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Summerland Basin
Hydrogeological Study

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SUMMERLAND BASIN

HYDROGEOLOGICAL STUDY

Abstract

This hydrogeological study of the Summerland Basin, British Columbia, is based on existing groundwater records and reports, chemical analysis of groundwater samples from springs, hydrogeological observations, evaluation of the basin groundwater budget, and computer modelling of groundwater flow and heat transport. No data was available from the deeper parts of the basin, and no identification could be made anywhere of water which had come from great depths. At present the dominant amount of groundwater recharge enters and discharges from shallow flow systems, and the natural groundwater flow through the deep basin across an 8-km section is estimated to be 3L/s.

ÉTUDE HYDROGÉOLOGIQUE
DU BASSIN SUMMERLAND

Résumé

La présente étude hydrogéologique du bassin Summerland en Colombie-Britannique se fonde sur des relevés et des rapports existants sur les eaux souterraines, l'analyse chimique d'échantillons d'eaux souterraines prélevés dans des sources, des observations hydrogéologiques, l'évaluation du bilan des eaux souterraines du bassin et une modélisation informatique de l'écoulement des eaux souterraines et du transfert de chaleur. Il n'y avait pas de données pour les parties les plus profondes du bassin et il n'a été possible de repérer nulle part des eaux provenant de très grandes profondeurs. Selon l'hypothèse d'une faible perméabilité du bassin profond, on estime que l'alimentation en eaux souterraines se fait principalement par les systèmes d'écoulement peu profond et que le débit naturel des eaux souterraines à travers la partie profonde du bassin est de 3 L/s pour une section de 8 km.

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SUMMERLAND BASIN

HYDROGEOLOGICAL STUDY

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1. INTRODUCTION

1.1 LOCATION

The Summerland Basin is a Tertiary volcanic centre located in the Okanagan Valley in the central interior of British Columbia (Fig. 1). It is situated on the west bank of Okanagan Lake and comprises approximately 28 Km^2 flat to sub-mountainous terrain in and around the town of Summerland, B.C.

1.2 TERMS OF REFERENCE

The presence of a high regional heat flow in basement rocks (Lewis and Werner, 1982) which are blanketed locally by the low thermal conductivity volcanogenic rocks and sediments in the basin, suggests that there is a good potential for developing a low temperature geothermal resource. High temperatures at the base of the basin could be present, and provided that an active groundwater flow system exists in these hot rocks, it may be economically feasible to use these thermal waters to supplement heating of local greenhouses and Municipal buildings in the area.

Prior to drilling a deep test hole, it was considered important that a hydrogeological assessment of the Summerland Basin be carried out. Such a study would provide indications as to whether local recharge and deep groundwater flow would be adequate to support an exploitable low temperature geothermal resource.

A contract (DSS Contract No. 06SB 23227-3-0668) to carry out a hydrogeological assessment of the Summerland Basin was awarded to Piteau & Associates Limited (P & A) on November 17, 1983 by Energy Mines and

Resources (EMR). Dr. Trevor Lewis of Earth Physics Branch, EMR, of the Pacific Geoscience Centre, B.C. was designated as the Scientific Authority for this project.

1.3 SCOPE OF STUDY

The hydrogeological study involved the following:

i) An office review of geologic and existing groundwater records and reports, to establish background knowledge of the Summerland Basin hydrogeology.

ii) A field visit to map hydrogeological features and collect samples of groundwater from springs or available drillholes.

iii) Carrying out an evaluation of the basin groundwater budget, and to determine the potential magnitude of deep groundwater flow systems in the basin.

iv) Computer modelling of the groundwater flow and heat transport within the basin.

v) Assessing the probable geochemical nature of deep groundwater chemistry in the basin.

2. PHYSICAL SETTING

2.1 RELIEF AND DRAINAGE

The Summerland Basin is formed by a flat plateau area contained on the east by Okanagan Lake and on the west, north and south by a series of hills and ridges (Fig. 2). The eastern boundary drops about 120m down an escarpment to the lake elevation of 342m (1123 ft.) asl. The plateau is located at an elevation of approximately 450m (1475 ft.) asl. Prominent ridges on the periphery of the basin are formed by volcanogenic rocks of the Summerland Basin, ranging up to approximately 915m (3000 ft.) asl (see Photos 1 and 2).

Both Trout Creek and Eneas Creeks drain through the Summerland Basin.

Eneas Creek flows across the northern periphery of the basin, following a channel cutting through the cliff forming silt deposits, to lake level. Trout Creek flows parallel to the western edge of the volcanic rocks in the southern half of the basin, turning east, to follow the Summerland Fault for approximately 1.5 Km.

With the exception of Trout Creek and Eneas Creek, there is very little surface water drainage in the Summerland area. South of Giant's Head, where some swampy areas drain towards Trout Creek, is the only other area where there is evidence of perennial natural surface water drainage.

2.2 GEOLOGY

Mapping the geology of the Summerland Basin and other Tertiary volcanic outlines, including the White Lake Basin, has been undertaken by the B.C. Ministry of Energy, Mines and Petroleum Resources (Church, 1973; Church et al, 1983). Most of the following has been extracted from these publications. The basic geology of the area, as represented by Church et al (1983) is shown in Fig. 2.

The Summerland volcanic basin has been interpreted as being a volcanic caldera covered to the east by Okanagan Lake and related silt deposits and truncated to the south by the Summerland Fault. Giant's Head, a central feature in the basin is viewed as a resurgent dome, completing the caldera cycle.

Five principal units comprise the volcanic assemblage. The Kettle River Formation, composed of granite boulder conglomerate and breccia, is exposed over a small area at the base of the succession. Overlying this basal conglomerate is the Marron Formation consisting of a lower feldspathic unit (Kitley Lake member) overlain by a thick sequence of trachyandesite ash and lava, which overlies the Nimpit Lake ash beds and is the youngest volcanic sequence present. Marama Formation dacite lava and breccia forms the Giant's Head, in the centre of the basin. The uppermost sequence is an assemblage of conglomerate, sandstone and shales, correlated with the White Lake Formation sediments (Church, 1973).

Much of geological evaluation is based on mapping bedrock exposures in the north and west part of the basin. Good exposures are found in road cuts along Highway 97, which presents a section encompassing most of the Tertiary sequence (Photos 3 and 4). The Kettle River Formation boulder conglomerate can be seen in outcrop on the western margin of the basin (Photo 5).

2.3 CLIMATE

Summerland is situated in the Okanagan Valley in the British Columbia central interior. The area is characterized by low precipitation, high evapotranspiration and winter temperatures moderated by the influence of Okanagan Lake.

Mean annual precipitation in the town of Summerland is less than 300 mm. In the Trout Creek basin located at a higher elevation to the west, precipitation averages 570 mm annually (Leach, 1974). The annual distribution of precipitation illustrated in Fig. 3 shows that winter snowfall and late spring rainfall are the periods of heaviest precipitation. Average total monthly precipitation ranges from 32.3 mm in January, to 15.7 mm in March.

The mean annual temperature in Summerland is 9.3°C and varies between a low of -2.7°C in January to 20.9°C in July (see Table I). Annual sunshine averages 2040 hrs.

The particularly low rate of precipitation, warm temperatures and high annual sunshine create a high potential evapotranspiration rate of 652 mm annually. This was measured at an altitude of 1132 ft. (345m) asl in Summerland. Low soil moisture, due to the high evapotranspiration rate, fosters a natural vegetative cover of dominantly grasses and sparse ponderosa pine trees. Irrigation in the basin has allowed local growers to establish orchards.

3. FIELD INVESTIGATION

3.1 SUMMARY OF FIELD ACTIVITIES

A field trip to the Summerland Basin was made by Mr. Ian Clark between November 3 and 6, 1983. During this time, groundwater seepages and springs were sampled, hydrogeological features were mapped and exposures of bedrock units in the area were studied. Local greenhouse owners were interviewed to better understand the requirements and nature of geothermal heating required. In addition, stops were made in the White Lake Basin area to become familiar with the geological setting and to sample available artesian drillholes.

3.1.1 Groundwater Sampling and Analysis

One purpose of the field visit was to sample groundwaters which could have been derived from deeply circulating waters. Unfortunately, there has been no deep drilling in the Summerland area for either groundwater development or for mineral exploration. This precluded the possibility of sampling groundwaters obtained from significant depths in the basin. However, samples were collected from two substantial springs and from a surface water body in Summerland (Fig. 3). One sample was collected from a flowing artesian drillhole (78-4) located in the White Lake Basin. The similarities in rock type between the two basins allow some correlation of geochemical data, providing a larger data base for predicting the probable chemical composition of deep groundwaters within the Summerland Basin.

During sampling, in situ measurements of geochemcial parameters were made. Eh (redox) and pH measurements were taken using an Orion 407A Ionalyser, with appropriate probes and standard solutions. Electrical conductivity (EC) was measured with an Horizon multi-range conductivity meter and temperature was measured with a standard mercury thermometer. Samples collected for analysis of metals were filtered through 0.45 micron pore diameter filter paper and acidified to a pH of 2 with nitric acid. Samples collected for analysis of anions were unfiltered and unpreserved.

Water samples were analysed for major ion and trace metal concentrations by Analytical Services Laboratories Ltd. (ASL). in Vancouver. Major and trace metals were determined by Inductively Coupled Argon Plasma Spectroscopy (ICP). Analysis of anions was carried out according, to procedures specified by the B.C. Ministry of the Environment. Results are shown in Table I and Appendix A.

3.1.2 Hydrogeological Mapping

An attempt was made to identify surface hydrogeological features which could be related to deeply circulating groundwater in the Summerland Basin. In the Okanagan Valley, this task is complicated by the characteristically dry climate which inhibits the development of active groundwater flow systems, and by extensive irrigation of orchards which mask most natural hydrogeological features.

Despite these difficulties, observed features were studied and mapped, and are presented on Fig. 4. Principal areas of interest include:

i) The Summerland Fault which acts as an obvious geological boundary and most likely as a hydrogeological boundary. The fault could act as a barrier inhibiting flow across it, or as a conduit, allowing flow along it's length.

ii) The major springs located in discharge areas, associated with shallow and intermediate depth groundwater flow systems.

iii) Outcrops of potential volcanogenic aquifer rocks that may be present in the deeper parts of the basin. The outcrops are exposed in roadcuts in the eastern extremity along Highway 97 and in the hills, west of Summerland.

3.2 HYDROGEOLOGICAL OBSERVATIONS

The major surface features of groundwater flow systems in the Summerland Basin are shown on Fig. 4. As discussed above, the dry climate combined with an extensive cover of surficial sediments and extensive irrigation in the Summerland area make it difficult to interpret the origin of natural groundwater discharges such as seepage faces and springs.

In many areas where the surficial sediment cover is thin and relatively permeable, groundwater flow in bedrock is steady but of limited quantities, while flow in the surficials is intermittent, follows the contours of the bedrock surface and generally discharges directly to the creeks with no visible discharge (Fig. 5).

3.2.1 Groundwater Discharges

a) Trout Hatchery Spring

The Trout Hatchery Spring (location shown on Fig. 4) is the largest spring in the Summerland area. This spring has a constant flow of about 67.5 L/s (900 igpm) and discharges from the base of a small gully, cut into the cliff formed of lacustrine silt deposits exposed along the Okanagan Lake shore. The elevation of this spring is approximately 358m (1175 ft) asl and is about 16 metres above the elevation of Okanagan Lake. This spring was documented in a report summarizing an evaluation of water supply for the Municipality of Summerland in 1932 (Anon, 1932). The spring has a year round continuous flow and a constant temperature of 11°C. This substantial, invariant flow and the location of the spring suggests that it is recharged by local runoff or flow in more permeable sediments underlying the lacustrine silts in the Eneas Creek valley. Some contributions from shallow bedrock flow systems, which are recharged in nearby upland areas located west of the town of Summerland, may also be possible.

A trout hatchery, utilizing the constant (11°C) water for spawning, is located on the shore of Okanagan Lake, near the spring.

b) Indian Springs

The Indian Springs discharge from surficial deposits and flow into Trout Creek, on the western side of the basin. The flow rate of these springs was visually estimated at 2 L/s and reportedly has a continuous discharge year round (Boerboom, 1983). The setting of these springs indicates that they are draining from a local catchment area and do not represent deeply circulating groundwaters. Most likely, they represent a groundwater discharge from surficial deposits.

c) Other Surficial Springs

Locations of other surficial springs in the Summerland area are noted on Fig. 4, none of these springs had anomalous salinity or temperature and offered no indication that they contained a component of thermal waters from deep groundwater flow systems.

d) Slumping Slopes

The perpetual slide area, so named for the chronic slumping slope (see Fig. 4) which is receeding northward from the Trout Creek Canyon, is probably a substantial diffuse groundwater discharge area. The groundwater could possibly originate from the nearby Summerland Fault. However, a more plausible source of the groundwater is irrigation water infiltrating from local orchards located on the high bench area, above the silty sand deposits forming the cliffs below. Intensive irrigation over the past 50 years or more has probably built up pore water pressures in this down gradient zone, causing gravity slumping and erosion of the canyon wall.

3.2.2 Summerland Fault Area

The Summerland Fault, discussed in Section 2.2, is a prominant geological feature which truncates the volcanic basin along its southern margin. Major faults such as this, can act as hydrogeological barriers, or no flow boundaries, which can significantly affect groundwater flow regimes. They also can act as conduits for groundwater flow, having a strongly anisotropic nature, focussing groundwater flow along its length.

Physical features of this fault, evident from topographic maps and air photos, include a rough correlation with topography (see Fig. 2). Trout Creek crosses the fault at the western boundary of the basin and swings back towards the north at which point it follows the fault trace for approximately 1.1 Km downstream. Thus, Trout Creek appears to be fault controlled along this portion, but the degree of hydraulic connection to the fault is difficult to assess. A comparison of data from flow gauging stations on Trout Creek, both upstream and downstream of this fault controlled section (Stations MPDA12 and MPDA13, on Fig. 4), show an increased average annual discharge of 7400 m^3 (6 acre ft.) which is commensurate with the incremental discharge increase for the remaining length of Trout Creek. Hence, there is no definite evidence for major gains or losses of flow in Trout Creek along the section where the fault intersects the Creek. However, there would only be significant natural flow from the creek into the fault zone if the hydraulic head in the fault was substantially lower than the surface of the creek (elevation 472m (1550 ft.) asl.). If the hydraulic head in the fault was lowered by pumping a geothermal well, seepage from the creek into the fault zone could be induced.

During the field visit a concerted effort was made to look for evidence of hydrogeological features in the vicinity of the Summerland Fault, which could provide evidence of its role in controlling the local and regional groundwater flow system. No significant springs were noted along the length of the fault intersection with the basin. Several swampy areas were mapped in the vicinity of the fault, and are shown in Fig. 4. These areas apparently predate settlement in the area and are slowly being reclaimed for farming and orchards by drainage and infilling. They are not likely to have developed as a result of irrigation in the area.

Field testing of the electrical conductivity (E.C.) of standing water in these areas, indicate low levels of total dissolved solids (TDS), see Table III. If these swampy areas were a result of deep groundwater seepage to surface, E.C. levels would likely be much greater. The values measured in the field are more consistent with shallow, local groundwaters or surface waters recharged in the immediate vicinity of the swampy areas.

3.2.3 Giant's Head Area

The area immediately west of the Giant's Head hill is a natural depression with no surface water outlet. In the past, a portion of this area (shown on Fig. 4) continuously experienced the build-up of salt precipitates, leaving a white crust over much of the ground (Wilson 1983). This feature, although partly masked by landfilling and development, suggests that the area, under natural conditions, is a groundwater discharge zone. Locations of two small ponds in this area are shown on Fig. 4. During the field visit, only the northerly pond (Ade-Clark pond) still existed. The adjacent southern pond has been largely infilled. The presence of accumulated salt deposits gives the impression that the groundwater in the area is quite saline and may suggest that discharge is from a deep regional flow system. However, in a dry climate such as found in Summerland, extensive evaporation of low salinity groundwaters can result in a ponding of high salinity water, accumulated from shallow groundwater discharge, where there is no surface drainage out of the basin.

Evaporation discharge zones such as these are common in the prairies and have been noted in the Kamloops area. Hence, this area is not believed to be discharging deep basin groundwaters.

4. GROUNDWATER BUDGET STUDY

A water budget basin study was carried out to determine the potential groundwater flow in the Summerland basin. Sources of data for the water budget study include climate data for the Summerland area, a study of water resources in the Okanagan Valley (Leach, 1974) and published hydrogeological studies in nearby areas (Lawson, 1968, Halstead, 1969). This existing data was supplemented by the results of steady state and transient finite element computer modelling, carried out for this assessment.

4.1 ESTIMATION OF HYDRAULIC CONDUCTIVITY VALUES

A study of groundwater flow in a given basin and an evaluation of a groundwater budget requires, among other things, information on water table elevations and the hydraulic conductivities of major rock units. Water table information can be estimated from field evidence, water well data and from topographic maps. However, without deep drilling and testing, estimates of hydraulic conductivity in the rock zones must be based upon other studies with consideration given to the local geological and structural setting.

The hydraulic conductivities of rock units in the Summerland Basin are likely to be fracture controlled, rather than intergranular, as found in many coarse sedimentary rocks and unconsolidated materials. Groundwater movement is, therefore, a function of the distribution of fractures and fracture aperture widths. These parameters can vary substantially in rock masses. For example, one fracture, having a very high hydraulic conductivity, can allow substantial flow through an otherwise very permeable rock mass. By using a porous media analogy, the fracture hydraulic conductivity is distributed over the whole rock mass, providing an estimate of "bulk hydraulic conductivity".

Hydraulic conductivity testing over a small section of a rock mass will generally show an erratic distribution of permeabilities, because the individual test zones may or may not incorporate permeable fractures. However, a trend towards decreasing permeabilities with depth is generally apparent due to increasing overburden pressures, which close the apertures.

A second control on hydraulic conductivities in a rock mass is the degree of infilling and alteration which may have occurred in a fracture. Precipitation of minerals such as calcite, chalcedony and amorphous silica will restrict flow along a fracture. Alteration of wall rock to hydrous clay minerals such as chlorite and montmorillonite will also restrict fracture flow. This may be a significant factor in the Summerland Basin where glassy volcanic tuffs and andesites comprise the bulk of the geologic section. These rocks are far more susceptible to rapid alteration to clay minerals than crystalline rock masses, such as the host granodiorites.

Observations of bedrock outcrops in Summerland, discussed in Section 2, indicate that fracturing is well developed. The most common joint sets include bedding surfaces and joints orthogonal to bedding. However, the degree of fracturing and certainly the fracture apertures will diminish with depth. Fracture coatings of calcite have also been observed in outcrop (see Photo 4).

Two published hydrogeological studies in the general area included hydraulic conductivity testing of fractured bedrock. The Trapping Creek Basin (Lawson, 1968) study involved testing piezometers completed in various bedrock zones between depths of 6.7m and 31.1m. Hydraulic conductivity values calculated from these tests range between 2.5×10^{-9} m/s to 7.8×10^{-5} m/s for tuff and andesite.

4.2 GROUNDWATER DISCHARGE ESTIMATE; BASED ON CREEK BASEFLOW

In a given area, the long term average recharge to the groundwater zone is equal to the average discharge.

4.2.1 Groundwater Recharge

Groundwater recharge is a function of the amount of precipitation available, ground conditions in the recharge area which control infiltration and the amount of evaporation and transpiration which take place. For most hilly and mountainous areas, average annual recharge to the groundwater table is generally in the order of 3 to 15 percent of the average annual precipitation. Although this is calculated on an annual basis, most of the recharge in the Summerland area occurs during spring as the snowpack melts. During summer months, precipitation is infrequent and as much as 95 to 98 percent is lost by surface water runoff and evapotranspiration (Fig. 3).

4.2.2 Groundwater Discharge

Groundwaters which discharge from shallow flow systems constitute most of the baseflow component in associated surface water drainage systems. The amount of baseflow, therefore, can be used to estimate the volume of shallow groundwater flow in a given area. Shallow systems generally have a depth of penetration in the order of 10 to 50m.

Deep groundwater flow generally represents only a small percent of the total groundwater recharge, and may stretch from several kilometers to tens of kilometers between recharge and discharge zones (see Fig. 6).

In the Summerland area, shallow flow systems would be recharged in the local upland areas and form the baseflow component in Darke Creek, Trout Creek and Eneas Creek. Recharge in higher upland areas (shown on Fig. 4), would supply the more regional groundwater that penetrate the deeper portions of the Summerland Basin. This groundwater flow system probably has a very diffuse discharge into Okanagan Lake and/or along the lake shore. Estimates of groundwater flux in the shallow flow systems can be established, and by deducting these values from total estimated recharge, a rough estimate of the potential steady state flux in the deep flow system can be made.

4.2.3 Calculated Groundwater Discharge to Trout Creek

Trout Creek is the major creek in the Summerland area and drains a 764 Km^2 area with terrain ranging in elevation from 6116 ft. (1864m) to the Okanagan Lake level at 1123 ft. (342m). Natural flow in Trout Creek and its major tributaries has been monitored for a limited period at fourteen locations. Estimated low monthly runoff and annual baseflow for these stations are shown on Table II.

Assuming that baseflow in Trout Creek is derived mostly from shallow groundwater flow into the creek, recharge to the groundwater table can be calculated. The January flow volume is assumed to represent the average baseflow, and values for different stations shown on Fig. 4 and Table II. Annual baseflow volumes, calculated by multiplying the one month baseflow value by twelve and dividing by the catchment area, provides an estimate of total annual groundwater recharge. As measured flow in a creek such as Trout Creek does not incorporate flow in the creek alluvium or evapotranspiration losses, the baseflow volumes have been increased by a factor of 1.3.

Values for calculated annual recharge to the shallow groundwater system vary between 12.8 mm and 25.5 mm, for the given catchment areas in the Trout Creek Basin. The average value, from Table II, is 20.2 mm which represents approximately 4% of the average annual precipitation of 569 mm (see Table I), for the Trout Creek basin. Considering that significant groundwater recharge likely only occurs during spring runoff and that rainfall during the summer and fall months is generally lost through evapotranspiration, a 4 % infiltration rate is reasonable for groundwater recharge.

4.2.4 Estimated Component of Groundwater Discharge from Deep Flow Systems

As discussed above, the dominant amount of groundwater recharge enters and discharges from shallow flow systems. Only a small percentage of recharge enters deep groundwater flow systems. Estimating this percentage is very difficult, as it depends upon the geometry of the flow system and hydraulic conductivity of the rock.

Lawson (1968) estimated that for the Trapping Creek Basin, located southeast of Kelowna, flow in deep systems amounts to less than 2% of the local flow system (less than 60m depth). This estimate was determined from calculations based on hydraulic conductivity data measured in shallow drillholes and extrapolated to greater depths. This analysis is considered to be conservative, although not unrealistic. For the purpose of this study, the component of regional groundwater flow is estimated to be approximately 5% of shallow flow system.

Assuming that conditions are similar for the recharge to the regional flow system in the Summerland Basin, there would be 5% of the 20 mm of shallow groundwater recharge, or 1 mm annual recharge (0.18% of average annual precipitation). The areas which could potentially contribute recharge to a regional flow system are outlined in Fig. 4. This is an area of approximately 165 Km^2, which would provide about 5 L/s of natural recharge to the deeper portion of the Summerland Basin. In these calculations, the deep groundwater recharge has been averaged over this whole area. In reality, this recharge would be concentrated in the high elevation areas noted in Fig. 4.

4.3 FLOW TUBE CALCULATION OF REGIONAL GROUNDWATER DISCHARGE

The theory of groundwater flow nets, based on the Darcy equation of groundwater flow can be used to make simple calculations for amounts of groundwater movement through various zones in a geologic cross section. The Darcy Equation is represented as:

$$Q = KIA$$

where Q = volume of groundwater flow
K = hydraulic conductivity
I = hydraulic gradient
A = cross sectional area of flow

Cross section A-A', through the Summerland Basin (location on Fig. 4), is shown in Fig. 6 with a flow net drawn to represent the best estimate of hydraulic head distribution and flow lines in the section. According to flow net theory, the flux into a particular flow tube, bounded by two flow lines, equals flow out at the down gradient end. In order to maintain the gradient along a flow tube, the flux (Q) must be balanced by the hydraulic conductivity (K). A check on the calculated value for Q can be made by determining whether groundwater recharge at the upgradient end can maintain the flow through the particular flow tube. If not, then the value for hydraulic conductivity may be too great.

To illustrate the concept, two flow tubes have been drawn from two upland areas in the Summerland Basin, as shown in Fig. 6, which both pass through the lower strata of the basin and discharge into or near Okanagan Lake.

The areas where recharge to these flow tubes would occur are shown on Fig. 6 and identified as areas RA and RB. In each case, these flow tubes pass through strata of contrasting hydraulic conductivity. For the purpose of the calculations, average hydraulic conductivity values were assumed, based on other studies (see Section 4.1). The quantity of flow (Q) along each of these tubes for a 1m wide slice are calculated as:

Flow Tube RA

$$Q = K\ (m/s)\ I\ (m/m)\ A\ (m^2)$$

$$= (4.5 \times 10^{-9})\ \frac{(3250-2350)}{16500}\ (750)$$

$$= 1.8 \times 10^{-7}\ m^3/s$$

$$= 1.8 \times 10^{-4}\ L/s$$

Flow Tube RB

$$Q = KIA$$
$$= (1.1 \times 10^{-8}) \frac{(2650-2350)}{6500} (350)$$
$$= 1.8 \times 10^{-7}\ m^3/s$$
$$= 1.8 \times 10^{-4}\ L/s$$

These two tubes probably represent the probable total bedrock flow towards the lake. Thus, the combined flow through a 1m wide slice through the basin would be in the order of 3.6×10^{-4} L/s. If the previously discussed (Section 4.2) gross annual precepitation recharge of 1 mm was assumed for the same 1m wide slice, through the basin, the calculated groundwater flux would be 5×10^{-4} L/s, which agrees reasonably well with that calculated from the Darcy equation. It must be remembered that actual annual recharge flux into the recharge areas RA and RB is much higher than 1 mm, as these are the only areas accepting recharge and the 1 mm figure is based on the gross catchment area, including both recharge and discharge areas. If the calculated 3.6×10^{-4} L/s flux is pro-rated along the approximate 8 Km length of basin, there would be an estimated 3 L/s of natural groundwater flow through the deep basin strata at this depth.

These calculations support the estimate that total natural steady state groundwater flow through the lower part of the Summerland Basin is less than 10 L/s and probably closer to 5 L/s. Although these calculations are very subjective and incorporate a simplified geology, they are useful in providing an "order of magnitude" estimate of the groundwater seepage.

Although this appears to be a very low amount of groundwater seepage, it should be remembered that this is for steady state conditions at a significant depth where the hydraulic gradient is very low. When transient, pumping conditions are imposed on a system like this, the hydraulic gradient changes substantially, inducing considerably more flow over the first few years and slowly increases recharge from other areas over the longer term. This aspect is discussed more fully in Section 5.5.

4.4 STEADY STATE SEEPAGE MODELLING

In addition to the simplifed approach described in the last section, a finite element computer program was used to analyze seepage flows along sections A-A' and B-B'. Locations of these sections are shown on Fig. 4.

The steady-state free-surface groundwater seepage model, called GEOSPG, was used. Finite element meshes were generated using our computer program GEOMSH. Both programs operate on an in-house Hewlett Packard HP 9845B desk top micro computer.

The finite element program is designed to establish the hydraulic head distribution over the cross section and to calculate the seepage flux across the upper surface of the model for a given water table configuration and assumed set of rock permeability values.

After carrying out a series of trial runs, a reasonable set of values for average rock hydraulic conductivity was determined. The values are listed in the legend of Fig. 6.

In both cross sections, an upper more permeable and lower less permeable zone in the basement granodiorite rocks were assumed, to account for the general decrease in hydraulic conductivity with depth. The volcanic rocks in the model were divided into two units, with a slightly higher hydraulic conductivity being assigned to the lower unit. This assumption was made based on the probable presence of a non-permeable zone in deeper portion of the basin. However, the results of seepage analysis show that the higher hydraulic conductivity in the lower volcanic rock units did not have a significant effect on the total calculated seepage into the model. The volcanogenic rocks were assigned higher values of hydraulic conductivity than the intrusive rocks on the basis of field observations of the high degree of fracturing (Section 3.1.2, Photos 3, 4 and 5).

Results of the modelling along sections A-A' and B-B' are presented in Figs. 6 and 7, showing contours of hydraulic head distributions. Along Section A-A', the total recharge into the model is 0.013 L/s over the 16,000m length of the model. This is equivalent to an annual average recharge of 26 mm along the full length of the one metre wide strip. Similarly, along section BB', the total recharge into the model is 0.0064 L/s over the 22,600m length of the model. Along the one metre wide strip, this represents 9 mm of annual recharge.

Recalling that estimated annual groundwater recharge, determined from creek baseflow calculations, was between 12.8 and 25.5 mm (Section 5.1), steady state modelling tends to support this range. Furthermore, this seepage flow analysis supports the observation that total groundwater recharge in the Summerland area is not substantial, averaging approximately 4 % of annual precipitation.

The deep bedrock component of groundwater flow estimated to be less than 5 percent of total groundwater recharge (section 4.1.4) therefore remains approximately 1 mm over the catchment area or about .18% of annual precipitation.

4.5 STORATIVITY AND BASIN YIELD

Neglecting consideration of steady-state or transient groundwater seepage through the lower strata in the Summerland Basin, calculations can be carried out to evaluate the potential amount of unreplenished water which can be withdrawn by pumping. This amount of water is drawn from "storage" and unless balanced by groundwater recharge to the aquifer, it must be considered to be a finite source.

The lower volcanic strata in the Summerland Basin, which is likely to be at a depth of 500 to 1000m, is probably confined. Despite uncertainties regarding the permeability of the units at the base of the volcanics, or of the presence of true confining layers, an aquifer at that depth would behave as confined. Freeze and Cherry (1979) define storativity of saturated confined aquifer as "the volume of water that an aquifer releases from storage per unit surface area of aquifer per unit decline in the component of hydraulic head normal to that surface". Therefore, the unreplenished yield from an aquifer would be equal to the product of its storativity, area and total decline in hydraulic head. Storativity values are dimensionless and are a function of the porosity and compressibility of the aquifer. Storativities for confined aquifers generally range between 0.005 to 0.00005 (Freeze and Cherry, 1979). The lower estimate is for fractured rock aquifers which have characteristically low porosity.

An estimate of the basin yield from Summerland area can be made based on the following parameters.

Area (m^2) = approximately 1.6×10^7 m^2 area for the central portion of the basis.

Hydraulic Head Decline (DH) = 200m as an average over the whole basin area of influence. More realistically, the drawdown would be in a cone centred on the geothermal well.

Storativity (S) = 0.0001, based on past experience and studies in similar geological environments. Total drainable porosity in fractured rock reservoirs is generally less than 2%.

The approximate net potential unreplenished volume of water that could be withdrawn from storage by pumping from a well would, therefore, be:

$$
\begin{aligned}
Q &= \text{Area} \times DH \times S \\
&= 3.2 \times 10^5 \text{ m}^3 \\
&= 3.2 \times 10^8 \text{ L}
\end{aligned}
$$

Thus, a geothermal well in the Summerland Basin could sustain a steady flow of 10 L/s, for over 12 months without recovering any recharge.

The sensitivity of this calculation to the parameter is such that a slightly more or less conservative estimate of S or H could reasonably provide a range for life of the well of 6 months to 5 years. In particular, if the pumping level were lowered to 400 or 500m below ground, drainage of some fractures would begin to occur. This switch from saturated to unsaturated conditions would increase the storage factor "S" in the above calculation by about 2 orders of magnitude and increase the life of the resource tremendously. However, the cost of electrical demands for pumping from this depth may offset the direct-use geothermal energy savings, and could be prohibitive.

These calculations do not take into account the recharge that would be induced from adjacent leaky aquifers and other sources such as the Summerland Fault and Trout Creek. The effect of these features would increase in relation to the decline of head in the aquifer. These concepts are discussed more fully in the following section.

4.6 TRANSIENT FLOW TO A GEOTHERMAL WELL

Low hydraulic conductivities and limited deep groundwater recharge under steady-state conditions appear to be the principal factors restraining natural groundwater flow through the basin. However, if a well was drilled which discharged groundwater from this depth, a steeper hydraulic gradient due to development of a zone of influence could induce flow from sources such as Trout Creek and from overlying aquifers. Potential unsteady flow of groundwater to a well in the Summerland Basin is discussed here.

4.6.1 Transient Finite Element Modelling

To determine the potential for inducing recharge from other sources and to examine the radius of influence that a geothermal well may have, a two dimensional plan of the basin was modelled using GEOAQF, an in-house BASIC version of the AQUAFEM-1 finite element program. Developed by M.I.T. Department of Civil Engineering, AQUAFEM-1 is a versatile groundwater flow model which solves both steady-state and transient problems which may incorporate a variety of boundary specifications.

The Summerland Basin was represented by the finite element grid shown in Fig. 8, divided into specific zones. For the purpose of this modelling exercise, the basin was assumed to incorporate an aquifer at depth with a relatively high hydraulic conductivity of $3x10^{-8}$ m/s and a thickness of 30m. The aquifer extends areally throughout the basin and terminates at the contact with the host granodiorites to the west and under Okanagon Lake to the east. The Summerland Fault was considered as a highly permeable conduit which was connected to Trout Creek. Constant head nodes were assigned in the the model along this boundary. This is a reasonable approach as if the hydraulic heads in the basin dropped substantially due to pumping, flow would be induced from Trout Creek via the surficial sediments. Another potential source of recharge is where Trout Creek follows along the contact between the volcanogenic rocks and the granodiorites. This zone was also assigned with constant head nodes to simulate seepage into the aquifer.

Vertical leakage to the aquifer from the overlying units in the basin, including Okanagan Lake, was allowed. This was incorporated in the model by specifying a leakage factor (K'/B', where K' = assumed vertical hydraulic conductivity and B' = the thickness of the overlying unit).

4.6.2 Radius of Influence

A contour plot of the potentiometric surface in the aquifer is shown in Fig. 8 for various times. These modelling results show that pumping from a well in an aquifer configuration such as this could potentially have a radius of influence of several kilometers.

This effect is typical for fractured rock masses which have characteristically low storage coefficients (low yields per unit drawdown in head) yet may have a fracture system which is areally very extensive.

As shown on Fig. 8, the radius of influence has reached as far as Trout Creek and the Summerland Fault. Induced flow from these features has eventually allowed steady state conditions to become established in the aquifer.

This model was set up and run with the intention of demonstrating how a well would induce flow from most of the basin area and induce recharge from surface features such as Trout Creek and Eneas Creek. As the geometry of the model chosen is very subjective, and hydrogeological boundaries are not well defined, the results are rather speculative. The model does however, demonstrate that from a hydrogeological viewpoint, flow to a deep well could be induced from surface hydrogeological features, sustaining a pumping rate of about 5 to 10 L/s.

5. GEOCHEMISTRY

Development of a direct use geothermal resource requires an evaluation of the water chemistry in order to predict potential environmental problems related to water disposal or technical problems related to the distribution system. If the thermal waters are discharged to surface waters, contamination by various dissolved metals may affect natural biota and human health. In addition, use of geothermal waters having a corrosive or scaling potential would create problems with well casings, piping and heat exchangers, reducing the economic benefits of the resource.

A variety of groundwater sources in the Summerland Basin and adjacent White Lake Basin have been sampled and analyzed in order obtain data so that the probable chemical nature of thermal waters in the lower volcanic strata can be determined.

There are no deep wells or drillholes in the Summerland Basin. Wells drilled for water supply are generally completed in surficial deposits and none extract groundwaters from bedrock units in the basin. Although there has been an interest in uranium exploration in Prairie Valley, west of Summerland, there has not been diamond drilling to date. As discussed in section 3.1.1, only two springs and one pond in a local groundwater discharge area were sampled during the site visit. These represent the only groundwaters sampled in the Summerland area.

Two deep artesian drillholes in the White Lake basin (78-4 and P-well) have been sampled in this and previous investigations (Michel and Fritz, 1981). The geology of the White Lake Basin is comprised of the same volcanic sequences found in the Summerland Basin. Therefore, the predictions of the deep Summerland Basin water chemistry has been based on extrapolating the data from the two White Lake Basin drillholes.

Data collected in this and previous studies is tabulated in Table III.

5.1 SUMMERLAND BASIN GROUNDWATERS

The waters sampled in the Summerland area from the two springs and from the pond have chemistries characterized by low total dissolved solids (TDS) and concentrations of trace metals which are near or below analytical detection limits (Table III). The major ion chemistry is dominantly calcium-bicarbonate with less abundant sodium and sulphate. Chloride levels are generally low and all are less than 10 mg/L.

Groundwaters with a calcium-bicarbonate chemistry are indicative of a shallowly circulating flow system, generally in surficial deposits. This is certainly the case for the Indian Spring waters which are related to local topography, apparently discharging from a local flow system. The Ade-Clark pond waters appear to be a local groundwater discharge area which has no natural outlet. Evaporation may be responsible for elevating the TDS level somewhat. The Trout Hatchery spring, discharging at 67.5 L/s represents the most significant groundwater discharge in the study area. However, the low TDS (414.9 mg/L), combined with the calcium-bicarbonate chemistry and oxidizing conditions (+180 mV) indicate these waters have been recently recharged and are not deeply circulating. The location of these springs suggests that they may flow through surficial deposits or along buried channels on the bedrock surface, with possible recharged from Eneas Creek or infiltration within the Summerland area.

If any of the groundwaters sampled in the Summerland area contain a component of deeply penetrating groundwaters related to a geothermal resource, dilution with local, shallow groundwaters has precluded their identification.

5.2 WHITE LAKE BASIN GROUNDWATERS

Geochemical data on groundwater samples for two artesian diamond drillholes P-well and 78-4, in the White Lake Basin are available. The P-well was drilled in the early 1960's to depth of approximately 390m, at a location about 1 Km northwest of the Dominion Observatory near White Lake. This hole was drilled for the Department of Energy, Mines and Resources as part of a thermal monitoring program. Drillhole 78-4 was drilled in 1978 to a depth of 450m, as part of a uranium-thorium exploration program conducted by Pacific Petroleum Ltd (now Petro-Canada). It is located on Highway 3A, 3 Km west of Highway 97.

The P-well and 78-4 were sampled in 1981 (Michel and Fritz, 1981). At the time of the field visit undertaken in the current study, only 78-4 remained under artesian conditions and could be sampled. The artesian water represents flow from a series of zones. Temperature gradient measurements in drillhole 78-4 supports interpretation of deep artesian conditions. Inflows to this well, indicated by inflection points on the temperature-depth profile, were detected at depths of 350 and 405m (Lewis, 1983). Below about 240m depth in drillcore from 78-4, zones of solution breccia, and weathered lava flow tops and fault gouge zones were identified (Guillermo, 1979). A high density of fault zones in the lowest 60m (below 330m depth) of the P-well was reported by Church (1973). Jessop and Judge (1971) determined from a temperature depth profile that inflows occured at depths of 73m, 167m and 209m. No faults were observed in the drillcore within the upper 200m of the hole. Thus, artesian inflows to the drillhole 78-4 are substantially deeper than those to the P-well.

The elevated dissolved solids content (1700 mg/L) and warm temperatures (11-14^{o}) is further evidence that these waters are not derived from shallowly circulating groundwaters.

The water from drillhole 78-4 is characteristically a sodium-chloride-sulphate type water with minor bicarbonate and a TDS level of approximately 1700 mg/L. Temperature is close to 14°C, pH values are neutral (7.32 and 7.81) and redox conditions are reduced (Eh=-210 mV).

Trace metal levels are all generally low with the exception of strontium which was as high as 13.2 mg/L in one sample. By contrast, the water sampled from the P-well has a dominantly sodium bicarbonate chemistry with minor chloride. The P-well water has a higher pH (8.33), temperature is lower (10.8°C) and TDS level similar (1774 mg/L) relative to the drillhole 78-4 sample.

The high TDS, Na-Cl chemistry and low Eh of water from drillhole 78-4 indicates a relatively deeply penetrating groundwater system which has experienced substantial interaction with minerals beyond atmospheric influences. Low dissolved oxygen and low pCO_2 values are also predicted.

Groundwaters sampled from the P-well have likely experienced a similar deep penetration and lengthy subsurface residence time. The high bicarbonate concentration has been attributed to oxidation of immature coal or methane by organisms at depth (Michel and Fritz, 1981). This theory was supported by low ^{13}C contents (-24.5‰) and low radiogenic carbon content (1 pmC).

The chemistry of groundwaters in these two drillholes suggests a geochemical evaluation towards a sodium-chloride facies indicating a flow direction roughly towards drillhole 78-4 from the P-well (Michel and Fritz, 1981). Hence,the Na-Cl(SO_4) water chemistry developed by flow through this sequence of volcanic rocks is probably representative of an intermediate depth groundwater in the White Lake Basin.

5.3 WATER QUALITY OF SUMMERLAND BASIN THERMAL WATERS

Water quality data from drillhole 78-4 is likely the best representation available for the geochemistry of deep groundwaters in the Summerland Basin.

The actual zone which would be developed in a geothermal well may be as deep as 1000m whereas groundwater from drillhole 78-4 are from no deeper than 450m. However, the longer flow path in the Summerland Basin is not likely to result in the evolution of groundwaters with substantially different geochemical facies. Most likely, the level of total dissolved solids would be higher and the concentration of bicarbonate would be less.

5.3.1 Mineral Solubility

Geochemical data from sample 78-4 has been analyzed using Piteau & Associates in-house computer program (GEOCHM), which is an enhanced BASIC version of the WATEQF chemical speciation and mineral solubility program developed by Plummer et al (1976). Results show that the principal minerals which are oversaturated in the groundwater are quartz and chalcedony (Appendix B). Calcite, gypsum and limonite ($Fe(OH)_3$), which are common scale forming minerals, are all undersaturated with respect to this groundwater.

Although quartz and chalcedony are oversaturated, these minerals seldom precipitate out of solution near the discharge point due to the slow rates of chemical reaction involved. Amorphous silica (silica gel) is more commonly the silica phase formed when precipitated from solution. In this sample, amorphous silica is in an undersaturated state.

The water chemistry for this sample was analyzed by GEOCHM a second time using revised values for temperature, Eh and D.O. (4^{o}C, 300 mV and 9 mg/L) in order to simulate conditions at the point of discharge after direct use of the geothermal waters. Again, the principal scale forming minerals, calcite, gypsum and amorphous silica are undersaturated. The supersaturated minerals include $Fe(OH)_3$ and strontianite and fluoride is very close to saturation. However, as these three minerals are present only in very low concentrations, they are unlikely to create scaling problems in the distribution system for the hot water resource.

The neutral pH, low salinity, and lack of detectable H_2S indicates that this groundwater is non-agressive and unlikely to cause any excessive corrosion to pipes or heat exchangers in a direct use system.

5.3.2 WASTE WATER DISPOSAL AND ENVIRONMENTAL IMPACT

The chemical quality of this groundwater has no apparent constituents which could be considered toxic although the analysis exceeds drinking water standards for TDS, Na, Cl, SO_4 and F. Strontium concentrations, although unusually high (13.2 mg/L), are not limited in drinking water standards. Other trace metals are likely to be near or below analytical detection.

If the geothermal waters are discharged to surface waters such as Trout Creek and Eneas Creek or to the storm sewer system and into Okanagan Lake, the amount of dilution which would take place would most likely remove any environmental concerns for biota and human health. Deep well injection, the alternative to surface water discharge, is an expensive and most likely an unnecessary disposal method. No consideration has been made in this evaluation of the effects on biota in surface waters due to discharge of warm waters. This can be readily determined when the temperature of the geothermal waters after utilization has been established.

6. HEAT FLOW MODELLING

6.1 INTRODUCTION

Upward heat flow from basement rocks through the volcanic units in the Summerland Basin has been simulated using a finite element, coupled heat flow-groundwater flow computer model. The model, GEOHTS, developed by Piteau & Associates, can be used in either steady-state or transient modes to solve two-dimensional heat flow problems. The solver utilizes the Galerkin finite element method in conjunction with Gaussian Elimination, allowing for nonhomogeneous and anisotropic conditions.

Groundwater seepage in the horizontal plane is used in convective heat transport calculations. Conductive heat transport is calculated in both horizontal and vertical directions.

A simplified cross section through the Summerland Basin, oriented roughly east-west, was used to produce the finite element mesh shown in Fig. 9.

The volcanic strata have been represented as one unit having a saturated density of 2552 Kg/m^3 and a specific heat of 920 (Joules per kilogram degree Kelvin) J/Kg-K. Specific heat of the fluid was assumed to be 4180 J/Kg-K. A value of 1.8 (Watts per metre per degree Kelvin) W/m/K for thermal conductivity was used, based on a range of 1.6 to 1.95 W/m/K given by Lewis (1983) for volcanic sediments in the White Lake Basin.

The model was structured to incorporate a 100m thick aquifer in the lowest portion of the volcanic basin, having a hydraulic conductivity assuming flow to be from a basin area of approximately 12.5 Km^2. This pumping rate was used in order to simulate a more stringent demand on the heat resource. As discussed in Section 4, the limited recharge to the aquifer will probably not allow a well to sustain a 43 L/s pumping rate.

The groundwater flow system is altered under these conditions, with flow towards the well rather than through the basin to the right. Linking the groundwater flow system to the heat flow system produced the temperature distribution pattern seen in Fig. 9. The predicted temperature of the pumped water is between 52°C and 59°C which is only a few degrees lower than the non pumping situation. Thus, pumping the well even at very high rates may not lower the water temperature significantly. However, the 80°C temperature fixed at nodes along the base of the model provides a steep upward temperature gradient beneath the well, which is also responsible for sustaining the high temperatures in the discharge water. In the real situation, heat flow from greater depths beneath the basin may not be able to sustain this high temperature for a great length of time.

6.4 TRANSIENT HEAT FLOW MODELLING

GEOHTS was run in the transient mode to establish the length of time required to attain the steady state temperature conditions determined in Section 7.2. Initial temperature conditions established in the natural steady-state modelling (Section 7.1) were used. The model was run, using a pumping rate from the "well" of 43 L/s, for a period of twenty years.

No significant trend towards the dynamic steady state situation was evident during this period, and so the time steps were increased to 100 year intervals. Fig. 10 shows the gradual trend towards dynamic steady-state temperatures for a node in the aquifer.

Evidently, the time period required to achieve steady state heat flow under pumping conditions would be quite substantial. Based on this modelling study, cooling of the thermal reservoir will apparently not be significant as the Summerland geothermal resource is developed.

7. SUMMARY

7.1 HYDRAULIC CONDUCTIVITY

i) Bulk hydraulic conductivity values for the deep basin volcanic rocks have been estimated to be between 3×10^{-8} and 8×10^{-8} m/s. These estimates are based on actual field data from studies in nearby areas (Lawson, 1968; Halstead, 1969; Golder, 1980).

ii) Groundwater flow would be distributed in discrete high permeability zones related to fracture zones on bedding planes.

iii) The volcanic rocks of the Summerland Basin show well developed fracture systems in outcrop, although overburden pressures at depth would reduce their potential to transmit flow.

iv) Evidence of discrete high permeability zones and groundwater flow at depths of up to 400m in the volcanic rocks of the White Lake Basin has been documented by Lewis (1983). Similar high permeability zones in the Summerland Basin are considered likely.

7.2 STEADY STATE GROUNDWATER SEEPAGE

i) Estimates of natural steady state groundwater seepage through the Summerland Basin have been made, using creek baseflow estimates, flow tube calculations, and steady state seepage modelling.

ii) Groundwater discharge from the deep basin flow system is estimated to be less than 5 percent of groundwater recharge or less than .2% of average annual precipitation, under natural flow conditions.

iii) On the basis of finite element computer modelling and hand calculations, the total amount of natural steady state flow in the vicinity of the volcanic strata is approximately likely to be in the 2-15 L/s range.

iv) Low annual precipiatation, high evapotranspiration in the recharge areas and low bulk hydraulic conductivities in the rock mass are considered to be the principal factors restricting groundwater recharge and flow.

7.3 BASIN YIELD

i) Neglecting natural or induced recharge to the aquifer, production of thermal waters at a rate of 10 L/s could possibly be sustained for a period of up to 5 years.

ii) Calculations of basin yield have assumed that saturated and confined conditions prevail and that no drainage of fractures occurs. This is reasonable if the pumping level in a geothermal well is less than about 300m below ground.

iii) Pumping levels deeper than 400m below ground in a well would likely cause dewatering of some fractures in the flow system, resulting in a short term (few years) higher well yield while the stored water in the rock is removed. However, the electrical costs in pumping from such depths would likely be prohibitive.

7.4 TRANSIENT FLOW AND INDUCED RECHARGE

i) Pumping thermal water from the base of the volcanic strata would have a substantial influence on the groundwater flow system throughout most of the area of the Summerland Basin. This is because at depths of between 500 and 1000m, the aquifer would behave under confined conditions where pressure changes can have an influence over distances of several kilometers.

ii) Finite element modelling in plan view of the basin demonstrates that the area of influence of a geothermal well could extend to the peripheries of the basin and that steady state well yield would depend on the hydraulic boundary conditions.

iii) Potential sources of recharge to the thermal aquifer under transient pumping conditions includes leakage from the overlying strata, inflows from Trout Creek and Eneas Creek and seepage from the upper zones of the grandiorite host rocks along the western boundary of the basin and possible diffuse recharge from Okanagan Lake.

7.5 GEOCHEMISTRY OF THERMAL WATERS

i) No springs in the Summerland Basin have been sampled which contain an apparent component of discharge from a deep thermal flow system.

ii) No drillholes or well exists in the Summerland area which are completed in bedrock and may have provided samples of groundwater from deeper portions of the basin.

iii) Two drillholes in the White Lake Basin, drilled for uranium exploration (hole 78-4) and for thermal gradient testing (P-well), were artesian at the time of sampling. They have provided geochemical data of groundwaters from depths of up to 450m in volcanic rocks of the same sequence as that found in the Summerland Basin. The similar geological settings of these basins has allowed extrapolation of the geochemical data for use in the study.

iv) Deep groundwaters in the Summerland Basin are likely to have a sodium-chloride chemical nature with minor sulphate, neutral pH and TDS levels of between 1700 and 2500 mg/L. Concentrations of fluoride and strontium may be as high as 6.8 and 10-15 mg/L respectively. Other trace metal concentrations are likely to be low or below analytical detection. Eh conditions are anticipated to be reducing (Eh = -200 to -300 mV).

v) The waters are not likely to have any aggressive or corrosive characteristics detrimental to the well or to thermal water distribution equipment.

vi) Mineral solubility calculations, using GEOCHM, a modified WATEQF program, indicate that the common scale forming minerals (calcite, gypsum amorphous silica and limonite) would likely be undersaturated in the thermal waters.

vii) No environmental problems related to chemistry are anticipated with the discharge of geothermal waters to surface water systems. As the final discharge temperature is likely to be low, the effects on stream biota resulting from elevated stream temperatures are likely to be minimal.

7.6 HEAT FLOW

i) Steady-state finite element modelling of heat flow was carried out assuming a 100m thick aquifer at the base of the volcanic strata. Temperatures in the underlying basement rocks were assumed to be 80°C.

ii) Temperature distribution patterns in the basin were determined under both natural flow conditions and under conditions with pumping at 43 L/s from a well. This high pumping rate is not likely to be achieved, however thermal analysis was carried out for this case to illustrate the insensitivity of thermal changes to the rate of discharge.

iii) Estimated discharge water temperatures are estimated to be between 54 and 60°C prior to pumping and decline to between about 52 and 59°C.

iv) This small decline in temperature may be due to the large size of the basin as compared with the relatively low pumping rate.

v) The length of time required to reach steady-state under pumping conditions may be as much as several decades to several hundred years.

8. CONCLUSIONS

i) A geothermal well drilled to the base of the Summerland basin should have a reasonable chance of producing between 3 and 10 L/s of groundwater.

ii) Estimated natural steady state recharge to the basin is about 5 L/s, with a possible high and low range being between 3 and 10 L/s.

iii) Unreplenished groundwater yield from the basin should sustain a discharge rate of 5 to 10 L/s for a period of up to 5 years. During this period a decline in the pumping rate and pumping level in the well can be anticipated.

iv) Under pumping conditions, groundwater flow would likely be induced from overlying strata and from surface waters such as Trout Creek and Eneas Creek. This would substantially increase recharge to the basin and allow a dynamic steady-state situation to become established, allowing sustained production at thermal water. Thus, under most favourable conditions a well capable of sustaining a rate of 40 L/s is possible, for a year or so, however this rate is likely to gradually decline eventually to between 3 and 10 L/s.

v) It is possible that long term pumping may not have a significant effect on temperatures in the lower basin strata.

9. RECOMMENDATIONS

i) A deep geothermal well should have a good prospect of encountering a sustained groundwater yield of 3 to 10 L/s. In the event that the yield of the well is low, stimulation techniques such as hydrofracturing should be considered, in order to intercept more fractures and increase productivity.

ii) If a geothermal well is drilled in the Summerland Basin area, it is recommended that a series of groundwater samples be collected during and after drilling. If artesian conditions are encountered, sampling during drilling is quite easy. However, if static water levels are below ground, it may not be possible to sample water until drilling has been completed. Ideally all samples should be obtained using inflatable packers set in the hole so that samples come from a discrete zone.

This sampling will allow a more comprehensive evaluation of down hole groundwater chemistry and temperatures.

iii) In situ hydraulic conductivity testing should be carried out at selected intervals during drilling. If a diamond drill is used, this can be carried out through the bit with minimal disruption to the drilling schedule. Hydraulic conductivity and hydraulic head data will greatly assist in refining the observations and conclusions presented in this study.

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Respectfully Submitted

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TABLE I

CLIMATE DATA

SUMMERLAND CDA EL 49° 34′N 119° 38′W 346 m	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Daily Maximum Temperature	0.3	4.4	9.1	15.0	20.4	24.4	28.3	27.6	21.9	14.6	6.5	2.5	14.6
Daily Minimum Temperature	−5.5	−2.9	−1.0	2.6	6.9	10.8	13.5	13.3	9.3	4.2	−0.1	−3.0	4.0
Daily Temperature	**−2.7**	**0.7**	**4.1**	**8.8**	**13.7**	**17.7**	**20.9**	**20.4**	**15.6**	**9.4**	**3.2**	**−0.2**	**9.3**
Standard Deviation, Daily Temperature	3.1	2.5	1.7	0.9	1.6	1.6	1.4	1.6	1.1	1.1	2.2	2.1	0.9
Extreme Maximum Temperature	12.8	12.8	20.0	24.4	31.7	37.2	35.6	37.2	34.4	25.0	15.6	12.2	37.2
Years of Record	14	14	14	14	14	14	14	14	13	12	12	13	
Extreme Minimum Temperature	−22.2	−21.1	−20.0	−6.7	−4.4	2.2	4.4	5.6	1.1	−3.9	−18.3	−20.0	−22.2
Years of Record	14	14	14	14	14	14	14	14	13	12	12	13	
Rainfall	6.4	10.0	11.1	18.8	26.2	29.0	19.9	28.5	19.5	15.7	14.9	11.1	211.1
Snowfall	27.4	8.4	3.6	0.1	0.0	0.0	0.0	0.0	0.0	0.4	6.8	22.0	68.7
Total Precipitation	**32.3**	**17.6**	**15.1**	**18.7**	**26.2**	**29.0**	**19.9**	**28.5**	**19.5**	**15.9**	**21.8**	**32.0**	**276.5**
Standard Deviation, Total Precipitation	12.7	8.8	7.5	15.3	13.9	15.1	16.9	17.0	15.9	17.9	12.6	18.3	53.7
Greatest Rainfall in 24 hours	11.4	14.2	10.4	12.2	22.4	21.8	39.1	22.4	17.8	17.3	13.7	8.9	39.1
Years of Record	15	15	15	15	15	16	16	16	15	13	14	15	
Greatest Snowfall in 24 hours	14.7	9.7	9.7	1.8	T	0.0	0.0	0.0	0.0	2.8	8.4	24.9	24.9
Years of Record	15	15	15	15	15	16	16	16	15	14	14	15	
Greatest Precipitation in 24 hours	15.5	20.1	10.4	12.2	22.4	21.8	39.1	22.4	17.8	17.3	13.7	24.9	39.1
Years of Record	15	15	15	15	15	16	16	16	15	13	14	15	
Days with Rain	3	5	5	7	9	8	7	8	7	8	8	5	80
Days with Snow	11	4	2	0	0	0	0	0	0	0	2	7	26
Days with Precipitation	13	9	7	7	9	8	7	8	7	8	10	12	105
Potential Evaporation	20.3	53	86	119	178	213	249	221	163	97	71	46	1514

SOURCE: Environment Canada

TABLE II

TROUT CREEK BASEFLOW AND GROUNDWATER RECHARGE

STATION (FIG. 3)		CATCHMENT[(1)] AREA (Km^2)	SURFACE RUNOFF FLOW ($m^3 \times 10^3$) LOW[(1)] MONTH	ANNUAL[(2)] BASEFLOW	ADJUSTED FOR[(3)] FLOW IN ALLUVIUM	ANNUAL RECHARGE[(4)] FOR CATCHMENT AREA (mm)
CPDA	1	24.7	33.3	399.7	600.0	24.3
	2	15.0	17.3	207.2	310.8	20.7
	3	6.1	8.6	103.6	155.4	25.5
	4	245.6	312.1	3744.9	5617.4	22.9
	5	1.62	1.2	14.8	22.2	13.7
MPDA	1	32.8	39.5	473.7	710.5	21.7
	2	306.7	379.9	4559.0	6838.5	22.3
	3	39.3	50.6	606.9	910.3	23.2
	4	394.2	489.7	5876.4	8814.6	22.4
	5	22.7	29.6	355.2	532.9	23.5
	6	446.4	550.1	6601.7	9902.5	22.2
	7	45.7	55.5	666.0	999.0	21.9
CPDA	6	13.8	9.9	118.4	177.6	12.9
MPDA	8	45.7	48.1	577.3	865.9	18.9
	9	558.5	674.7	9096.7	12145.0	21.7
CPDA	7	1.2	1.2	14.8	22.2	18.5
	8	17.8	19.7	236.8	355.2	20.0
MPDA	10	10.1	40.7	488.5	732.7	18.3
	11	76.1	54.3	651.3	976.9	12.8
	12	683.9	758.6	9103.2	13654.8	20.0
	13	717.9	766.0	9192.0	13788.1	19.2
	14	749.1	772.2	9266.4	13900.0	18.6

(1) From Leach, 1974.

(2) Annual baseflow = runoff for low month x 12 months. Assumes runoff from low month is all groundwater discharge (baseflow).

(3) Correction factor of 1.3 used to account for unmeasured flow of water in creek alluvium.

(4) Annual recharge assumed to be equal to annual baseflow discharge adjusted for flow in alluvium.
Annual recharge for catchment area = adjusted annual baseflow/catchment area.

TABLE III

GEOCHEMISTRY OF GROUNDWATERS

SAMPLE DESCRIPTION				FIELD AND LAB PARAMETERS						MAJOR IONS (Mg/L)									TRACE METALS (mg/L)							
SAMPLE	LOCATION	DATE	DEPTH[1] (m)	TEMP (°C)	pH Field	pH Lab	EH[2] (mV)	E.C. (uS/cm) Field	E.C. (uS/cm) Lab	HCO_3^-	SO_4^{2-}	Cl^-	F^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	SiO_2	Al	B	Ba	Fe	Li	Mr	Sr	TDS
DRILLHOLE 78-4	Highway 3A White Lake Basin	83-11-3	450 Artesian	13.8	7.32	7.86	-210	2000	2090	150	440	495	6.0	468	1.6	34.2	0.58	19.9	0.11	1.03	0.032	LD	0.13	0.02	13.2	1629.7
DRILLHOLE[3] 78-4	Highway 3A White Lake Basin	81-10	450 Artesian	15.0	7.81	-	-	1890	-	244	394	512	5.72	480	1.82	44.0	0.87	-	-	-	-	22.7	-	LD	11.1	1716.2
P-WELL[3]	Dominion Observatory White Lake Basin	81-10	390 Artesian	10.8	8.33	-	-	1350	-	1154	2.77	183	4.10	400	2.80	19.4	1.50	-	-	-	-	4.27	-	0.08	2.11	1774.0
TROUT HATCHERY SPRING	Lower Summerland	83-11-6	Surface	11.3	6.75	7.75	+180	570	506	179	75	9.50	-	20.1	4.2	87.5	17.1	21.4	0.24	0.08	0.082	LD	LD	LD	0.73	414.9
TROUT HATCHERY[4] SPRING	Lower Summerland	51-11-2	Surface	-	7.4	-	-	-	-	132	48.0	6.7	0.5	26.5	-	68.8	12.7	16.8	LD	-	-	0.14	-	-	-	312.1
INDIAN SPRINGS	Trout Creek West Summerland	83-11-5	Surface	9.2	5.78	7.15	+158	170	127	51.3	8.0	LD	-	4.07	1.6	18.2	3.41	17.6	0.05	LD	0.045	LD	LD	LD	0.27	104.6
ADE-CLARK POND	Giants Head	83-11-6	Surface	7.0	6.90	7.60	+180	740	605	250	72	6.50	0.54	54.6	17.7	46.4	37.7	23.1	0.08	0.06	0.029	LD	LD	0.01	0.48	509.2

(1) Depth of well; sample collected from artesian flow at surface.

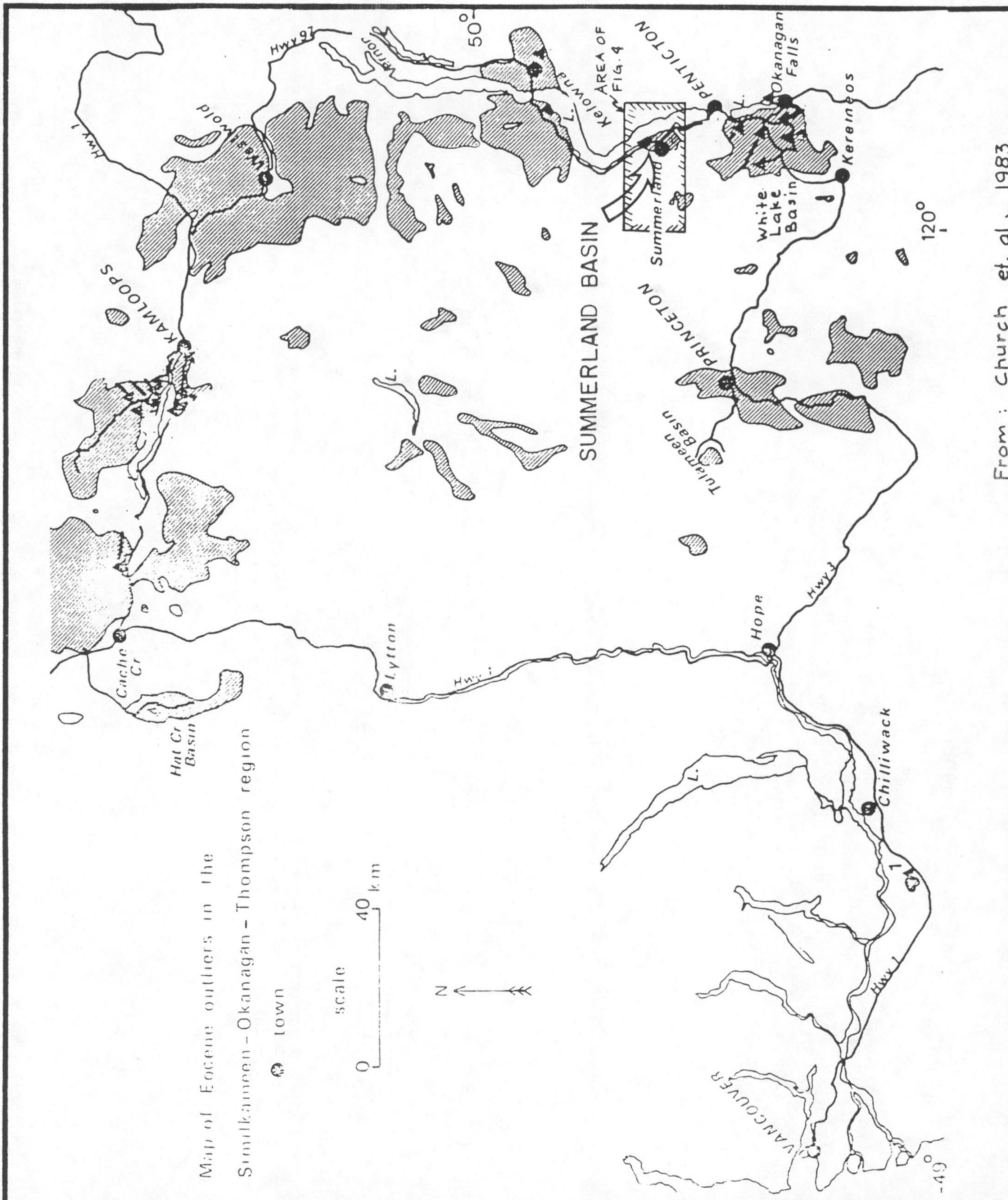
(2) Eh = oxidation, reduction potential (redox) in multivolts (mV).

(3) Analysis from Michel and Fritz (1981).

(4) Analysis from Ministry of Environment, Fish and Wildlife Branch.

LD = Less than detection.

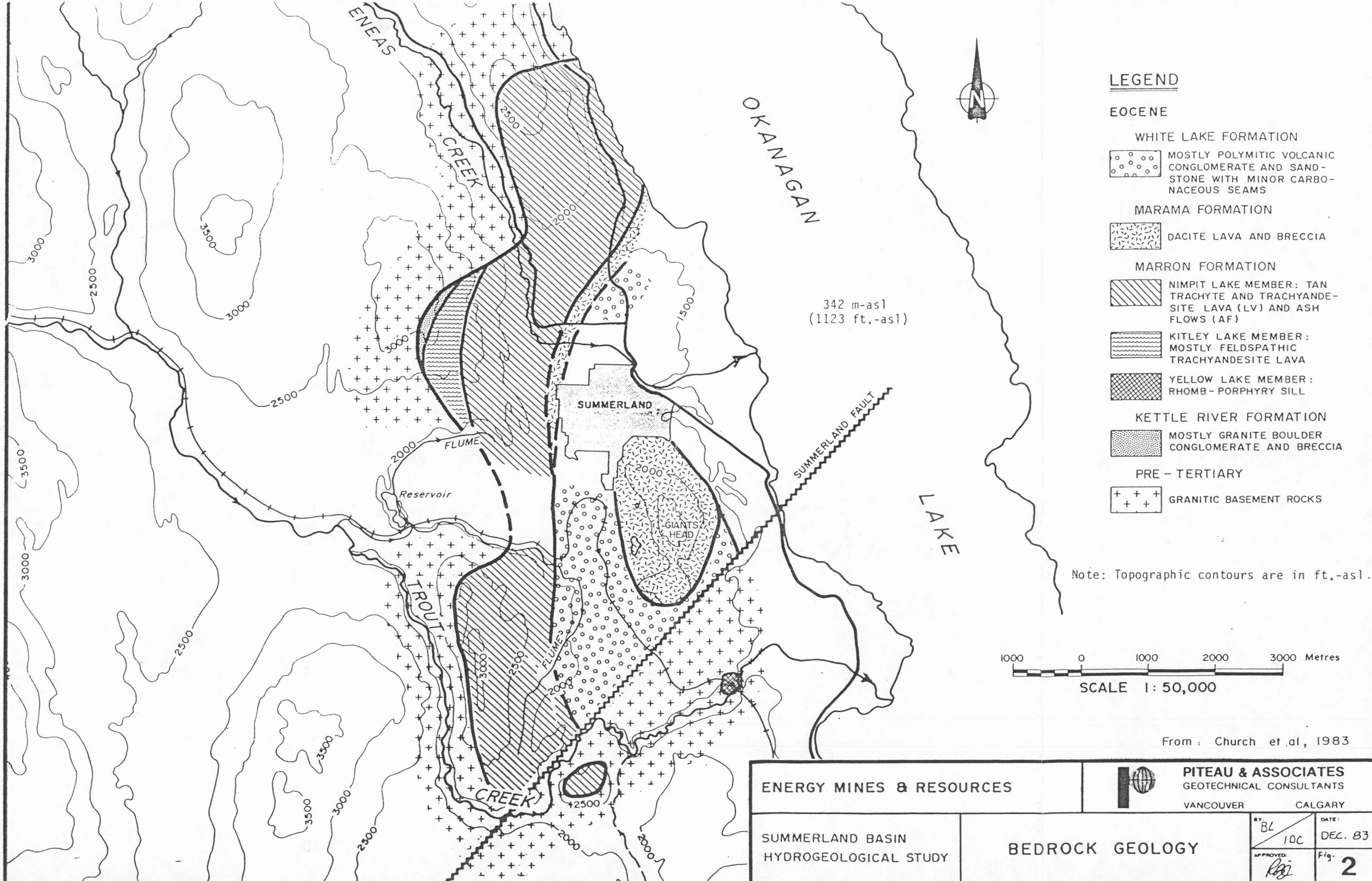
JOB NUMBER 83-610



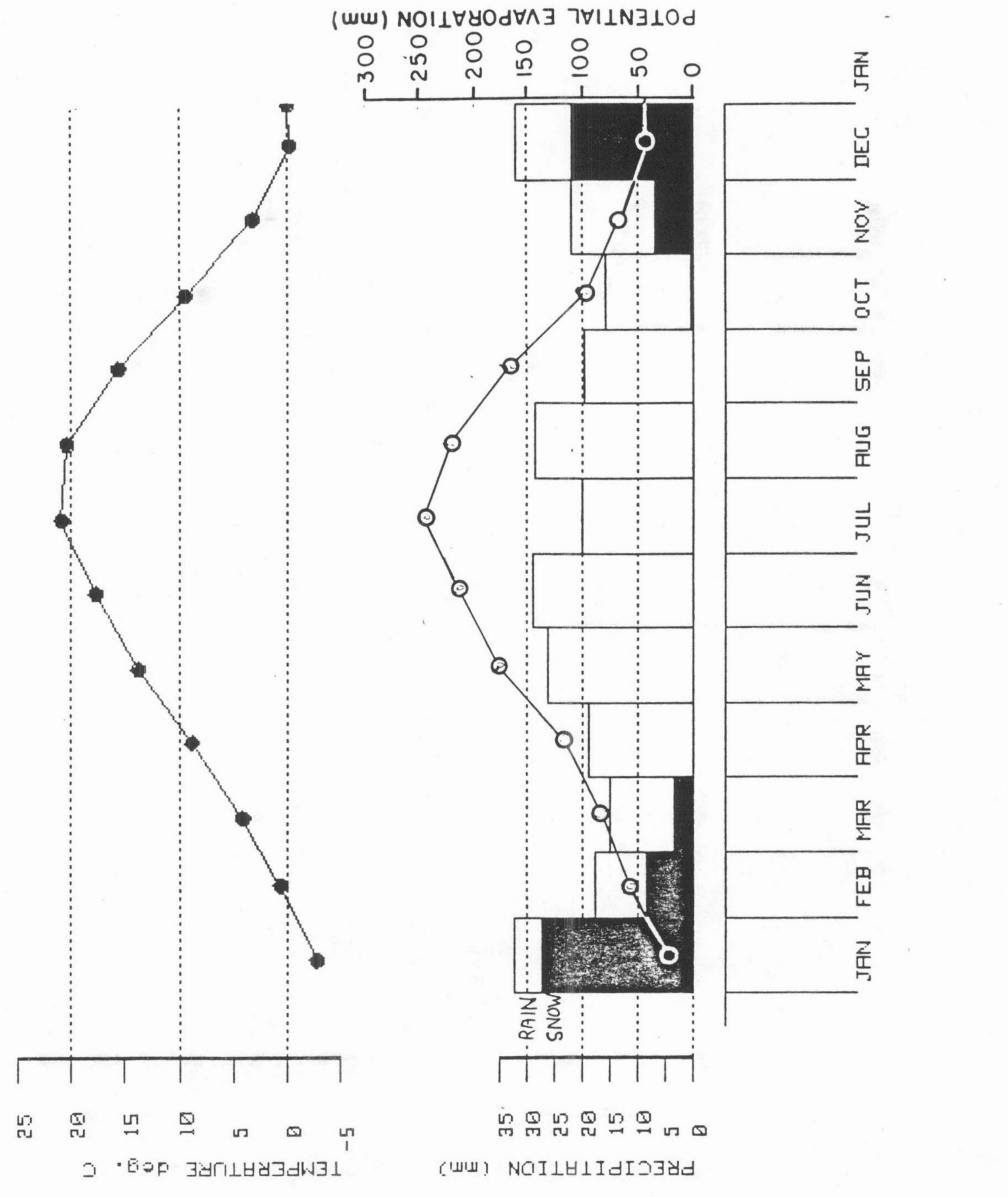
ENERGY MINES & RESOURCES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	LOCATION MAP	BY: I.D.C.	DATE: JAN. 84
		APPROVED: RD	Fig. 1

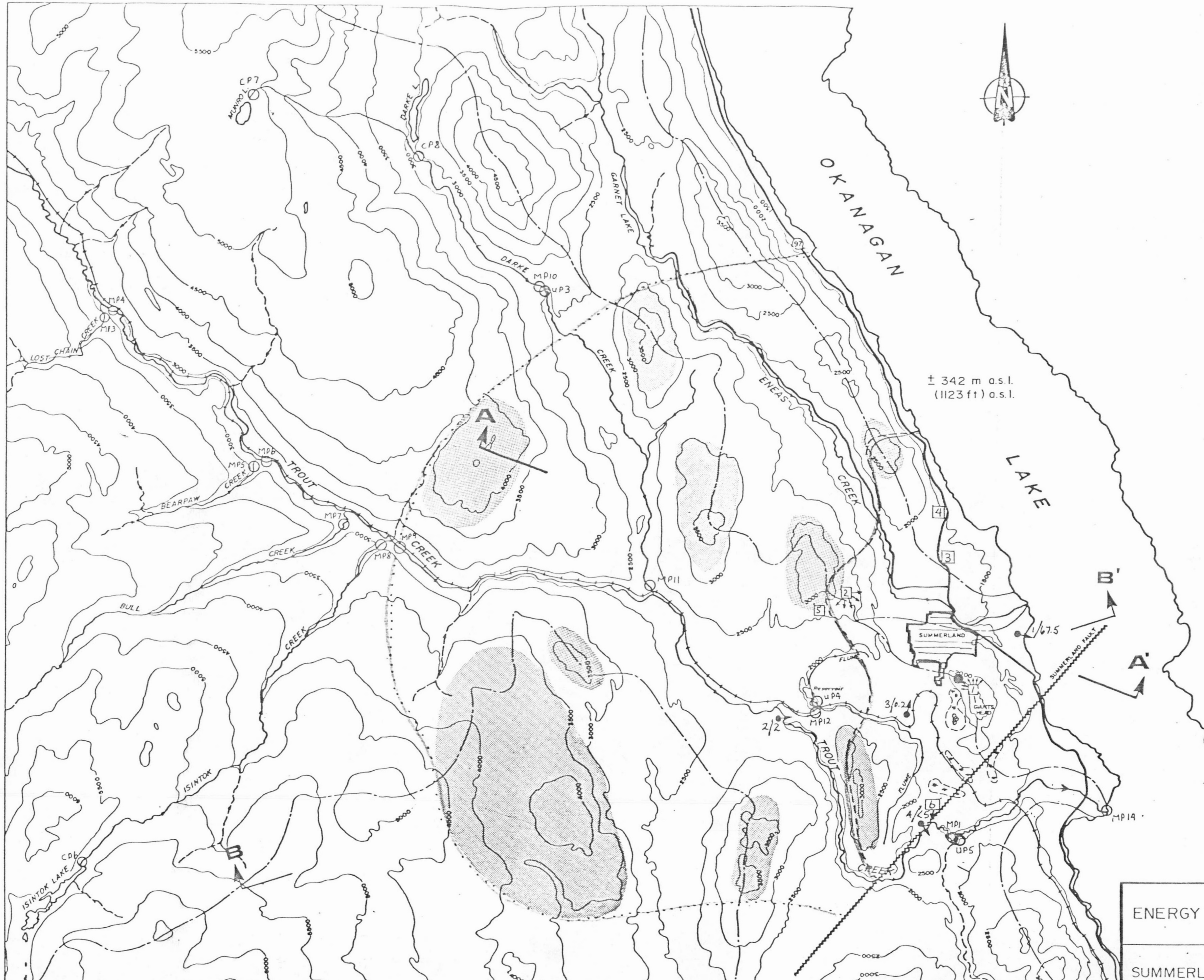

JOB NUMBER 83-610
ENEAS CREEK
OKANAGAN LAKE
TROUT CREEK
SUMMERLAND
SUMMERLAND FAULT
GIANTS HEAD
FLUME
Reservoir
342 m-asl
(1123 ft.-asl)
3500
3000
2500
2000
1500
LEGEND
EOCENE
WHITE LAKE FORMATION
MOSTLY POLYMITIC VOLCANIC CONGLOMERATE AND SANDSTONE WITH MINOR CARBONACEOUS SEAMS
MARAMA FORMATION
DACITE LAVA AND BRECCIA
MARRON FORMATION
NIMPIT LAKE MEMBER: TAN TRACHYTE AND TRACHYANDESITE LAVA (LV) AND ASH FLOWS (AF)
KITLEY LAKE MEMBER: MOSTLY FELDSPATHIC TRACHYANDESITE LAVA
YELLOW LAKE MEMBER: RHOMB-PORPHYRY SILL
KETTLE RIVER FORMATION
MOSTLY GRANITE BOULDER CONGLOMERATE AND BRECCIA
PRE-TERTIARY
GRANITIC BASEMENT ROCKS
Note: Topographic contours are in ft.-asl.
1000 0 1000 2000 3000 Metres
SCALE 1:50,000
From: Church et al, 1983
ENERGY MINES & RESOURCES
PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY
BEDROCK GEOLOGY
BY: BL 10C
DATE: DEC. 83
APPROVED:
Fig. 2

JOB NUMBER 83-610



SOURCE: ENVIRONMENT CANADA

ENERGY MINES & RESOURCES	PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY		
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	CLIMATE DATA	BY: J.B./I.O.C. APPROVED: RAD	DATE: Feb./84 Fig. 3



LEGEND

Surface Runoff Drainage Divide

Outline of Summerland Basin

Creek; Intermittent

Marshy Area; Pond

1/67.5 Spring; Number 1/Discharge (L/S)

Disposed Well (Summerset Inn)

MP8 Creek Flow Gauging Station

General Area of Deep Groundwater Recharge

Approximate Outline of Catchment Area For Deep Groundwater Flow

A' Cross Section A-A' (See Fig.6)

B' Cross Section B-B' (See Fig.7)

1 Location and Direction of Photo 1

Note: Topographic contours are in ft.-asl.

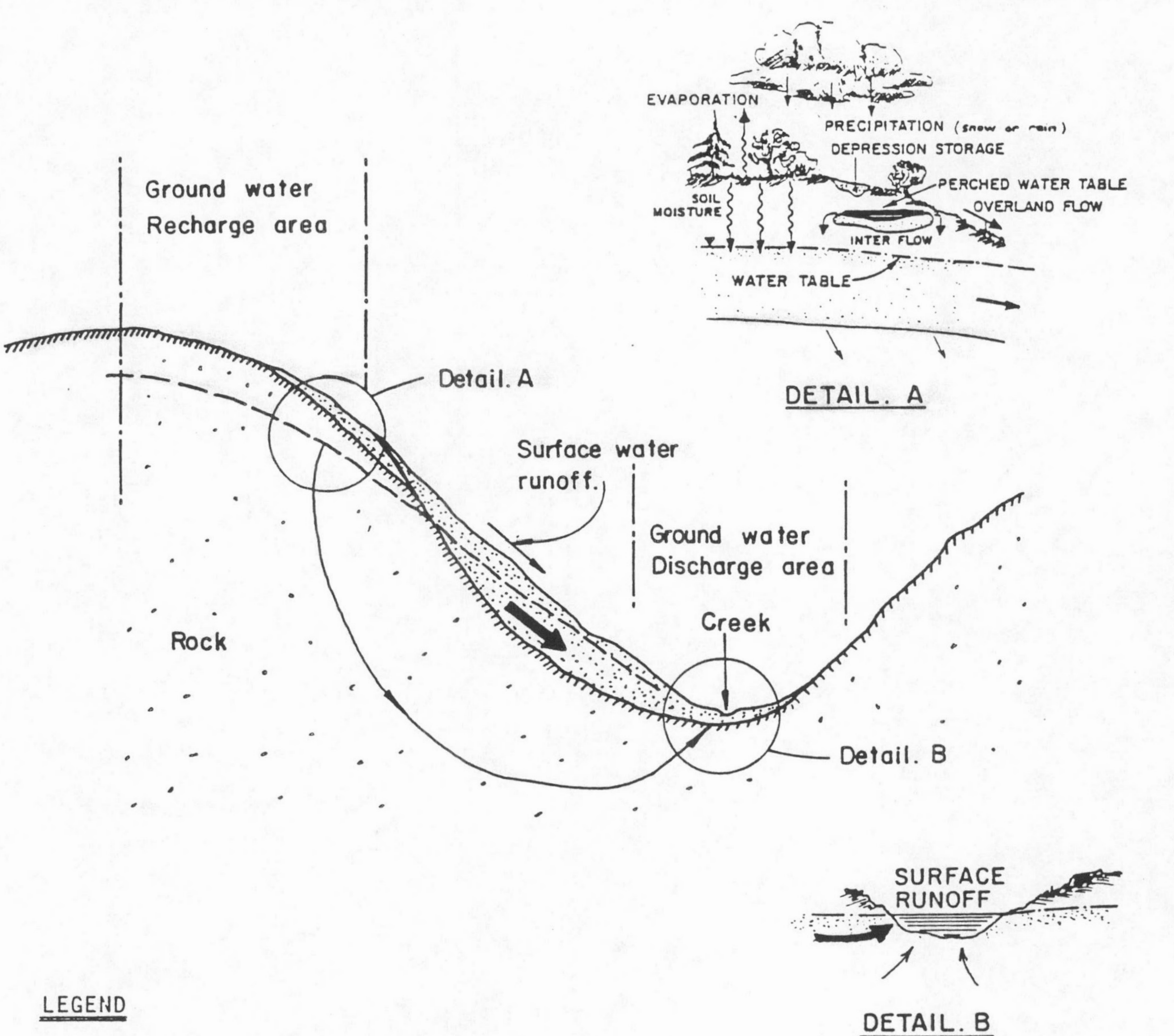
Springs

1 Trout Hatchery
2 Indian
3 Hoeben
4 Perpetual Slide

SCALE
1:100,000

ENERGY MINES & RESOURCES	PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY	
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	MAP OF HYDROGEOLOGICAL FEATURES	BY: I.D.C. / B.L. DATE: DEC. 83 APPROVED: [illegible] FIG: 4

Job Number:



LEGEND

Deep low permeability rock

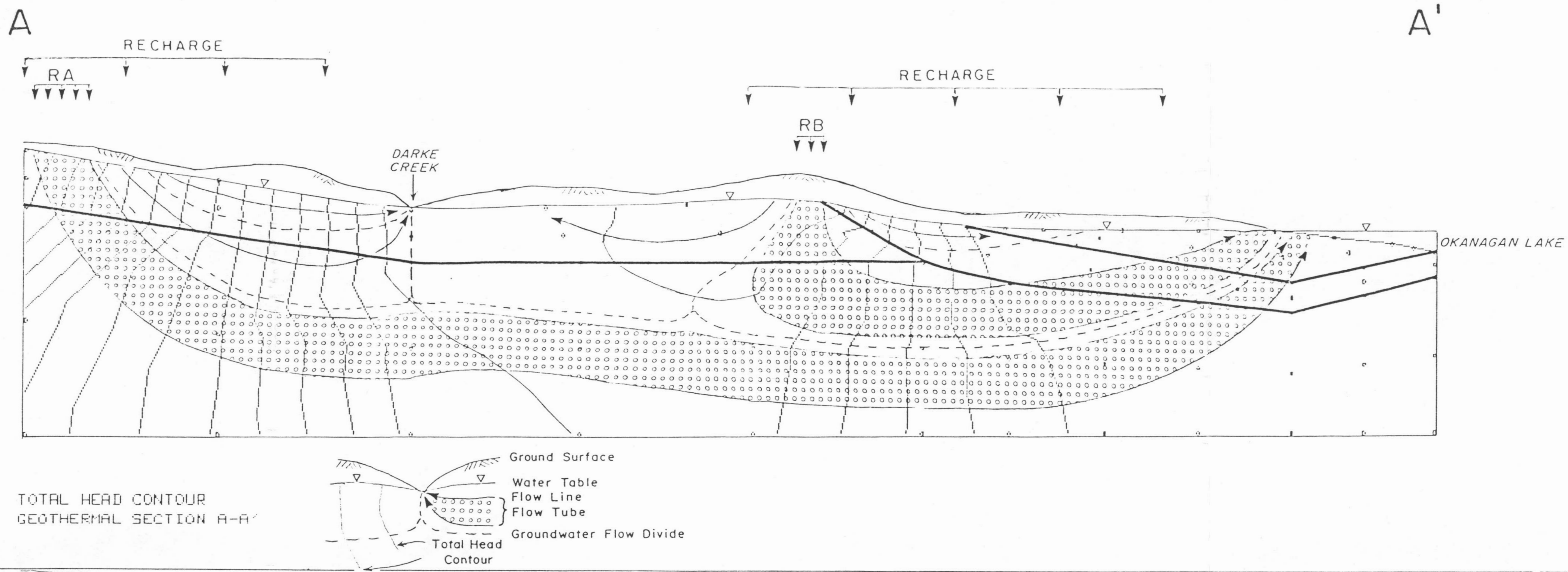
Fractured and weathered near surface rock

Colluvium

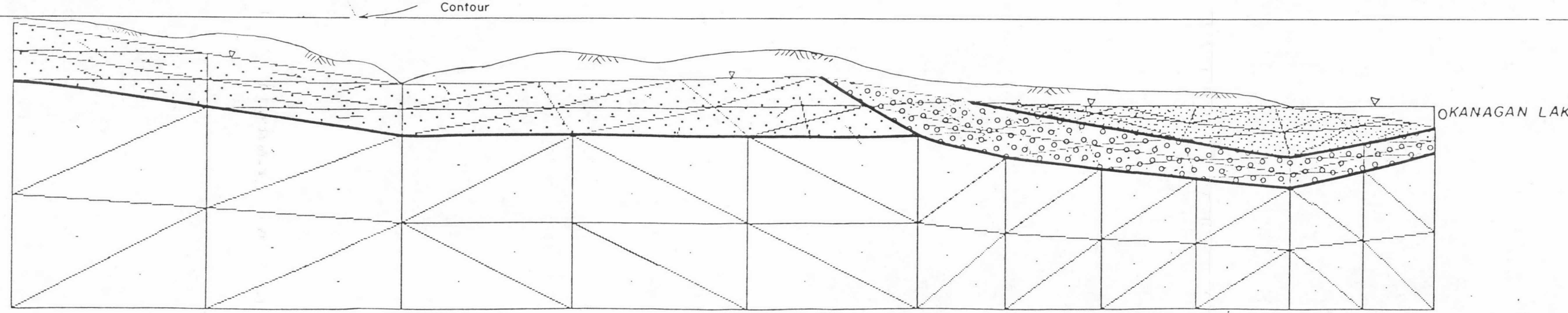
Relatively small groundwater flows penetrating deep into the rock

Significant groundwater flows in shallow fractured rock and in colluvium

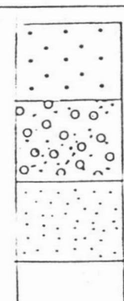
ENERGY MINES & RESOURCES	PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY		
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	SCHEMATIC REPRESENTATION OF GROUND WATER RECHARGE AND DISCHARGE AREAS	BY: I.D.C.	DATE: JAN. 84
		APPROVED: [signature]	Fig. 5



TOTAL HEAD CONTOUR
GEOTHERMAL SECTION A-A'



VELOCITY-ELEMENTS
GEOTHERMAL SECTION A-A'
VELC SCALE : 1cm - 7.38E-09 m/s



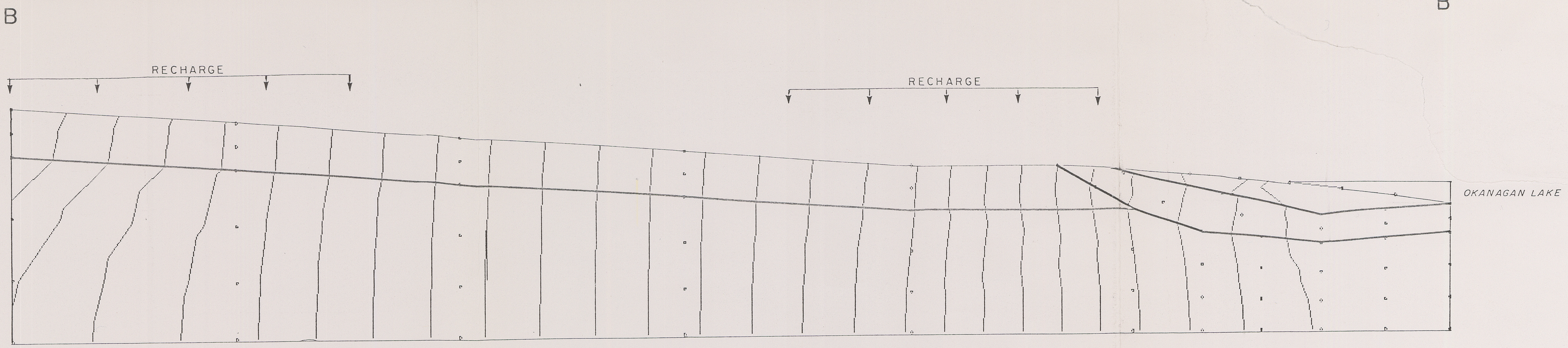
SCALE: 1cm = 500.00 m

Section A-A' location shown on Fig. 4

ENERGY MINES & RESOURCES		PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY	
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	CROSS SECTION A - A'	BY I.D.C. APPROVED RAB.	DATE JAN. 84 Fig. 6

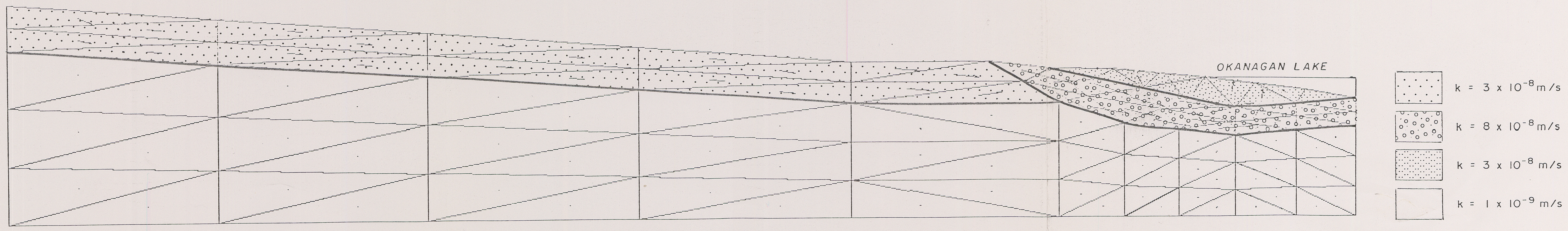
JOB NUMBER

JOB NUMBER 83-610



TOTAL HEAD CONTOUR
GEOTHERMAL SECTION B-B'

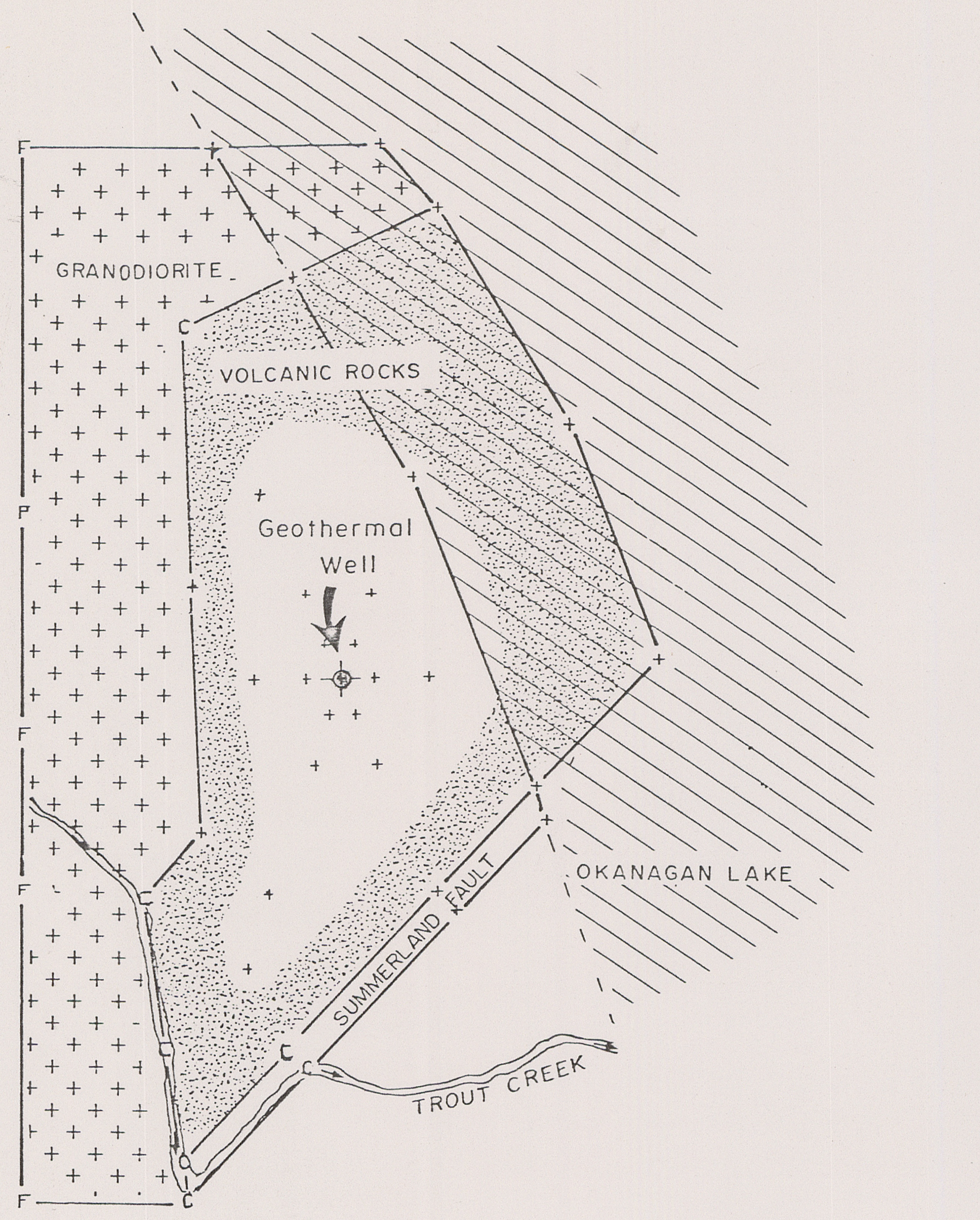
PLOT SCALE : 1cm = 500.00 m
PLOT RANGE : X= 0 TO 22600 m
Y- 0 TO 7327 m



VELOCITY-ELEMENTS
GEOTHERMAL SECTION B-B'

VELC SCALE : 1cm - 3.47E-09
PLOT SCALE : 1cm = 500.00 m
PLOT RANGE : X= 0 TO 22600 m
Y- 0 TO 7327 m

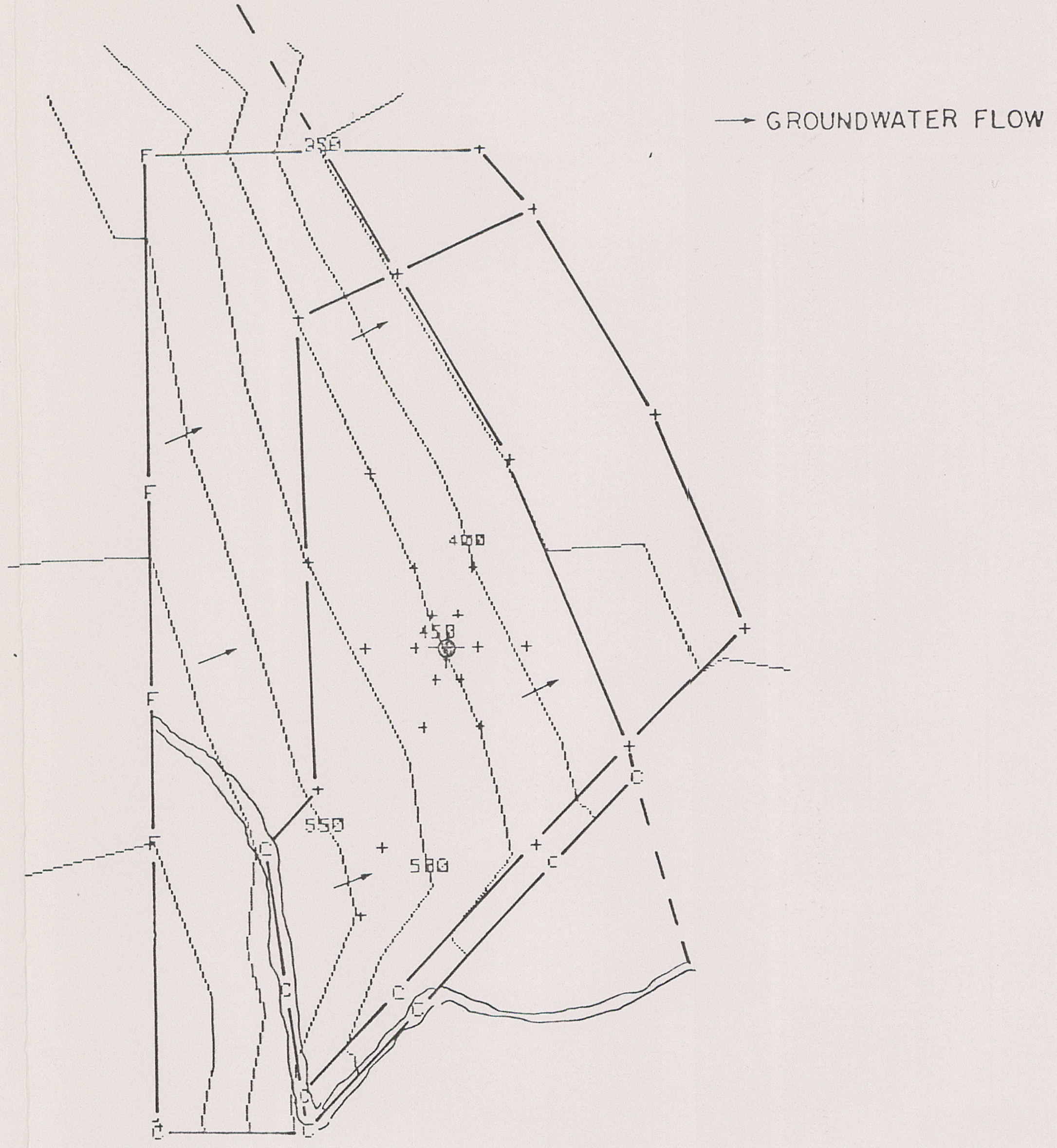
ENERGY MINES & RESOURCES		PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY	
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	CROSS SECTION B- B'	BY I. D. C. APPROVED RES	DATE JAN 84 Fig 7



SYMBOLS: +=INTERNAL, C=CONST HEAD, F=SIDE FLUX
PLOT SCALE : 1cm - 1023

SUMMERLAND BASIN GEOTHERMAL WELL

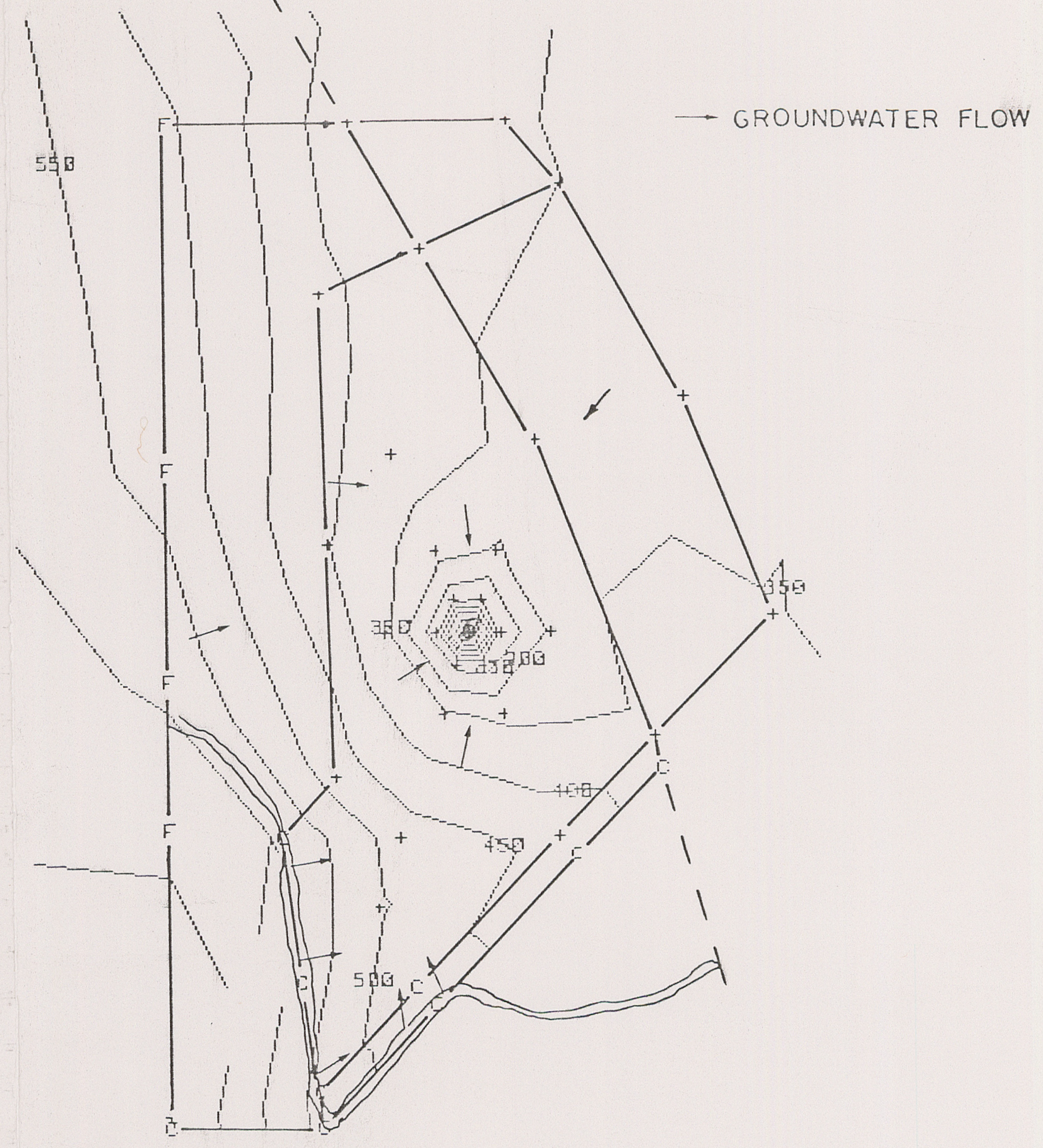
KEY MAP



SYMBOLS: +=INTERNAL, C=CONST HEAD, F=SIDE FLUX
CONTOUR PLOT
OF TOTAL HEAD
PLOT SCALE : 1cm - 1023

SUMMERLAND BASIN GEOTHERMAL WELL

NON-PUMPING CONDITIONS



SYMBOLS: +=INTERNAL, C=CONST HEAD, F=SIDE FLUX
CONTOUR PLOT
OF TOTAL HEAD
PLOT SCALE : 1cm - 1023m

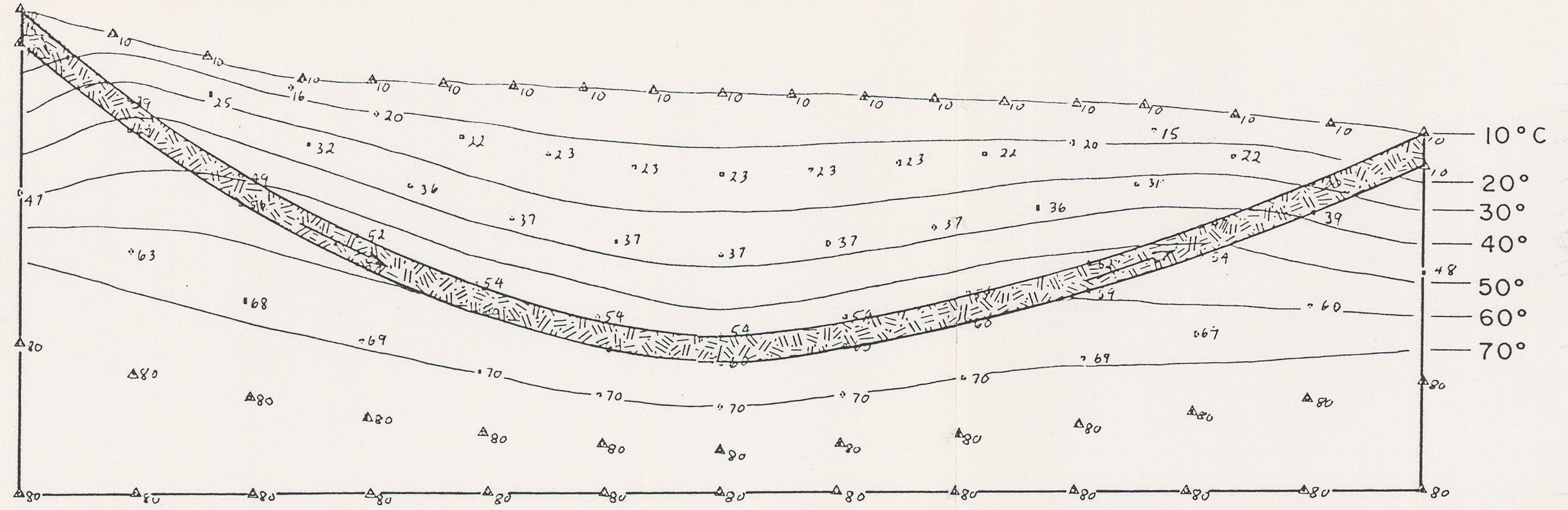
SUMMERLAND BASIN GEOTHERMAL WELL

PUMPING CONDITIONS, Discharge = 5 L/s

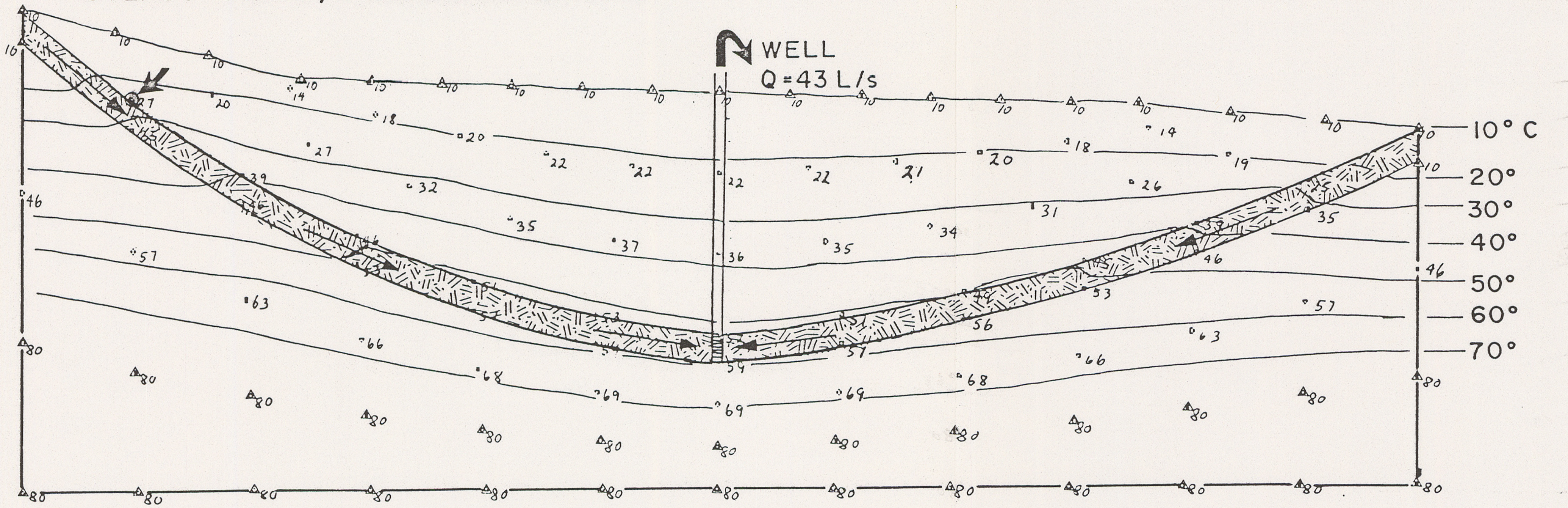
ENERGY MINES & RESOURCES	PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY		
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	AQUAFEM MODEL OF TRANSIENT FLOW TO WELL	BY I.D.C.	DATE Feb. 84
		APPROVED [illegible]	Fig. 8

JOB NUMBER 83 610

STEADY-STATE, NATURAL CONDITIONS



STEADY-STATE, PUMPING CONDITIONS



LEGEND

AQUIFER K=3x10^{-8} m/s

FLOW DIRECTION

ISOTHERM

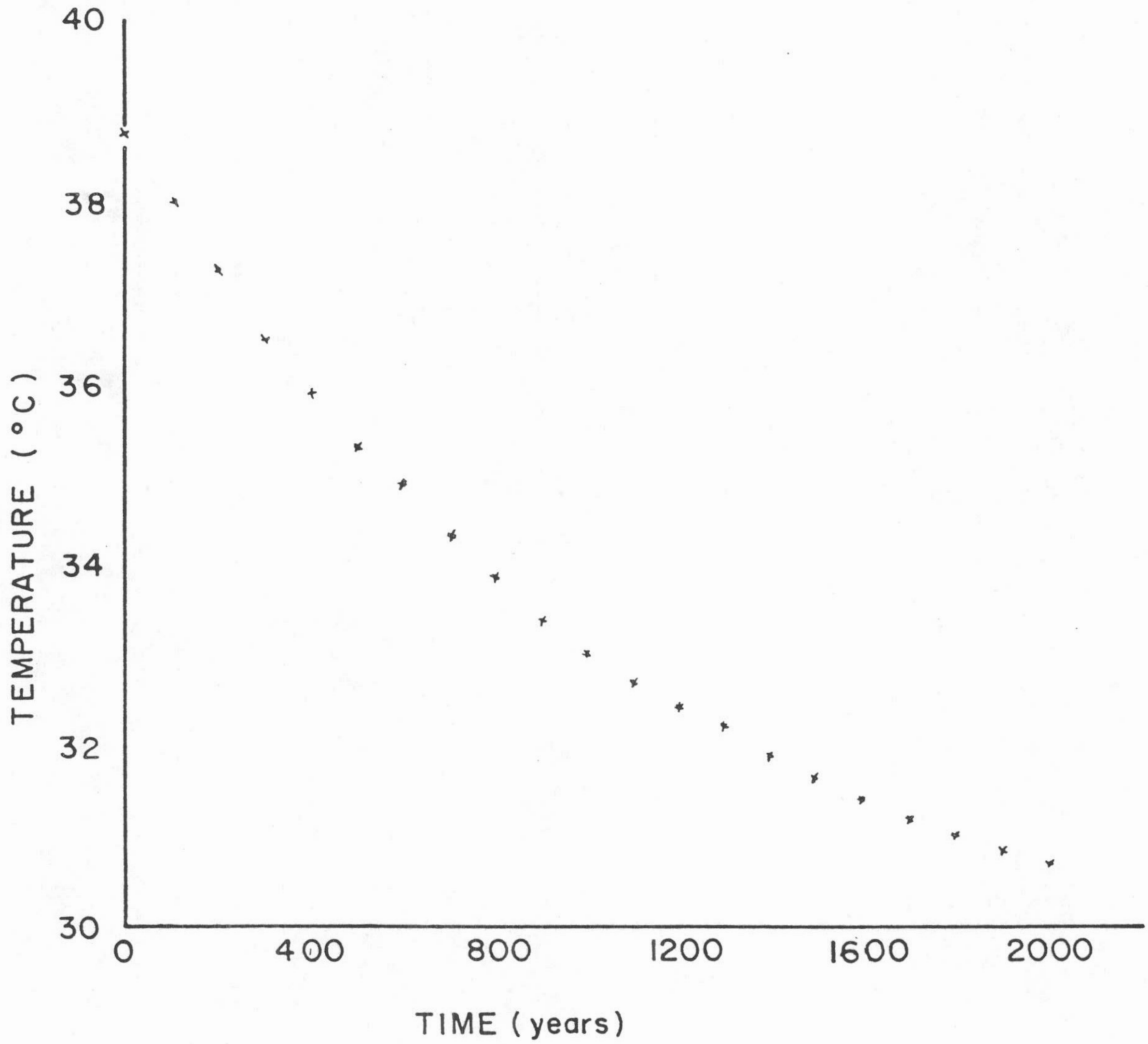
NODAL POINT; Temperature

NODE 12 (Fig.10)

CONSTANT TEMPERATURE NODE

SCALE : 1cm = 200.00
RANGE : X= 0 TO 5000
Y- 1000 TO 3931

ENERGY MINES & RESOURCES		PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY	
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	STEADY-STATE HEAT FLOW	BY I.D.C.	DATE Feb. 84
		APPROVED RED.	Fig. 9



Decline in temperature at node 12 (Fig. 9) as transient condition approach steady-state. Lengthy time required to reach steady-state due to small discharge rate in comparison to large basin size.

ENERGY MINES & RESOURCES		PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY	
SUMMERLAND BASIN HYDROGEOLOGICAL STUDY	TRANSIENT HEAT FLOW	BY: I. D. C.	DATE: Feb. 84
		APPROVED: [signature]	Fig. 10

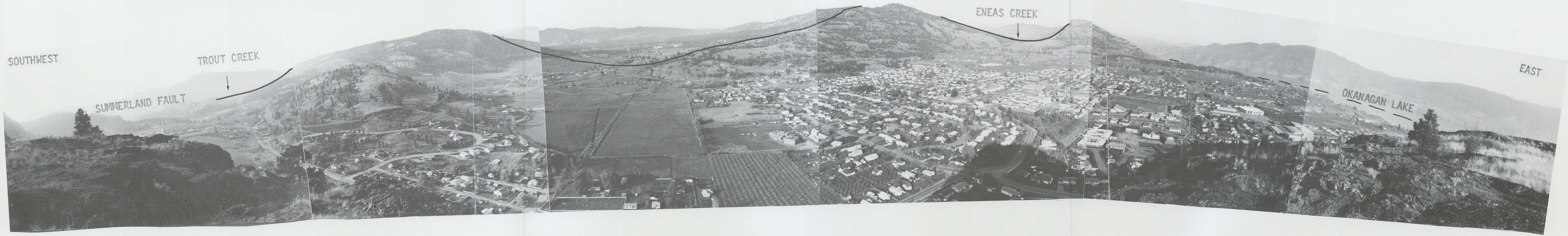


PHOTO 1. Summerland Basin looking west, north and east from Giant's Head. Trout Creek valley at left of panorama; Prairie Valley to left of centre; Eneas Creek Valley located above town of Summerland. Photo location shown on Fig. 4.

⌒ Approximate outline of Summerland Basin

— — Assumed boundary of Summerland Basin

PHOTO 2. Summerland Basin looking east to southwest. Okanagan Lake in left side of panorama (east); Prairie Creek in central portion; Trout Creek watershed in distance at right side of panorama. Photo location shown on Fig. 4

—— Approximate outline of Summerland Basin

— — Assumed boundary of Summerland Basin

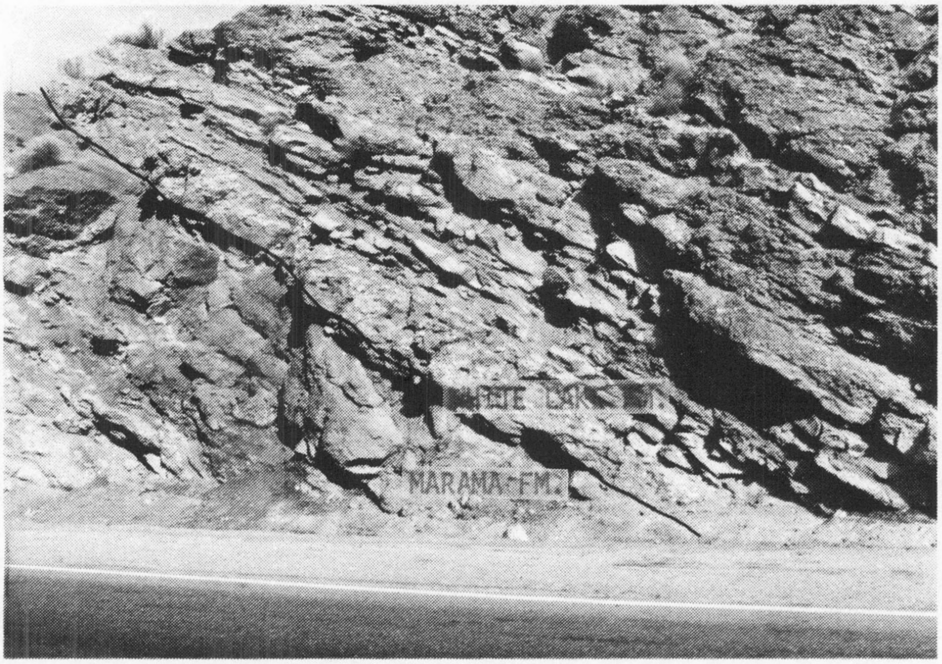


PHOTO 3. Well fractured volcanic strata in upper section of basin. White Lake Formation volcanic conglomerate overlying Marama Formation dacite.

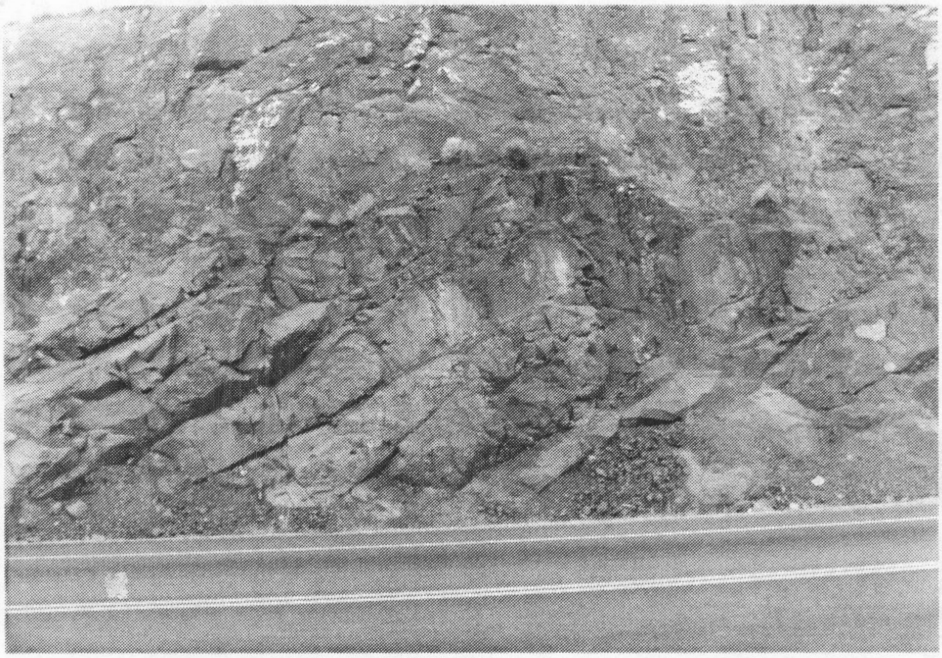


PHOTO 4. Marron Formation (Nimpit Lake Member) trachyandesite lava and tuff. Note bedding fractures. Minor calcite (white) evident on some fracture faces.

PHOTO 5. Outcrop of Kettle River Formation granite boulder conglomerate and breccia. Silicic cementing apparent in field. For photo location, see Fig. 4.

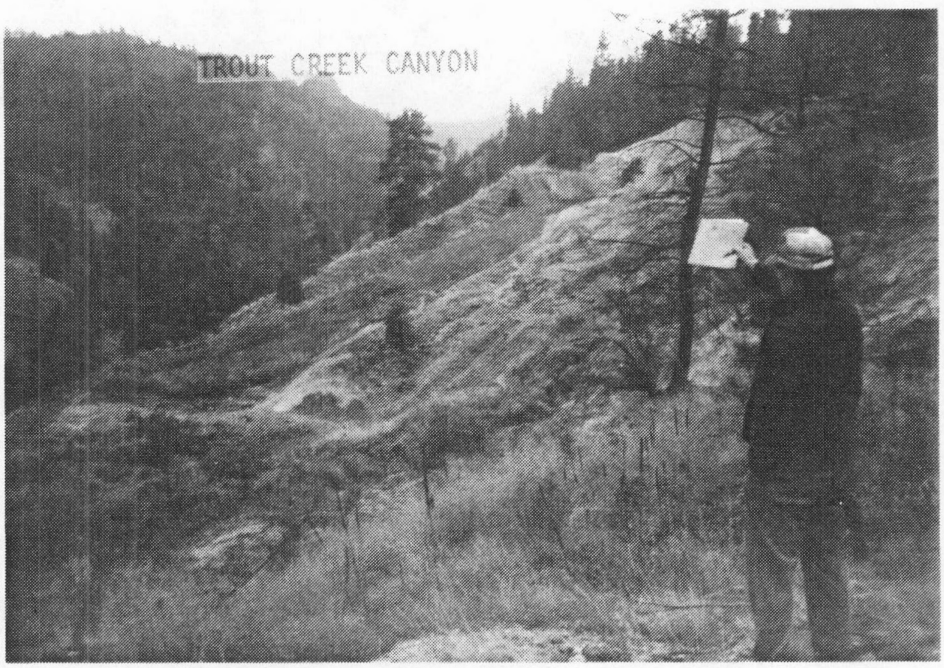


PHOTO 6. Trout River Canyon and perpetual slide area (view to west)

APPENDIX A

GEOCHEMICAL ANALYSES

ASL analytical service laboratories ltd.
1650 pandora st · vancouver, b.c. · V5L 1L6
(604) 253-4188

PITEAU ... LTD.
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NOV 28 1983

Report On: Water Analysis File #: 634A

Report To: Piteau & Associates Date: Nov. 23
408-100 S. Park Royal
West Vancouver, B.C.
V7T 1A2

Attn: ian Clark

We have analysed the water samples submitted on Nov. 10, 1983, and report as follows.

SAMPLE INFORMATION

The samples were submitted in proper laboratory containers labelled as shown in **Results of Analysis.**

METHOD OF ANALYSIS

The analyses were carried out using procedures specified by the B.C. Ministry of the Environment. The metals were determined by Inductively Coupled Argon Plasma Spectroscopy (ICP).

RESULTS OF ANALYSIS

See attached tables.

ASL ANALYTICAL SERVICE LABORATORIES LTD.

John M. Park, B.Sc.
Senior Partner

JMP:sis

ASL

TABLE 1

Parameter	Drillhole 78-4	Ade-Clark Pond	Hatchery Springs	Indian Springs
pH	7.86	7.60	7.75	7.15
Alkalinity (T)	196.	327.	234.	67.0
Alkalinity (HCO_3)	150.	250.	179.	51.3
Conductivity	2090.	605.	506.	127.
Sulphate	440.	72.	75.	8.0
Chloride	495.	6.50	9.50	L0.50
Fluoride	6.0	0.54	---	---
Nitrate - N + Nitrite	L0.005	0.72	---	---

L = Less than

Results are expressed as milligrams per liter, except ph, and conductivity (umhos/cm).

ASL

TABLE 2 : **MULTI-ELEMENT ANALYSIS**

Parameter		Sample Identification			
		Drillhole 78-4	Ade-Clark Pond	Hatchery Springs	Indian Springs
Scan 1		Dissolved	Dissolved	Dissolved	Dissolved
Aluminum	Al	0.11	0.08	0.24	0.05
Barium	Ba	0.032	0.029	0.082	0.045
Calcium	Ca	34.2	46.4	87.5	18.2
Iron	Fe	L0.003	L0.003	L0.003	L0.003
Potassium	K	1.6	17.7	4.2	1.6
Lithium	Li	0.13	L0.05	L0.05	L0.05
Magnesium	Mg	0.58	37.7	17.1	3.41
Manganese	Mn	0.02	0.011	L0.001	L0.001
Sodium	Na	468.	54.6	20.1	4.07
Phosphorus	P	L0.1	L0.1	L0.1	L0.1
		10.9	[illegible]	21.4	[illegible]
Silicon	Si	9.28	10.8	9.97	8.23
Strontium	Sr	13.2	0.48	0.73	0.27
Titanium	Ti	L0.001	L0.001	L0.001	L0.001
Thallium	Tl	---	---	---	---
Zirconium	Zr	L0.005	L0.005	L0.005	L0.005
Scan 2					
Arsenic	As	L0.2	L0.2	L0.2	L0.2
Boron	B	1.03	0.06	0.08	L0.01
Beryllium	Be	L0.001	L0.001	L0.001	L0.001
Bismuth	Bi	L0.2	L0.2	L0.2	L0.2
Cadmium	Cd	L0.002	L0.002	L0.002	L0.002
Cobalt	Co	L0.01	L0.01	L0.01	L0.01
Chromium	Cr	L0.002	L0.002	L0.002	L0.002
Copper	Cu	L0.005	0.012	0.007	L0.005
Mercury	Hg	L0.05	L0.05	L0.05	L0.05
Molybdenum	Mo	0.02	L0.01	0.02	L0.01
Nickel	Ni	L0.01	L0.01	L0.01	L0.01
Lead	Pb	L0.05	L0.05	L0.05	L0.05
Antimony	Sb	L0.05	L0.05	0.08	L0.05
Selenium	Se	L0.05	L0.05	L0.05	L0.05
Thorium	Th	L0.1	L0.1	L0.1	L0.1
Uranium	U	L0.3	L0.3	L0.3	L0.3
Vanadium	V	L0.002	L0.002	0.003	L0.002
Zinc	Zn	0.006	0.063	L0.005	0.022

All results expressed as milligrams per litre

L = less than

C O P Y

[illegible]

#75-07
S'Land Water

DEPARTMENT OF NATIONAL HEALTH AND WELFARE
PUBLIC HEALTH ENGINEERING DIVISION

CHEMICAL ANALYSIS OF WATER

LOCATION: Lower Summerland, B.C.
IDENTIFYING MARKS: Tap, Hatchery

DATE SAMPLED: Nov. 2, 1951
SAMPLED BY: F. R. Alcock, S.I.
SUBMITTED BY: Kelowna, B.C.

Ions, Etc.	Parts Per Million
Calcium (Ca)	68.8
Magnesium (Mg)	12.7
Sodium (Na) calculated	26.5
Bicarbonate as Carbonate (CO_3)	132.0
Carbonate (CO_3)	nil.
Sulphate (SO_4)	48.0
Chloride (Cl)	6.7
NITRATE (NO3)	3.65
Fluoride (F)	0.5
Silica (SiO_2)	16.8
Alumina & Iron oxide (R_2O_3)	negligible
Loss on ignition at 600°C	32.0
Total dissolved solids (calculated)	347.7
Total dissolved solids (determined)	340.0
Phenolphthalein Alkalinity as $CaCO_3$	nil.
Methyl Orange Alkalinity as $CaCO_3$	220.0
Total Calcium and Magnesium Hardness	224.0
Ammonia Nitrogen	0.017
Albuminoid Ammonia Nitrogen	0.017
Nitrite Nitrogen	nil.
Nitrate Nitrogen	0.823
Dissolved Oxygen (O_2)	-
Free Carbon Dioxide (CO_2)	-
Colour (Hazen)	5
Sediment	slight
Iron (Fe) in solution	0.14
pH	7.4

Remarks:

Iodine? [illegible]

Date: December 21/51

F. E. Artlett - Chemist

APPENDIX B

MINERAL SOLUBILITY DATA

FIELD DATA : DIAMOND DRILLHOLE 78-4, WHITE LAKE BASIN, 83-11-3

INITIAL SOLUTION

TEMPERATURE = 13.80 DEGREES C   ANALYTICAL EPMCAT = 22.453
PH = 7.320   ANALYTICAL EPMAN = 25.897

**** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 0.000 MG/L

EH MEASURED WITH CALOMEL = -.2100 VOLTS

FLAG	CORALK	PECALC	IDAVES
2	3	1	0

MEASURED EH OF ZOBELL SOLUTION = -.2300 VOLTS
CORRECTED EH = -.2100 VOLTS

PE COMPUTED FROM CORRECTED EH = -3.688

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
Ca	2	85.46853E-05	-3.0682	34.20000E+00
Mg	2	23.89545E-06	-4.6217	58.00000E-02
Na	1	20.39006E-03	-1.6906	46.80000E+01
K	1	40.98537E-06	-4.3874	16.00000E-01
Cl	-1	13.98492E-03	-1.8543	49.50000E+01
SO4	-2	45.87866E-04	-2.3384	44.00000E+01
HCO3	-1	24.62329E-04	-2.6087	15.00000E+01
SiO2 Tot	0	33.17388E-05	-3.4792	19.90000E+00
Fe	2	53.80582E-09	-7.2692	30.00000E-04
Sr	2	15.08963E-05	-3.8213	13.20000E+00
F	-1	31.63312E-05	-3.4999	60.00000E-01

*** CONVERGENCE ITERATIONS ***

ITER-ATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	32.973956E-06	71.744261E-05	94.133155E-08	00.000000E-01	59.242392E-07
2	16.878918E-07	29.360137E-06	15.274804E-08	00.000000E-01	73.734700E-09
3	32.445200E-09-	45.376651E-08-	19.237100E-10-	00.000000E-01	35.734000E-10-

**** DESCRIPTION OF SOLUTION ****

```
         ANALYTICAL  COMPUTED            PH                 ACTIVI~Y H2O =    .9993

EPMCAT     22.453      21.872          7.320                PCO2= 56.734015E-04
EPMAN      25.897      25.317                               LOG PCO2 =  -2.2462

                                     TEMPERATURE            PO2 = 31.484834E-74
EH = -.2100  PE =  -3.688            13.80 DEG C            PCH4 = 21.395740E-08

PE CALC S = 10.000000E+01                                   CO2 TOT = 27.448317E-04

PE CALC DOX=10.000000E+01            IONIC STRENGTH         DENSITY =    1.0000

PE SATO DOX= 10.000000E+01            28.394327E-03         TDS =     1628.5MG/L
TOT ALK =  2.462329 MEQ/KG H2O
CARBONATE ALK= 24.617634E-01  MEQ/KG H2O
ELECT   = 34.503497E-01- MEQ/KG H2O
```

IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE = -3.688   EQUIVALENT EH =   -.210VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	LOG MOL	ACTIVITY	LOG ACT	ACT. COEFF.	A	LOG COF
1	Ca	2	2.7548E+01	6.8844E-04	-3.16	3.77929E-04	-3.42	5.490E-01		-.260
2	Mg	2	4.7343E-01	1.9505E-05	-4.71	1.08715E-05	-4.96	5.574E-01		-.254
3	Na	1	4.6229E+02	2.0141E-02	-1.70	1.72560E-02	-1.76	8.567E-01		-.067
4	K	1	1.5792E+00	4.0452E-05	-4.39	3.43945E-05	-4.46	8.503E-01		-.070
64	H	1	5.4862E-05	5.4515E-08	-7.26	4.78630E-08	-7.32	8.780E-01		-.057
5	Cl	-1	4.9482E+02	1.3980E-02	-1.85	1.18864E-02	-1.92	8.503E-01		-.070
6	SO4	-2	4.0308E+02	4.2029E-03	-2.38	2.27653E-03	-2.64	5.417E-01		-.266
7	HCO3	-1	1.4784E+02	2.4268E-03	-2.61	2.08873E-03	-2.68	8.607E-01		-.065
18	CO3	-2	1.7178E-01	2.8673E-06	-5.54	1.57339E-06	-5.80	5.487E-01		-.261
86	H2CO3	0	1.6523E+01	2.6682E-04	-3.57	2.68787E-04	-3.57	1.007E+00		.003

27	OH	-1	1.7407E-03	1.0251E-07	-6.99	8.70779E-08	-7.06	8.494E-01	-.071
62	F	-1	5.9820E+00	3.1538E-04	-3.50	2.67893E-04	-3.57	8.494E-01	-.071
19	MgOH	1	6.4523E-06	1.5641E-10	-9.81	1.35524E-10	-9.87	8.665E-01	-.062
23	MgSO4 Aq	0	4.7013E-01	3.9119E-06	-5.41	3.93760E-06	-5.40	1.007E+00	.003
22	MgHCO3	1	2.4810E-02	2.9123E-07	-6.54	2.48287E-07	-6.61	8.526E-01	-.069
21	MgCO3 A	0	1.1496E-03	1.3656E-08	-7.86	1.37452E-08	-7.86	1.007E+00	.003
20	MgF	1	7.1477E-03	1.6530E-07	-6.78	1.41428E-07	-6.85	8.556E-01	-.068
29	CaOH	1	5.0425E-05	8.8474E-10	-9.05	7.64323E-10	-9.12	8.639E-01	-.064
32	CaSO4 Aq	0	2.1440E+01	1.5774E-04	-3.80	1.58771E-04	-3.80	1.007E+00	.003
30	CaHCO3	1	6.7832E-01	6.7205E-06	-5.17	5.80579E-06	-5.24	8.639E-01	-.064
31	CaCO3 Aq	0	6.8096E-02	6.8147E-07	-6.17	6.85937E-07	-6.16	1.007E+00	.003
49	CAF+	1	4.6186E-02	7.8305E-07	-6.11	6.72212E-07	-6.17	8.585E-01	-.066
44	NaSO4	-1	2.6481E+01	2.2279E-04	-3.65	1.91754E-04	-3.72	8.607E-01	-.065
43	NaHCO3	0	1.6885E+00	2.0136E-05	-4.70	2.02685E-05	-4.69	1.007E+00	.003
42	NaCO3	-1	2.6938E-02	3.2509E-07	-6.49	2.79800E-07	-6.55	8.607E-01	-.065
94	NaCl	0	2.9729E-01	5.0951E-06	-5.29	5.12850E-06	-5.29	1.007E+00	.003
46	KSO4	-1	7.0422E-02	5.2186E-07	-6.28	4.49156E-07	-6.35	8.607E-01	-.065
95	KCl	0	7.8608E-04	1.0561E-08	-7.98	1.06302E-08	-7.97	1.007E+00	.003
63	HSO4	-1	8.8293E-04	9.1107E-09	-8.04	7.79475E-09	-8.11	8.556E-01	-.068
96	H2SO4	0	5.0734E-14	5.1813E-19	-18.29	5.21524E-19	-18.28	1.007E+00	.003
93	HCl	0	4.7903E-12	1.3159E-16	-15.88	1.32458E-16	-15.88	1.007E+00	.003
24	H4SiO4 A	0	3.1783E+01	3.3121E-04	-3.48	3.33386E-04	-3.48	1.007E+00	.003
25	H3SiO4	-1	4.9909E-02	5.2562E-07	-6.28	4.48123E-07	-6.35	8.526E-01	-.069
26	H2SiO4	-2	7.9601E-07	8.4731E-12	-11.07	4.64949E-12	-11.33	5.487E-01	-.261
8	Fe	2	2.5093E-03	4.5006E-08	-7.35	2.50672E-08	-7.60	5.570E-01	-.254
9	Fe	3	4.7362E-20	8.4946E-25	-24.07	2.63307E-25	-24.58	3.100E-01	-.509
10	FeOH	2	1.2855E-15	1.7674E-20	-19.75	9.59826E-21	-20.02	5.431E-01	-.265
11	FeOH	1	8.9060E-06	1.2244E-10	-9.91	1.05111E-10	-9.98	8.585E-01	-.066
12	Fe(OH)3	-1	1.1237E-11	1.0532E-16	-15.98	9.04133E-17	-16.04	8.585E-01	-.066
77	Fe(OH)2	1	1.5680E-12	1.7478E-17	-16.76	1.50430E-17	-16.82	8.607E-01	-.065
78	Fe(OH)3	0	1.3314E-11	1.2479E-16	-15.90	1.25609E-16	-15.90	1.007E+00	.003
79	Fe(OH)4	-1	1.7912E-12	1.4483E-17	-16.84	1.24654E-17	-16.90	8.607E-01	-.065
80	Fe(OH)2	0	3.9931E-10	4.4508E-15	-14.35	4.48003E-15	-14.35	1.007E+00	.003

15	FeSO4	1	9.4179E-19	6.2098E-24	-23.21	5.33081E-24	-23.27	8.585E-01	-.066
16	FECl	2	7.7914E-21	8.5478E-26	-25.07	4.64212E-26	-25.33	5.431E-01	-.265
28	FeCl	1	1.2909E-21	1.0201E-26	-25.99	8.75686E-27	-26.06	8.585E-01	-.066
33	FeCl3	0	1.6527E-24	1.0206E-29	-28.99	1.02727E-29	-28.99	1.007E+00	.003
34	FeSO4	0	1.3134E-03	8.6601E-09	-8.06	8.71686E-09	-8.06	1.007E+00	.003
88	Sr	2	1.3200E+01	1.5090E-04	-3.82	8.19485E-05	-4.09	5.431E-01	-.265
89	SrOH	1	5.3183E-06	5.0914E-11	-10.29	4.37071E-11	-10.36	8.585E-01	-.066

CL/CA = 16.3627E+00	CL/CA = 20.3067E+00	LOG CA/H2 = 11.2174
CL/MG = 58.5255E+01	CL/MG = 71.6734E+01	LOG MG/H2 = 9.6763
CL/NA = 68.5870E-02	CL/NA = 69.4089E-02	LOG NA/H1 = 6
CL/K = 34.1217E+01	CL/K = 34.5591E+01	LOG K/H1 = 2.8565
CL/AL = 13.9849E+27	CL/AL = 13.9798E+27	LOG AL/H3 = -8.0400
CL/FE = 25.9915E+04	CL/FE = 31.0624E+04	LOG FE/H2 = 7.0391
CL/SO4 = 30.4824E-01	CL/SO4 = 33.2624E-01	LOG CA/MG = 1.5411
CL/HCO3= 56.7955E-01	CL/HCO3= 57.6050E-01	LOG NA/K = 2.7005
CA/MG = 35.7677E+00	CA/MG = 35.2955E+00	
NA/K = 49.7496E+01	NA/K = 49.7906E+01	

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT	DELGR
18	Anhydrit	8.6037E-07	3.6293E-05	-6.065	-4.44	2.3706E-02	-1.6251	-2.1339
22	Aragonmi	5.9463E-10	7.4072E-09	-9.226	-8.13	8.0278E-02	-1.0954	-1.4383
151	Artin	1.7003E-27	3.8526E-19	-26.769	-18.41	4.4134E-09	-8.3552	-10.9707
20	Brucite	8.2434E-20	3.6786E-12	-19.084	-11.43	2.2409E-08	-7.6496	-10.0442
13	Calcite	5.9463E-10	3.8149E-09	-9.226	-8.42	1.5587E-01	-.8072	-1.0599
144	Celest	1.8656E-07	1.1380E-06	-6.729	-5.94	1.6393E-01	-.7853	-1.0312
98	Chalc	3.3387E-04	2.2130E-04	-3.476	-3.66	1.5087E+00	.1786	.2345
21	Chrysotl	6.2035E-65	2.5754E-53	-64.207	-52.59	2.4088E-12	-11.6182	-15.2551
30	Clenstit	2.7542E-23	8.6904E-18	-22.560	-17.06	3.1692E-06	-5.4990	-7.2204
100	Cristo	3.3387E-04	1.8057E-04	-3.476	-3.74	1.8489E+00	.2669	.3505
29	Diopside	2.6370E-44	1.5009E-37	-43.579	-36.82	1.7569E-07	-6.7553	-8.8699
12	Doplomit	1.0171E-20	1.6488E-17	-19.993	-16.78	6.1690E-04	-3.2098	-4.2146
113	FeOH3A	2.3962E-03	7.6736E+04	-2.620	4.89	3.1226E-08	-7.5055	-9.8550
120	FeSPPT	1.0939E-03	1.2162E-04	-2.961	-3.92	8.9947E+00	.9540	1.2526
63	Flour	2.7123E-11	2.8591E-11	-10.567	-10.54	9.4865E-01	-.0229	-.0301

28	Forstrit	2.2720E-42	5.6322E-29	-41.644	-28.25	4.0340E-14	-13.3943	-17.5871
111	Goeth	1.7398E-46	1.1720E-42	-45.760	-41.93	1.4845E-04	-3.8284	-5.0268
112	Greena	7.6601E-73	6.4565E-64	-72.116	-63.19	1.1864E-09	-8.9258	-11.7199
19	Gypsum	8.5912E-07	2.4129E-05	-6.066	-4.62	3.5606E-02	-1.4485	-1.9019
65	Halite	2.0511E-04	3.5953E+01	-3.688	1.56	5.7050E-06	-5.2437	-6.8852
109	Hemati	5.7542E-06	7.5063E-04	-5.240	-3.12	7.6658E-03	-2.1154	-2.7776
118	Huntite	2.9760E-42	1.6864E-30	-41.526	-29.77	1.7647E-12	-11.7533	-15.4325
39	Hydmag	4.1346E-52	8.1299E-38	-51.384	-37.09	5.0856E-15	-14.2937	-18.7681
68	Mackit	1.0939E-03	2.3388E-05	-2.961	-4.63	4.6772E+01	1.6700	2.1928
99	Magadi	3.3109E-22	5.0119E-15	-21.480	-14.30	6.6061E-08	-7.1801	-9.4277
110	Maghem	5.7542E-06	2.3442E+06	-5.240	6.37	2.4546E-12	-11.6100	-15.2444
11	Magnesit	1.7105E-11	8.6394E-09	-10.767	-8.06	1.9799E-03	-2.7034	-3.5496
108	Magnet	1.5719E-08	3.9647E-09	-7.804	-8.40	3.9646E+00	.5982	.7855
67	Mirabi	6.7299E-07	2.2071E-02	-6.172	-1.66	3.0493E-05	-4.5158	-5.9294
59	NaHCOL	3.6043E-05	2.2160E-01	-4.443	-.65	1.6265E-04	-3.7888	-4.9748
61	Natron	4.6513E-10	1.7360E-02	-9.332	-1.76	2.6792E-08	-7.5720	-9.9423
150	Nesque	1.7068E-11	8.3023E-06	-10.768	-5.08	2.0558E-06	-5.6870	-7.4672
102	Quartz	3.3387E-04	6.5623E-05	-3.476	-4.18	5.0877E+00	.7065	.9277
37	Sepiolit	2.5262E-49	1.3835E-41	-48.598	-40.86	1.8260E-08	-7.7385	-10.1609
10	Siderite	3.9441E-14	4.0034E-11	-13.404	-10.40	9.8519E-04	-3.0065	-3.9476
101	Silgel	3.3387E-04	7.1776E-04	-3.476	-3.14	4.6515E-01	-.3324	-.4365
143	Stront	1.2894E-10	3.3301E-12	-9.890	-11.48	3.8719E+01	1.5879	2.0850
38	Talc	6.9702E-72	2.6349E-64	-71.157	-63.58	2.6453E-08	-7.5775	-9.9496
66	Thenar	6.7788E-07	6.8764E-01	-6.169	-.16	9.8580E-07	-6.0062	-7.8864
62	Thrnat	4.6817E-10	1.6038E+00	-9.330	.21	2.9190E-10	-9.5348	-12.5195
62	Thrnat			-9.330	.21		-15.4336	-20.2649
60	Trona	1.6862E-14	5.2475E-01	-13.773	-.28	3.2134E-14	-13.4930	-17.7168
154	SEP PT	2.5262E-49	6.1376E-38	-48.598	-37.21	4.1159E-12	-11.3855	-14.9496

Ph-sat is the Ph required for the SI Calcite = 1.0

FIELD DATA : DIAMOND DRILLHOLE P-WELL, WHITE LAKE BASIN, 81-10

IRON AND/OR MANGANESE HAVE BEEN SPECIFIED WITHOUT REDOX INFORMATION
PE HAS BEEN SET TO ZERO

INITIAL SOLUTION

TEMPERATURE = 10.80 DEGREES C — ANALYTICAL EPMCAT = 18.763
PH = 8.330 — ANALYTICAL EPMAN = 24.348

**** OXIDATION - REDUCTION *****

DISSOLVED OXYGEN = 0.000 MG/L

EH MEASURED WITH CALOMEL = 0.0000 VOLTS

FLAG	CORALK	PECALC	IDAVES
2	3	0	0

MEASURED EH OF ZOBELL SOLUTION = 0.0000 VOLTS
CORRECTED EH = 0.0000 VOLTS

PE COMPUTED FROM CORRECTED EH = 0.000

*** TOTAL CONCENTRATIONS OF INPUT SPECIES ***

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
Ca	2	48.48921E-05	-3.3144	19.40000E+00
Mg	2	61.80757E-06	-4.2090	15.00000E-01
Na	1	17.42994E-03	-1.7587	40.00000E+01
K	1	71.73484E-06	-4.1443	28.00000E-01
Cl	-1	51.70936E-04	-2.2864	18.30000E+01
SO4	-2	28.88691E-06	-4.5393	27.70000E-01
HCO3	-1	18.94628E-03	-1.7225	11.54000E+02
Fe	2	76.59477E-06	-4.1158	42.70000E-01
Sr	2	24.12405E-06	-4.6175	21.10000E-01
F	-1	21.61912E-05	-3.6652	41.00000E-01

*** CONVERGENCE ITERATIONS ***

ITER- ATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	32.521917E-05	39.424320E-07	70.054703E-08	00.000000E-01	19.371488E-07
2	31.040963E-07	21.343691E-09	15.843956E-09	00.000000E-01	40.559800E-10

**** DESCRIPTION OF SOLUTION ****

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        ANALYTICAL  COMPUTED            PH               ACTIVITY H2O =   .9993

EPMCAT    18.763     18.498            8.330              PCO2= 40.924544E-04
EPMAN     24.348     24.080                               LOG PCO2 =  -2.3880

                                    TEMPERATURE           PO2 = 15.536593E-56
EH = 0.0000  PE =   0.000           10.80 DEG C           PCH4 = 12.021951E-45

PE CALC S = 10.000000E+01                                 CO2 TOT = 19.036516E-03

PE CALC DOX=10.000000E+01           IONIC STRENGTH        DENSITY =   1.0000

PE SATO DOX= 10.000000E+01           22.038901E-03        TDS =    1774.0MG/L
TOT ALK = 18.946278 MEQ/KG H2O
CARBONATE ALK= 18.935263E+00  MEQ/KG H2O
ELECT   = 55.920472E-01- MEQ/KG H2O
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IN COMPUTING THE DISTRIBUTION OF SPECIES,
PE =   0.000   EQUIVALENT EH =   0.000VOLTS

DISTRIBUTION OF SPECIES

I	SPECIES		PPM	MOLALITY	LOG MOL	ACTIVITY	LOG ACT	ACT. COEFF.	A	LOG COF
1	Ca	2	1.6925E+01	4.2303E-04	-3.37	2.46200E-04	-3.61	5.820E-01		-.235
2	Mg	2	1.2767E+00	5.2605E-05	-4.28	3.09944E-05	-4.51	5.892E-01		-.230
3	Na	1	3.9646E+02	1.7276E-02	-1.76	1.50311E-02	-1.82	8.701E-01		-.060
4	K	1	2.7995E+00	7.1722E-05	-4.14	6.20287E-05	-4.21	8.649E-01		-.063
64	H	1	5.3005E-06	5.2677E-09	-8.28	4.67735E-09	-8.33	8.879E-01		-.052
5	Cl	-1	1.8294E+02	5.1693E-03	-2.29	4.47064E-03	-2.35	8.649E-01		-.063
6	SO4	-2	2.5662E+00	2.6762E-05	-4.57	1.54140E-05	-4.81	5.760E-01		-.240
7	HCO3	-1	1.1131E+03	1.8274E-02	-1.74	1.59615E-02	-1.80	8.734E-01		-.059
18	CO3	-2	1.1669E+01	1.9480E-04	-3.71	1.13382E-04	-3.95	5.820E-01		-.235
86	H2CO3	0	1.3148E+01	2.1236E-04	-3.67	2.13595E-04	-3.67	1.006E+00		.003
27	OH	-1	1.3671E-02	8.0524E-07	-6.09	6.95883E-07	-6.16	8.642E-01		-.063

34	FeSO4	0 1.5001E-02	9.8928E-08	-7.00	9.94315E-08	-7.00	1.005E+00	.002
88	Sr	2 2.1100E+00	2.4124E-05	-4.62	1.39229E-05	-4.86	5.771E-01	-.239
89	SrOH	1 6.9609E-06	6.6649E-11	-10.18	5.80914E-11	-10.24	8.716E-01	-.060

CL/CA = 10.6641E+00	CL/CA = 12.2196E+00	LOG CA/H2 = 13.0513
CL/MG = 83.6619E+00	CL/MG = 98.2655E+00	LOG MG/H2 = 12.1513
CL/NA = 29.6670E-02	CL/NA = 29.9219E-02	LOG NA/H1 = 7
CL/K = 72.0840E+00	CL/K = 72.0738E+00	LOG K/H1 = 4.1226
CL/AL = 51.7094E+26	CL/AL = 51.6926E+26	LOG AL/H3 = -5.0100
CL/FE = 67.5103E+00	CL/FE = 71.3737E+00	LOG FE/H2 = 12.2901
CL/SO4 = 17.9006E+01	CL/SO4 = 19.3158E+01	LOG CA/MG = .9000
CL/HCO3= 27.2926E-02	CL/HCO3= 28.2873E-02	LOG NA/K = 2.3844
CA/MG = 78.4519E-01	CA/MG = 80.4161E-01	
NA/K = 24.2977E+01	NA/K = 24.0873E+01	

	PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT	DELGR
18	Anhydrit	3.7949E-09	3.8918E-05	-8.421	-4.41	9.7511E-05	-4.0109	-5.2115
22	Aragonmi	2.7915E-08	7.8246E-09	-7.554	-8.11	3.5676E+00	.5524	.7177
151	Artin	3.3209E-24	3.8172E-19	-23.479	-18.42	8.6999E-06	-5.0605	-6.5751
20	Brucite	1.5009E-17	3.6211E-12	-16.824	-11.44	4.1449E-06	-5.3825	-6.9935
13	Calcite	2.7915E-08	3.9024E-09	-7.554	-8.41	7.1531E+00	.8545	1.1103
144	Celest	2.1461E-10	1.1605E-06	-9.668	-5.94	1.8493E-04	-3.7330	-4.8503
12	Dolomit	9.8097E-17	1.9225E-17	-16.008	-16.72	5.1026E+00	.7078	.9196
113	FeOH3A	1.7810E+07	7.6736E+04	7.251	4.89	2.3209E+02	2.3657	3.0737
120	FeSPPT	1.4562E+02	1.2162E-04	2.163	-3.92	1.1973E+06	6.0782	7.8975
63	Flour	8.5446E-12	2.7792E-11	-11.068	-10.56	3.0745E-01	-.5122	-.6655
111	Goeth	6.1589E-37	7.2995E-43	-36.210	-42.14	8.4374E+05	5.9262	7.7000
19	Gypsum	3.7895E-09	2.4012E-05	-8.421	-4.62	1.5782E-04	-3.8018	-4.9398
65	Halite	6.7198E-05	3.5347E+01	-4.173	1.55	1.9011E-06	-5.7210	-7.4333
109	Hemati	3.1787E+14	1.3292E-03	14.502	-2.88	2.3913E+17	17.3786	22.5802
118	Huntite	1.2115E-33	2.7178E-30	-32.917	-29.57	4.4575E-04	-3.3509	-4.3539
39	Hydmag	6.5278E-43	1.3044E-37	-42.185	-36.88	5.0043E-06	-5.3007	-6.8872
68	Mackit	1.4562E+02	2.3388E-05	2.163	-4.63	6.2260E+06	6.7942	8.8278
110	Maghem	3.1787E+14	2.3442E+06	14.502	6.37	1.3559E+08	8.1322	10.5663
11	Magnesit	3.5142E-09	9.6855E-09	-8.454	-8.01	3.6283E-01	-.4403	-.5721

62	F	-1	4.0883E+00	2.1557E-04	-3.67	1.86296E-04	-3.73	8.642E-01	-.063
19	MgOH	1	1.3996E-04	3.3933E-09	-8.47	2.98022E-09	-8.53	8.783E-01	-.056
23	MgSO4 Aq	0	8.8757E-03	7.3866E-08	-7.13	7.42418E-08	-7.13	1.005E+00	.002
22	MgHCO3	1	5.2405E-01	6.1524E-06	-5.21	5.33267E-06	-5.27	8.668E-01	-.062
21	MgCO3 A	0	2.2584E-01	2.6831E-06	-5.57	2.69674E-06	-5.57	1.005E+00	.002
20	MgF	1	1.2789E-02	2.9582E-07	-6.53	2.57136E-07	-6.59	8.692E-01	-.061
29	CaOH	1	2.5317E-04	4.4426E-09	-8.35	3.89227E-09	-8.41	8.761E-01	-.057
32	CaSO4 Aq	0	9.2095E-02	6.7767E-07	-6.17	6.81118E-07	-6.17	1.005E+00	.002
30	CaHCO3	1	3.0369E+00	3.0093E-05	-4.52	2.63651E-05	-4.58	8.761E-01	-.057
31	CaCO3 Aq	0	3.0777E+00	3.0805E-05	-4.51	3.09613E-05	-4.51	1.005E+00	.002
49	CAF+	1	1.9090E-02	3.2371E-07	-6.49	2.82146E-07	-6.55	8.716E-01	-.060
44	NaSO4	-1	1.5077E-01	1.2687E-06	-5.90	1.10812E-06	-5.96	8.734E-01	-.059
43	NaHCO3	0	1.1254E+01	1.3423E-04	-3.87	1.34916E-04	-3.87	1.005E+00	.002
42	NaCO3	-1	1.4124E+00	1.7048E-05	-4.77	1.48903E-05	-4.83	8.734E-01	-.059
94	NaCl	0	9.7525E-02	1.6717E-06	-5.78	1.68019E-06	-5.77	1.005E+00	.002
46	KSO4	-1	8.0019E-04	5.9307E-09	-8.23	5.18016E-09	-8.29	8.734E-01	-.059
95	KCl	0	5.3391E-04	7.1740E-09	-8.14	7.21045E-09	-8.14	1.005E+00	.002
63	HSO4	-1	5.3103E-07	5.4803E-12	-11.26	4.76362E-12	-11.32	8.692E-01	-.061
96	H2SO4	0	3.2848E-18	3.3552E-23	-22.47	3.37222E-23	-22.47	1.005E+00	.002
93	HCl	0	1.2484E-13	3.4300E-18	-17.46	3.44745E-18	-17.46	1.005E+00	.002
8	Fe	2	4.0376E+00	7.2425E-05	-4.14	4.26712E-05	-4.37	5.892E-01	-.230
9	Fe	3	2.9678E-13	5.3236E-18	-17.27	1.82636E-18	-17.74	3.431E-01	-.465
10	FeOH	2	7.0782E-08	9.7328E-13	-12.01	5.61720E-13	-12.25	5.771E-01	-.239
11	FeOH	1	1.1959E-01	1.6444E-06	-5.78	1.43326E-06	-5.84	8.716E-01	-.060
12	Fe(OH)3	-1	1.0953E-05	1.0268E-10	-9.99	8.94934E-11	-10.05	8.716E-01	-.060
77	Fe(OH)2	1	1.3430E-03	1.4972E-08	-7.82	1.30772E-08	-7.88	8.734E-01	-.059
78	Fe(OH)3	0	1.1860E-01	1.1117E-06	-5.95	1.11739E-06	-5.95	1.005E+00	.002
79	Fe(OH)4	-1	1.6065E-01	1.2991E-06	-5.89	1.13474E-06	-5.95	8.734E-01	-.059
80	Fe(OH)2	0	4.1984E-05	4.6803E-10	-9.33	4.70414E-10	-9.33	1.005E+00	.002
15	FeSO4	1	3.8815E-14	2.5597E-19	-18.59	2.23106E-19	-18.65	8.716E-01	-.060
16	FECl	2	1.6352E-14	1.7942E-19	-18.75	1.03551E-19	-18.98	5.771E-01	-.239
28	FeCl	1	1.4906E-15	1.1781E-20	-19.93	1.02682E-20	-19.99	8.716E-01	-.060
33	FeCl3	0	7.2874E-19	4.5007E-24	-23.35	4.52357E-24	-23.34	1.005E+00	.002

108	Magnet	2.6517E+13	8.4211E-09	13.424	-8.07	3.1488E+21	21.4981	27.9327
67	Mirabi	3.4578E-09	1.5525E-02	-8.461	-1.81	2.2272E-07	-6.6522	-8.6433
59	NaHCOL	2.3992E-04	2.0685E-01	-3.620	-.68	1.1599E-03	-2.9356	-3.8142
61	Natron	2.5434E-08	1.2968E-02	-7.595	-1.89	1.9613E-06	-5.7075	-7.4157
150	Nesque	3.5067E-09	9.0326E-06	-8.455	-5.04	3.8822E-04	-3.4109	-4.4318
10	Siderite	4.8381E-09	4.4187E-11	-8.315	-10.35	1.0949E+02	2.0394	2.6498
143	Stront	1.5786E-09	3.1876E-12	-8.802	-11.50	4.9524E+02	2.6948	3.5014
66	Thenar	3.4825E-09	6.9497E-01	-8.458	-.16	5.0110E-09	-8.3001	-10.7844
62	Thrnat	2.5598E-08	1.6893E+00	-7.592	.23	1.5153E-08	-7.8195	-10.1599
60	Trona	6.1371E-12	7.3245E-01	-11.212	-.14	8.3788E-12	-11.0768	-14.3922

Ph-sat is the Ph required for the SI Calcite = 1.0

PHSAT = 7.48　　PH - PHSAT= .85

LOGKT CALCITE= -8.409　　PKTBICARB= 10.479

LACT BICARB= -1.797　　LACTY CA++= -3.609