	29.258			
	16:55	1615	29.538			
	18:20	1700	29.660			
	20:00	1800	29.779			
	21:40	1900	29.904			
	23:20	2000	30.047			
23-8-78	01:00	2100	30.178			
	02:40	2200	30.288			
	04:20	2300	30.419			
	06:00	2400	30.541			
	07:40	2500	30.629			
	11:00	2700	30.834			
	12:40	2800	30.928			
	14:20	2900	31.023			
	17:40	3100	31.144			
	19:20	3200	31.248			
	22:40	3400	31.425			
24-8-78	02:00	3600	31.577			

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WELL OWNER NORCEN RESOURCES WELL NO. DDH 2 DRAWDOWN ☑
LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q GPM		REMARKS
24-8-78	05:20	3800	31.821			
	08:40	4000	31.876			
	12:00	4200	31.961			
	15:20	4400	32.062			
	18:40	4600	32.178			
	20:20	4700	32.208			
	22:00	4800	32.260			
	23:40	4900	32.284			
25-8-78	01:20	5000	32.370			
	04:40	5200	32.464			
	08:00	5400	32.586			
	11:20	5600	32.687			
	18:00	6000	33.031			
	21:20	6200	33.013			
26-8-78	00:40	6400	33.059			
	04:00	6600	33.156			
	07:20	6800	33.226			
	10:40	7000	33.305			
	17:20	7400	33.430			
	20:40	7600	33.494			
27-8-78	00:00	7800	33.586			
	03:20	8000	33.656			
	06:40	8200	33.769			
	08:50	8330	33.766			
	10:00	8400	33.766			
	13:20	8600	33.824			
	16:40	8800	33.866			
	20:00	9000	33.906			
	23:20	9200	34.019			
28-8-78	02:40	9400	34.058			
	06:00	9600	34.110			
	09:20	9800	34.162			

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WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO. DDH 2
JOB NO. 78-089
DRAWDOWN ☑
RECOVERY ☑

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q GPM		REMARKS
28-8-78	12:20	9980	34.183			
	12:25	9985	34.192			
	→ END PUMPING WW2 — BEGIN RECOVERY					
	12:52	12	34.080			
	13:00	20	34.031			
	13:20	40	33.933			
	13:30	50	33.894			
	14:20	100	33.650			
	19:00	380	32.467			
5-9-78	10:05	11365	25.231			

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WELL OWNER NORCEN RESOURCES WELL NO. ______ DRAWDOWN ☐

LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q GPM		REMARKS
						— PUMPING WELL WW2
— OBSERVATION WELL WW1 —						
21-8-78	09:00	0	13.643			
	23:10	550	14.100			
22-8-78	07:50	1070	14.944			
23-8-78	08:10	2530	16.892			
24-8-78	09:10	4030	18.318			
25-8-78	08:20	5420	19.312			
26-8-78	08:20	6860	20.156			
	18:35	7475	20.431			
27-8-78	08:10	8290	20.824			
28-8-78	12:15	9975	21.458			
— OBSERVATION HOLE DDH 4 —						
21-8-78	14:00	0	22.281			
	14:20	20	22.589			
	15:00	60	23.110			
	15:30	90	23.384			
	19:00	300	24.927			
	20:40	400	25.512			
	22:20	500	25.881			
22-8-78	08:20	1100	27.709			
	11:40	1300	28.096			
23-8-78	11:00	2700	29.910			
24-8-78	08:40	4000	30.925			
26-8-78	10:40	7000	32.376			
27-8-78	08:50	8330	33.766			
28-8-78	12:20	9980	33.302			

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WELL OWNER NORCEN RESOURCES WELL NO. ____ DRAWDOWN ☐
LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q GPM		REMARKS
						— PUMPING WELL WW2
— OBSERVATION HOLE DDH 91 —						
21-8-78	09:00	0	7.388			
22-8-78	08:50	1130	8.580			
23-8-78	08:15	2535	9.717			
24-8-78	09:15	4035	10.784			
25-8-78	08:25	5425	11.247			
26-8-78	08:25	6865	12.061			
27-8-78	08:15	8295	12.561			
— OBSERVATION HOLE DDH 104 —						
21-8-78	09:00	0	17.066			
22-8-78	09:25	1165	20.178			
23-8-78	08:50	2570	22.762			
24-8-78	09:35	4055	24.286			
25-8-78	08:45	5445	25.283			
26-8-78	09:10	6910	26.060			
27-8-78	08:40	8320	26.627			
— OBSERVATION HOLE DDH 117 —						
21-8-78	09:00	0	34.549			
22-8-78	09:35	1175	37.140			
23-8-78	08:35	2555	39.578			
24-8-78	09:35	4055	41.066			
25-8-78	08:40	5440	41.499			
26-8-78	09:05	6905	41.956			
27-8-78	08:20	8300	42.672			

WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO.
JOB NO. 78-089
DRAWDOWN ☐
RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q / GPM		REMARKS
						— PUMPING WELL WW2
	— OBSERVATION	HOLE	DDH 118 —			
21-8-78	09:00	0	17.672			
22-8-78	18:20	1700	19.980			
23-8-78	08:55	2575	21.092			
24-8-78	09:40	4060	22.473			
25-8-78	08:50	5450	23.415			
26-8-78	09:15	6915	24.110			
27-8-78	08:45	8325	24.991			
	— OBSERVATION	HOLE	DDH 124 —			
21-8-78	09:00	0	34.037			
22-8-78	09:40	1180	34.314			
23-8-78	08:40	2560	36.341			
24-8-78	09:25	4045	36.792			
25-8-78	08:35	5435	38.018			
26-8-78	09:00	6900	38.481			
27-8-78	08:25	8305	39.584			
	— OBSERVATION	HOLE	DDH 127 —			
21-8-78	09:00	0	42.221			
22-8-78	09:50	1190	42.087			
23-8-78	08:30	2550	42.129			
24-8-78	09:20	4040	42.245			
25-8-78	08:30	5430	40.453			
26-8-78	08:55	6895	41.340			
27-8-78	08:30	8310	41.438			

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WELL OWNER NORCEN RESOURCES
WELL NO. ______
DRAWDOWN ☐
LOCATION BLIZZARD PROPERTY
JOB NO. 78-089
RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q GPM		REMARKS
					—	PUMPING WELL WW2
	— OBSERVATION		HOLE	DDH	134 —	
21-8-78	09:00	0	20.717			
22-8-78	18:20	1700	20.784			
23-8-78	09:00	2580	20.812			
24-8-78	09:45	4065	21.187			
25-8-78	08:50	5450	21.574			
26-8-78	09:20	6920	21.940			
27-8-78	08:45	8325	22.260			

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PAGE 1

WELL OWNER NORCEN RESOURCES WELL NO. WW3 DRAWDOWN ☑
LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q US GPM		REMARKS
6-9-78	08:20	0	3.901			
		0.5	4.447	7.5		
		1	4.642			
		1.5	4.782			
		2	4.898			
		2.5	4.987			
		3	5.060			
		3.5	5.136			
		4	5.197			
	08:25	5	5.304			
		6	5.374			
		7	5.474			
		8	5.535			
		9	5.590			
	08:30	10	5.645			
		12	5.749			
		14	5.840			
		16	5.925			
		18	5.992			
	08:40	20	6.047			
	08:45	25	6.175			
	08:50	30	6.264			
	08:55	35	6.361			
	09:00	40	6.456			
	09:10	50	6.599			
	09:20	60	6.721			
	09:30	70	6.812			
	09:40	80	6.901			
	09:50	90	6.937			
	10:00	100	6.995			
	10:50	150	7.260			
	11:40	200	7.455	7.5		

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PAGE 2

WELL OWNER NORCEN RESOURCES WELL NO. WW3 DRAWDOWN ☑
LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q US GPM		REMARKS
6-9-78	12:30	250	7.638	7.5		
	13:20	300	7.785			
	14:10	350	7.922			
	15:00	400	7.998			
	15:50	450	8.138			
	16:40	500	8.199	7.5		INCREASE TO 15 US gpm @ 16:40
	16:45	505	9.196	15.0		
	16:50	510	9.641			
	17:00	520	9.860			
	17:30	550	10.677			
	18:20	600	10.839			
	19:10	650	11.067			
	20:00	700	12.018			
	20:50	750	12.314			
	21:40	800	12.561			
	22:30	850	12.771			
	23:20	900	12.966			
7-9-78	00:10	950	13.180			
	01:00	1000	13.359			
	02:40	1100	13.628			
	04:20	1200	13.810			
	06:00	1300	13.999			
	07:40	1400	14.124			
	09:20	1500	14.234			TEMPERATURE OF WATER 7 °C
	11:00	1600	14.387			
	12:40	1700	14.542			
	14:20	1800	14.636			
	16:00	1900	14.841			
	17:40	2000	14.978			
	19:20	2100	15.072			
	21:00	2200	15.167			
8-9-78	00:20	2400	15.347	15.0		

WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO. WW3
JOB NO. 78-089
DRAWDOWN ☑
RECOVERY ☑

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q US GPM	T/T'	REMARKS
8-9-78	03:40	2600	15.508	15.0		
	07:00	2800	15.621			
	10:20	3000	15.862			
	13:40	3200	15.984			
	17:00	3400	16.215			
	20:20	3600	16.383			
	23:40	3800	16.276			– DIAMOND DRILL INTERFERENCE
9-9-78	03:00	4000	16.258			"
	06:20	4200	16.340			"
	09:40	4400	16.374			
	13:00	4600	16.407			
	16:20	4800	16.490			
	19:40	5000	16.541			
	23:00	5200	16.630			
10-9-78	02:20	5400	16.706			
	05:40	5600	16.758			
	09:00	5800	16.831			
	12:20	6000	16.855	15		
	—— END OF TEST PUMPING —— BEGIN RECOVERY					
		0.5	15.917		12001	
		1	15.779		6001	
		1.5	15.475		4001	
		2	15.210		3001	
		2.5	15.039		2401	
		3	14.868		2001	
		3.5	14.731		1715	
		4	14.606		1501	
		4.5	14.463		1334	
	12:25	5	14.393		1201	
		6	14.240		1001	
	12:27	7	14.070		858	

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WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO. WW3
JOB NO. 78-089
DRAWDOWN ☐
RECOVERY ☑

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q / GPM	T/T'	REMARKS
10-9-78	12:28	8	13.917		751	
		9	13.801		668	
	12:30	10	13.695		601	
		12	13.493		501	
		14	13.344		430	
		16	13.195		376	
		18	13.055		334	
	12:40	20	12.945		301	
	12:45	25	12.701		241	
	12:50	30	12.466		201	
	12:55	35	12.299		172	
	13:00	40	12.219		151	
	13:05	45	12.030		134	
	13:10	50	11.896		121	
	13:20	60	11.692		101	
	13:30	70	11.509		86.7	
	13:40	80	11.357		76.0	
	13:50	90	11.180		67.7	
	14:00	100	11.046		61.0	
	14:50	150	10.488		41.0	
	15:40	200	10.055		31.0	
	16:30	250	9.723		25.0	
	17:20	300	9.327		21.0	
	18:10	350	9.043		18.1	
	19:00	400	8.797		16.0	
	19:50	450	8.568		14.3	
11-9-78	08:00	1180	6.383		6.08	
	10:00	1300	6.178		5.62	
5-10-78	08:00	34560	3.048		1.21	

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WELL OWNER NORCEN RESOURCES WELL NO. ______ DRAWDOWN ☐
LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q / GPM		REMARKS
						— PUMPING WW3
— OBSERVATION WELL WW1 —						
6-9-78	07:40	0	16.444			
7-9-78	08:00	1420	15.700			
	11:35	1635	15.648			
8-9-78	08:00	2860	15.539			
9-9-78	08:50	4350	15.389			
10-9-78	08:05	5745	15.286			
11-9-78	09:00	—	15.246			
— OBSERVATION HOLE DDH 134 —						
6-9-78	07:50	0	23.689			
7-9-78	08:10	1430	23.689			
8-9-78	08:30	2890	23.671			
9-9-78	08:45	4345	23.662			
10-9-78	08:15	5755	23.649			
— OBSERVATION HOLE DDH 152 —						
5-9-78	13:10	0	0.360			
6-9-78	10:25	125	0.527			
	14:05	345	0.536			
7-9-78	09:40	1520	0.588			
8-9-78	09:00	2920	0.762			
9-9-78	11:20	4500	1.128			
10-9-78	12:00	5980	1.457			
11-9-78	10:15	—	1.573			
— OBSERVATION HOLE DDH 153 —						
6-9-78	08:10	0	5.614			
	08:40	20	5.639			
	09:00	40	5.672			
	09:20	60	5.709			

WELL OWNER NORCEN RESOURCES
LOCATION BLIZZARD PROPERTY
WELL NO.
JOB NO. 78-089
DRAWDOWN ☐
RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q / GPM		REMARKS
— OBSERVATION HOLE DDH 153 (CONT) — PUMPING WW3						
6-9-78	09:40	80	5.745			
	10:00	100	5.773			
	10:50	150	5.843			
	11:40	200	5.898			
	13:50	330	6.035			
	15:50	450	6.075			
	19:15	655	6.370			
7-9-78	09:20	1500	7.574			
	12:40	1700	7.769			
	19:20	2100	8.095			
8-9-78	08:55	2915	8.672			
9-9-78	09:40	4400	9.068			
10-9-78	11:40	5960	9.662			
	12:40	20	9.662	— RECOVERY		
	13:00	40	9.632			
	13:20	60	9.604			
	13:40	80	9.583			
	14:00	100	9.540			
11-9-78	10:00	1300	7.986			
— OBSERVATION HOLE DDH 154 —						
5-9-78	12:45	0	5.849			
6-9-78	08:10	0	5.806			
	10:05	105	5.858			
	13:50	330	5.816			
	19:15	655	5.858			
7-9-78	09:20	1500	6.239			
8-9-78	09:25	2945	7.650			
9-9-78	09:45	4405	8.967			
10-9-78	11:45	5965	9.717			
11-9-78	10:05	—	9.266			

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WELL OWNER NORCEN RESOURCES WELL NO. ______ DRAWDOWN ☐

LOCATION BLIZZARD PROPERTY JOB NO. 78-089 RECOVERY ☐

DATE	TIME	ELAPSED TIME MINUTES	DEPTH TO WATER	Q / GPM		REMARKS
						— PUMPING WW3
	— OBSERVATION HOLE DDH 163 —					
6-9-78	10:20	120	17.441			
	14:00	340	17.438			
	19:25	665	17.441			
7-9-78	09:35	1515	17.435			
8-9-78	09:40	2960	17.438			
9-9-78	09:55	4415	17.432			
10-9-78	11:55	5975	17.432			
	— OBSERVATION HOLE DDH 175 —					
5-9-78	12:40	0	4.612			
6-9-78	10:15	115	4.648			
	13:55	335	4.691			
7-9-78	09:30	1510	4.926			
8-9-78	09:35	2955	5.111			
9-9-78	10:35	4455	5.215			
10-9-78	12:00	5980	5.386			
11-9-78	10:10	—	5.407			
	— OBSERVATION HOLE DDH 183 —					
5-9-78	12:55	0	12.838			
6-9-78	10:10	110	12.731			
	13:55	335	12.716			
	19:20	660	12.707			
7-9-78	09:25	1505	12.667			
8-9-78	09:30	2950	12.835			
9-9-78	09:50	4410	13.125			
10-9-78	11:50	5970	13.207			
11-9-78	10:05	—	13.207			

APPENDIX II

APPENDIX II

Chemical Analyses by Chemex Labs Ltd.

Table A - Water Test Wells

GROUNDWATER TEST WELL	WW78-1	WW78-2	WW78-3	Spring*	C.D.W.S.&O. *****
PARAMETER					Acceptable Limit
S. Solids (mg/l)**	40	11	170	120	
D. Solids (mg/l)	120	130	160	82	
T. Solids (mg/l)	160	150	320	200	1000
Alkalinity (mg/l CaCo$_3$)	76.6	107	106	30	500
Sulphate (mg/l) D	<1.0	3.5	2.0	<1.0	500
Chloride (mg/l) D	5.1	1.4	1.3	11	250
Calcium (mg/l) T	12	16	14	8.0	200
Magnesium (mg/l) T	10	16	14	4.4	150
Sodium (mg/l) T	9.0	7.8	7.6	5.6	
Potassium (mg/l) T	3.3	3.0	3.0	2.3	
T. Phosphorous (mg/l) T	0.03	0.04	<0.01	0.07	0.2
Nitrate (N) (mg/l) T	0.13	<0.01	0.09	<0.01	10.0******
Ammonia (N) (mg/l) T	<0.01	0.06	0.05	<0.01	0.5
T.K. Nitrogen (mg/l) T	0.16	0.14	0.20	0.60	
T.O. Carbon (mg/l)				9	
Nitrite (mg/l) T	0.02	<0.01	<0.01	<0.01	10.0******
Iron (mg/l) T	14	7.4	7.5	0.29	0.3
Manganese (mg/l) T	0.18	0.28	0.35	0.02	0.05
Cadmium (ug/l)*** T	<1	<1	<1	<1	10
Mercury (ug/l) T	<0.05	<0.05	<0.05	<0.05	
Uranium (ug/l) T	29	34	52	19.5	5000
Vanadium (ug/l) T	<50	<50	<50	<50	
Gross Alpha (pCi/l)****	38 ± 15	14 ± 6	8 ± 4	12 ± 4	1
Gross Beta (pCi/l)	188 ± 50	48 ± 15	20 ± 10	16 ± 8	10
Ra 226 (pCi/l) T	6.1	5.2	7.2	3.0	
Th 228 (pCi/l) T				<0.3	
Th 230 (pCi/l) T				<0.3	
Th 232 (pCi/l) T				<0.3	

* At north end of deposit.

** mg/l - milligrams per litre or parts per million.

*** ug/l - micrograms per litre or parts per billion.

**** pCi/l - picocuries per litre, picocurie equals curie x 10^{-12}.

***** Canadian Drinking Water Standards and Objectives mg/l.

****** Total nitrogen.

D - Dissolved ion content.

T - Total ion content.

APPENDIX II

Chemical Analyses by Chemex Labs Ltd.

Table B - Piezometers (WP)

PIEZOMETER	1-1	2-2	2-3	3-1	3-2	3-3	4	5	6-1	6-2	6-3	7
PARAMETER												
Total Calcium Dissolved Calcium	54? 5?	45 43	40 34	47 34	42 41	78 80	38 38	32 36	19 23	28 30	36 40	49? 14?
Total Magnesium Dissolved Magnesium	30 35	12 15	9 11	9.2 5.0	16 15	18 20	40 40	9.6 9	6.2 6	10 10	24 24	25 15
Total Sodium Dissolved Sodium	250 240	190 180	100 100	120 90	160 160	130 120	410 380	28 25	110 110	180 180	370 370	200 170
Total Iron Dissolved Iron	9.6 <0.02	3.1 <0.02	0.56 <0.02	14 <0.02	0.50 <0.02	2.0 0.24	0.52 0.14	0.30 <0.02	0.84 0.02	0.86 <0.02	0.76 <0.02	0.17 <0.02
Total Manganese Dissolved Manganese	0.42 0.16	0.14 <0.02	0.46 0.08	0.62 0.04	0.08 0.04	0.50 0.46	0.14 0.10	0.40 <0.02	0.04 0.02	0.08 0.06	0.06 0.02	0.14 <0.02
Total Uranium ug/l Dissolved Uranium ug/l	44 5.0	3.2 <0.2	11.2 7.0	26 13.7	4.4 2.6	9.1 5.6	2.4 1.3	14.7 14.1	13.8 9.0	7.4 5.3	60 60	1.6 <0.2
Total Zinc Dissolved Zinc	18 9.6	1.9 0.02	0.3 0.02	3.2 0.42	2.1 1.4	4.5 3.4	1.0 0.78	0.52 0.30	0.38 0.26	1.3 0.82	1.4 0.36	5.6 0.02
Total Copper Dissolved Copper	0.38 <0.02	0.42 <0.02	0.06 <0.02	0.22 <0.02	0.28 <0.02	0.38 <0.02	0.14 <0.02	0.04 <0.02	0.22 <0.02	0.10 <0.02	0.14 <0.02	0.14 <0.02
Total Mercury ug/l	0.2	<0.05	<0.05	<0.05	<0.05	0.2	<0.05	<0.05	0.1	0.2	0.3	0.3

Note: All in mg/l (parts per million) except where noted.
* ug/l - micrograms per litre (parts per billion).

APPENDIX II

PARTIAL RESULTS OF THE 1977 GEOCHEMICAL SAMPLING PROGRAM ON THE BLIZZARD PROPERTY.

CHEMICAL ANALYSES BY GEOCHEMICAL SECTION LABORATORIES OF THE GEOLOGICAL SURVEY OF CANADA

Sample Number	Type	Total U (Sed) (ppm)	Total U (H_2O) (ppb)
1060	Stream	15.2	0.54
1063	Stream	16.3	0.98
1084	Spring	178.0	18.00
1085	Stream	13.4	0.30
1086	Stream	15.8	0.32
1087	Stream	----	0.44
1088	Stream	----	0.10
1089	Stream	18.2	0.34
1090	Stream	10.9	0.46
1160	Stream	9.2	0.32
1161	Seep	19.7	0.46
1162	Seep	6.2	0.46
1176	Trench	----	5.60
1181	Seep	10.2	0.83
1182	Seep	14.5	0.17
1183	Seep	12.5	0.53
1185	Seep	39.2	4.00
1210	Seep	7.9	0.60
1213	Seep	----	2.20
1214	Seep	----	2.60