82L/3 #9

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DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES

WATER RESOURCES SERVICE

9

A HYDROGEOLOGICAL STUDY OF THE KALAMALKA-WOOD LAKE BASIN

DATE February 1974

FILE

E.G. Le Breton, P.Eng.

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WATER INVESTIGATIONS BRANCH
BRITISH COLUMBIA WATER RESOURCES SERVICE
DEPARTMENT OF LANDS, FORESTS AND WATER RESOURCES
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SUMMARY

The present information available on the bedrock and surficial geology, water well data, hydrograph records and chemical analyses of groundwaters permits a reasonable interpretation of the regional hydrogeology from the south end of Kalamalka Lake to the south end of Ellison Lake.

The bedrock comprises mainly low permeable metamorphic and intrusive igneous rocks and some conglomerate and basalt. The overlying surficial deposits are mainly sand and gravel with some till on the east and west sides of the valley, commonly less than 50 feet thick. The thickness of the overburden in the valley bottom is known to be 530 feet thick near Winfield. The strata comprises a sequence of till; or silt, sand and gravel; with some lacustrine deposits of clay, silt and sand. The main aquifer in the area is considered to be sand and gravel mainly within the depth range of about 100 to 200 feet below ground surface. It is known only between Wood and Ellison Lakes along the west side of the valley and just to the east of Winfield Creek. The present interpretation of the hydrogeology suggests that most of the groundwater in this part of the area moves through this aquifer. Underflow figures approximating 5 cfs have been calculated. This agrees with surface water losses in the upper Vernon Creek-Ellison Lake area, calculated to be 4.8 cfs by Mr. Coulson, Hydrology Division. This area is considered the main recharge area for the valley floor deposits. About half of the flow through this aquifer is discharged by Winfield Creek.

The main source of inflow from the east side of Wood Lake appears

to be as return groundwater flow from irrigation water. The calculated return flow amounted to about 28% of the applied water for the 1973 irrigation season. In the Winfield Creek basin return flow is calculated as being less than 1%. If return flow to Winfield Creek is substantially higher either the path of return is not apparent or present instrumentation and data is inadequate to enable return flow to be detected in this basin. However, the results available represent only very early attempts to assess return flow directly by groundwater studies. The above figures should be considered as only tentative at this stage. By combining groundwater flow calculations with average nutrient concentrations for total nitrogen and total soluble phosphate only low quantities of these constituents appear to be entering Wood Lake from groundwater sources. Data is too limited to make estimates for quantity of groundwater flow into Kalamalka Lake except for the main aquifer at the south end of Wood Lake, which may discharge 1½ to 2½ cfs directly into this lake. The actual concentration of the nutrients in deep aquifers which may be discharging water into Kalamalka Lake at the south end of Vernon Creek valley is moderately low and from the Coldstream valley is quite low. So if underflow is moderately high, groundwater may not be a serious source of pollution to lakes in the Kalamalka-Wood Lake Basin when compared to surface water sources. A summary of the anticipated quantity of nitrogen and total soluble phosphates entering Wood Lake is given below:

SUMMARY OF NUTRIENT INPUT TO KALAMALKA,

WOOD AND ELLISON LAKES

Aquifer(s) Source	To Lake	Total Nitrogen(N) (lbs/yr)	Total Soluble Phosphate(P) (lbs/yr)
Confined (163'-200')	South End Kalamalka	3,240	270
Water Table & confined	South End Wood	260	7
Water Table	East Side Wood	8,814	37.5
Water Table & confined?	Ellison	200	20

A HYDROGEOLOGICAL STUDY

OF THE KALAMALKA-WOOD LAKE BASIN

INTRODUCTION

The purpose of this study was to consider the role of groundwater as a source of nutrient input into Wood and Ellison and parts of Kalamalka Lakes. To this end the available data on ground water and geology in the Groundwater Division files have been analysed to present an understanding of the hydrogeology of the area. Relevant published and unpublished reports have also been read. This work was supplemented by groundwater field mapping, collection of water samples for chemical analysis from 105 sites including 37 newly installed observation wells and 5 pumping tests.

Methods of Investigation

The work comprised an office study of existing data and fieldwork in 1972 and 1973. Reference was made to available geological and groundwater reports and maps. Basic water-well data and some lithologic logs were plotted on maps to scales of 1 inch to 500 feet and 1 inch to 1,000 feet. Plan view maps showing water-level contours, geology and groundwater features have been prepared where possible. Use was also made of lithologic and electric logs supplied by water-well drillers to construct hydrogeological cross sections of the area. Air photos were used to supplement these studies. Chemical analyses were run on nutrients in 3 to 13 samples of groundwaters from each of 105 springs, creeks and wells, mainly in the Wood and Ellison Lake area. This data was collected over a period of 17 months from March 1972 to July 1973 inclusive. Some information collected in 1969 under the Okanagan Valley Water Quality Data Collection Program, Interim Federal-Provincial Sub Committee No. 2 was used for the Coldstream Valley. Preliminary work forming an early phase of this study was the collection of 28 water samples from wells and springs deriving water supplies from different aquifers distributed around Ellison and Wood Lakes as a basis for subsequent work.

Previous Investigations

Previous investigations to study ground water in the area were made by Nasmith (1962) and by Livingston (1966). The latter work, discussed in an internal report (July 19, 1966, File: 0249723/0256956), was carried out specifically to consider development of groundwater resources on the east side of Wood Lake. It thus provides a very important contribution particularly at this time. A copy of Mr. Livingston's report is submitted as Appendix A. Very helpful geological reports and maps were those by Fulton, R. (1968, Map 1245A) and Jones, A.G. (1959). As part of groundwater investigations conducted under the Canada-British Columbia Okanagan Basin Agreement, a very short report (Halstead, 1972) was written covering the upper part of Vernon Creek Basin above Ellison Lake. Most of the area covered by this report is adjacent to the part of the basin covered under this study.

Acknowledgements

The author wishes to acknowledge personnel of the Groundwater Division, Dr. J.C. Foweraker, Division Chief, for discussions in the planning stages and during the programme; Mr. D. Johanson for supervising test drilling and observation-well installations under Contract 49 and summarizing drilling data; Mr. J. Jaundrew for supervising aquifer testing under Contract 50 and compiling results of the programme. Mr. E. Livingston, consulting groundwater geologist, supervised test drilling and observation-well installations under Contracts 47 and 48. The respective contractors engaged on these programmes were Mr. W. Szachas, Lakeside Drilling Limited, Kelowna; Mr. S. Fraser, Aqua-Flow Testing and Equipment Limited, Langley; A.C. Drillers Limited, Keremeos; and Mr. L. Crampton, Quality Water Wells, Okanagan Falls.

Mr. L. Hunt, B.C. Research Council, conducted the entire water-sampling programme and measured all the observations wells from March 1972 to April 1973. The author is appreciative of B.C. Research Council staff concerning advice on chemical constituents to be analysed and for running the analyses.

The helpful assistance of Mr. E.D. Anthony, District Engineer and staff, Water Rights Branch, Kelowna, is gratefully appreciated.

Mr. C.H. Coulson and Mr. W. Mottram, Hydrology Division, established a weir complete with automatic recorder on Ribbleworth Creek for groundwater return flow studies and supplied daily hydrograph data.

The author also wishes to acknowledge the cooperation of Dr. W.K. Oldham, Assistant Professor, Department of Civil Engineering, U.B.C., and his staff and other participants on the basin study. Mr. G. Marrion, summer assistant, installed and measured temporary weirs to monitor spring and creek flow in 1973 as part of his fieldwork. Mr. A. Campbell was the summer field assistant in 1972.

GEOGRAPHY

Location and Extent of the Area

The main area covered by this study is about 45 square miles (Fig. 1). It lies between parallels of latitude 49°58' and 50°07' north, and between meridians of longitude 119°20' and 119°26' west. However, the Vernon Creek drainage basin divide to the east of Wood Lake extends much further east to 119°07' west. A short strip of the east shoreline of Kalamalka Lake, between latitude 50°13' and 50°14' is included in this study where Coldstream Creek enters this valley.

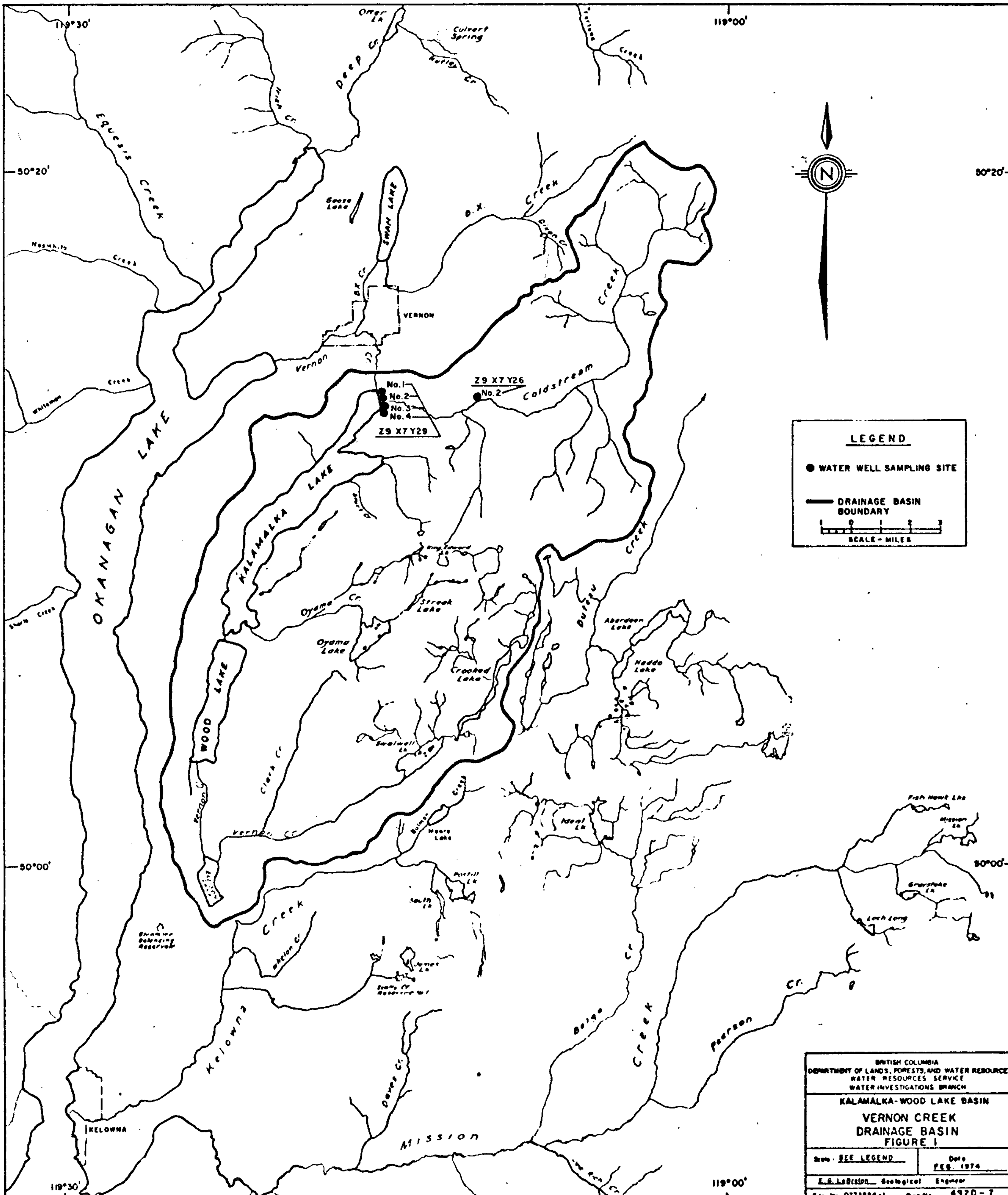
Topography and Drainage

The area lies entirely within the Vernon Creek drainage basin, the major tributary valley in the Okanagan River Basin. The source of Vernon Creek is in the Grizzly Hill Provincial Forest where it flows southwest to Ellison Lake before turning north to flow to Kalamalka Lake. The northward flow of Vernon Creek from Ellison through Wood and Kalamalka Lakes is contrary to the regional Okanagan drainage from north to south.

The drainage basin divide to the west of Wood Lake rises to 3,300 feet, and to the east of Wood Lake rises to 5,400 feet. Most of the area covered by this study lies between elevations of 1,283 feet (at Wood Lake) and 2,500 feet AMSL (above mean sea level).

Climate

The climate of the area is semi-arid. The mean annual temperature may be expected to be about 47°F., and the mean annual precipitation to be about 13 inches in the valley bottom. These values fall between figures for the weather stations at Kelowna and Vernon. At an elevation of 3,000 feet (Rutland Mission creek weather station) the mean annual precipitation increases to about 20 inches.


119°30'
119°00'
50°20'
50°00'
N
LEGEND
WATER WELL SAMPLING SITE
DRAINAGE BASIN BOUNDARY
SCALE - MILES
Z9 X7 Y26
No. 2
Z9 X7 Y29
No. 1
No. 2
No. 3
No. 4
OKANAGAN LAKE
KALAMALKA LAKE
WOOD LAKE
SWAN LAKE
VERNON
KELOWNA
Otter Lk
Culvert Spring
Deep Cr.
Equesis Creek
B.X. Creek
BX Cr.
Vernon
Coldstream
Creek
Oyama Cr.
Oyama Lake
Streak Lake
Crooked Lake
Clark Cr.
Vernon Cr.
Duteau Creek
Aberdeen Lake
Haddo Lake
Ideal Lk
Fish Hawk Lks
Grouse Lk
Loch Long
Creek
Whelan Cr.
Kelowna
Daves Cr.
Mission
Belgo Cr.
Creek
Pearson Cr.
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KALAMALKA-WOOD LAKE BASIN
VERNON CREEK
DRAINAGE BASIN
FIGURE 1
Scale: SEE LEGEND
Date FEB. 1974
Geological Engineer
Dwg No 4920 - 7

GEOLOGY

Bedrock Geology

The bedrock exposures in the study area fall largely into two main classifications. These are exposures of the Monashee Group occurring on the east side of Ellison, Wood and Kalamalka Lakes, and of the Coast Intrusions Formation occurring on the west side of these lakes (Fig. 2, In Pocket). Rocks of the Monashee Group are flat-lying and comprise mainly gneiss, but schist, quartzite and marble are common. These rocks, of sedimentary origin, have been subjected to high-grade matamorphism (Jones, A.G. 1959, p.11). Rocks of the Coast Intrusions as their name implies, are of intrusive origin and are granitic in type. The rocks within each classification are dense with very low percentages of void space which is limited to fractures. Both the number and size of fractures are commonly expected to decrease with depth. Conglomerate and volcanic rocks of Tertiary age overlie the Monashee Group on parts of the east sid of the valley.

Structure

The structure of this region is very complex. Kalamalka, Wood and Ellison Lakes occur directly along a major fault system - the Sicamous-Vernon fault. The dips of most faults are unknown but are probably nearly vertical. From a study of air photographs there would appear to be lineaments trending from southwest to northeast. One of these trends is considered to coincide with the lower reaches of Ribbleworth Creek and to continue northeast about three quarters of a mile to the northwest of Oyama Lake. A second parallel lineament possibly coincides with the upper reaches of Vernon Creek. This latter trend runs northeast through Swalwell Lake and may possibly be a minor extension of a fault cutting across the southern part of Mabel Lake (Jones, A.G. 1959). A set of minor north to south trending fractures are discernible on air photos in parts of the area on the east side of Kalamalka Lake, and these may have been accentuated by glaciation or during deglaciation. The possible importance of faults and limeaments as conduits of groundwater flow in the study area is not currently known.

Surficial Geology

Much of the area of study is covered by unconsolidated surficial deposits and these are mainly of glacial origin. The published work of Nasmith (1962), Fulton (1968) and an internal file report of Livingston (1966) show some disagreement on the methods of deposition and some differences in classification of the deposits. However, it is agreed that mainly sand and gravel deposits flank the east side of Wood Lake. These deposits are accompanied by minor exposures of till (Livingston, 1966; Le Breton, 1973). Further south toward Vernon Creek, sand and gravel deposits again occur, but with till (Fulton, 1968) occupying the lower slopes of the valley.

Fan deposits of poorly sorted gravel, sand and silt occur in the Winfield area where Vernon Creek enters the north-south valley. The bottom valley sediments to the north of this fan are present day alluvium, probably very thin, consisting of silt, sand and gravel. Along the west valley wall are lacustrine materials of silt, sand and gravel, with outwash gravels occurring on the divide. The known variation of the surficial deposits with depth obviously depends on drilling records. These are mainly for shallow wells less than 100 feet deep. Some water-well drillers' logs complete with electric logs are for wells to 200 feet deep with one Groundwater Division test hole (Z7X6Y17No.23) reaching 547 feet. This data has been correlated where possible to construct cross sections of the subsurface surficial geology (Figs. 3, 4 and 5).

East Side of Wood Lake

In this part of the area (Fig. 2) drill hole data show sand and gravel, of varying thickness and often less than 50 feet thick, overlies either bedrock or till. Where till is logged above bedrock its thickness ranges from 1 to 6 feet thick. Near the northeast corner of Wood Lake the drift thickness increases rapidly towards Wood Lake denoting a very steeply sloping surface to the buried bedrock valley wall. Test holes sited over the buried valley wall or local bedrock "highs" are likely to be either permanently dry or to contain water only intermittently.

West Side of Valley from Wood Lake to Ellison Lake

On the west side of the valley drillers' logs to about 200 feet show a succession of deposits described as till; water-bearing gravel; till, cemented sand or dry gravel; and till, or clay, gravel and rocks between elevations of about 1,[illegible]50 feet to 1,400 feet AMSL. A factor aiding correlation of well logs was the noticeably high resistance shown on the electric logs by the zone of cemented sand or dry gravel. This same phenomenon may permit some correlation of the logged units down, as well as along the valley wall. The above description of the geology illustrated by figure 3 is anticipated to apply to a north-south zone only about 1,000 to 2,000 feet wide. It is known that the depth to bedrock along Pretty Road 1,000 feet west of the southwest corner of Wood Lake varies between 30 and 6[illegible] feet, and it is considered that further south the depth to bedrock may be about the same. To the east of Winfield Creek in the valley floor the geological sequence is quite different (Fig. 4). Thus it is concluded the above zone is quite narrow. In the vicinity of the north-south cross section (Fig. 3) drilling records suggest a steeply sloping buried bedrock valley wall, but to the west of this zone the underlying bedrock surface is less steeply sloping and may be partly terraced.

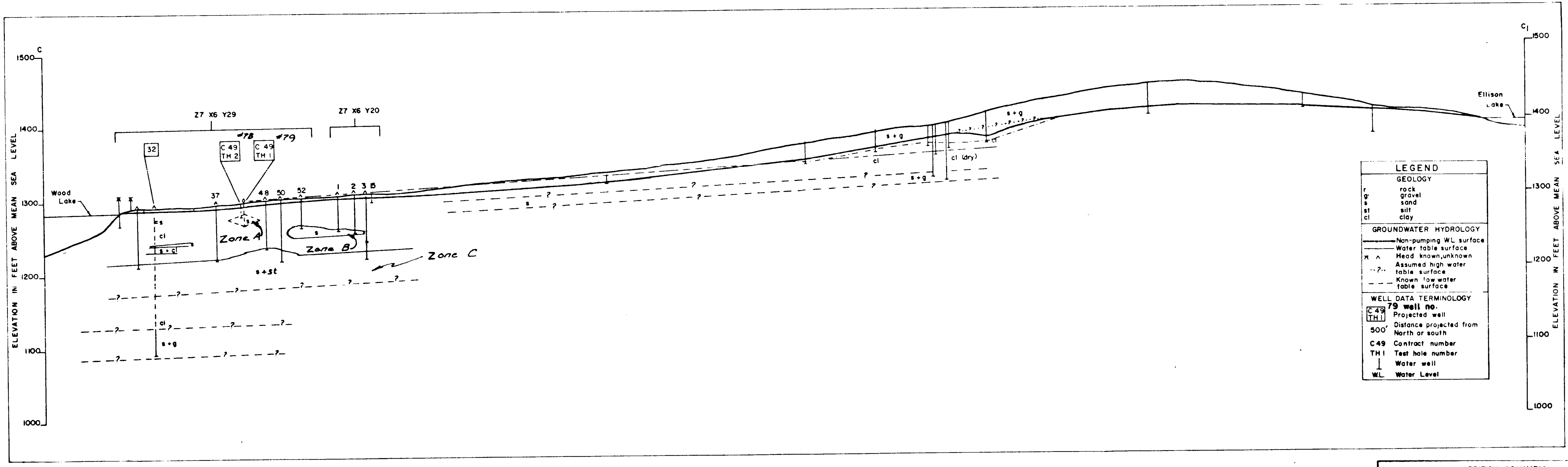
Field mapping suggests the surficial deposits are primarily sand and gravel with some silt and clay. Locally till may be present in the sequence as indicated in well C49 TH7 (Z7X6Y30No.24) where three sand and gravel zones are separated by till about 25 feet thick.

Valley Floor Area between Wood and Ellison Lakes

Most of the water-well records for the valley floor are for wells less than 100 feet deep commonly giving little geological information. From well depth completions there would appear to be a main zone of sand with some silt encountered from 60 to 115 feet below ground surface with minor beds or lenses as shallow as 15 feet to about 130 feet deep (Fig. 5). Summary descriptions of the lithology combined with some complete descriptive logs with electric logs suggest thin sand and silty sand beds within lacustrine clay and silt deposits. This occurs to depths of about 160 feet within one-half mile of the south end of Wood Lake.

Between Winfield and Beaver Lake Road several shallow well logs record thicknesses of about 40 feet of sand and gravel overlying clay. This sand and gravel marks the northwesterly extent of a fan deposit of sand and gravel where Vernon Creek enters the main valley from the source area at high elevations to the east. Interfingering of deeper deposits of the Vernon Creek fan are expected to occur with the valley-floor deposits. There is limited evidence to support this as for a new well drilled to replace Z7X6Y17No.8. In this new well, clay from 40 to 60 feet separates sand and gravel deposits above and below this clay bed.

From the data available cross sections have been drawn for the shallow sub surface surficial deposits. From figure 4 it would appear there is a facies change from locally thick deposits of sand and gravel near the base of the west valley wall (C49 TH4) to clay, silt with some sand, overlying sand and gravel (Z7X6Y29No.32). In the Groundwater Division Test Hole (Z7X6Y17No.23) 547 feet deep, put down by E. Livingston, the log shows bedrock was encountered at 530 feet and records 3 till units separated by silt, sand and gravel deposits. It is thought possible that the upper silt, sand and gravel zone from 135 to 235 feet (Z7X6Y17No.23) may be continuous with sand and gravel from 163 to 200 feet in well Z7 X6 Y29 No. 32.



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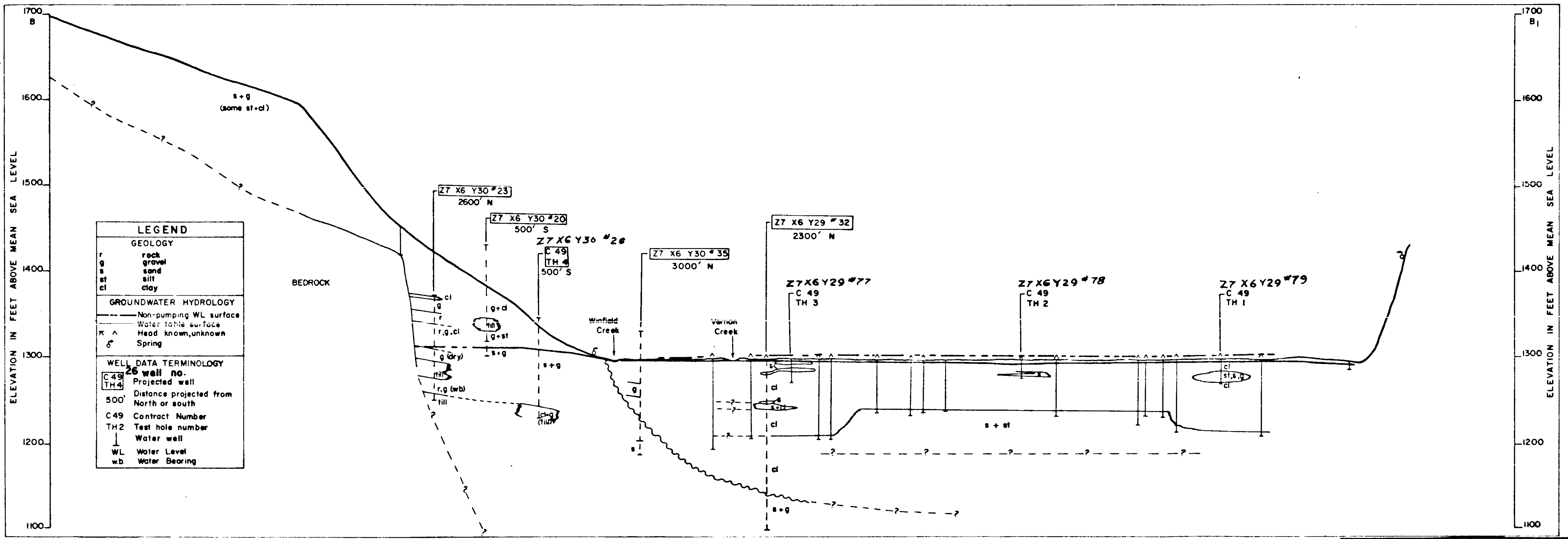
KALAMALKA-WOOD LAKE BASIN STUDY
HYDROGEOLOGICAL CROSS SECTION C-C1

SCALE: HOR.1" = 1,000'	DATE
GEOLOGICAL ENGINEER	E. G. Le BRETON
FILE No. 0273896-1	DWG. No. FIGURE 5



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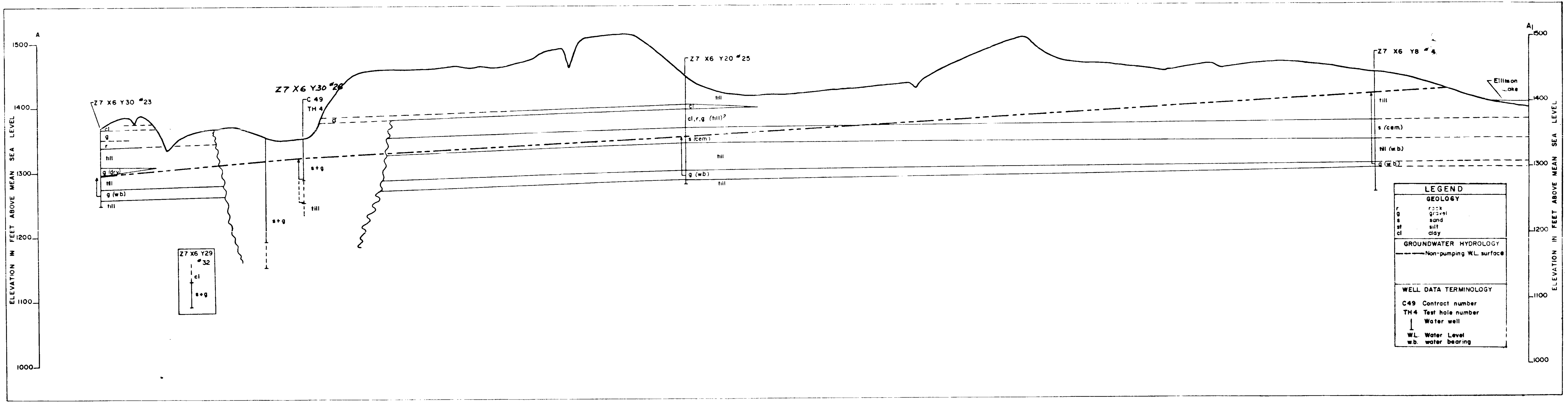
HYDROGEOLOGICAL CROSS SECTION B-B1

SCALE: HOR. 1" = 500'	DATE
GEOLOGICAL ENGINEER	E. G. LeBRETON
FILE No. 0273896-1	DWG. No. FIGURE 4



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KALAMALKA-WOOD LAKE BASIN STUDY
HYDROGEOLOGICAL CROSS SECTION A-A1

SCALE: HOR. 1" = 1000' | DATE

GEOLOGICAL ENGINEER E.G. LeBRETON

HYDROGEOLOGY

Source, Occurrence and Movement of Ground Water

It is highly probable that connate ground waters contained in the surficial deposits during glacial times and also shallow bedrock ground waters were very low in total dissolved solids. Post-glacial recharge from precipitation moving through unconsolidated rather insoluble rock materials of igneous and metamorphic origin is expected to result in only minor chemical solution of the weathered products. The chemistry of the ground waters is therefore anticipated to show fresh water low in mineral concentration.

Within the bedrock, ground water occurs in rock fractures commonly expected to decrease both in size and number with depth. Groundwater movement is confined to these fractures and most ground water moving through the bedrock is anticipated to be restricted to about the upper 50 feet. Though high permeability may occur in these fractures, especially along some lineaments, the percentage of void space is commonly small, so that the overall permeability for the bedrock is quite low. The volume of water held in storage also will likely be small. Thus the quantity of groundwater moving through the bedrock as underflow, or discharged as springs will be minor as far as water-balance studies are concerned.

Within the surficial deposits of gravel, sand, silt and clay, groundwater movement is primarily intergranular though locally as in till, groundwater movement may be largely through fractures. While the regional movement of groundwater is expected to conform with that of the slope of the topography, buried bedrock or moraine ridges and bedrock channels may locally modify groundwater flow. Bedrock or moraine ridges may deflect groundwater movement towards the surface creating discharge as springs or spring seepage. Also some channelling of groundwater and locally significant irregularities in the topography of impermeable materials underlying sand and gravel may combine to produce small unsaturated areas in the surficial deposits. This is believed to occur under the U.B.C. study area to the northeast of Wood Lake.

Basic Water-Well Data

The basic water-well data on file has been plotted and analysed. Much of this data is for wells less than about 50 feet deep supplying information mainly on the depth of the well and the depth to the water level below ground surface. Though well logs are often not supplied, sometimes the lithology of the aquifer material is noted. A limited amount of data is also available regarding groundwater sources from water wells 100 to 200 feet deep. However, almost no data is supplied on bail and pumping tests to enable values of permeabilities to be calculated.

To the available data has been added information gathered from about 70 new test holes including pumping tests at 5 sites. However, the main emphasis was placed on drilling for the purpose of constructing wells to monitor changes in nutrient content of groundwaters close to Kalamalka, Wood and Ellison Lakes. Basic data has enabled some mapping of the areal extent and thickness of some aquifers, drawing water-level contours for water-table aquifers and determining the hydraulic gradients of water-table and of confined aquifers in parts of the study area.

Aquifers between Wood and Ellison Lakes

The deepest known aquifer, (in Well Z7X6Y29No.32) is encountered at a depth of 160 feet, elevation about 1,130 feet AMSL to the south of Wood Lake. It is logged as clean sand to 200 feet, elevation 1,090 feet AMSL but the lower limit of the aquifer is not known. This well and a nearby recent new well flow at rates of 35 to 49 igpm (imperial gallons per minute). About 500 feet east of these wells is a second new well (Hruschak, J. personal communication Nov. 1973) about 140 feet deep with a flow of 9 igpm. These wells probably draw water from the same gravel aquifer 1,275 feet AMSL which supplies groundwater to the wells along the west valley wall (Fig. 3). This aquifer is locally unconfined near Winfield Creek and is the source of spring discharge about 1,500 to 3,500 feet south of Wood Lake. Here spring discharge forms several "streamlets" which flow into Winfield Creek. The combined estimated flow of these "streamlets" has been reported as just under 1 cfs (cubic feet per second) but visual opinions are considered as only rough flow estimates. Further, Winfield Creek, which is of groundwater origin and has a near steady flow of 2½ cfs, is considered to be supplied from this same aquifer. With spring discharge from the valley wall of 1 cfs (or 0.64 cfs, see Table 1b) the major portion of flow of 1½ to 2 cfs is assumed to be fed by direct vertical discharge from the aquifer. This is presumed to be the case because of the close proximity of Winfield Creek to the proposed facies change from sand and gravel to clay and silt shown in figure 4. From the combined information on geology and groundwater hydrology it would appear the water supplying the wells along the west valley wall, Winfield Creek and the adjacent line of springs, and the deep wells near the southwest corner of Wood Lake moves through one major aquifer. It is considered that much of the groundwater moving to the Wood Lake area through this aquifer originates in the Ellison Lake area.

Several confined aquifers (mainly sand) from which water is commonly reported to flow at less than 3 igpm, occur within two-thirds of a mile from the south end of Wood Lake (Fig. 6, In Pocket). The main developed source of groundwater is between 60 and 100 feet deep (1,170-1,230 feet AMSL) in the central part of the valley. Some groundwater is obtained from confined aquifers as shallow as 35 feet to as deep as 130 feet, with free flow having occurred as shallow as 15 feet (Z7X6Y29No.79). The head measurements (1972 and 1973) range from about 1 foot above ground surface near the southern limit of the flowing wells to 16 feet above ground level at the south end of Wood Lake. The occurrence of artesian head is taken to indicate rather limited hydraulic continuity between the aquifers and the water in Wood Lake.

Overlying these aquifers is the water table aquifer consisting of fine-to medium-grained sand, silty sand or sandy clay with some coarse sand. This is the description from test hole logs in the area in which septic tank effluent studies were conducted by the University of British Columbia. The thickness of the zone of saturation is considered to range from a minimum of 2 feet to an average of 5 feet of low permeable (10 United States gallon per day per square foot - US gpd/ft^2) materials.

These limits for saturated thickness are considered reasonable when allowance is made for a confining bed overlying an aquifer with artesian flow encountered from as shallow as 15 feet and depths to the water table of 2 to 6 feet. The hydraulic gradient of the water table is about 5.5 x 10^{-3} ft./ft. and is used for underflow calculations in Table 4a. Though there is very little information on the water table aquifer between the septic tank study areas and the Village of Winfield, the occurrence of both the aquifer and the water table are deeper below ground surface towards the south. The base of the aquifer in the Winfield area is about 45 feet below ground surface and the depth to the water table about 35 feet.

Between Winfield and Beaver Lake Road unconfined groundwater occurs in sand and gravel deposits of the Vernon Creek fan. In this part of the fan the deposits are about 40 feet thick and the saturated thickness of the water-table aquifer is commonly from about 4 to 10 feet. A well in this aquifer may sometimes go dry (Well Z7X6Y17No.8). This has led to deeper drilling and to development of groundwater between 70 to 90 feet deep from a sand and gravel aquifer below the water table. Water-level data from this deeper zone has been used in conjunction with head measurements of flowing wells at the south end of Wood Lake to determine the hydraulic gradient for the confined aquifers. The gradient is about 5.5 x 10^{-3} ft./ft. Groundwater movement from the Vernon Creek fan is expected to be an important source of recharge for aquifers between Ellison and Wood Lakes.

Aquifers occurring up on the west side of Vernon Creek valley from 1,500 to 1,700 feet AMSL are frequently represented by spring discharge.

The main zone of discharge is revealed by springs at about 1,550 to 1,600 feet AMSL. Field observations show creeks appear and disappear. This observation and spring discharge reflect the presence or absence of underlying impermeable beds. These beds may be silt and clay or cemented gravel. Such beds or lenses have been observed in the surficial deposits which are mainly sand and gravel. Low creek flows, less than 50 igpm, originating up to 1,600 feet AMSL are considered to reflect possibly small total contributions of groundwater from the higher aquifers along the west valley wall.

Ellison Lake Area

Groundwater inflow to Ellison Lake is from bedrock fractures on the west side of the lake, from lacustrine deposits of silt, sand and gravel on the east side of the lake, and possibly as underflow near Vernon Creek at its point of entry into the lake. Groundwater inflow to this lake is expected to be small. This is considered to be so because of the anticipated very low permeability of the bedrock on the west side of the lake and the dry appearance of the land surface on the east side of the lake suggesting low groundwater flow into this lake.

East Side of Wood Lake

Data available for the east side of Wood Lake show a thinly saturated, commonly less than 5 feet thick, water-table aquifer consisting of sand and gravel directly overlying bedrock or sometimes over till. This aquifer is recharged either directly from precipitation, by discharge from the bedrock, or by underflow from creeks originating high up the valley wall. The last method of recharge is best illustrated by Elliot Creek. This creek possibly originates from the Tertiary conglomerate at about 3,000 feet, as do some springs such as the one from Somerville Mine. The source of recharge are many 10 to 20 feet deep fissures in the overlying volcanic rocks. These are reported (Mr. Holt, personal communication) to store precipitation as snow or ice all summer long (Fig. 7). Elliot Creek possibly loses water to storage as it crosses fan deposits of silt, sand, and gravel up to 150 feet thick. This fan (Fig. 8, In Pocket) supplies water to many springs and wells at topographically lower elevations.

Weber's spring (Fig. 8, In Pocket), the main inflow to Ribbleworth Creek is believed to be fed by underflow in a manner similar to that illustrated by Elliot Creek. Two miles further north is an unnamed creek diverging from Ribbleworth Creek which also conveys water either as surface or subsurface flow. In this case some of the subsurface flow occurs within the bedrock.

Water-Level Surfaces

The water-level surface of an aquifer is an imaginary surface that everywhere coincides with the nonpumping level of the water in an aquifer. Water-level contours have been drawn where possible for the aquifers previously discussed. Water-level contours drawn for the Vernon Creek water-table aquifer are interpreted to portray a significant influence on the groundwater hydrology due north of Ellison Lake. The

FISSURE AT GROUND LEVEL

(East side of Wood Lake, elevation 3,500 feet approximately)

ICE INSIDE FISSURE

(In late summer)

FIGURE 7. Ice in Fissure in Volcanic Rock

water table in the Vernon Creek fan forms a groundwater mound in the main valley. As groundwater flow from this fan enters the main valley, it is discharged both towards the north and the south. The occurrence of this mound is believed to create a rather effective but not necessarily fully effective barrier to the possible movement of groundwater to the north from Ellison Lake within the water-table aquifer (Fig. 6). Topographic control shows Ellison Lake to occur in almost a closed depression. In this case very little or no surface water may flow out at low lake level (Fig. 6). One local resident reported that although Vernon Creek has been known to go dry at the outlet of this lake, flow resumes about one-eighth of a mile downstream. In conformity with surface drainage it is considered the entire or most groundwater flow is to the north from the Ellison Lake-Vernon Creek fan area. Data for 3 wells, two at the north and one at the south end show Ellison Lake is primarily a body of surface water perched on lacustrine clays. The water level in the lake is about 10 to 20 feet higher than in these nearby wells. One of these wells (Z7X6Y5No.7) was put down under this study. In three other wells (Z7X6Y5Nos.4, 5 and 6) on the east side of Ellison Lake the water level in the wells is continuous with that of the lake level. Brief reference is now made to the estimated annual water losses from Ellison Lake of 1,500 acre feet per year (Coulson, 1973). There is some evidence to suggest this lake is perched. Further as Test Hole Z7X6Y8No.11 was reported dry to 20 feet, where a hard layer was encountered, there is some evidence to suggest Vernon Creek is a perched creek in this part of the area. The losses can be accounted for by vertical leakage at a rate of 0.06 US gpd/sq.ft. This is an acceptable permeability figure for a stratum of very low permeability. It is believed that losses from this lake combined with 2,000 acre feet per year from Vernon Creek above Ellison Lake provide the major source of groundwater recharge to aquifers in the valley floor between Ellison and Wood Lakes. The total losses of 3,500 acre feet per year are equivalent to a flow of 4.8 cfs. About 2.5 cfs is discharged by Winfield Creek leaving a total of 2.3 cfs to be accounted for by underflow.

From the north end of Vernon Creek fan to Wood Lake there is moderate control for contouring the water table reasonably well. Use has been made of the water-table contours to obtain the hydraulic gradient for underflow calculations (Fig. 6, In Pocket). To the south of Wood Lake are numerous flowing wells but the data is insufficient to map the water-level surfaces of these zones. The source of the groundwater is likely moving down valley from deep aquifers in the Ellison Lake area to the south, and not as previously stated (Le Breton, Nov. 1971, p.12) groundwater locally entering this part of the area from aquifers on the east side of the valley. "Locally" is emphasized because of the occurrence of bedrock at ground surface at the southeast corner of Wood Lake and at about 3/4 mile due south (Fig. 6, In Pocket). It was previously assumed that a moderately thick cover of glacial deposits might possibly permit significant quantities of groundwater recharge to occur to the confined aquifers from the east valley wall in the locality of artesian flow. From field mapping of bedrock outcrops in the summer of 1973 between these points, it is now known that bedrock occurs along the east valley wall from Wood Lake to Beaver Lake Road and that the overlying glacial deposits are quite thin. The bedrock is also not considered as an important source of groundwater supply. This opinion is considered to be supported by fieldwork in 7 sub-basins in the Okanagan River Basin (Halstead, Hall and Le Breton, 1970). However, one cannot rule out the possible occurrence of unknown major fracture zones acting as conduits for groundwater movement. With only a thin cover of glacial deposits and the bedrock commonly transmitting only small quantities of groundwater, it is believed the east side of the valley is not the major source of groundwater recharge to the aquifers in the valley floor area.

It was also previously considered that groundwater movement along the base of the west valley wall was distinct from that in the valley bottom. However, more recent information indicates one main aquifer may be present along the west valley wall and at a depth of about 160 feet in the valley floor area. Hydraulic gradients for the confined aquifers are comparable for the north to south cross sections. Differences at the south end (Well Z7X6Y8No.4) shows quite a high water level may be due to local sources of groundwater supply from the west side of the valley. The steeply sloping gradient (Well Z7X6Y30No.23) showing a water level only somewhat higher than the level of Wood Lake indicates local hydraulic continuity with lake water. This is in contrast to levels about 20 feet above lake level along the south shore of the lake. The thin ice and open water (Dr. I. Birtwell, 1973, personal communication) reported last winter along the west lake margin about 1 mile north of the southwest corner of the lake may be partly due to vertical leakage from this or overlying aquifers. However, this is not certain as it may come from bedrock fracture systems.

The other part of the area where the water table may be readily contoured is the east side of Wood Lake (Fig. 9, In Pocket). The contours show a steeply sloping surface with a gradient of about 770 feet per mile. Locally, even though irrigation is extensively carried out in the summer months, some test holes remain permanently dry above the first impermeable layer. In such localities groundwater is thought to flow in subsurface channels but there is insufficient detailed test hole control to confirm this.

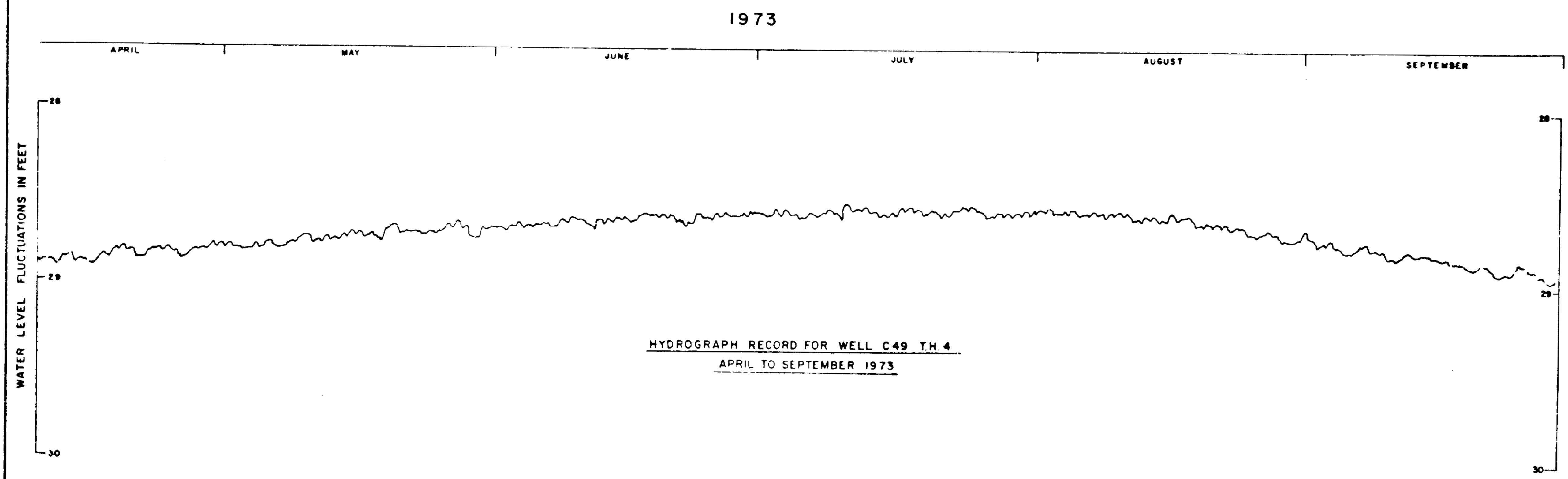
Hydrograph Records

The hydrograph records in the study area can be divided into several groups. Selected examples are shown in Appendix B. Those wells along the south end of and northeast corner of Wood Lake (Appendix B, No. 1), some between Wood and Kalamalka Lakes, and bordering Kalamalka Lake show fluctuations varying generally in accordance with lake level. Two wells in the area between these two lakes show significantly different trends. These are believed to reflect the affects of underflow related to stream losses accompanying the freshet or release of water from storage (Appendix B, No. 2). It may also be noted there has been an overall decline in the water level throughout the period of record. This latter observation is to be noticed on several other hydrograph records. Such wells (Appendix B, No. 2 and No. 3) occur near the east side of Wood Lake and in the Hiram Walker plant grounds on the Vernon Creek fan (U.B.C. records). Water levels in these wells have declined as much as 6 feet after allowing for seasonal recharge and denote loss of groundwater from storage. This phenomenon is considered a response to the change in precipitation and runoff from very high precipitation and runoff in 1971-72 to the opposite in 1972-73.

Five hydrograph records illustrate the effects of irrigation practices and show increases in groundwater levels ranging from ½ to 6½ feet. Water-level fluctuations due to irrigation are shown for one well (Appendix B, No. 4).

Aquifer Tests and Groundwater Return Flow from Irrigation

Data from pumping tests conducted under Contract 50, from return flow irrigation studies and from pressure recovery tests are summarized in Appendix C, Tables 1 to 3. The important pump test for this study on Well C49TH4 is summarized in Table 1a. The average permeability value of 1,590 US gpd/ft.^{2} derived from this test is used in calculating groundwater return flow to Winfield Creek, along a length of 5,000 feet (Appendix C, Table 1), in relation to the continuous hydrograph record for this well (Fig. 10). The period of record, May-September, shows a rise and decline in the water level which would appear to reflect the effect of the full irrigation season. The average rise in the water level is 0.25 feet. The rate of return flow derived from calculation No. 1 (Appendix C, Table 1b) is 0.016 cfs which is only ½% of the total applied irrigation water. Because of good control concerning: (a) the depth to bedrock and distance to the bedrock wall in the vicinity of this well; (b) knowledge of the aquifer and occurrence of springs discharging water from the aquifer; (c) hydrograph records for Winfield Creek; (d) direction of groundwater flow and; (e) some information to suggest small rates of groundwater discharge from the bedrock, it is considered local evaluation



HYDROGRAPH RECORD FOR WELL C49 T.H.4
APRIL TO SEPTEMBER 1973

BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

KALAMALKA - WOOD LAKE BASIN STUDY
HYDROGRAPH RECORD FOR WELL C49 TH 4
APRIL TO SEPTEMBER 1973

SCALE: VERT. 3" = 2'-0"
HOR. MONTHS
DATE

GEOLOGICAL ENGINEER E.G. Le BRETON

FILE No. DWG. No. FIGURE 10

of return flow for the year 1973 may be reasonably accurate. There is no obvious way to account for storage and discharge for a high percentage of return flow from irrigation water applied at a rate of about 3.7 cfs. In other words it is believed that in 1973 consumptive use in the Winfield Creek basin was at a rate approaching maximum available water supply.

Calculation No. 2 (Appendix C, Table 1b) is an attempt to show possible groundwater discharge by springs or seepage for a saturated thickness of the aquifer averaging about 10 feet above the elevation of Winfield Creek, over a length of 5,000 feet. A third calculation of discharge was made allowing for an average saturated thickness of 20 feet above Winfield Creek along a 2,000 feet length of the creek (Fig. 6, In Pocket). The flows for these two calculations totalled 0.64 and 0.50 cfs, respectively. The latter figure was an attempt to compare the sum of visual estimates of "streamlet" flow into Winfield Creek which were about 9/10 cfs with calculated flow using moderately good aquifer test data. The comparisons are acceptable when it is considered visual stream flow estimates are likely to give only a rough indication of actual flow. The above analysis was an attempt to integrate findings from geologic control, test drilling, aquifer test data, observations from field mapping and well and stream hydrograph records.

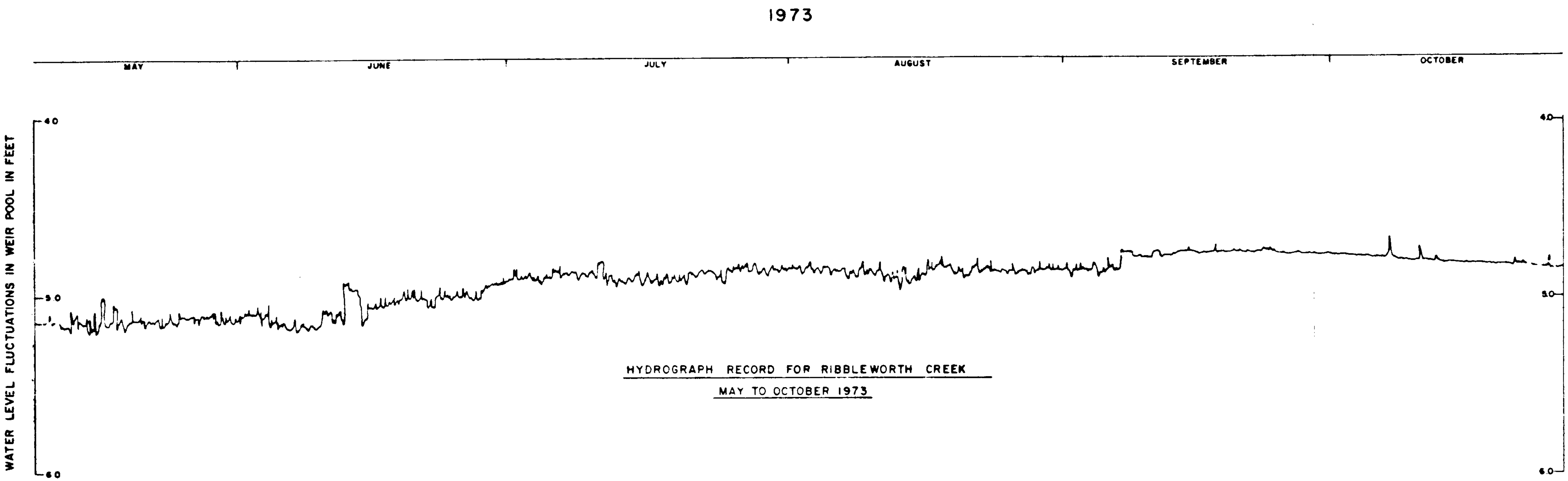
Return groundwater flow calculations were also made for the Ribbleworth Creek drainage basin. These are tabulated in Appendix C, Table 2 and are combined with figures for the La Fleche Creek basin to obtain a percentage of return flow.

The hydrograph record (Fig. 11) shows an increase in stream flow did not begin until June and the return flow period has been arbitrarily terminated for November. The fact that the decline in stream flow is slower than anticipated is thought to be due to precipitation on the basin after irrigation ceased. The average increase in stream flow due to irrigation is about 0.28 cfs which figure is used to obtain an equivalent volume of water of 100 ac ft (acre feet).

A return flow calculation was made for La Fleche Creek basin by averaging the daily increase in flow up to the point of peak flow. The average flow figure is 0.13 cfs. The first flow measurement was used as the base flow figure as this was taken near the time when Ribbleworth Creek flow began to increase. A decline in flow for La Fleche Creek equivalent to its increase in flow is assumed for return flow calculation purposes. The average increase in flow was equivalent to a volume of water of 40 ac ft. Again the slower decline compared to increase in flow is considered the result of precipitation which is known to have occurred soon after peak flow (Fig. 12).

This gives a total volume of water for both creeks of 140 ac ft. If allowance is made for one important withdrawal of creek water above the stream gauge of 0.167 cfs (45 ac ft) the potential return flow to Wood Lake from the Ribbleworth Creek-La Fleche Creek basins increases. However, the extent to which this water is diverted from these basins is unknown, but for the present purposes about half of this water (22 ac ft) is considered to be diverted. The quantity of return flow is that measured at the gauges, 140 ac ft and the diverted flow of 22 ac ft for a total of 162 ac ft. The last figure has to be compared to the total quantity of applied water to derive a percentage for return flow. The volume of irrigation water applied to the Ribbleworth Creek-La Fleche Creek basins is 506 ac ft. To this has to be added about 3.2 inches of precipitation during the irrigation season, which is equal to 49 ac ft of water. Along with 23 ac ft of re-applied irrigation water, the total volume of applied water is 578 ac ft. The 162 ac ft of return flow gives a figure of 28% return groundwater flow from irrigation. This figure of 28% is thought to be reasonable and is applied to the remainder of the east side of Wood Lake. The results from actual observations, made possible because groundwater discharge is forced to return to Wood Lake (Fig. 13) over the bedrock, are considered applicable to the rest of the area which is predominantly a similar hydrogeological environment but all return flow is as underflow. It must be stressed that although groundwater return flow figures from irrigation practices have been cited for two basins showing 28% and less than 1%, the period of record is very short. The methods of deriving these results require much further study before being allowed to challenge any longer term regional observations for the Okanagan River Basin.

The 1% figure for return flow from the Winfield Creek basin requires further comment and clarification. This is the result obtained by relating the information derived from the pumping test and the hydrograph record. Only a very small increase in groundwater flow, which covers the entire irrigation season, is shown by this method of analysing the available data. Control data on geology, and groundwater and surface water hydrology show no evidence to suggest that groundwater return flow from this basin can be higher. However, if return flow from irrigation



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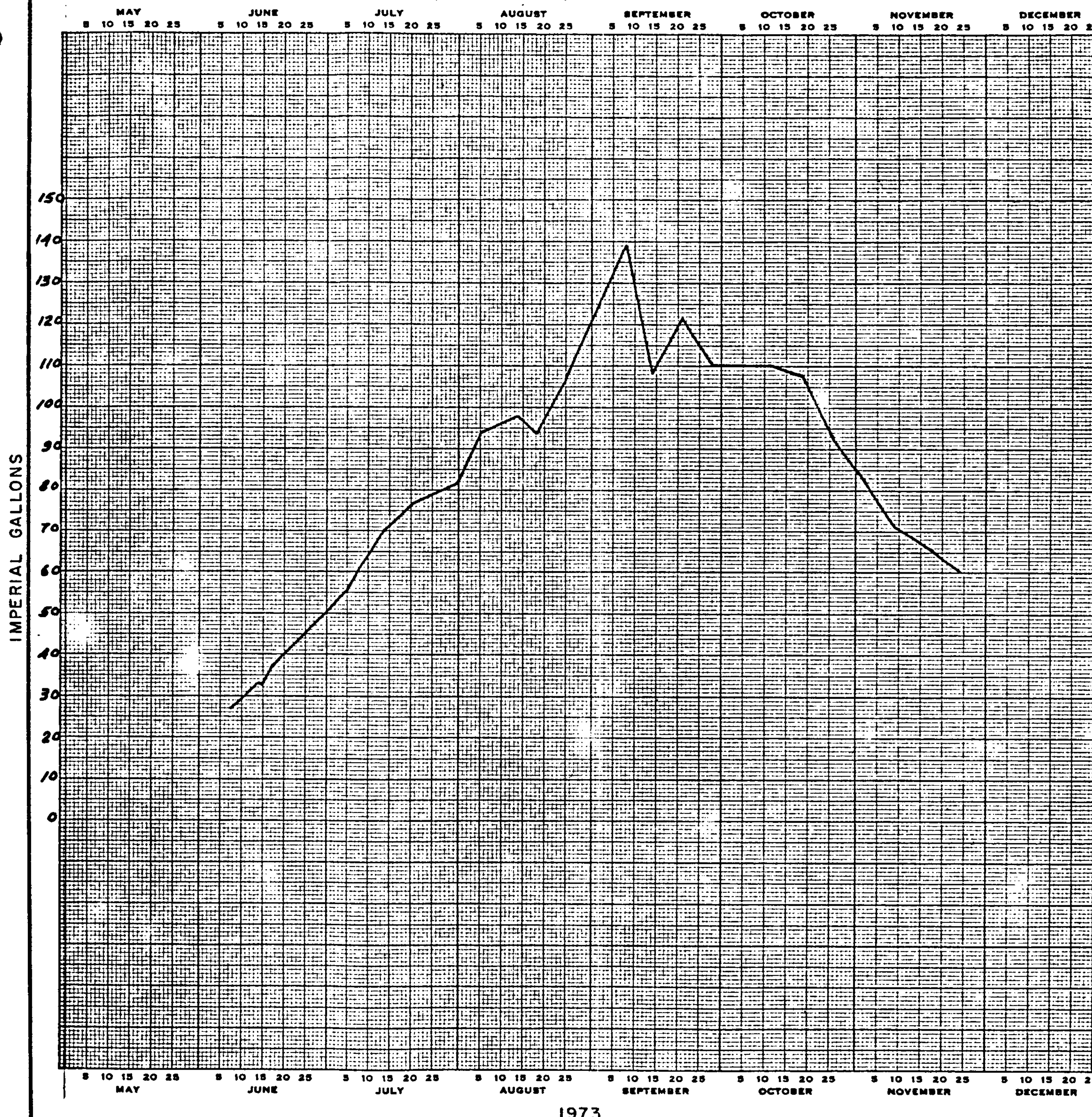
KALAMALKA-WOOD LAKE BASIN STUDY
HYDROGRAPH RECORD-RIBBLEWORTH CREEK
MAY TO OCTOBER 1973

SCALE: VERT. 3" = 2'-0" HOR. MONTHS	DATE
GEOLOGICAL ENGINEER	E.G. LeBRETON
FILE No.	DWG. No. FIGURE 11



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HYDROGRAPH RECORD
La FLECHE CREEK

SCALE:

DATE

E. G. Le Breton GEOLOGICAL ENGINEER

FILE No.

DWG. No. FIGURE 12

FIGURE 13. RIBBLEWORTH CREEK WATERFALL

is indeed substantially greater, there is no apparent explanation for this at the present time. With the present understanding of the geology of the area it is difficult to conceive of large groundwater flow (28%) returning to Wood Lake or Winfield Creek from this part of the study area without being detected in some way.

The calculated permeability (K) values shown in Appendix D, Table 3, were derived from short pressure recovery tests, conducted after free flowing tests or short periods of pumping the well. The data collection was an alternative to quite expensive drilling and pumping test programmes and was included in part of normal field mapping. The results have been used in groundwater flow calculations to determine nutrient input to Wood Lake from confined aquifers between 15 and 115 feet deep at the south end of the lake. The results of these calculations are shown in Appendix D, Table 5a and 5b.

Groundwater Flow and Nutrient Input Calculations

Following a study of the geology and groundwater hydrology some underflow calculations have been made for water-table aquifers and for confined aquifers where possible. Although it has been previously stated that there is very little data in the study area available for calculation of permeability values for the surficial deposits, assumed values can be used. The guide for the assumptions made is taken from Todd (1959, p. 53). The range of values shown by Todd have been drawn from considerable data available from groundwater studies.

In making underflow calculations, the following formula is used:

$$Q = KIA$$

where Q = quantity of water in US gallons per day (US gpd)

K = permeability in US gallons per day per square foot (US gpd/ft^2)

I = hydraulic gradient in feet per foot (ft/ft)

A = cross-sectional area in square feet through which groundwater moves (sq ft)

As stated above, values for K are assumed or taken from 1972 pump test data; I is known from cross sections or water-level contours; A is measured from available geological and topographical control. The main weakness in the approach is lack of K values for the study area. The other control is of varying quality. Calculations for different cross-sectional areas are presented in Appendix C, Tables 4 to 6.

The results obtained from groundwater flow calculations, from groundwater return flow calculations from irrigation, flow measurements for some creeks, and baseflow estimates have been used, together with average nutrient concentrations of groundwaters along lake margins to calculate the total quantity of nutrients entering a lake. The nutrient concentrations are shown in Appendix C, Tables 4 to 12, with an overall summary in Appendix C, Table 13. The nutrient input in pounds per year (lbs/yr) has been derived by using an approximate conversion factor that 1 cfs and 1 ppm (part per million) produce an input of 2,000 lbs/yr.

The main findings from the groundwater studies on the quantity of nutrients entering Kalamalka, Wood and Ellison Lakes are briefly stated. Further details are to be found in the tables in Appendix C.

The confined aquifer from 163 to 200 feet below ground surface at the south end of Wood Lake is estimated to supply 3,240 lbs of nitrogen (as N) and 270 lb. of total soluble phosphate (as P) per year to Kalamalka Lake. The water-table aquifer and underlying confined aquifers to a depth of about 100 feet below ground surface at the south end of Wood Lake are estimated to supply a total of 260 lbs of nitrogen and 7 lbs of total soluble phosphate per year to Wood Lake. The water-table aquifer on the east side of Wood Lake is estimated to supply 8,81 lbs of nitrogen and 37½ lbs of total soluble phosphate to this lake. These figures give a total of 12,314 lbs of nitrogen and 314½ lbs of total soluble phosphate being supplied to Kalamalka-Wood Lakes directly from groundwater sources.

The corresponding figures for the Ellison Lake Basin show a total quantity of 200 lbs of nitrogen and 20 lbs of total soluble phosphate. These nutrients are either directly entering Ellison Lake, or possibly partly entering this lake and partly entering regional groundwater flow moving from the Ellison Lake area towards Wood Lake. In calculating nutrient contribution to groundwaters in the Ellison Lake Basin the return flow figure of 28% derived from the Ribbleworth Creek Basin study was also used for this basin. To this was added results based on a theoretical calculation of groundwater inflow to Ellison Lake.

Hydrogeochemistry

About 150 full chemical analyses of the main cations and anions, plus total dissolved solids and conductivity were run by B.C. Research Council or the Provincial Water Resources Laboratory. Much of the data has yet to be processed, plotted and studied. This phase of the work is to form part of a more detailed report of the hydrogeology of the area. The emphasis has been placed on the nutrient constituents analysed under this program to meet the present objective - to consider the role of groundwater as a source of nutrient input to the lakes. Additional staff time and map work is necessary to complete a study of the main cations and anions.

Generally the groundwaters are of low total dissolved solids (300-500 ppm) of calcium-magnesium bicarbonate type water. For nutrient studies the following constituents were regularly analysed: Calcium, magnesium, total organic carbon, total kjeldahl nitrogen, nitrate and nitrite nitrogen, total soluble phosphate, iron, manganese and ph. The calcium and magnesium contents of groundwaters commonly varied very little, and iron and manganese were often recorded in only very low concentrations (0.10 ppm and 0.05 ppm respectively).

A brief study of ph values for the water-table aquifer in the Vernon Creek fan displayed a gradual increase from a low of about 6.5 towards about 6.9 with a further increase to about 7.5 in the direction of groundwater movement to Wood Lake. In the area south of Wood Lake there is no marked variation in nutrient concentrations of the water-table and confined aquifers (Appendix D, Nos 1 to 8). Nitrogen values of groundwaters in much of the study area range between 2 to 5 ppm and for total soluble phosphate the concentration is often close to 0.01 ppm (Appendix D, Nos 9 to 12). The graphs selected for Appendix D are shown to illustrate some of the results obtained from the nutrient study of groundwaters in the Kalamalka-Wood Lake Basin. The above selection includes observation wells specially installed for this program and some existing water wells (Fig. 6).

Analyses of water samples collected in 1969 from a flowing well (producing about 3/4 cfs) which penetrated aquifers between 140 and 200 feet deep showed low nutrient concentrations for deep groundwaters. Total nitrogen averaged 0.12 ppm and total phosphate averaged 0.03 ppm.

CONCLUSIONS

The present information available on the bedrock and surficial geology, water-well data, hydrograph records and chemical analyses of groundwaters permits a reasonable interpretation of the regional hydrogeology from the south end of Kalamalka Lake to the south end of Ellison Lake.

The bedrock comprises mainly low permeable metamorphic and intrusive igneous rocks and some conglomerate and basalt. The overlying surficial deposits are mainly sand and gravel with some till on the east and west sides of the valley, commonly less than 50 feet thick. The thickness of the overburden in the valley bottom is known to be 530 feet thick near Winfield. The strata comprises a sequence of till; or silt, sand and gravel; with some lacustrine deposits of clay, silt and sand.

The main aquifer in the area is considered to be sand and gravel mainly within the depth range of about 100 to 200 feet below ground surface. It is known only between Wood and Ellison Lakes along the west side of the valley and just to the east of Winfield Creek. The present interpretation of the hydrogeology suggests that most of the groundwater in this part of the area moves through this aquifer. Underflow figures approximating 5 cfs have been calculated. This agrees with surface water losses (Coulson, 1973) in the Vernon Creek-Ellison Lake area, which are equivalent to a flow of 4.8 cfs. This area is considered the main recharge area for the valley floor deposits. About half of the flow through this aquifer is discharged by Winfield Creek.

The main source of inflow from the east side of Wood Lake appears to be as return groundwater flow from irrigation water. The calculated return flow amounts to about 28% of the applied water for the 1973 season. In the Winfield Creek basin return flow is calculated as being less than 1%. For qualifying remarks on this 1% figure the reader is referred to page 23. Because of this anomalously low result this figure is only reported and is not applied elsewhere in the study for return flow calculation purposes. However, the results available represent only very early attempts to assess return flow directly by groundwater studies. The above figures should be considered as only tentative at this stage. By combining groundwater flow calculations with average nutrient concentrations for total nitrogen and total soluble phosphate only low quantities of these constituents appear to be entering Wood Lake. Data is too limited to make estimates for quantity of flow into Kalamalka Lake except for the main aquifer at the south end of Wood Lake, which may discharge 1½ to 2½ cfs directly into this lake. The actual concentrations of the nutrients in deep aquifers which may be discharging water into Kalamalka Lake at the south end of Vernon Creek valley is moderately low and from the Coldstream Valley is quite low. So even if underflow is moderately high, groundwater may not be a serious source of pollution to lakes in the Kalamalka-Wood Lake Basin when compared to surface water sources. A summary of the anticipated quantity of nitrogen and total soluble phosphate entering Kalamalka, Wood and Ellison Lakes is given below:

Summary of Nutrient Input to Kalamalka, Wood and Ellison Lakes

Aquifer(s) Source	To Lake	Total Nitrogen (N) (lbs/yr)	Total Soluble Phosphate (P) (lbs/yr)
Confined (163'-200')	South End Kalamalka	3,240	270
Water Table & Confined	South End Wood	260	7
Water Table	East Side Wood	8,814	37.5
Water Table & Confined?	Ellison	200	20

RECOMMENDATIONS

It is recommended that some consideration be given to further improving knowledge of groundwater hydrology in the Kalamalka-Wood Lake Basin. Two specific aspects requiring better understanding seem worthy of further study. These are (1) groundwater return flow from irrigation, (2) the areal extent of the main aquifer and its hydrologic properties. Both studies would include test drilling and aquifer testing of three deep wells in the main valley, and about five wells in Ribbleworth Creek basin, and fully instrumented observation wells. Also gauging of some carefully selected small streams as in the case of Ribbleworth Creek which are of groundwater origin, could probably lead to a much better understanding of groundwater movement, quality and yield in an area. This work could be combined with continued systematic hydrogeological mapping in the Kelowna area. This suggestion is put forward with the intention of conducting regional groundwater programmes - well inventorying, sampling of groundwaters for chemical analysis, study of field features, etc., - for the purpose of more knowledge of groundwater movement and resources, and combining this work with some practical work such as test drilling and possibly minor groundwater investigations. It is also known that requests for groundwater studies in the Rutland area have been made to the Water Investigations Branch.

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NOTES ON THE OCCURRENCE OF GROUND WATER AT WOODS LAKE IMPROVEMENT DISTRICT AND RECOMMENDATION FOR FURTHER INVESTIGATION

On instructions from Mr. V. Raudsepp, Chief Engineer, Water Investigations Branch, I spent several days in the field in June in the area of the Woods Lake Improvement District to determine, if possible, whether there might be a suitable source of ground water for winter domestic supply for the rebuilt combined irrigation-domestic system now being considered. Mr. Towgood, Chairman of the District and Mr. Webber of the Water Rights Branch, pointed out that additional land, mostly under cultivation, not now in the District, could be brought into the District if enough ground water could be found to serve as a source for irrigation of this land. This land is mostly at the south end of the present District.

The area is underlain by metamorphic rocks of the Monashee Group with a very irregular "benched" surface overlain in part by Pleistocene sediments mostly sand with minor gravel. Till underlies the gravel in some places according to well records but can be seen on surface only at the south end. The bedrock topography was very important in determining the thickness and to some extent the character of the overlying Pleistocene deposits which may be aquifers in some places.

To the east, the metamorphic rocks are overlain by gravel and sand which is in turn overlain by basalt flows probably part of the Kamloops group of Oligocene or Miocene age. The contact of this gravel and sand with the underlying rock is at an elevation about 3,200 feet in the Woods Lake area.

The map included with this memo shows all the outcrop I was able to find and a number of other topographic features. The part at the south end is probably more speculative than the northern part.

The distribution of the Pleistocene sediments over the bedrock was controlled mostly by two factors namely the supply of material available at a given time and the level of the lake occupying the valley at that time. The source of sand and gravel in this area was melting ice of the retreating glaciers. In the opinion of Nasmith and Fulton who have done work on this area, the last ice in this area was left in the main valleys. I think the reverse may be true and there may have been ice in the high area to the east after all ice has melted from the main valleys. Numerous exposures in this area show bedding in the sand always dipping away from the valley wall. Contortion and slump structures which are usually found in gravels deposited against a valley wall from valley ice are absent.

When a large supply of sand and gravel was moved into the valley, deposition was largely localized at the edge of the lake filling the valley at that time. When lake level was stable for a long period, deltas were formed. When deposition took place while the lake level was falling sloping terraces were formed. The shape and size of these features is, of course, dependent on the topography of the surface on which deposition took place.

In the Okanagan Valley, deltas were formed at an elevation of about 1,600 feet. Evidence in many places indicates that deposition probably started when the lake level was above 1,600 feet perhaps as high as 1,775 feet. Some of these terraces or raised deltas are quite large near tributaries which supplied much sediment. Many of them are kettled showing that ice was buried in the sand and gravel of which the deltas are composed. There are other less prominent terraces below 1,600 feet in some places. There are also other terraces and deltas above about 1,775 feet some as high as 2,200 feet but these are seldom prominent. In many places, they are extensively dissected and remain only as small remnants. They may be older than the terraces below 1,775 feet but were probably formed under very similar conditions.

The terraces, as described above, are present in the Woods Lake area and may serve as aquifers. Four main factors determine the capacity of such terraces as aquifers. These are the character of the material, the thickness of the material, how much of it is saturated and how much water is recharged. In this area, all exposures especially those in the several gravel pits show that the outwash of which the lower terraces are composed, is mostly medium grained sand with minor gravel. It seems to be quite free of silt and clay and should have a high permeability.

The thickness of sand on the several terraces in the area is unknown as there is no sub-surface information on these terraces. In some places rock outcrops on the terraces; this tends to indicate that the thickness of sand is thin but this is inconclusive because the bedrock topography is unknown.

A number of well records gives some idea of thicknesses of sand and gravel off the main terraces. Many are shallow dug wells which stop in gravel but there are three fairly deep wells near the north end which show significant thickness of gravel. All of these are on the sloping fronts of terraces. A drilled well at the intersection of Easthill Road and Todd Road penetrated 78 feet of gravel and sand over till. A dug well on the east side of Middle Bench Road about 1,000 feet south of Easthill Road, encountered 63 feet of sand over till. Another dug well about 1,000 feet further south went through 60 feet of sand. Other wells show up to about 32 feet of sand.

The thickness of saturated sand is dependent on the topography of the underlying impermeable bedrock, the permeability of the material, and the rate of recharge. All of these factors in this case are relatively unknown.

Recharge in the terrace deposits in summer is from irrigation water including slight ditch leakage and in winter from direct precipitation and from water moving downslope from the east over relatively impermeable rock or till. From some information on hand about fluctuation of springs, creeks and water levels in wells, the recharge by irrigation water is probably much greater than by precipitation.

On the map I have shown terraces using three colours. The two lower ones coloured green and yellow are probably both part of the "1,600-foot terrace" although there seems to be two levels, one at 1,600 feet to 1,675 feet, and the other around from about 1,675 to about 1,775 feet. The other terraces coloured orange are from 1,900 feet to 2,000 feet. The orange area east of Woodsdale may not be a true terrace at all.

If a permeable terrace is built out over a sloping bedrock surface one would expect that it will probably be well drained and the saturated thickness will be small. If it is built on a bedrock bench or in a small depression, one would expect the drainage to be slow and that it might be more favourable as an aquifer. One indication of this may be a fairly high static level, so in trying to determine a favourable location for testing on these terraces a high static level may be a valid criterion.

At the south end of the Irrigation District are several moraine ridges and a large fan. Moraine ridges are not found in the northern part of the map but are very common further south toward Winfield. The Moraines are fresh-looking with bouldery surfaces. I think they may be related to ice moving down toward the valley from the east but this is in direct disagreement with Nasmith and Fulton who believe that the last ice in this area was in the main valleys.

The moraines are partly buried by a large fan and by slopewash from the steep slope above. For this reason, it is difficult to determine the maximum westward extent of these features. A few road cuts show that they are composed of an unsorted material much like sandy till but less compact.

There are no sub-surface exposures on the main part of the fan. The gravel pit on the southwest corner of the lower part of the fan shows sandy gravel. Several exposures near springs near points 20 and 16 show sand and sandy gravel; this is probably fan gravel partly burying the moraine.

The upper part of the fan seems to be impounded against the moraine ridges. The lower part may have formed when continued deposition caused the upper part of the fan to spill over the moraine forming the lower part. The lower part may also be partially behind another set of moraine ridges. Under these conditions, the upper (and possibly also the lower) part of the fan may contain water dammed by the less permeable moraine ridge. The thickness of saturated material, etc. cannot be estimated from data on hand.

The fan at present is supplying water to a number of springs which are used for irrigation and domestic water in this area. A spring at the upper end of the fan along with several along the moraine ridge near points 16 and 20 are used to irrigate land below. The water collected from all three is estimated to be about 30-40 gallons per minute. This is only part of the discharge and there are other discharge areas (marked DA on the map) to the west. These springs may be considered overflow from the aquifer if it contains water ponded behind the moraine ridges.

In this area all the recharge for this fan is by natural means in contrast to the recharge of the terraces by irrigation water as discussed above. A source of recharge here which has not been described is from the Tertiary (?) gravels under the volcanic flows which occur just to the east. In these gravels there are two (or more) adits which were driven in search of placer gold. These are described by Jones as being at the base of the gravels but the two I saw are certainly not at the base but are in gravelly beds in an interbedded series of silt, sand and gravel. One adit is about 150 feet long, the other of unknown length. Water is flowing from one at several gallons per minute - the portal of the other is enclosed and any water cannot be seen. From this, I believe that these sediments are discharging a significant quantity of water toward the valley. This water would run down the slope and would be collected at the foot of gulleys by fans.

If the fan is impounded behind the moraine as I suggest the place to drill is just above the moraine where the thickness of the fan is likely to be a maximum. It is probably also worth while to test the lower part of the fan which may also be fairly thick. One advantage of water from this fan is that it could be conveyed by gravity to any part of the proposed system.

An effort should be made to check water quality of any holes drilled in the terraces to make sure that it is not contaminated with insecticide residues or nitrates from fertilizer. This is unlikely as enough water has been used from wells and springs in this area so that such a problem would probably be known.

I recommend that some rotary test drilling be done in this area. First, however, I think we should consider investigating the thickness of gravel present on the various terraces by means of the hammer seismograph which we have borrowed in the past from the Testing Branch of B.C. Department of Highways. Under these conditions, it should be able to determine gravel thickness as great as 50 feet or 60 feet. It may be possible with this to determine the water table as saturated gravel has a higher velocity than dry gravel.

The rotary drilling followed by electric logging of holes would be to determine the nature of the gravels and their thickness. To check water quality, a small casing could be put in certain holes and enough water pumped out for a test of water quality. If conditions are found to be favourable for wells, a test well could then be constructed using cable tool equipment.

I think we should concentrate on the "1,600-foot" terraces and the fan at the south end using the hammer seismograph. The terrace coloured yellow on the map along Middle Bench Road should be tested near the point (A) on the map. South of this, the terrace coloured green on the map should be tested near (B) and at Ribbleworth Creek marked (C). South of Ribbleworth Creek, the terrace coloured yellow should be tested near Trewhitt Road and Oyama Road near point (D).

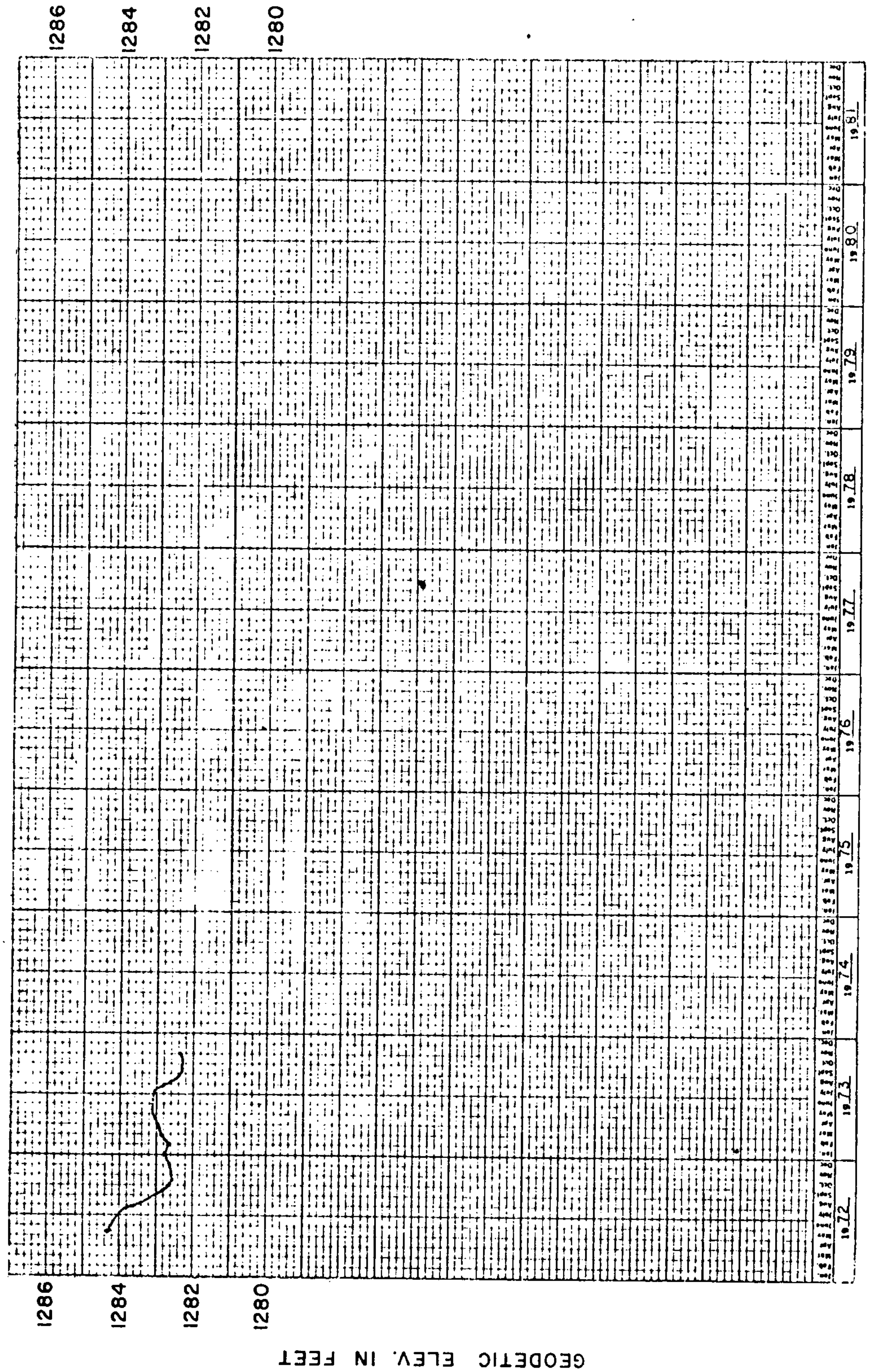
The fan at the south end should be tested just above the moraine ridges point (E) and if this is not favourable, the lower part near (F) could also be tested.

Following this, three rotary drill holes should be drilled at the most favourable locations with at least one hole in the fan at the south end.

E. Livingston, Chief
Groundwater Division
(July, 1966)

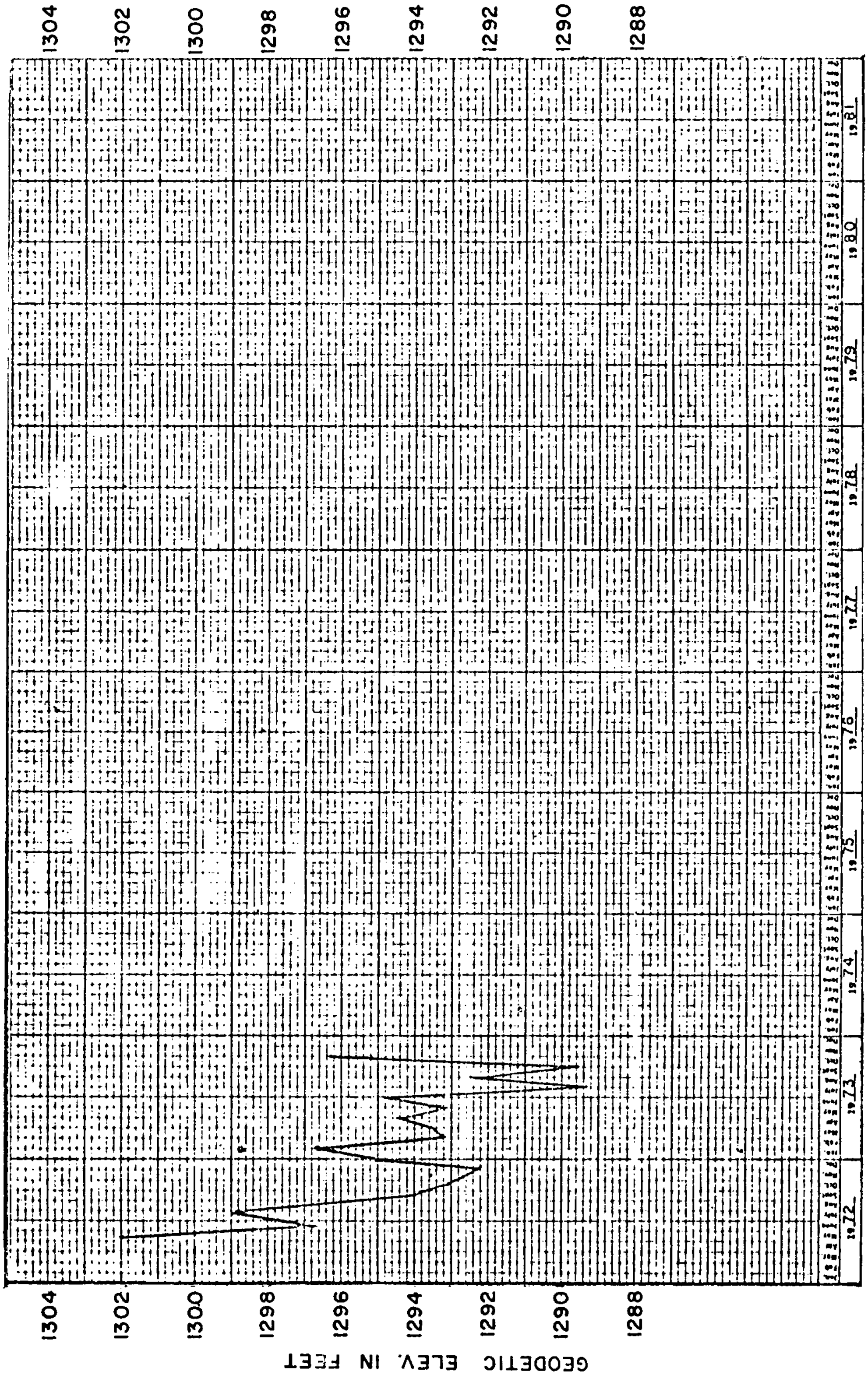
APPENDIX B

SELECTED WATER-WELL HYDROGRAPH RECORDS



HYDROGRAPH
No. I
C 47 No. 29
Z7 X6 Y29 No. 83

BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH		TO ACCOMPANY REPORT ON **KALAMALKA WOOD LAKE BASIN**
SCALE: VERT. .... HOR.	DATE MAR. 15 / 1974	E. GORDON Le BRETON GEOLOGICAL ENGINEER FILE No. .... DWG. No. ....



HYDROGRAPH
No. 2
C 48 No. 7
Z8 X6 Y15 No. 3

BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

TO ACCOMPANY REPORT ON

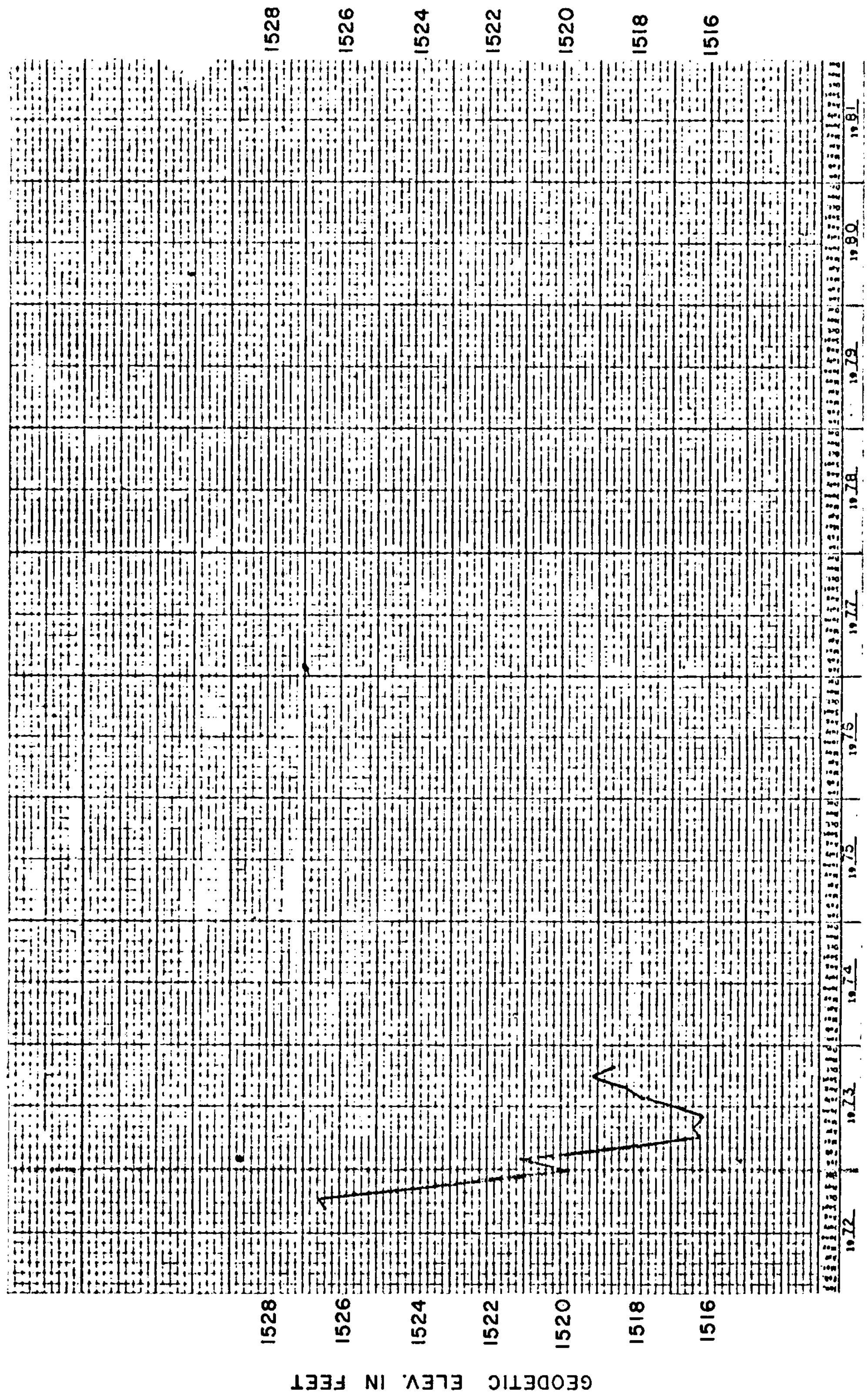
KALAMALKA \OOD LAKE BASIN

SCALE: VERT. ....
HOR. ....

DATE
MAR. 15 / 1974

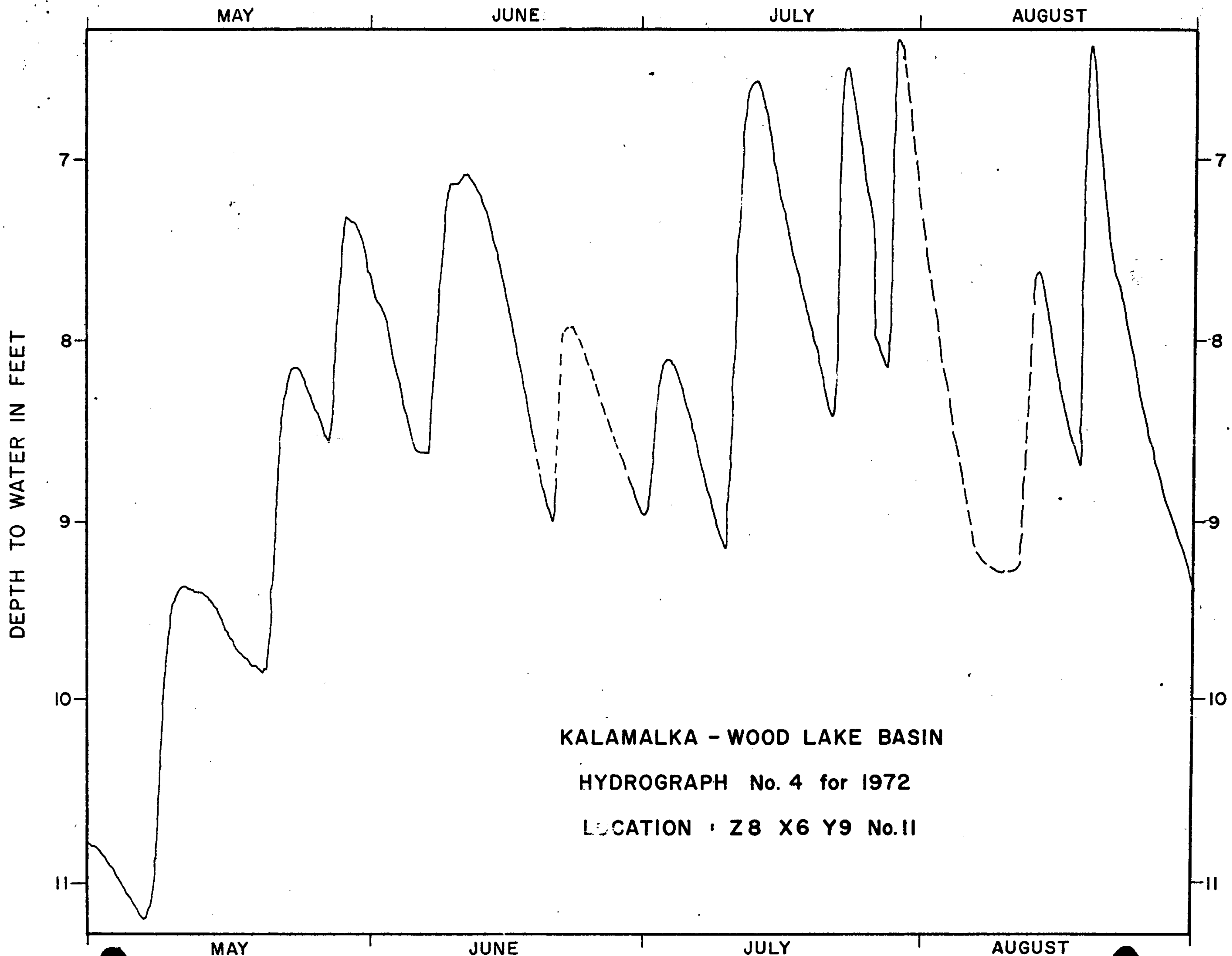
E. GORDON Le BRETON GEOLOGICAL ENGINEER

FILE No. .... DWG. No. ....



HYDROGRAPH
No.3
C 49 T.H.7
Z7 X6 Y30 No. 24

BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON **KALAMALKA WOOD LAKE BASIN**
SCALE: VERT. .... HOR. .... — DATE MAR. 14 / 1974	E. GORDON Le BRETON GEOLOGICAL ENGINEER FILE No. .... DWG. No. ....


MAY
JUNE
JULY
AUGUST
DEPTH TO WATER IN FEET
7
8
9
10
11
KALAMALKA - WOOD LAKE BASIN
HYDROGRAPH No. 4 for 1972
LOCATION : Z8 X6 Y9 No.11

APPENDIX C

TABLES OF GROUNDWATER FLOW AND NUTRIENT INPUT CALCULATIONS

Table 1 a

Winfield Creek Basin Analysis

C49 TH4 Summary of Pump Test Results

(Well Z7X6Y30 No. 26)

Type of Well	Transmissivity US gpd/ft	Remarks
Pumped	7.85×10^4	Pumping rate 54 US gpm Aquifer thickness 74 feet Length of test 48 hours
Observation No. 1	1.345×10^5	Average k 1.59×10^3 US gpd/ft^2 excluding Observation Well No. 3. There is no obvious reason for low T value to Well No. 3.
Observation No. 2	1.40×10^5	Distances of observation wells from the pumping well are: Well No. 1 50 feet
Observation No. 3	3.17×10^4	Well No. 2 100 feet Well No. 3 217 feet
Aver.	1.59×10^3	

Table 1 b

Groundwater Flow Calculations

for Winfield Creek Basin

Calculation No.	K US gpd/ft²	I ft/ft	A(sq.ft) Width x Thickness	Flow US gpd	Flow cfs
1.	1.59×10^3	5.175×10^{-3}	$5.0 \times 10^3 \times 2.5 \times 10^{-1}$	1.03×10^4	0.016
2.	1.59×10^3	5.175×10^{-3}	$5.0 \times 10^3 \times 1.0 \times 10'$	4.11×10^5	0.64
3.	1.59×10^3	5.175×10^{-3}	$2.0 \times 10^3 \times 2.0 \times 10'$	3.3×10^5	0.50

Notes: Calculation No. 1 shows return flow to Winfield Creek.
Calculation No. 2 shows flow to Winfield Creek from West Valley side.
Calculation No. 3 shows flow to Winfield Creek along line of plotted "streamlets".

Table 2

Return Flow from Ribbleworth Creek Basin

Months	Flow (cfs)	Base Flow (cfs)	Return Flow (cfs)
May	0.030	0.030	-
June	0.130		0.100
July	0.364		0.334
August	0.395		0.365
September	0.438		0.408
October	0.400		0.370
November	0.130		0.100
		Aver.	0.2795

Notes: Use a return flow figure of 0.28 cfs.

Figures from May to September are for measured flows. For October and November, the figures have been assumed.

Table 3

Basic Data for Groundwater Flow Calculations for Confined Aquifers South End of Wood Lake

Zones in feet	Well Location & No.	Well Depth (in feet)	Head (in feet)	Transmissivity (T) US gpd/ft	Permeability (K) US gpd/ft^2	Aquifer thickness (feet)	Q (gpm)	
A (15-30)	C49 TH1	30	4	-	(20)	15	-	
B (45-50)	-	40 to 50	-	-	(20)	5	-	
C (60-115)	34	60	4.6	280	6		3.3	P
C	35	68	2.3	490	11		1.25	F
C	19	90	11.9	1,460	32	45	2.25	F
C	28	90	17.1	660	15		1.7	F
C	4.3	90	11.6	1,025	23		3.3	F
C	10	116	2.9	220	5		2	F

Notes: P - Calculations based on pumping test.

F - Calculations based on free flow rates.

Permeability values in brackets are assumed values.

All wells are located in Z 7 X 6 Y 29.

Table 4 a

Water Table Aquifer, South End of Wood Lake

Groundwater Flow Calculations

Calculation No.	K (US gpd/ft^2)	I (ft/ft)	A(Sq ft) Width x thickne	Q (Flow) US gpd	cfs
1	1.0×10^1	5.5×10^{-3}	$5.0 \times 10^3 \times 2$	5.5×10^2	0.0009
2	1.0×10^2	5.5×10^{-3}	$5.0 \times 10^3 \times 5$	1.38×10^4	0.02

Notes: K value from pump test on C49 TH5 (Z7X6Y29No.83) is not applicable because the pumping well is completed in a hydrologic system continuous with that of the lake water. Therefore, a K value was assumed.

In Calculation No. 1 a minimum saturated thickness of 2 feet was used for the aquifer and in Calculation No. 2 a thickness of 5 feet was used.

Table 4 b

Water Table Aquifers, South End of Wood Lake

Nutrient Input Calculations

Calculation No.	Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/yr)	Aver. P* (ppm)	Tot. Sol. P (Input) (lbs/yr)
1.	0.0009	3.21	6	0.033	0.1
2.	0.02	3.21	128	0.033	0.7

Notes: P* = Total Soluble Phosphate (as P) N = Total Nitrogen

Analyses for this aquifer are available from 7 sites. All 7 were used for deriving an average value for Total Nitrogen (as N). One site showing an anomalously high average for Total Soluble Phosphate was rejected.

Table 5 a

Confined Aquifers between 15 and 115 feet deep

South End of Wood Lake

Groundwater Flow Calculations

Zone (in feet)	K (US gpd/ft^2)	I (ft/ft)	A (Sq ft) Width x thickness	Q (Flow) US gpd	cfs
A (15-30)	20?	5.5×10^{-3}	$5.0 \times 10^{2} \times 1.5 \times 10^{1}$	(1.1×10^{3})	(0.002)
B (45-50)	20?	5.5×10^{-3}	$5.0 \times 10^{2} \times 5$		
C (60-115)	15	5.5×10^{-3}	$3.2 \times 10^{3} \times 4.5 \times 10^{1}$	1.2×10^{4}	0.02

Note: For Zones A & B Quantity of flow is based on K = 20 US gpd/ft^2 assumed, I is measured, and A is estimated (Table 3).

Table 5 b

Confined Aquifers between 15 and 115 feet deep

Nutrient Input Calculations

Zone	Flow cfs.	Aver. N ppm	N Input (lbs/yr)	Aver. P (ppm)	Tot. Sol. P Input (lbs/yr)
A&B	0.002	4.13	16	0.07	0.3
C	0.02	2.80	116	0.16	6

Notes: N = Total Nitrogen
P = Total Soluble Phosphate

Nutrient input for Zones A & B is based on chemical analyses for three sites for Zone B and on 5 sites for Zone C. No corrections have been made for partial penetration and the average K value of 15 US gpd/ft^2 is considered too low for wells reported to be completed in sand. The flow values are probably low by one order of magnitude.

Table 6 a

Confined Aquifer, 163-200 feet deep

South End of Wood Lake

Groundwater Flow Calculations

Calculation No.	K (US gpd/ft^2)	I (ft/ft)	A (Sq ft) Width x thickness	Q (Flow) US gpd	cfs
1.	1.59×10^3	5.5×10^{-3}	$5.0 \times 10^3 \times 4.0 \times 10'$	1.75×10^6	2.7
2.	1.0×10^3	5.5×10^{-3}	$5.0 \times 10^3 \times 1.0 \times 10^2$	2.75×10^6	4.1

Notes: In Calculation No. 1 the K value is taken from C497 [illegible]4 pump test; I is measured between wells Z 7, X 6, Y 17, No. 8 and Z 7, X 6, Y 29, No. 30, and aquifer thickness is chosen after reference to a well log and E log for Z 7, X 6, Y 29, No. 32

In Calculation No. 2 for test hole Z 7, X 6, Y 17, No. 23, a K value is assumed for an aquifer 100 feet thick consisting of silt, sand and gravel.

In both cases it is assumed that the aquifer extends the full width of the valley.

Table 6 b

Confined Aquifer, 163-200 feet deep

South End of Wood Lake

Nutrient Input for Calculation No. 1, Table 6a

Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/yr)	Aver. P. (ppm)	Total Sol. P. Input (lbs/yr)
2.7	0.63	3,240	0.05	270

Notes: N = Total Nitrogen

P = Total Soluble Phosphate

Table 7 a

Ribbleworth Creek Basin Flow

Data for "6-Month Irrigation Flow" Calculation

Months	Flow (cfs.)	Measured (M) Assumed (A)
June	0.130	M
July	0.364	M
August	0.395	M
September	0.438	M
October	0.400	A
November	0.130	A
Aver.	0.31	

Table 7 b

Nutrient Input for "6-Month Irrigation Flow"

on Ribbleworth Creek

Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/½yr)	Aver. P. (ppm)	Tot.Sol.P. Input (lbs/½yr)
0.31	3.01	933	0.03	9

Notes: N = Total Nitrogen

P = Total Soluble Phosphate

Table 8

La Fleche Creek Basin Flow

Nutrient Input for "6 Month Irrigation Flow"

Months	Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/½yr)	Aver. P. (ppm)	Tot.Sol.P. (lbs/½yr)
June-November	0.21	3.59	755	0.02	4

Table 9

Mazey Creek Basin Flow

Nutrient Input for "6-Month Irrigation Flow"

Months	Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/½yr)	Aver. P. (ppm)	Tot.Sol.P (lbs/½yr)
June-November	0.035	3.23	114	0.06	2

Notes: N = Total Nitrogen

P = Total Soluble Phosphate

Table 10 a

Groundwater Flow North of Ribbleworth Creek Basin

East Side of Wood Lake

(a) Using 28% return flow from irrigation, the flow is 1.75 cfs. This figure is derived from 1694 acre feet of water (U.B.C. data) applied during a period of 135 days.

(b) Average Total Nitrogen (as N) 3.5 ppm.

(c) Average Total Soluble Phosphate (as P) 0.01 ppm.

Table 10 b

Groundwater Flow North of Ribbleworth Creek Basin

East Side of Wood Lake

Nutrient Contribution from Irrigation

Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/½yr)	Aver. P. (ppm)	Tot.Sol.P. Input (lbs/½yr)
1.75	3.5	6,125	0.01	17.5

An allowance is also made for a base flow of ¼ cfs for the entire east side of Wood Lake. The additional nutrient inflow is tabulated below:

Table 11

East Side of Wood Lake

Nutrient Input from Base Flow

Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/½yr)	Aver. P. (ppm)	Tot.Sol.P. Input (lbs/½yr)
0.25	3.55	887	0.02	5

Notes: N = Total Nitrogen

P = Total Soluble Phosphate

Table 12 a

Ellison Lake Basin

Nutrient Contribution from Irrigation

Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/½yr)	Aver. P. (ppm)	Tot.Sol.P. Input (lbs/½yr)
0.90	0.20	180	0.02	18

Table 12 b

Ellison Lake Basin

Nutrient Contribution from Base Flow

Flow (cfs)	Aver. N. (ppm)	N. Input (lbs/½yr)	Aver. P. (ppm)	Tot.Sol.P. Input (lbs/½yr)
0.1	0.20	20	0.02	2

Notes: N = Total Nitrogen

P = Total Soluble Phosphate

Table 13

Summary of Nutrient Input to Kalamalka,

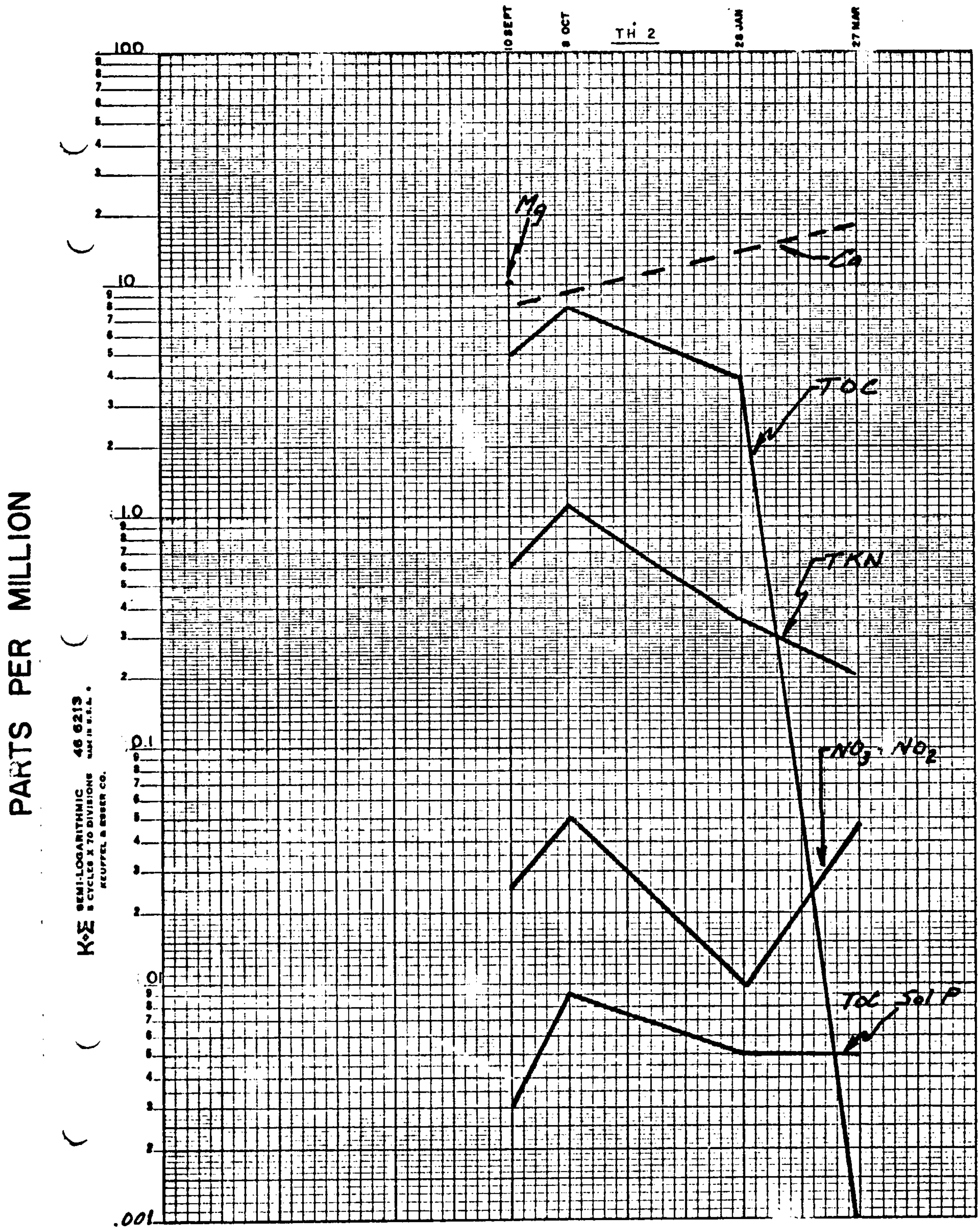
Wood and Ellison Lakes

Source	Total Nitrogen (N) (lbs/yr)	Total Soluble Phosphate (P) (lbs/yr)
Water Table Aquifer South End of Wood Lake	128	0.7
Confined Aquifers South End of Wood Lake	16 116	0.3 6
Confined Aquifer 163'-200' South End of Wood Lake	3,240	270
Ribbleworth Creek Basin	933	9
La Fleche Creek Basin	755	4
Mazey Creek Basin	114	2
Basin Irrigation, North of Ribbleworth Creek Basin	6,125	17.5
Base Flow, East Side of Wood Lake	887	5
TOTALS	12,314	314.5
Ellison Lake Basin	200	20

APPENDIX D

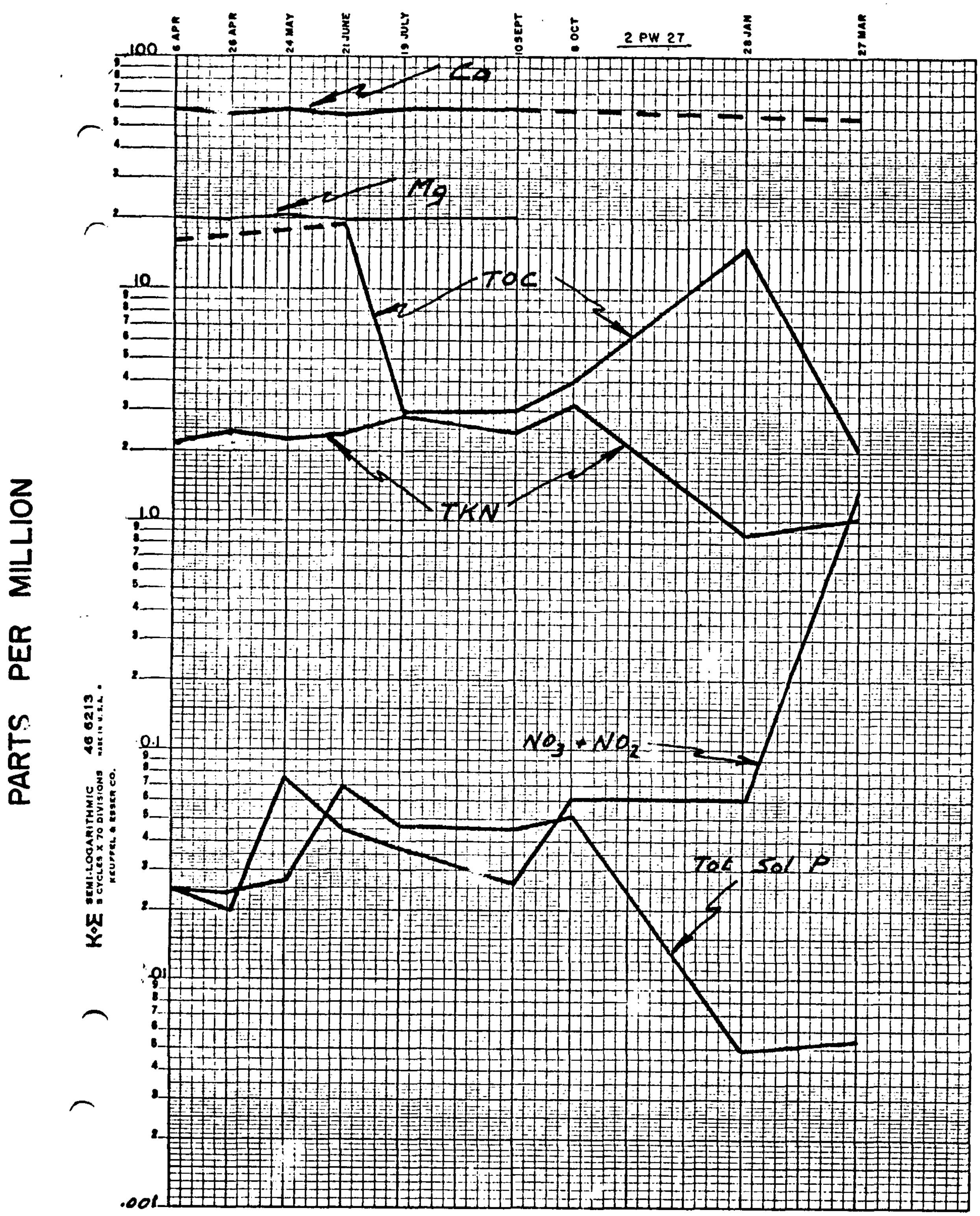
SELECTED NUTRIENT GRAPHS

Well Location Z7 X6 Y29 #78 Depth 17 Feet



BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON Kalamalka-Wood Lake Basin Study Nutrient Graph
SCALE: VERT. .... HOR. .... — DATE	E.G. Le Breton, Geological ENGINEER FILE No. .... DWG. No. ....

Well Location Z7 X6 Y29 #81 Depth 20 Feet



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WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

TO ACCOMPANY REPORT ON

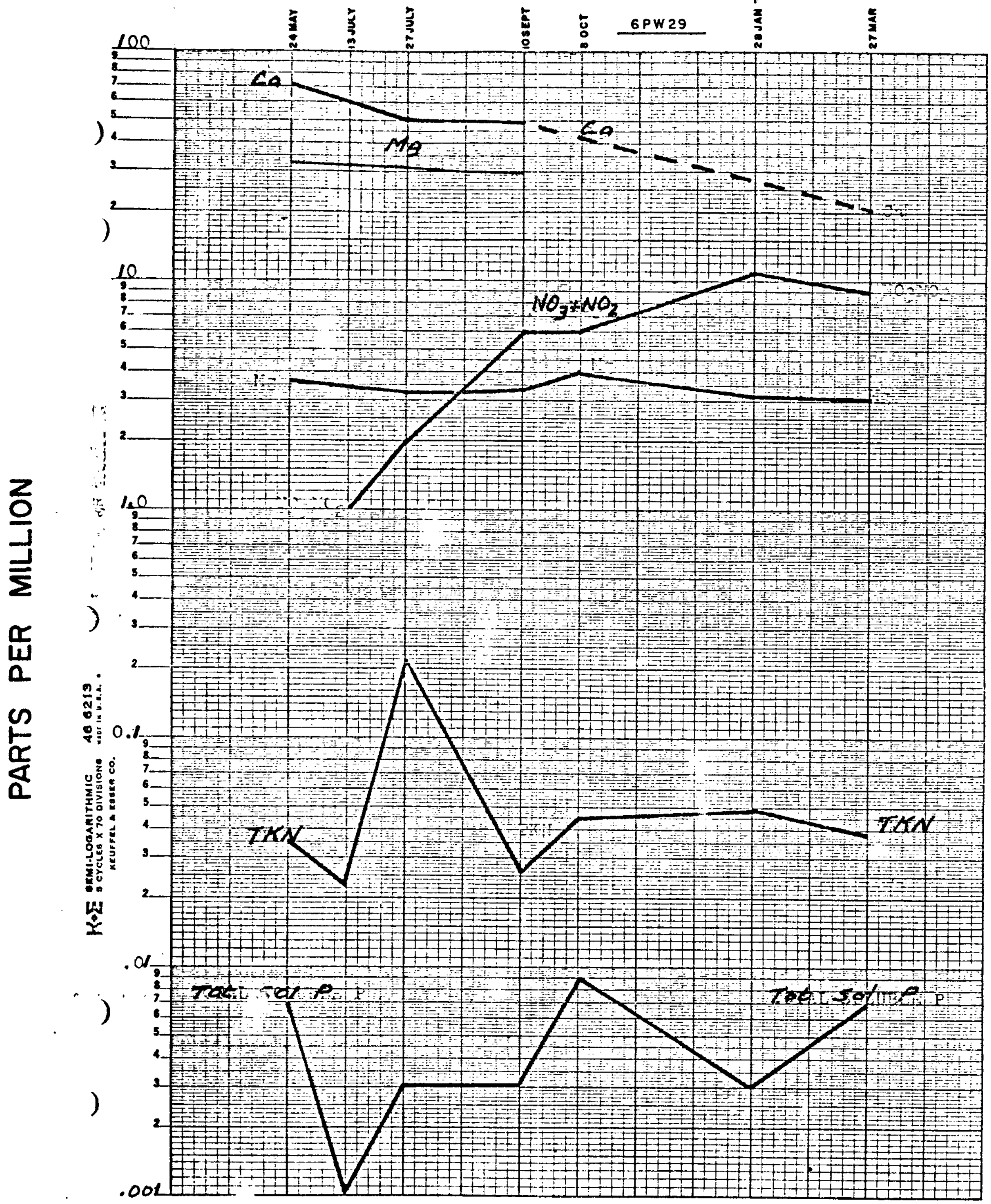
Kalamalka-Wood Lake Basin Study
Nutrient Graph

SCALE: VERT.
HOR.
DATE

E.G. Le Breton, Geological ENGINEER

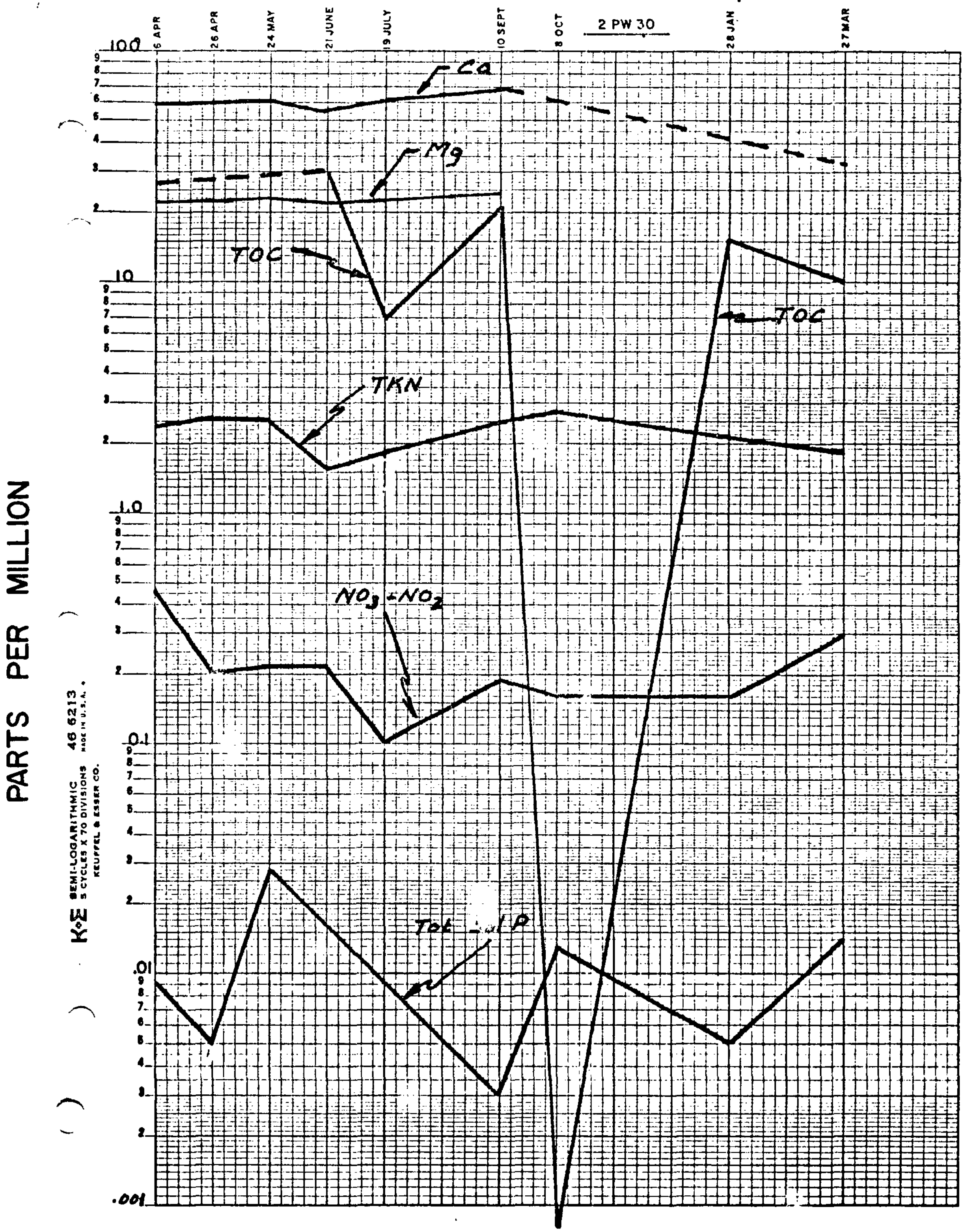
FILE No. DWG. No.

Well Location Z7 X6 Y29 #83 Depth 20 Feet



BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON Kalamalka-Wood Lake Basin Study Nutrient Graph
SCALE: VERT. .... DATE HOR.	E.G. Le Breton Geological ENGINEER FILE No. .... DWG. No. ....

Well Location Z7 X6 Y29 #84 Depth 12.0 Feet



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WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

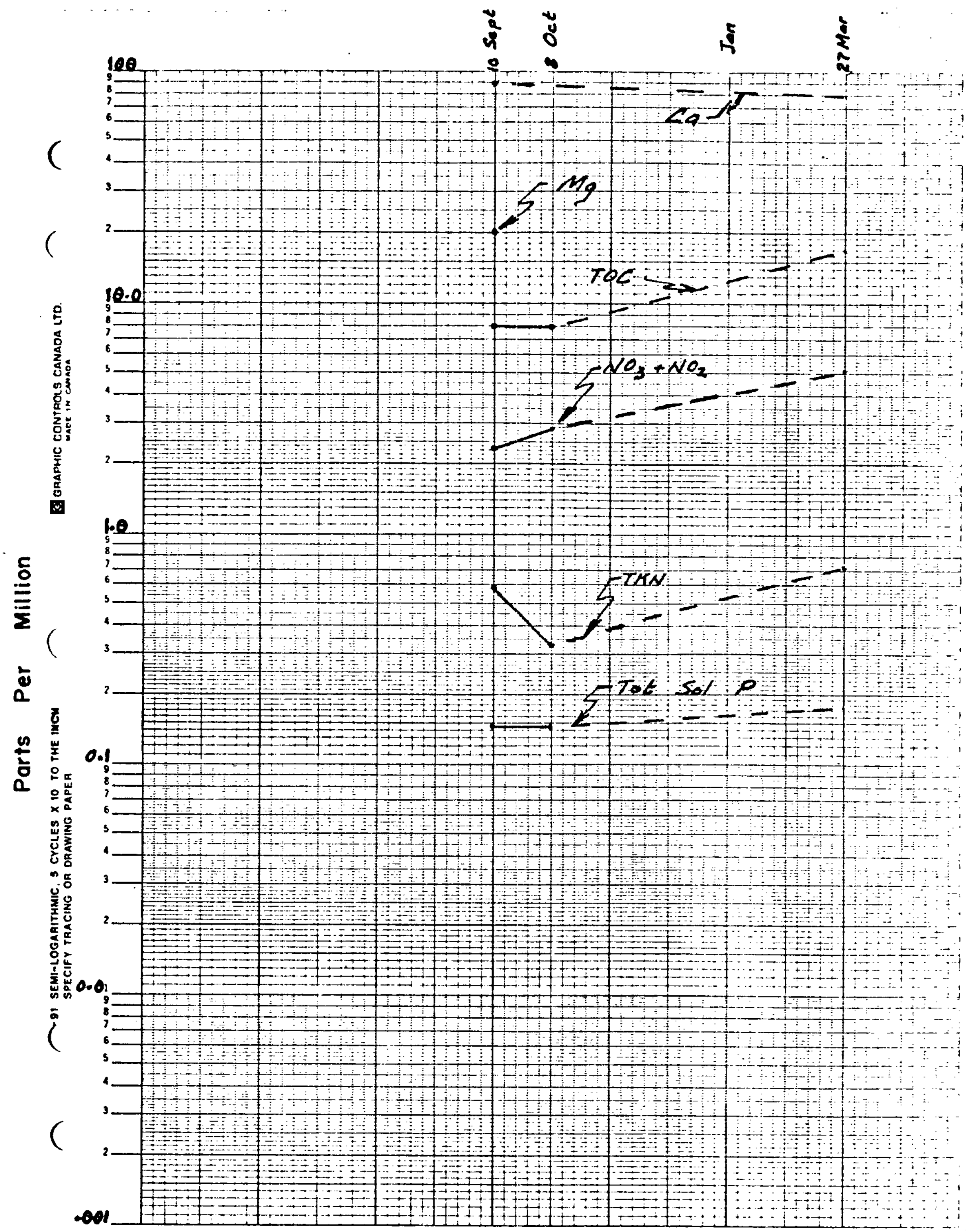
TO ACCOMPANY REPORT ON
Kalamalka-Wood Lake Basin Study
Nutrient Graph

SCALE: VERT.
HOR.
DATE

E.G. Le Breton, Geological ENGINEER

FILE No.
DWG. No.

Well Location Z 7 X6 Y29 No. 4 Depth Spr. Feet



BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

TO ACCOMPANY REPORT ON

Kalamalka-Wood Lake Basin Study
Nutrient Graph

SCALE: VERT.

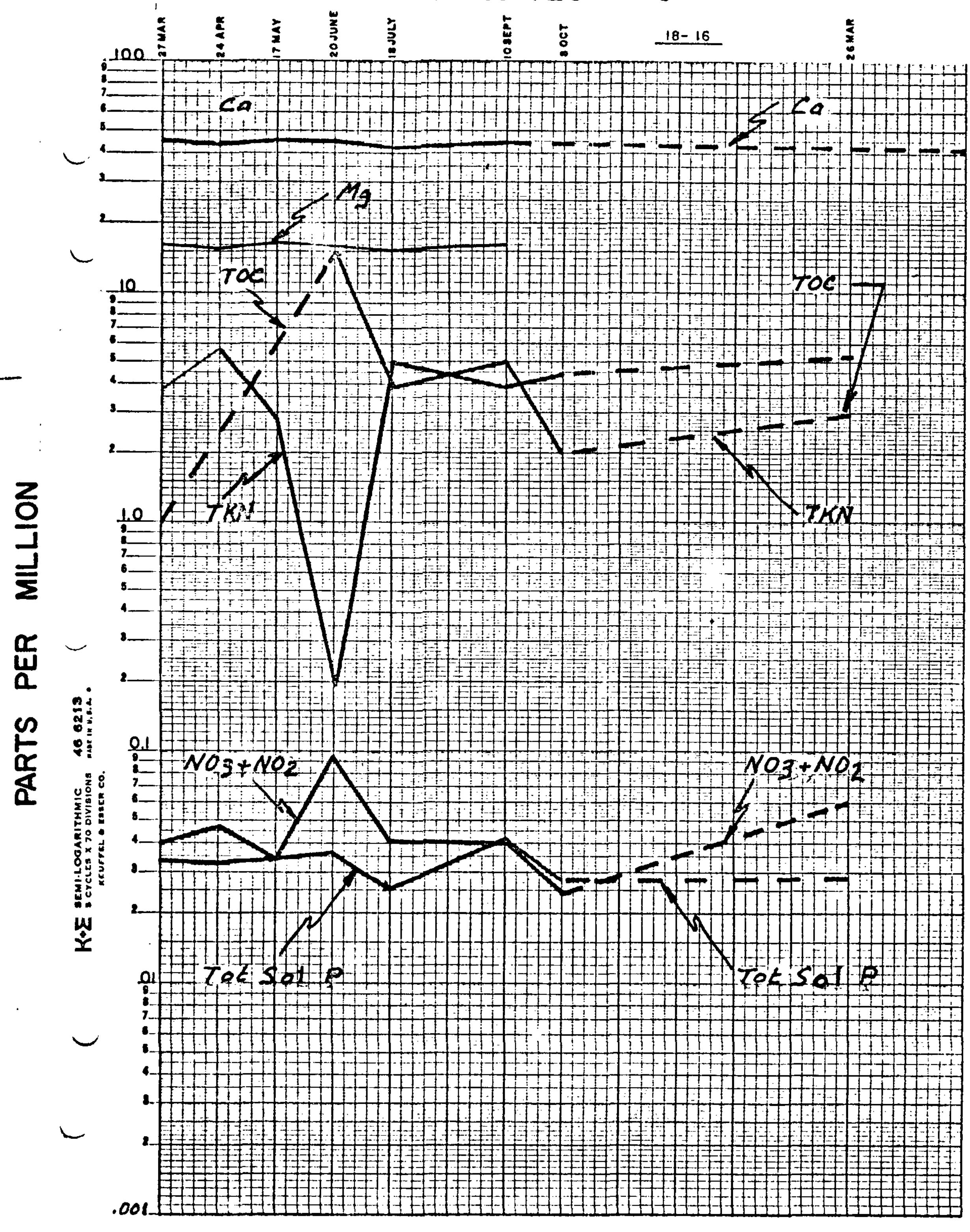
HOR.

DATE

E.G. Le Breton, Geological ENGINEER

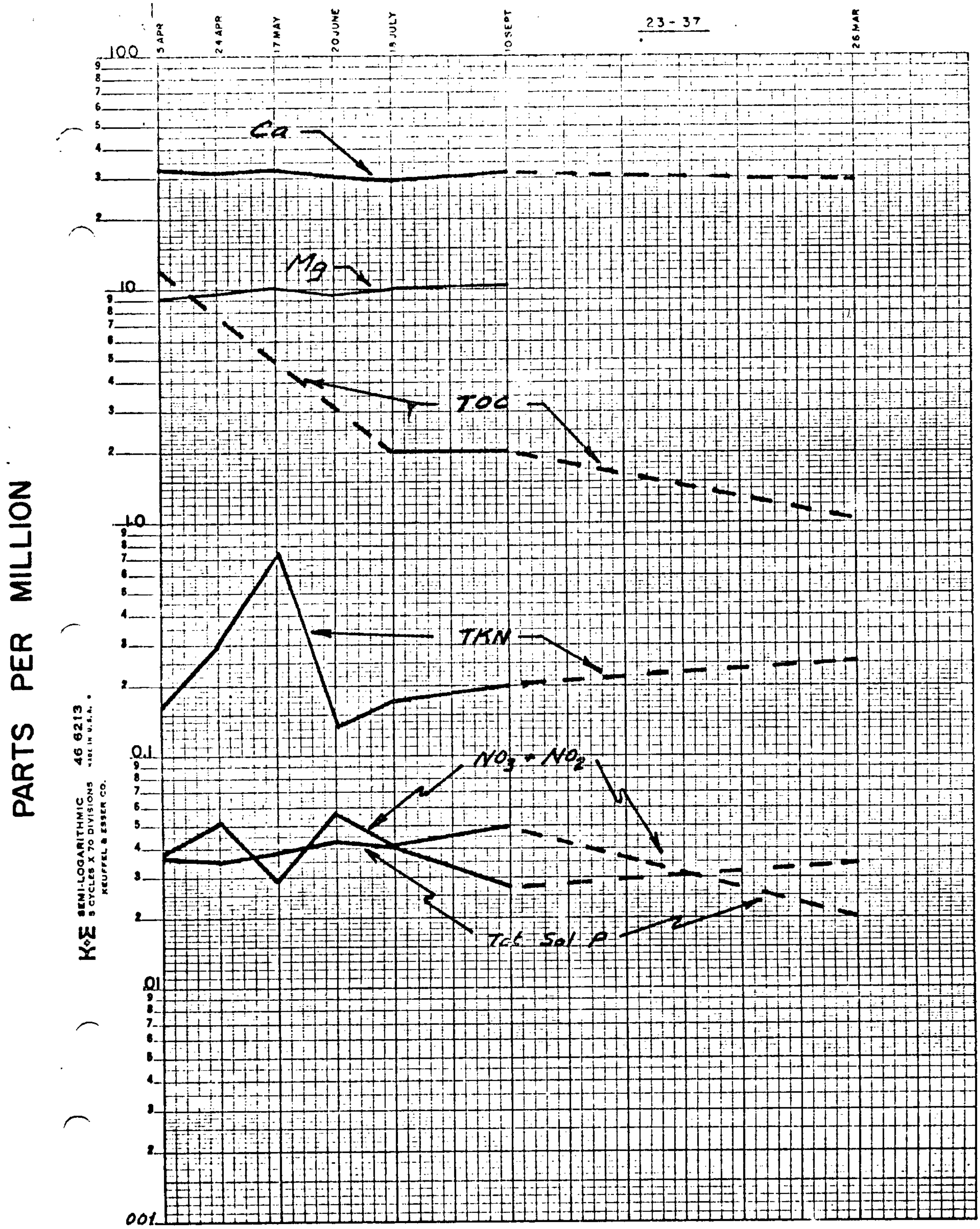
FILE No. DWG. No.

Well Location Z7 X6 Y29 # 16 Depth 48 Feet



BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON Kalamalka-Wood Lake Basin Study Nutrient Graph
SCALE: VERT. ...... HOR. ...... DATE	E.G. Le Breton, Geological ENGINEER FILE No. ...... DWG. No. ......

Well Location Z7 X6 Y29 #37 Depth 75 Feet

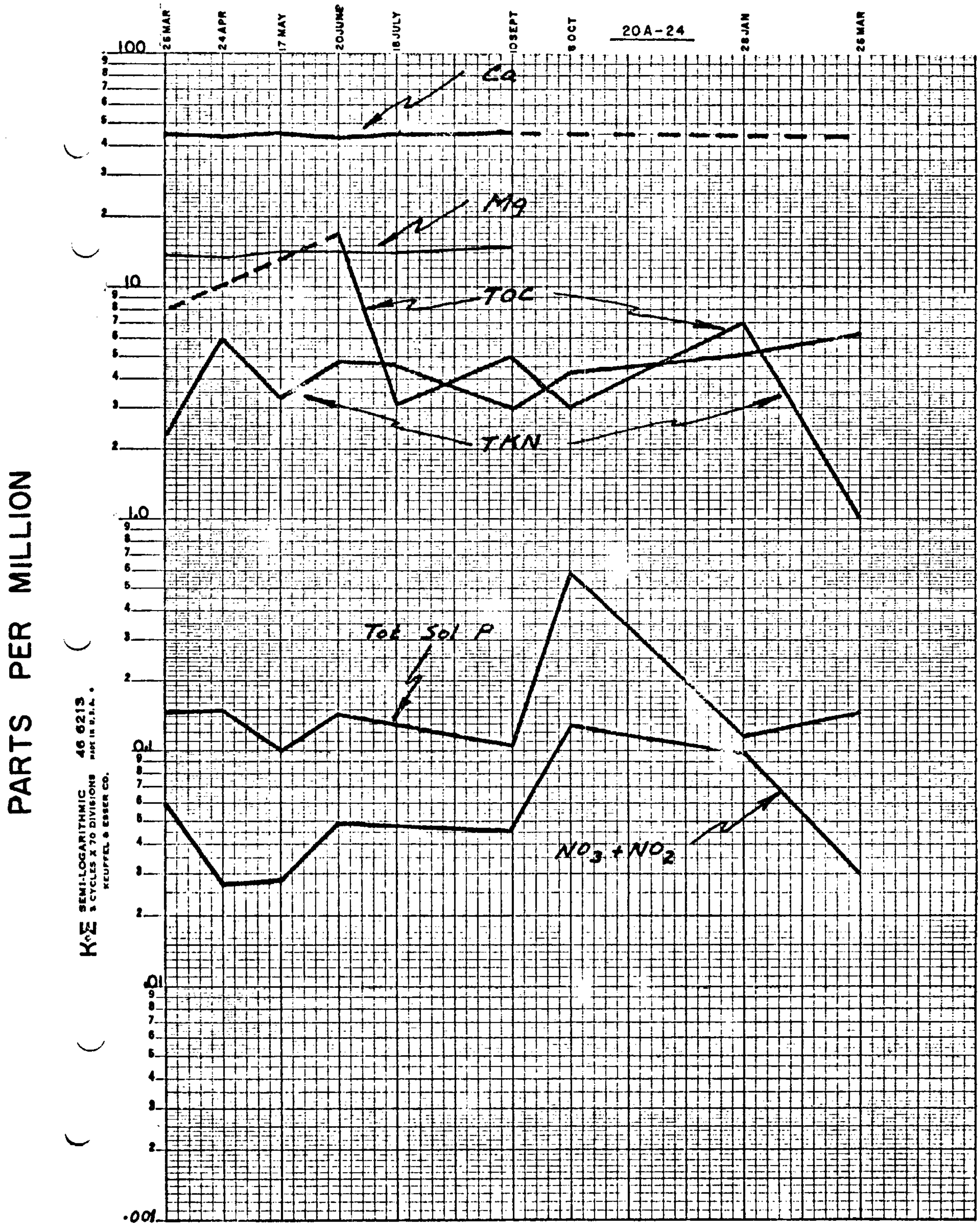


BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

TO ACCOMPANY REPORT ON
Kalamalka-Wood Lake Basin Study
Nutrient Graph

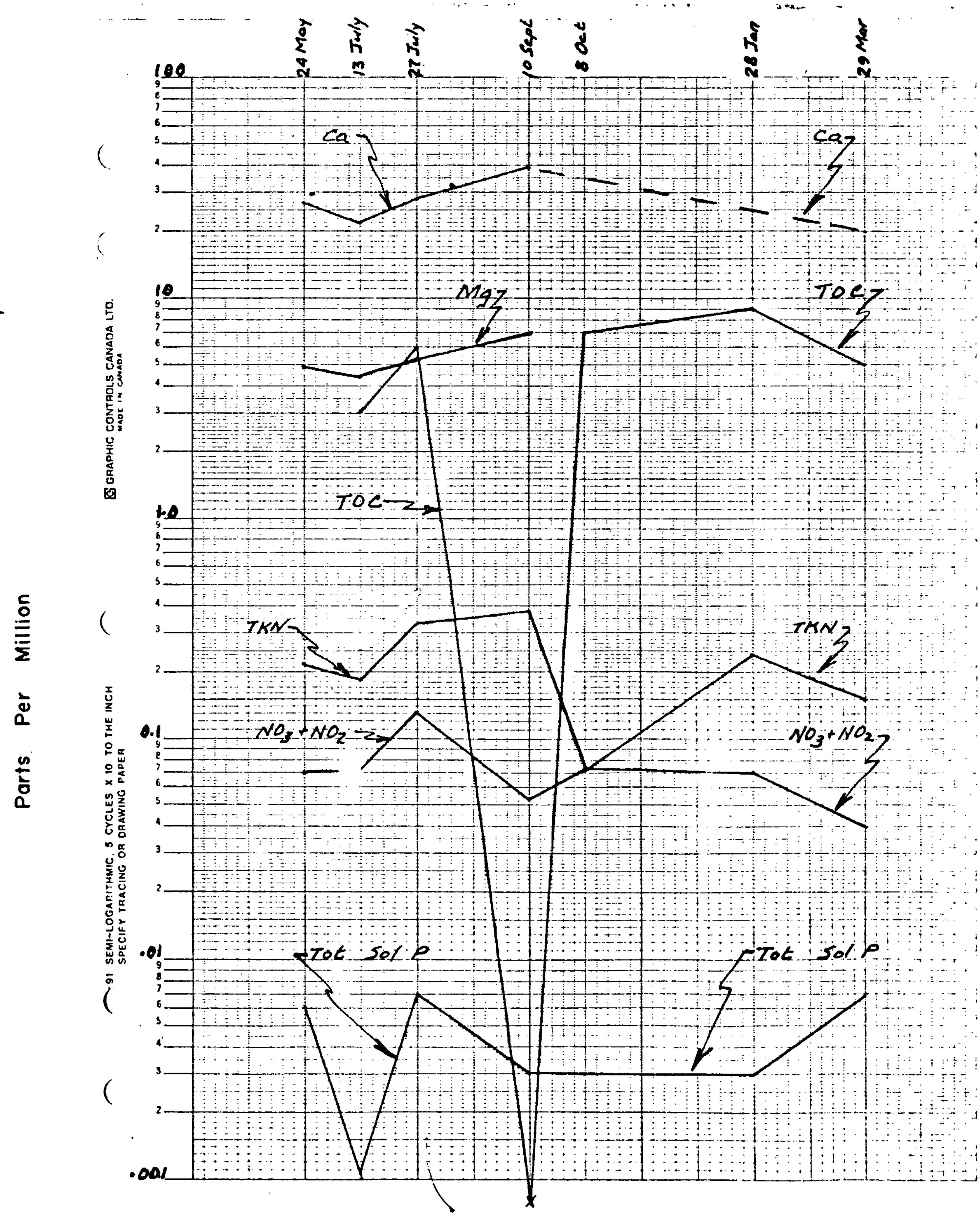
SCALE: VERT.
HOR.
DATE
E.G. Le Breton, Geological ENGINEER
FILE No. DWG. No.

Well Location Z7 X6 Y29 #24 Depth 90 Feet



BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON Kalamalka-Wood Lake Basin Study Nutrient Graph
SCALE: VERT. .... HOR. .... / DATE	E.G. Le Breton, Geological ENGINEER FILE No. .... DWG. No. ....

Well Location Z 7 X6 Y5 No. 4 Depth29 Feet

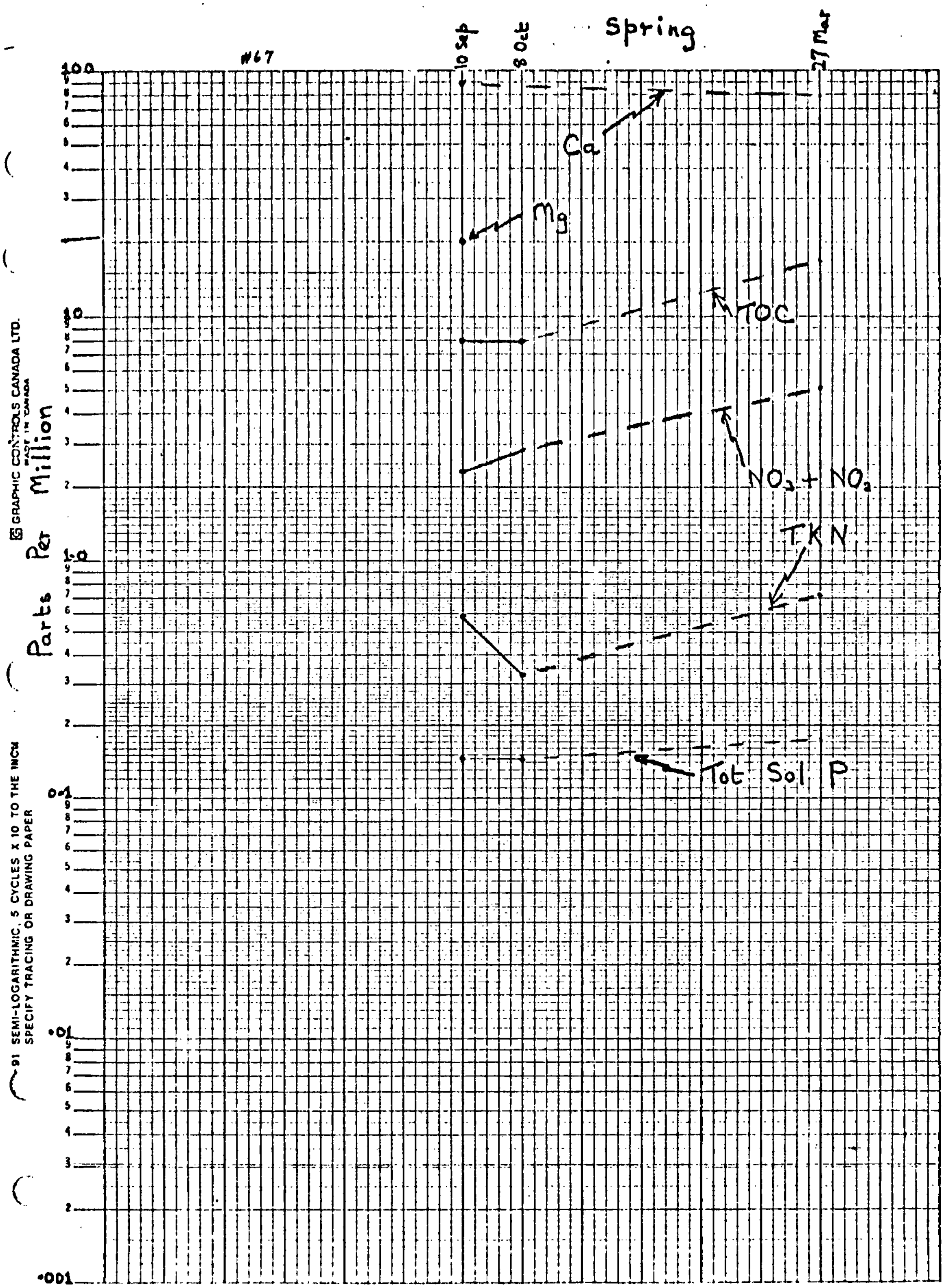


BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

TO ACCOMPANY REPORT ON
Kalamalka-Wood Lake Basin Study
Nutrient Graph

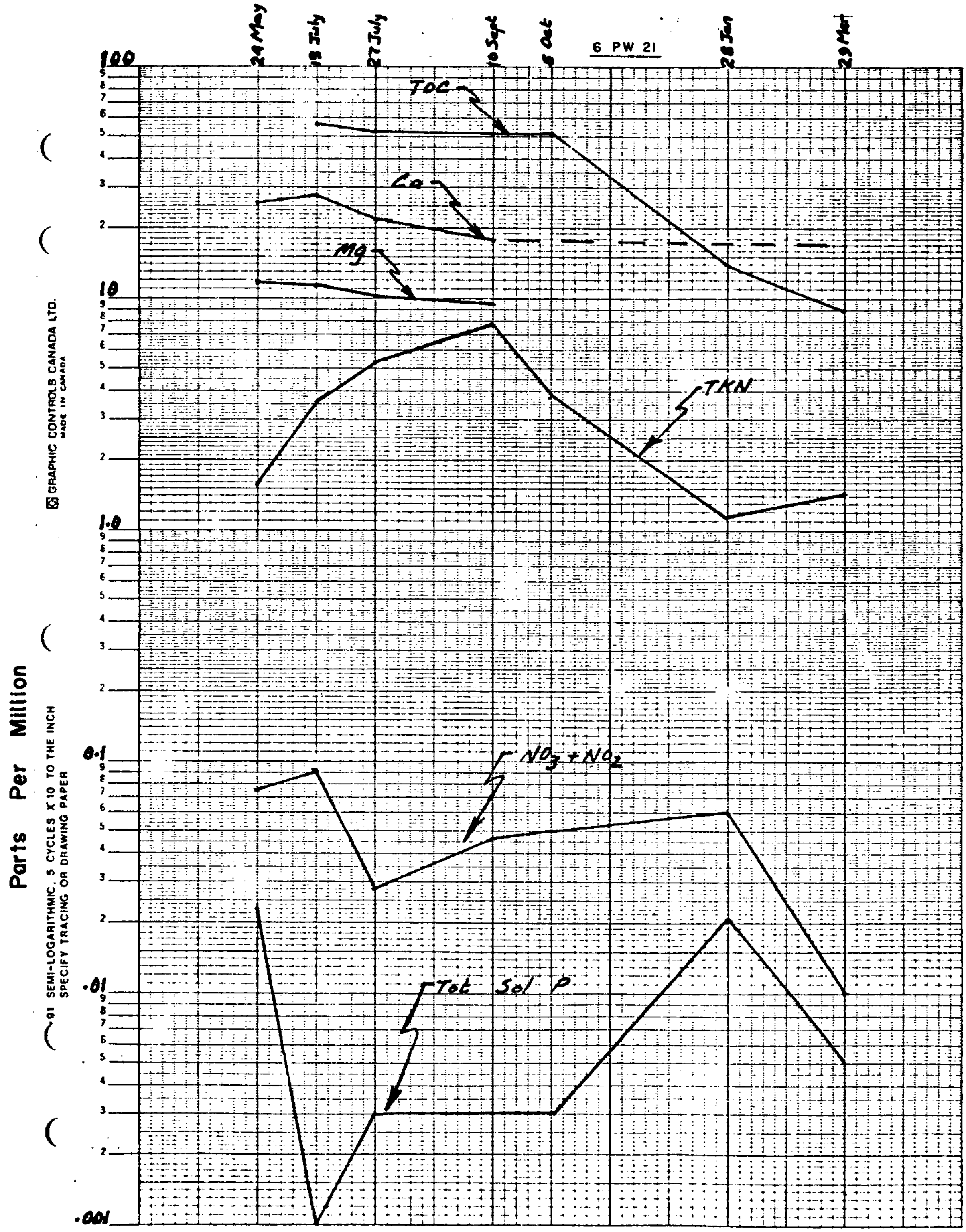
SCALE: VERT. ....
HOR. ....
DATE
E.G. Le Breton, Geological ENGINEER
FILE No. .... DWG. No. ....

Well Location Z7 X6 Y19 #3



BRITISH COLUMBIA DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES **WATER RESOURCES SERVICE** WATER INVESTIGATIONS BRANCH	TO ACCOMPANY REPORT ON Kalamalka-Wood Lake Basin Study Nutrient Graph
SCALE: VERT. .... HOR. .... | DATE	E.G. Le Breton, Geological ENGINEER FILE No. .... DWG. No. ....

Well Location Z8 X6 Y9 No. 11 Depth 20 Feet



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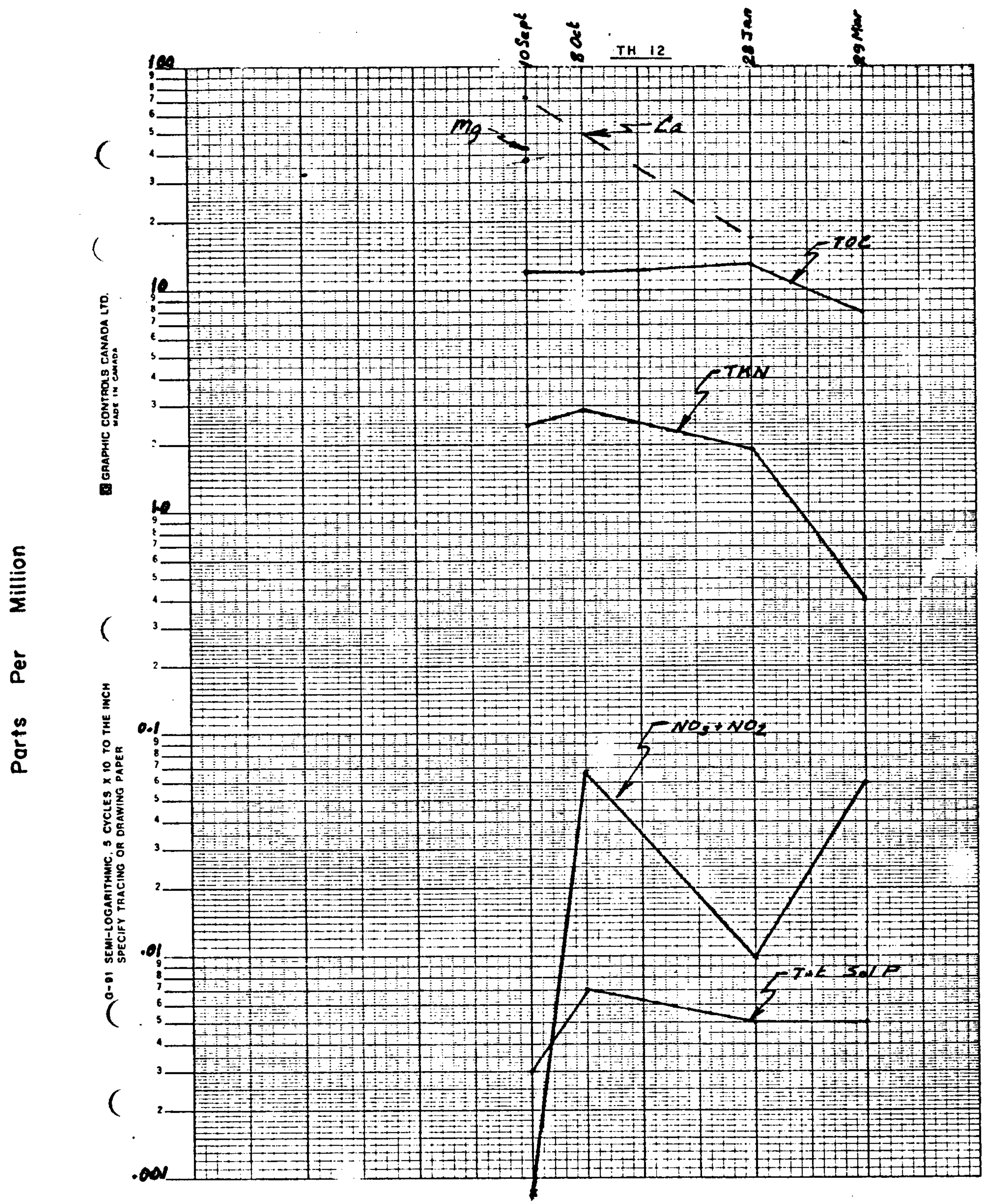
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

TO ACCOMPANY REPORT ON
Kalamalka-Wood Lake Basin Study
Nutrient Graph

E.G. Le Breton, Geological ENGINEER

SCALE: VERT.	DATE	FILE No.
HOR.		DWG. No.

Well Location Z9 X7 Y29 No.4 Depth 44 Feet



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WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH

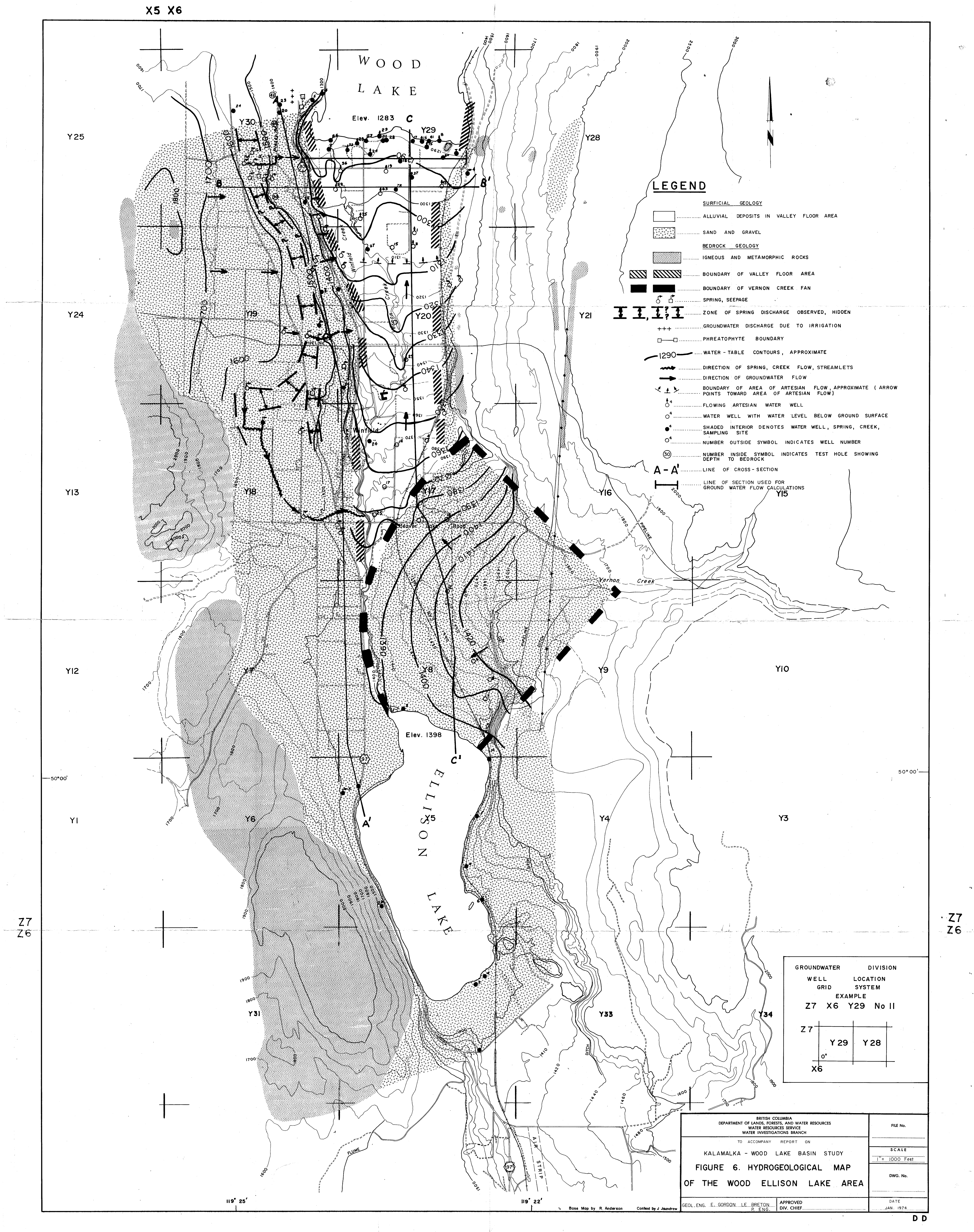
TO ACCOMPANY REPORT ON
Kalamalka-Wood Lake Basin Study
Nutrient Graph

E.G. Le Breton, Geological ENGINEER

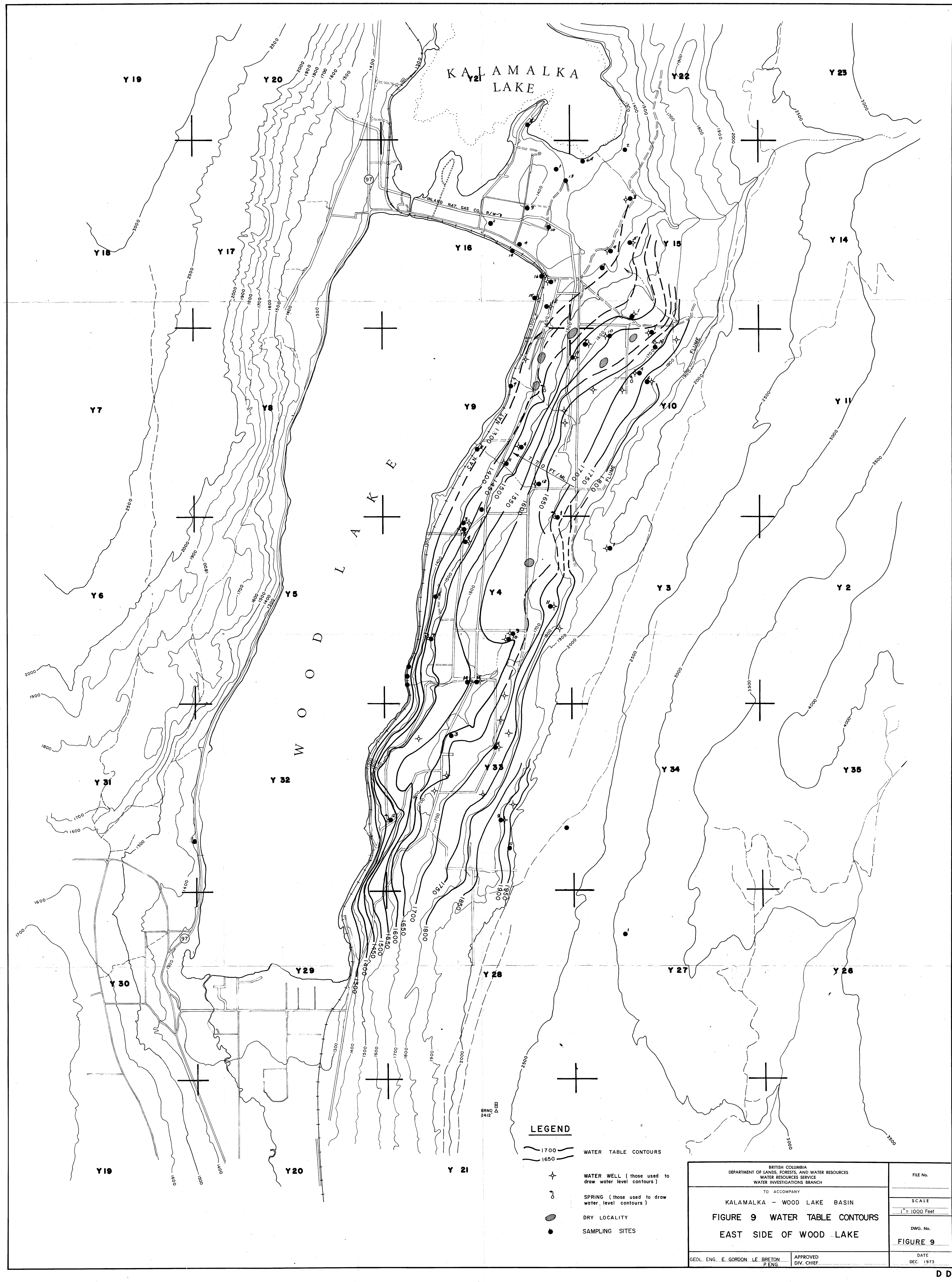
SCALE: VERT. ....
HOR. ....

DATE

FILE No. ....
DWG. No. ....


X5 X6
WOOD LAKE
Elev. 1283
LEGEND
SURFICIAL GEOLOGY
ALLUVIAL DEPOSITS IN VALLEY FLOOR AREA
SAND AND GRAVEL
BEDROCK GEOLOGY
IGNEOUS AND METAMORPHIC ROCKS
BOUNDARY OF VALLEY FLOOR AREA
BOUNDARY OF VERNON CREEK FAN
SPRING, SEEPAGE
ZONE OF SPRING DISCHARGE OBSERVED, HIDDEN
GROUNDWATER DISCHARGE DUE TO IRRIGATION
PHREATOPHYTE BOUNDARY
WATER - TABLE CONTOURS, APPROXIMATE
DIRECTION OF SPRING, CREEK FLOW, STREAMLETS
DIRECTION OF GROUNDWATER FLOW
BOUNDARY OF AREA OF ARTESIAN FLOW, APPROXIMATE (ARROW POINTS TOWARD AREA OF ARTESIAN FLOW)
FLOWING ARTESIAN WATER WELL
WATER WELL WITH WATER LEVEL BELOW GROUND SURFACE
SHADED INTERIOR DENOTES WATER WELL, SPRING, CREEK, SAMPLING SITE
NUMBER OUTSIDE SYMBOL INDICATES WELL NUMBER
NUMBER INSIDE SYMBOL INDICATES TEST HOLE SHOWING DEPTH TO BEDROCK
A - A' LINE OF CROSS - SECTION
LINE OF SECTION USED FOR GROUND WATER FLOW CALCULATIONS
Winfield
Vernon Creek
Elev. 1398
ELLISON LAKE
50°00'
Z7
Z6
GROUNDWATER DIVISION
WELL LOCATION GRID SYSTEM
EXAMPLE
Z7 X6 Y29 No 11
Y29 Y28
119° 25'
119° 22'
FLUME
AIR STRIP
Base Map by R. Anderson
Contest by J. Jaundrew
BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH
TO ACCOMPANY REPORT ON
KALAMALKA - WOOD LAKE BASIN STUDY
FIGURE 6. HYDROGEOLOGICAL MAP OF THE WOOD ELLISON LAKE AREA
FILE No.
SCALE 1" = 1000 Feet
DWG. No.
GEOL. ENG. E. GORDON LE BRETON P. ENG.
APPROVED DIV. CHIEF
DATE JAN. 1974
DD

X5 X6



KALAMALKA LAKE
WOOD LAKE
INLAND NAT. GAS CO. R/W
CAN. NAT.
FLUME
97
LEGEND
1700
1650
WATER TABLE CONTOURS
WATER WELL (those used to draw water level contours)
SPRING (those used to draw water level contours)
DRY LOCALITY
SAMPLING SITES
BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH
TO ACCOMPANY
KALAMALKA - WOOD LAKE BASIN
FIGURE 9 WATER TABLE CONTOURS
EAST SIDE OF WOOD LAKE
GEOL. ENG. E. GORDON LE BRETON P.ENG.
APPROVED
DIV. CHIEF
FILE No.
SCALE
1" = 1000 Feet
DWG. No.
FIGURE 9
DATE
DEC. 1973
BRNO 2412'

Z8 Z7

D D


KALAMALKA LAKE
WOOD LAKE
INLAND NAT. GAS CO. R/W
CAN. NAT.
FLUME
97
Mozey Creek
La Fleche Creek
Ribbleworth Creek
Weber
Elliot Creek
Somerville Mine
BRNO 2412
LEGEND
WELL; DAM; DEVELOPED SPRING
SPRING; SEEPAGE
CREEK ; GROUNDWATER Showing direction of flow
DRAINAGE BASIN DIVIDE
BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH
TO ACCOMPANY
KALAMALKA - WOOD LAKE BASIN
FIGURE 8. GROUNDWATER FEATURES
EAST SIDE OF WOOD LAKE
FILE No.
SCALE
1" = 1000 Feet
DWG. No.
FIGURE 8
GEOL. ENG E. GORDON LE BRETON P. ENG
APPROVED DIV. CHIEF
DATE
DEC. 1973
DD


KALAMALKA LAKE
WOOD LAKE
VERNON - SICAMOUS FAULT
INLAND NAT. GAS CO. R/W
CAN. NAT.
97
LEGEND
SURFICIAL GEOLOGY
SAND AND GRAVEL
TILL (clay ; silt ; sand ; pebbles)
BEDROCK GEOLOGY
CONGLOMERATE
MONASHEE GROUP (gneiss etc.)
DEPTH TO BEDROCK
LINEAMENTS, FAULTS
BRITISH COLUMBIA
DEPARTMENT OF LANDS, FORESTS, AND WATER RESOURCES
WATER RESOURCES SERVICE
WATER INVESTIGATIONS BRANCH
TO ACCOMPANY
KALAMALKA - WOOD LAKE BASIN STUDY
FIGURE 2. GEOLOGIC MAP
EAST SIDE OF WOOD LAKE
FILE No.
SCALE
1" = 1000 Feet
DWG. No.
FIGURE 2
GEOL. ENG. E. GORDON LE BRETON P. ENG.
APPROVED
DIV. CHIEF
DATE
DEC. 1973

D D