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GROUNDWATER DEVELOPMENT

REDROOFS ESTATES TEST HOLES 3 AND 4

Sechelt Peninsula, British Columbia

for

Morgan A. R. Stewart & Co.

by

W. L. Brown, P.Eng.
R. A. Dakin, P.Eng.

July 1973

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INTRODUCTION

This report summarizes work done to construct two test holes for the Redroofs Estates property on the Sechelt Peninsula. The property is located on the Redroofs Peninsula west of Sargeant Bay which is about six miles west of the Village of Sechelt (see location map Figure 1). The property forms part of District Lot 1325.

The two holes referred to as Test Holes 3 and 4 were drilled to depths 340 and 560 feet respectively. Test Hole No. 4 was successful and, after pump testing, has a rated safe yield of 70 US gpm (58 Igpm). This hole is now referred to as Production Well No. 1. The water tastes good and meets the Canadian and American Drinking Standards for inorganic water quality.

Based on the former Public Utility Commission's requirement for 340 Imp. gpd for each lot a yield of 70 US gpm will service approximately 200 homes provided that adequate storage is available.

175/200

GEOHYDROLOGY

The Redroofs peninsula rises steeply up from the sea shore and is approximately flat on top. The average elevation is about 250 feet above mean sea level. Observations along the cliffs at the sea shore indicate that there are no bedrock exposures and that the peninsula is comprised of beds of fine sands silts and clays. The first 250 feet of the logs of the two test holes (see Figures 2 and 3) show that these sediments follow a similar sequence to the exposed sediments on the sea cliffs. A simplified cross-section of the sediments is as follows:

Elevations		Zone	Description
+150	+250 ft.	Upper Clay:	dense blue clay with some fine sand interbeds W.B.
+100	+150 ft.	Intermediate Sands:	silts sands and gravels, cross-bedded
-100	+100 ft.	Lower Clay:	dense blue clay
-200	-100 ft.	Lower Sands:	inter-bedded silts sands and gravel, marine

Upper Clay Zone: This clay zone is the clay cap which extends over most of the peninsula. Swamps have formed on the ground surface in places where the surface drainage is poor. Some water-bearing sand interbeds were encountered. These zones represent perched groundwater systems which are fed by infiltrating water from the near ground surface. One zone encountered in TH-4 (depths 35 to 39 feet) yielded approximately 6 gpm. The long term yield of a well developed in such a zone would be considerably less than 6 gpm and would probably be suitable for supplying the water requirements of only one or two houses.

Present plans for the subdivision call for sewage disposal by means of septic tanks. It is our opinion that wells yielding water from these shallow zones on this proposed subdivision, would eventually become contaminated.

Intermediate Sands: These sands are very fine, uniform and in places are water-bearing. The water-bearing zones are perched and would not be a reliable source of groundwater. The average grain size for these sands was approximately 3 thousandths of an inch. Exposures of this sand unit indicate that the zone is severely dissected and cross-bedded.

Lower Clay: This dense clay unit is similar in texture to the upper clay unit. It is a little more dense and more cohesive than the upper clay. The clay acts as a cap to the water-bearing zone below.

Lower Sands: These sediments were probably laid down in an inter-tidal environment. Evidence of a marine environment are in the presence of sea shells and by dissolved hydrogen sulphide gas in the water. The wood fragments and well rounded grain particles suggest the presence of an old marine beach.

Production Well 1 has a screen set in the lower part of these sands. The pump test indicates the presence of a number of hydrologic boundaries. The well recovery from this test indicates that there is a regional groundwater flow system in these sands. Based on previous experience with similar geologic environments we would expect that the water has infiltrated into the ground in an area north of the property near where the granitic bedrock is exposed (see Figure 1). These infiltrated waters would then flow south in sands and gravels along the top of the bedrock and in the fractured bedrock below.

Observations of the static water level in Production Well No.1 indicate that the water table is influenced by the movement of the tide.

Fractured Bedrock: The zone below the lower sands appears to be a fractured shale at the TH-4 site. As this zone was drilled using mud this identification is not positive, but all evidence indicates a shale which is a light grey colour. The location of the fractures are given in Figure 3. The fractures in the shale are probably hydraulically connected to the lower sand zone. Production Well No. 1 has a slotted casing, set to pick up water from these fractures.

Both wells were located so that if drilled into bedrock they would encounter a fracture zone. See location of bedrock fractures in Figure 1.

CONSTRUCTION

All drilling work was carried out using a rotary drilling machine with attached pneumatic casing hammer. Test Holes 1 and 2, reported to be approximately 300 and 100 feet deep, respectively, were drilled earlier and are not described in this report. Test Holes 3 and 4 were drilled under our company direction and the construction is described in this report.

Test Hole: 3

This hole is located in the north-east corner of the property. Drilling commenced on May 31, 1973. Ten-inch casing was driven into the clay to a depth of 15 feet. Eight-inch casing was then set concentrically in the hole and drilled to 336 feet, where a boulder or possibly bedrock was encountered (see Figure 2). Four feet of open hole drilling was made into the rock.

The overall drilling rates average 10 feet per hour for the drilling and casing of 340 feet of hole. Samples of sediments from clean water-bearing zones were collected at regular intervals. These samples were sent to a laboratory for sieve analyses (see Figures 5, 6 and 7).

A potentially good water-bearing zone was encountered between 320 and 336 feet depth. To test this zone 10 feet of 20 slot size continuous wire-wound well screen was set, the casing pulled back and the well surged. A short pump-test was run but the yield did not exceed 5 gpm. The well was then surged again using a cable tool machine, which was capable of applying a more vigorous surging action. Constant checks were run on the productivity of the well and when it was evident that the surging was not improving the well, surging was stopped. We can conclude that the aquifer material must be severely cross-bedded and not sufficiently extensive to yield a good supply of water. The screen was later pulled out and the 8-inch casing driven back to the top of the hard rock.

Test Hole: 4

This hole is located approximately 1000 feet from TH-3 and is on the edge of a swamp in the middle of the property.

Drilling commenced on June 18, 1973 and the final pump test was finished by July 23. The average drilling rate was 9 feet per hour. This rate does not include time spent in telescoping casing and moving equipment. The construction procedure was similar to TH-3. The 10-inch casing was drilled to the 10 foot depth and 8-inch to 300 feet. The 8-inch could not be driven any deeper and so 6-inch casing was set and drilled to 447 feet where a granitic boulder was encountered. A 6" hole was drilled through the boulder and into a good water-bearing zone at 454 feet. Attempts were made to try to split the boulder by driving the casing, but the boulder became firmly wedged and began to sink with the driving action. Attempts to split the boulder by driving were abandoned when the boulder was driven down approximately 4 feet. As the casing could not be driven the hole was "mudded" up using a special artificial "mud" which forms a gel in water. This mud enabled drilling to proceed without the necessity for driving casing. The 6-inch hole was drilled down to bedrock at 459 feet and then drilled into bedrock to a total depth of 560 feet.

A screen and liner assembly was welded up and installed as shown in Figure 3. This assembly consisted of a four foot length of 6-inch telescopic size well screen. The screen is a stainless steel continuous wire-wound screen with a 30/1000 inch slot opening. Five-inch blank pipe was welded top and bottom and two 6-inch size neoprene type "K" packer assemblies were welded top and bottom (see Figure 3). The top packer was designed to fit into the 6-inch casing and the lower packer into the 6-inch rock hole. A 5x4 inch pipe reducer was fitted and 4-inch threaded pipe fitted below the lower packer. The 4-inch pipe was slotted using an oxy-acetylene cutting torch. Twelve slots were located opposite each fracture encountered in the bedrock. The slots were arranged in two rows of 6 at ten-inch centres. All slots were cut vertically and were approximately 2" long by 1/8" wide.

Samples of the potentially good water-bearing sands and gravels encountered in the hole were collected and sent for sieve analysis (see Figures 8 and 9).

When the screen assembly was in place the hole was pumped out and air surging commenced. When the surged water brought up very little sand surging was stopped and the well construction was complete.

TESTING

1. Hydraulics of Wells

Test Hole: 3: This hole was pump-tested but did not prove to be productive at depths 326-336. If this hole is deepened, a further pump test should be run to test any potential water-bearing zones.

Test Hole: 4: The completed well was continuously pump-tested for 50 hours. The pumping rates were stepped in the following manner:

50 US gpm	for a period of	7 hours
70 US gpm	for a period of	17 hours
100 US gpm	for a period of	26 hours

At the end of this test the drawdown was 323 feet below ground. The pump was turned off and recovery water levels were recorded for 3½ hours.

Using the data from the pump test and the subsequent well recovery the hydraulic characteristics of the well were calculated. The long term pumping characteristics of the well were evaluated using this data and our previous experience with wells of this type. At a pumping rate of 70 US gpm the predicted water level after 100 days of continuous discharge should be 327 feet below ground (see Figure 4). This rate would provide a 165% factor of safety against the well running dry after a long dry summer. The large factor of safety is necessary to ensure that salt-water intrusion does not occur and to allow for possible additional negative boundaries in the aquifer.

2. Inorganic Water Quality

A sample of the pumped water was taken from the well just after the pumping started and again just before the pump was turned off. These samples were submitted to a chemical laboratory for inorganic analysis (see the Chemist's reports at the back of this report).

The Chemist reports that the water was moderately hard and mineralized. The dissolved mineralization was primarily sodium bicarbonate. The phosphate (0.49 ppm) is a little over the standard recommended by American Public Health Association (0.20 ppm). This level (0.20 ppm) is not based on a health criteria but is recommended to ensure minimal algae growth in water tanks open to direct sunlight. As we believe that you will have covered storage tanks the phosphate will not be a problem.

When the well was pumped we noted a small amount of hydrogen sulphide gas was emitted. This gas is a troublesome gas with a pungent odour, which is dissolved in the groundwater and is released when the water pressure is reduced to atmospheric pressure. The best way to eliminate the gas is to arrange the distribution system so that the well pumps directly to an open storage tank. This tank should be covered and have an air vent to allow for gas emission.

3. Checking Log of Drilled Holes

Portions of the drilled holes were logged using a gamma ray logger. This instrument records the rate of natural gamma ray emissions from a sediment or rock unit. As the gamma rays will penetrate the steel casing it is possible to record emissions in both cased and uncased holes.

The gamma ray logs have been plotted alongside the logs of the two test holes (figures 2 and 3). The higher readings represent cleaner units with a lower clay content. Generally the driller's log corresponds very well with the gamma ray log. It appears that no potentially good water-bearing zones have been missed.

WELL OPERATION AND MAINTENANCE

1. Pump

   Based on available data this well is capable of producing a continuous discharge flow of 70 US gallons per minute. The expected pumping level for continuous pumping at this rate for 100 days is 327 feet below present ground surface.

   A submersible type pump is recommended. The bottom of the pump motor should be set at 440 feet below ground.

2. Pump Housing

   The submersible well head fitting is best housed in a below ground manhole structure. This will protect the well head fittings and controls from both vandalism and freezing temperatures. The manhole cover should be located directly over the well to allow the pump to be readily set and withdrawn. A small 3 gpm capacity sump pump with automatic controls should be set at the bottom on the manhole to keep it dry. No surface water should be allowed to run into the ground in the annular space immediately outside the surface casing. To prevent this the concrete floor or pad should be laid up against this surface casing.

If a pump house is being considered it should be so designed that the pump can be withdrawn from the well. One wall should be within two feet of the well and a window or removable section of the wall installed in this wall so that machine operators can see the well. Also a 4'x4' removable section of the roof should be placed over the pump.

Great care and supervision will be necessary during pump house or manhole construction to ensure that no debris, cement, etc., enters the well. We emphasize this as we have had past experiences of wells being junked by innocent carelessness.

3. A program of water level and flow measurements must be started on a weekly schedule when production starts. This means that the access hole provided should be maintained free so that a 3/8-inch probe can easily pass. These records should be reviewed by us at regular intervals during the first year of production.

CONCLUSIONS

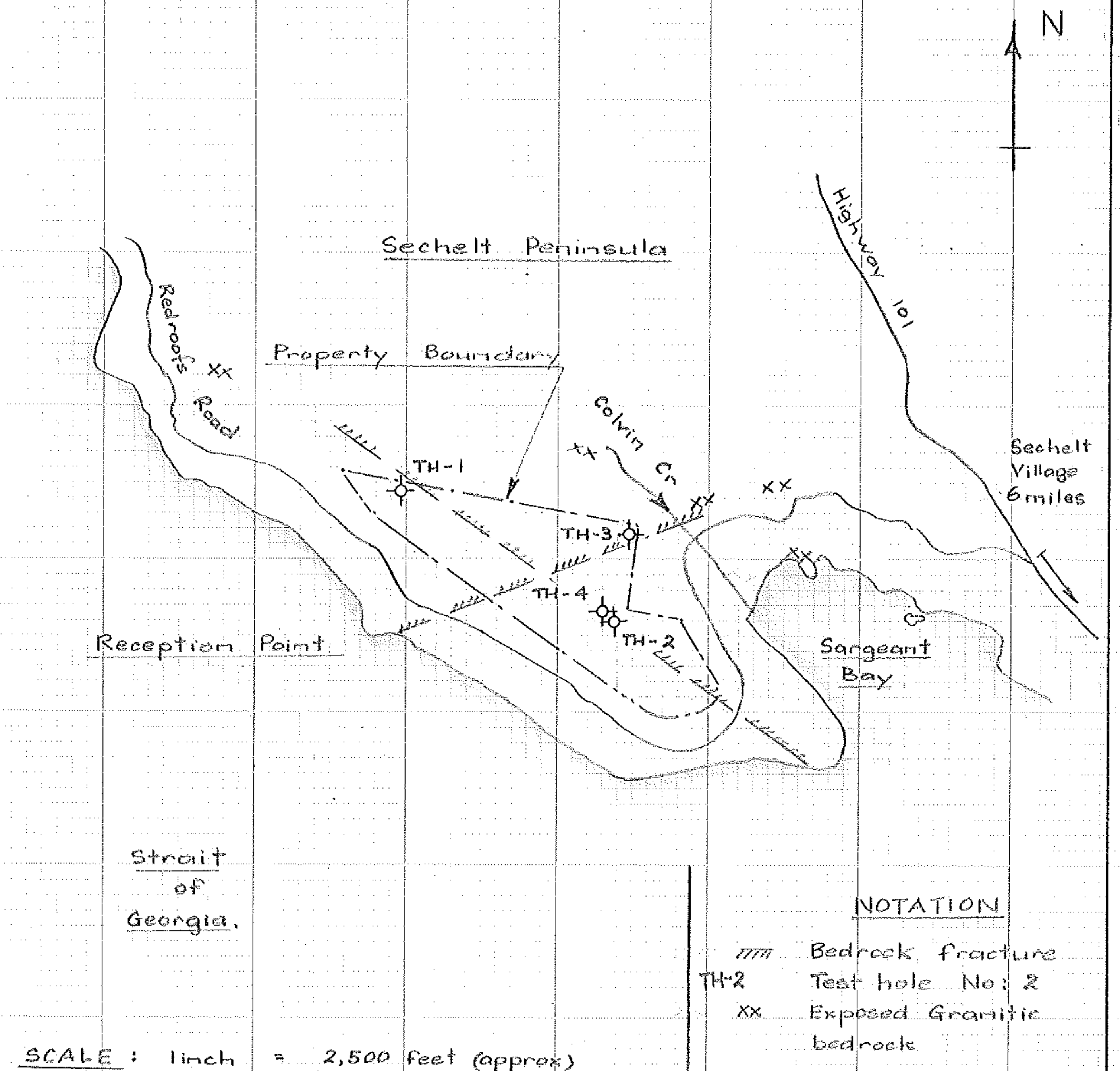
1. Based upon available data we judge that Production Well No. 1 (alias Test Hole No. 4) has a safe pumping capacity of 70 US gpm (58 Imp. gpm).

2. The water quality is good and should be acceptable.

3. The water-bearing zones encountered in TH-3 to date, are not sufficiently productive to make a high capacity water well. This well can be deepened and would possibly encountered better water-bearing zones below the boulder or in the bedrock.

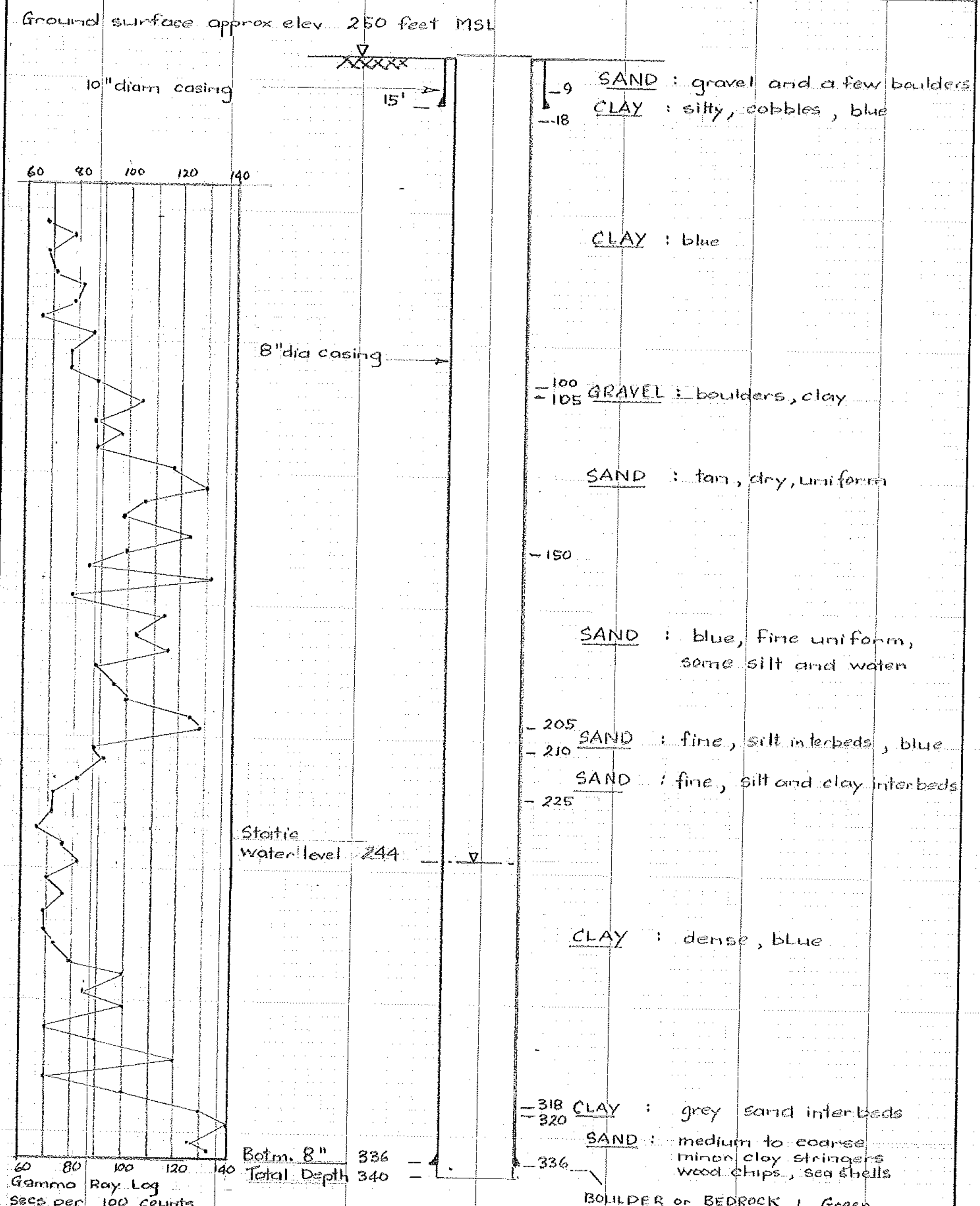
RECOMMENDATIONS

1. A submersible type pump should be set with the bottom of the pump motor at a depth of 440 feet below ground.
2. The well and pump fittings should be chlorinated prior to use.
3. Sufficient storage should be provided to hold the water for a minimum of 1 day prior to consumption. The storage tank or reservoir should be well ventilated and pumped water should go direct to the storage.
4. The well operation and maintenance program set out in this report be closely followed.
5. TH-3 should be deepened.

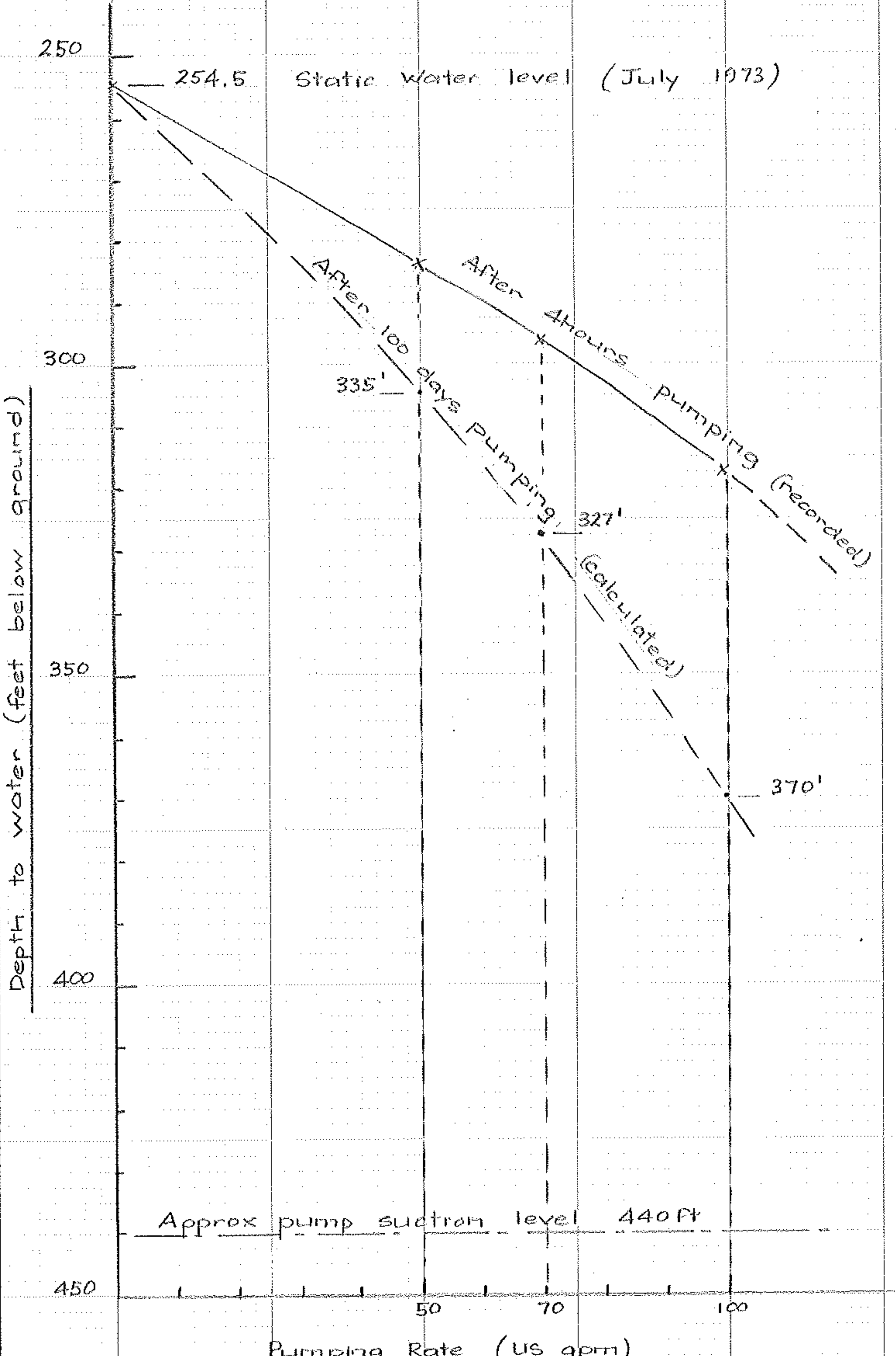


Morgan A. R. Stewart & Co.	LOCATION OF TEST HOLES	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
REDROOFS AREA SECHELT, B. C.		July 1973 — Fig: 1

WTN 27941

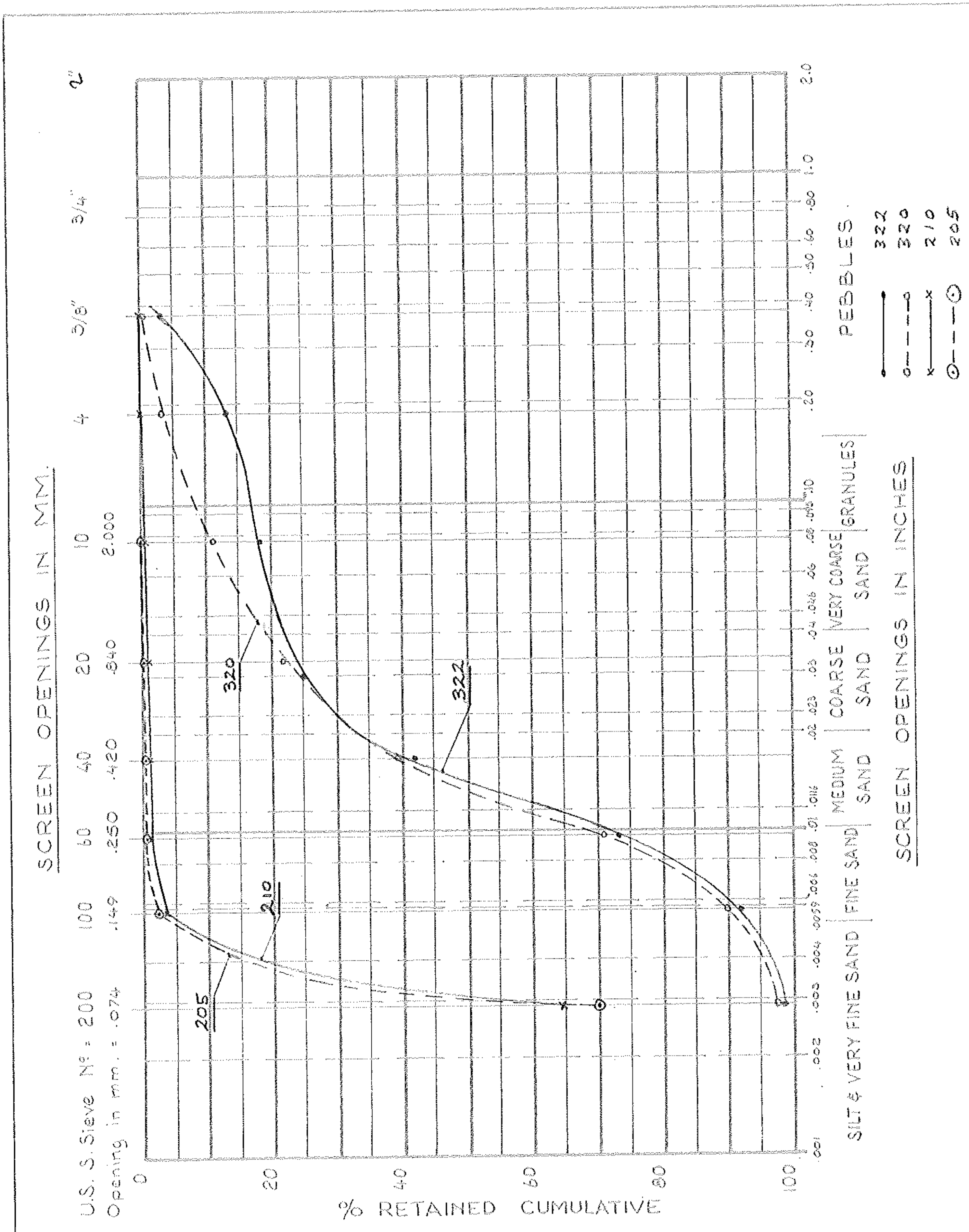


Morgan A. R. Stewart & Co.	L O G TEST WELL No. 3	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
REDROOFS AREA SECHELT, B. C.		July 1973 / Fig: 2



MORGAN A.R. STEWART & CO.	DRAWDOWN & PUMP RATE CURVE PRODUCTION WELL #1	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
REDROOFS AREA SECHELT, B. C.		July 1973 — Fig: 4

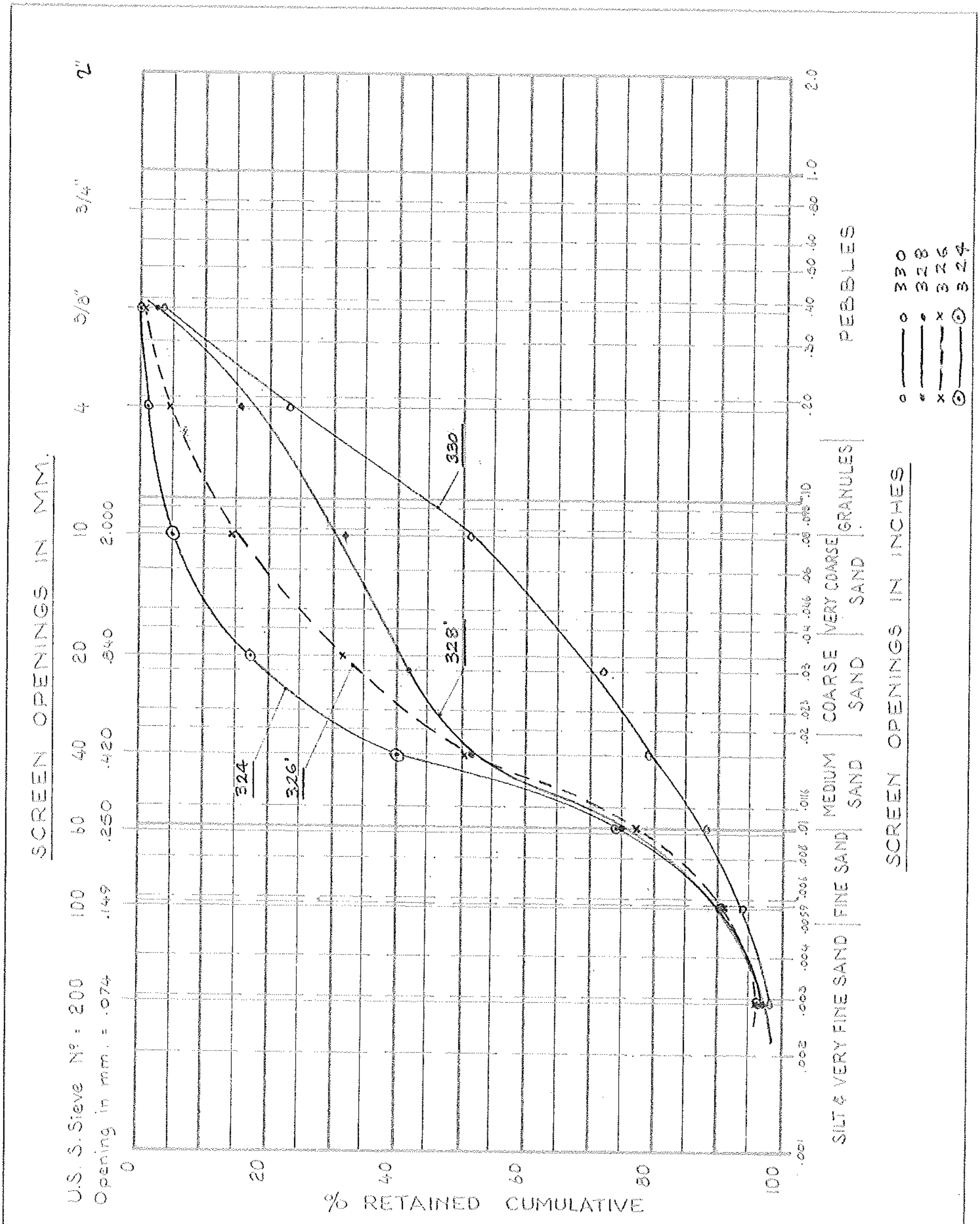
FORM D1-59-1



ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, 1 - B.C.	
Morgan A. R. Stewart & Co. Redroof Estates	SIEVE ANALYSIS Test Hole: 3	By: RB. / Date: Jun. 73
		Job: B73-30 / Dwg: Fig. 5

BCIL - 2993 - R.A.S.

FORM D1.59.1



ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, 1 - B.C.		
Morgan A. R. Stewart & Co. Redroofs Estates	SIEVE ANALYSIS Test Hole: 3	By: RAB	Date: Jun. 73
		Job: B73-301	Dwg: Fig. 6

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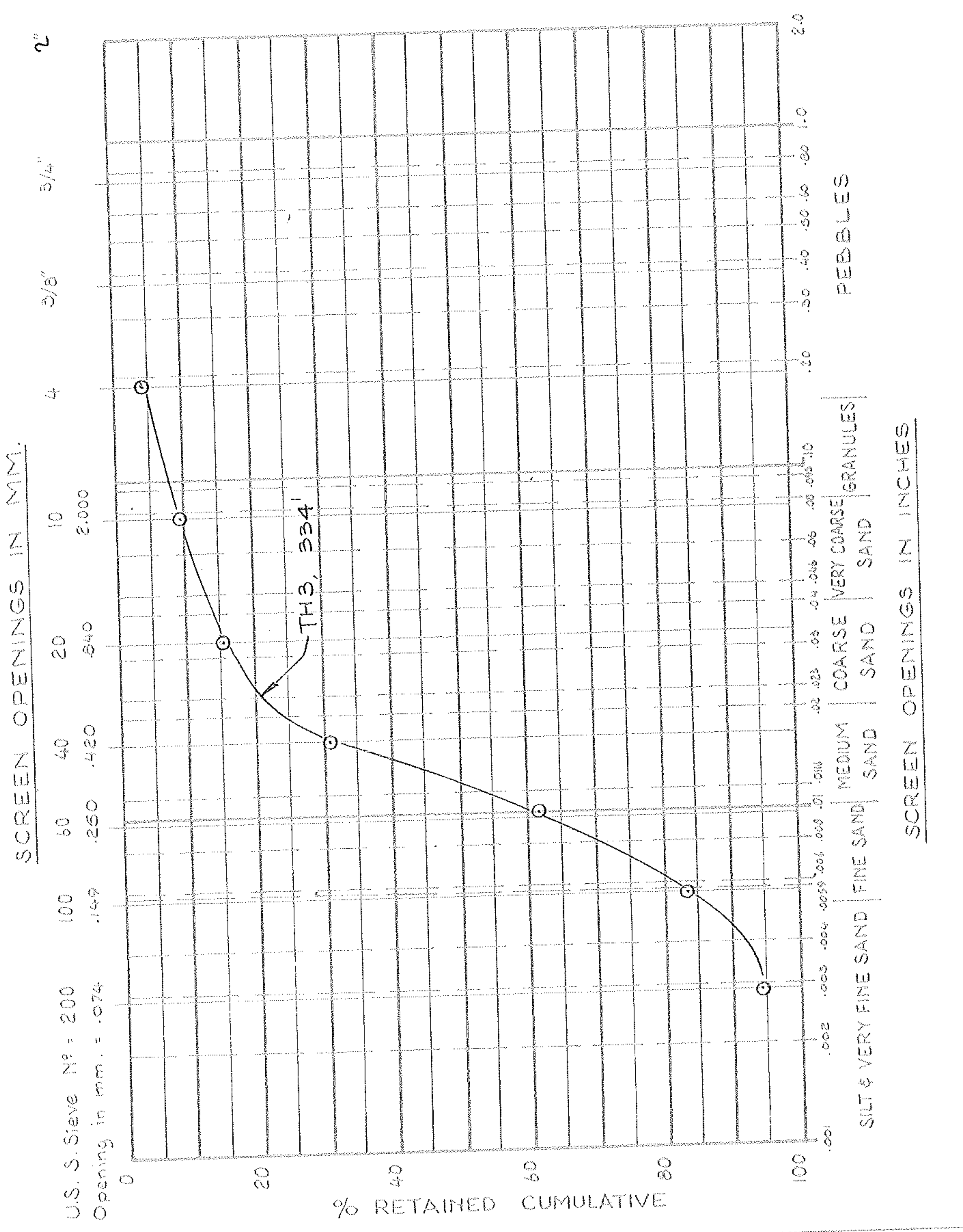

ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, 1 - B.C.	
Morgan A. R. Stewart & Co.	SIEVE ANALYSIS	By: /LL
		Date: Jul.6/7
REDROOFS ESTATES	Test Hole: 3	Job B73-301
		Dwg: Fig: 7

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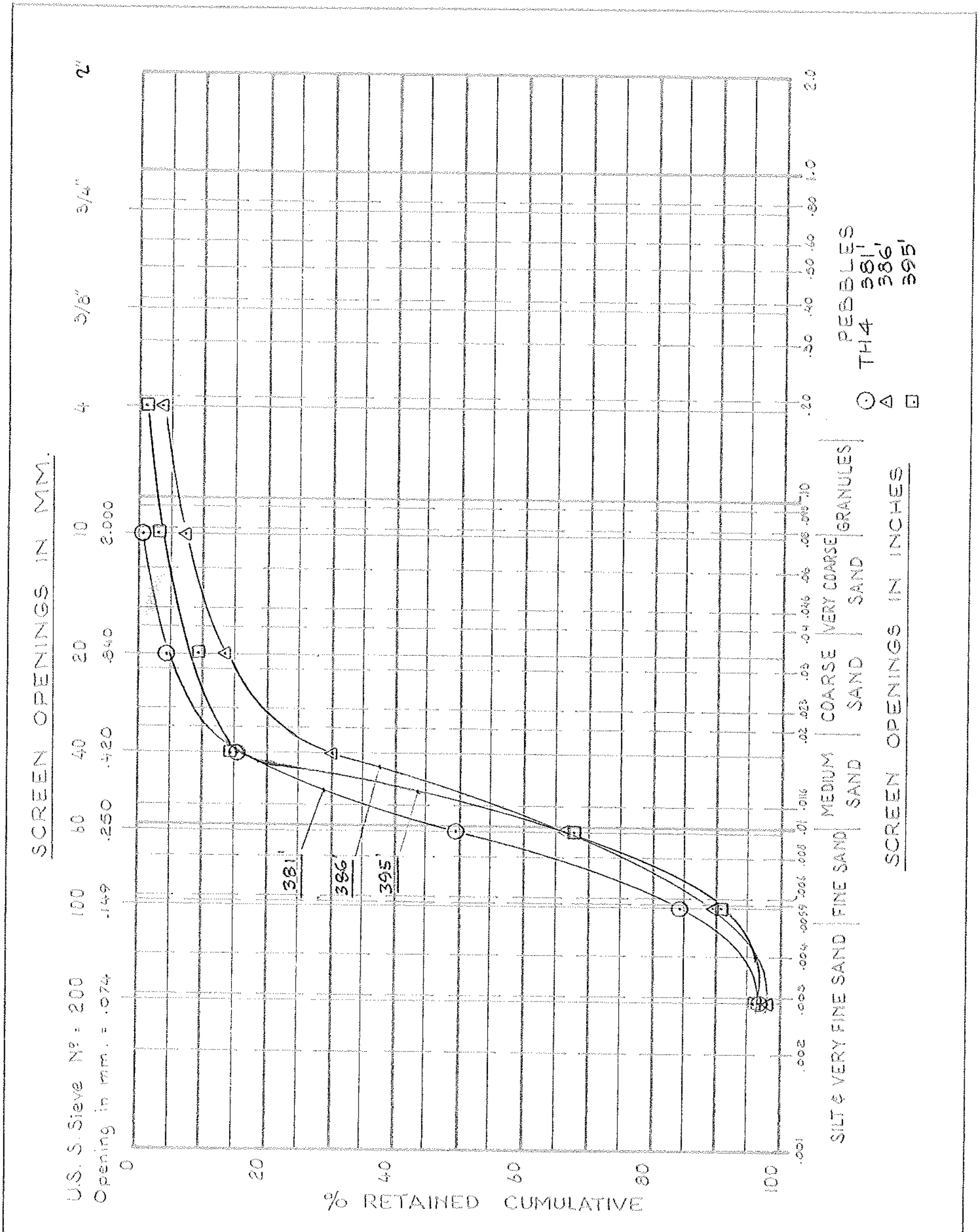
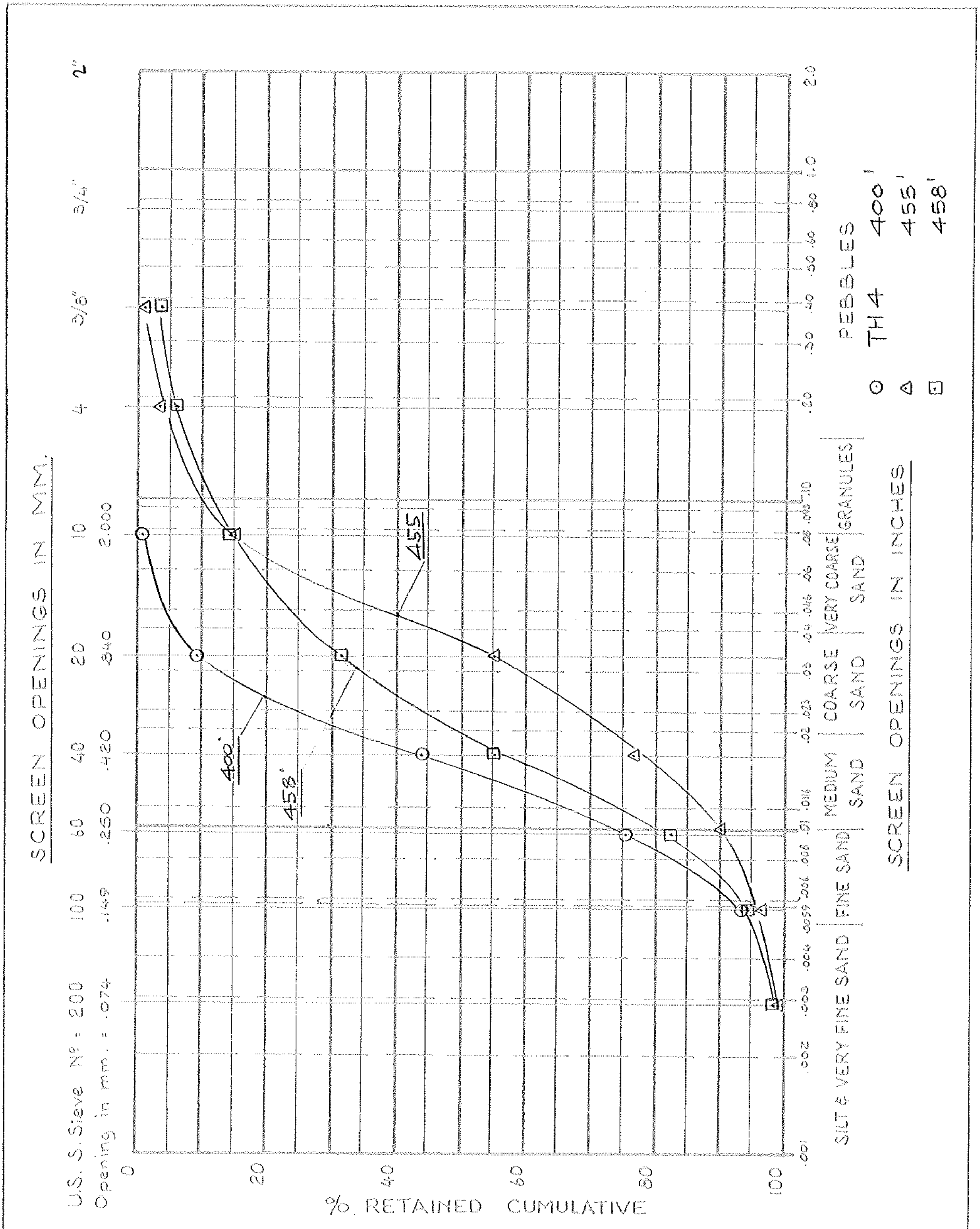
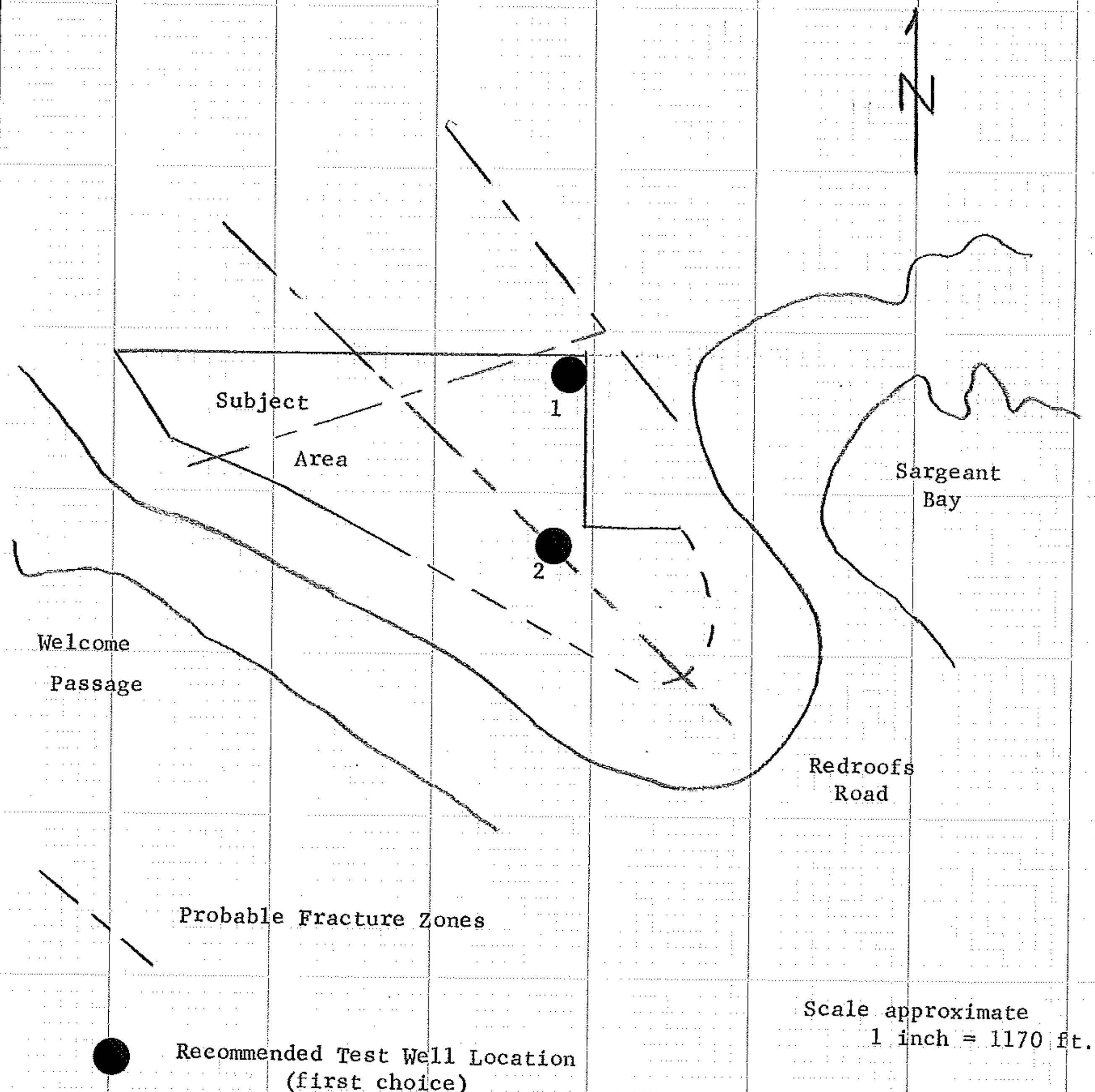


ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, 1 - B.C.	
Morgan A. R. Stewart & Co. REDROOFS ESTATES	SIEVE ANALYSIS Test Hole: 4	By: JKL Job: B73-301
		Date: Jul.6/73 Dwg: Fig: 8

FORM D1-59-1



ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, 1 - B.C.	
Morgan A. R. Stewart & Co. REDROOFS ESTATES	SIEVE ANALYSIS Test Hole: 4	By: JKL Job: B73-301	Date Jul. 6/73 Dwg: Fig: 9



HOWARD STURROCK & ASSOCIATES	PROBABLE FRACTURE ZONES REDROOFS	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
REDROOFS		APRIL 1973

CAN TEST LTD.

1650 PANDORA STREET, VANCOUVER 6, B.C. • TELEPHONE 254-7278

Report On Water Samples for Chemical Analysis

File No. 5181 A

Report No.

Reported to Robinson , Roberts & Brown
1632 McGuire
NORTH VANCOUVER, B.C.

Date June 15, 1973

We have tested the sample of water submitted by you on June 14, 1973 and report as follows:

Sample Identification

The sample was submitted in plastic bottle labelled-

Redroofs
Testwell #3
June 13, 1973

Method of Testing

The samples were tested in accordance with the procedures set down in "Standard Methods for the Examination of Water and Wastewater" - 13th Edition, published by the American Public Health Association, 1971.

Test Results

pH	8.7
Chloride (Cl)	23.0 ppm
Total Sodium (Na)	55.0 ppm
Nitrates (NO_3)	L 0.1 ppm
Dissolved Iron (Fe)	L 0.05 ppm

CAN TEST LTD.

L = less than

D. Timuss
Laboratory Supervisor

Form No. 7

CAN TEST LTD.

1650 PANDORA STREET, VANCOUVER 6, B.C. • TELEPHONE 254-7278

Report On Water Samples for Chemical Analysis

File No. 5476 A

Report No.

Reported to Robinson, Roberts & Brown
1632 McGuire
North Vancouver, BC

Date July 31, 1973

We have tested the samples of water submitted by you on July 23, 1973 and report as follows:

<u>Sample Identification</u>

The samples were submitted in plastic bottles labelled -

Sample 1 Redroofs TH #4 - July 21, 1973 - 1400 hours $T = 52^{o}$ F

Sample 2 Redroofs TH #4 - July 23, 1973 - 1400 hours $T = 52^{o}$ F

<u>Method of Testing</u>

The samples were tested in accordance with the procedures set down in "Standard Methods for the Examination of Water and Wastewater" - 13th Edition, published by the American Public Health Association, 1971.

Chemical Analysis of Water Samples

Test		1	2	
pH (electrometric)		7.0	7.75	
Color (Pt-Co scale)		-	10.5	ppm
Turbidity (SiO_2 scale)		-	5.0	ppm
Suspended Matter		-	10.7	ppm
Fixed		-	4.0	ppm
Volatile		-	6.7	ppm
Hardness (Calculated)		-	89.1	ppm
Dissolved Anions				
Alkalinity				
Bicarbonates	HCO_3	254.	235.	ppm
Carbonates	CO_3	nil	nil	ppm
Hydroxyl Ion	OH	nil	nil	ppm
Chlorides	Cl	78.5	71.5	ppm
Sulfates	SO_4	-	L 0.5	ppm
Phosphates	PO_4	-	0.49	ppm
Nitrates	N	-	L 0.1	ppm
Dissolved Cations				
Silica	SiO_2	-	25.4	ppm
Iron	Fe	-	0.10	ppm
Aluminum	Al	-	0.05	ppm
Calcium	Ca	-	18.4	ppm
Magnesium	Mg	-	10.5	ppm
Sodium	Na	97.0	92.1	ppm
Potassium	K	7.1	6.1	ppm
Manganese	Mn	-	L 0.05	ppm
Copper	Cu	-	L 0.005	ppm
Lead	Pb	-	L 0.005	ppm
Zinc	Zn	-	L 0.005	ppm
Total Iron	Fe	-	0.40	ppm
Total Silica	SiO_2	-	27.2	ppm
Total Dissolved Solids		-	462.	ppm
Fixed		-	344.	ppm
Volatile		-	118.	ppm

L = less than

Remarks

Examination of the above results indicated that the water as represented by the submitted sample was a moderately hard and mineralized water. The dissolved mineralization was primarily sodium bicarbonate.

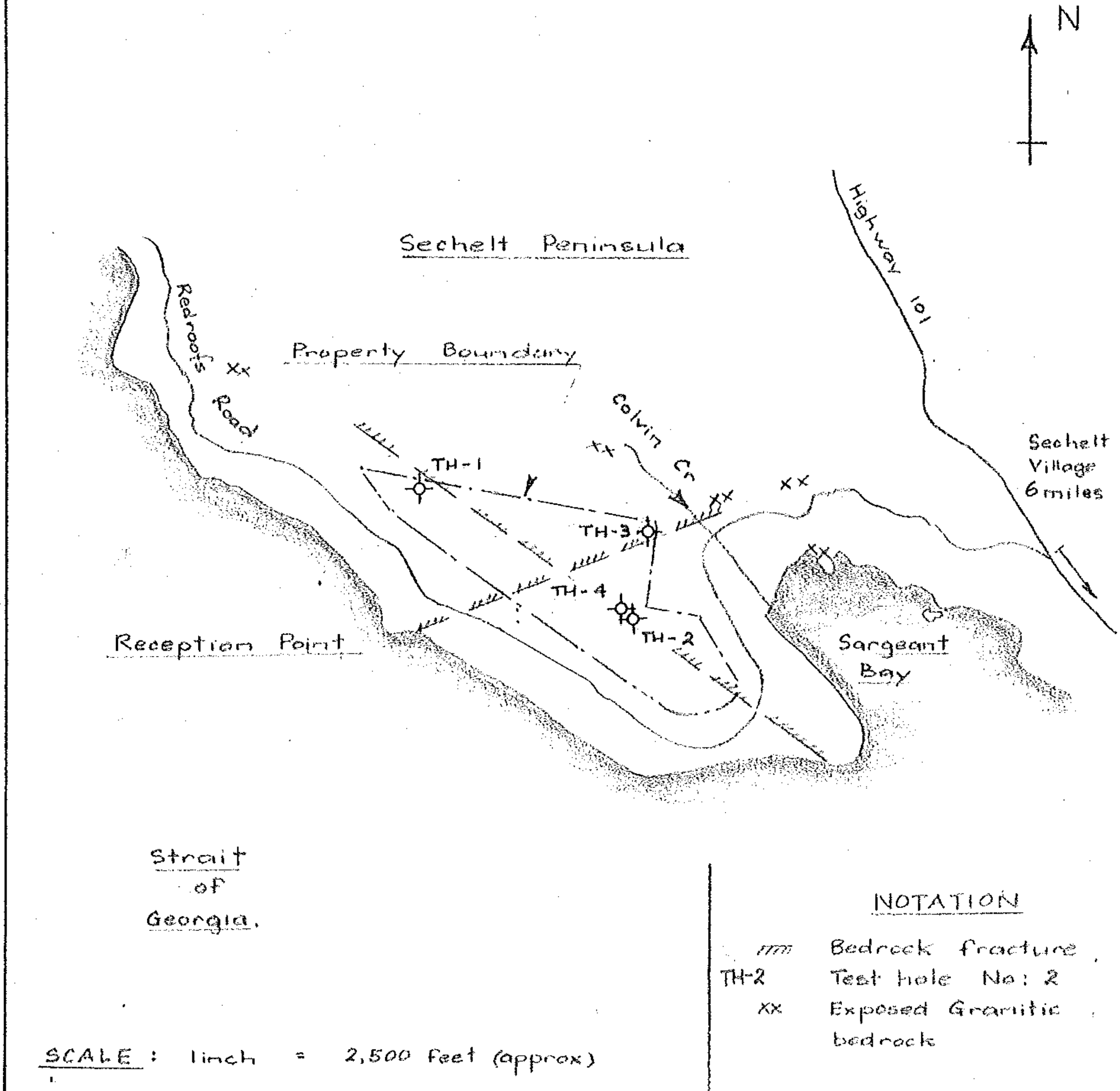
The water was within American Public Health Association standards for domestic water supplies on all tests conducted with the exception of phosphate content (APHA maximum = 0.2 ppm).

It was noted that there was a difference in pH between the samples and this was rechecked and verified.

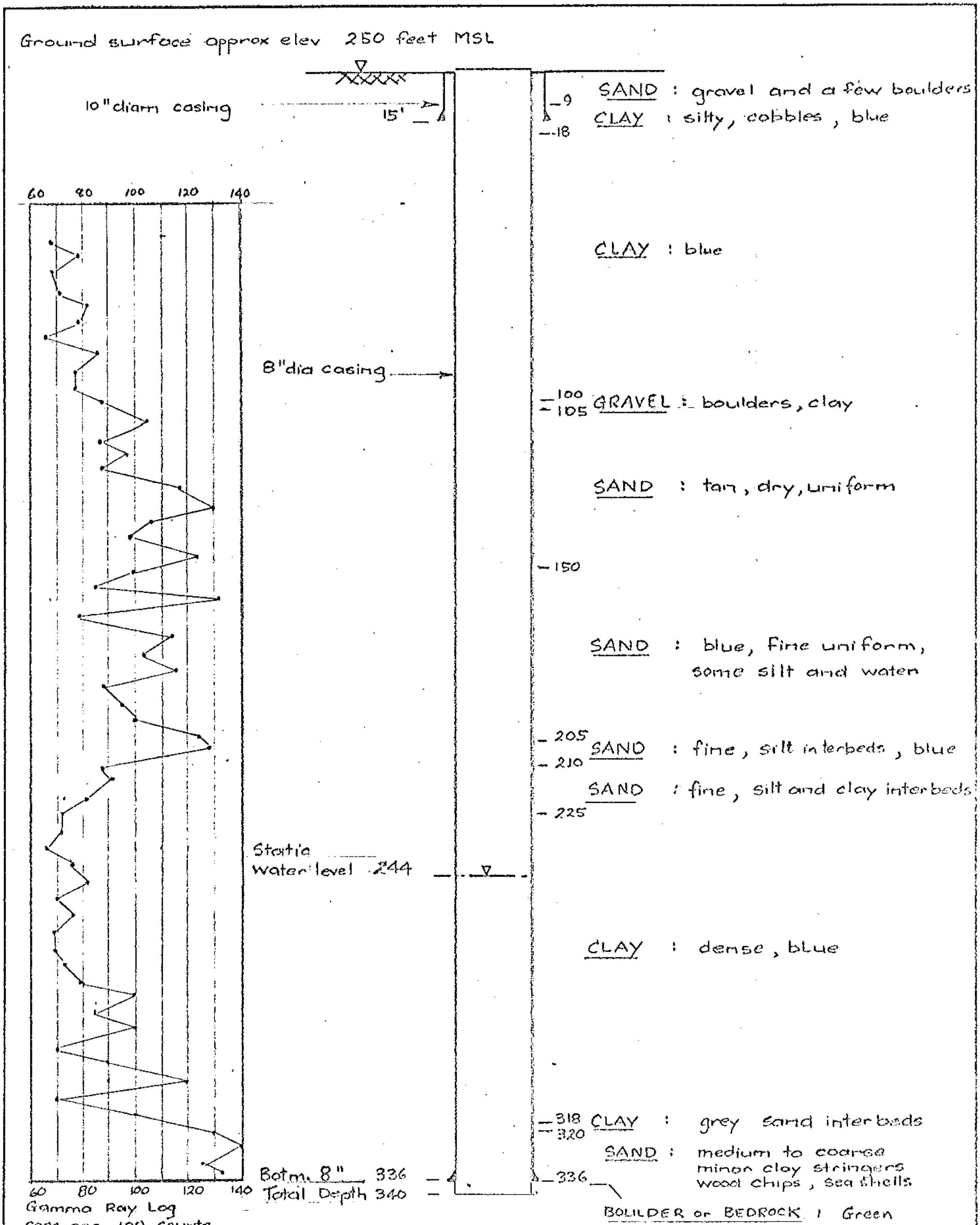
Prior to its use for drinking purposes we would recommend that the water be tested for its bacteriological purity.

CAN TEST LTD.

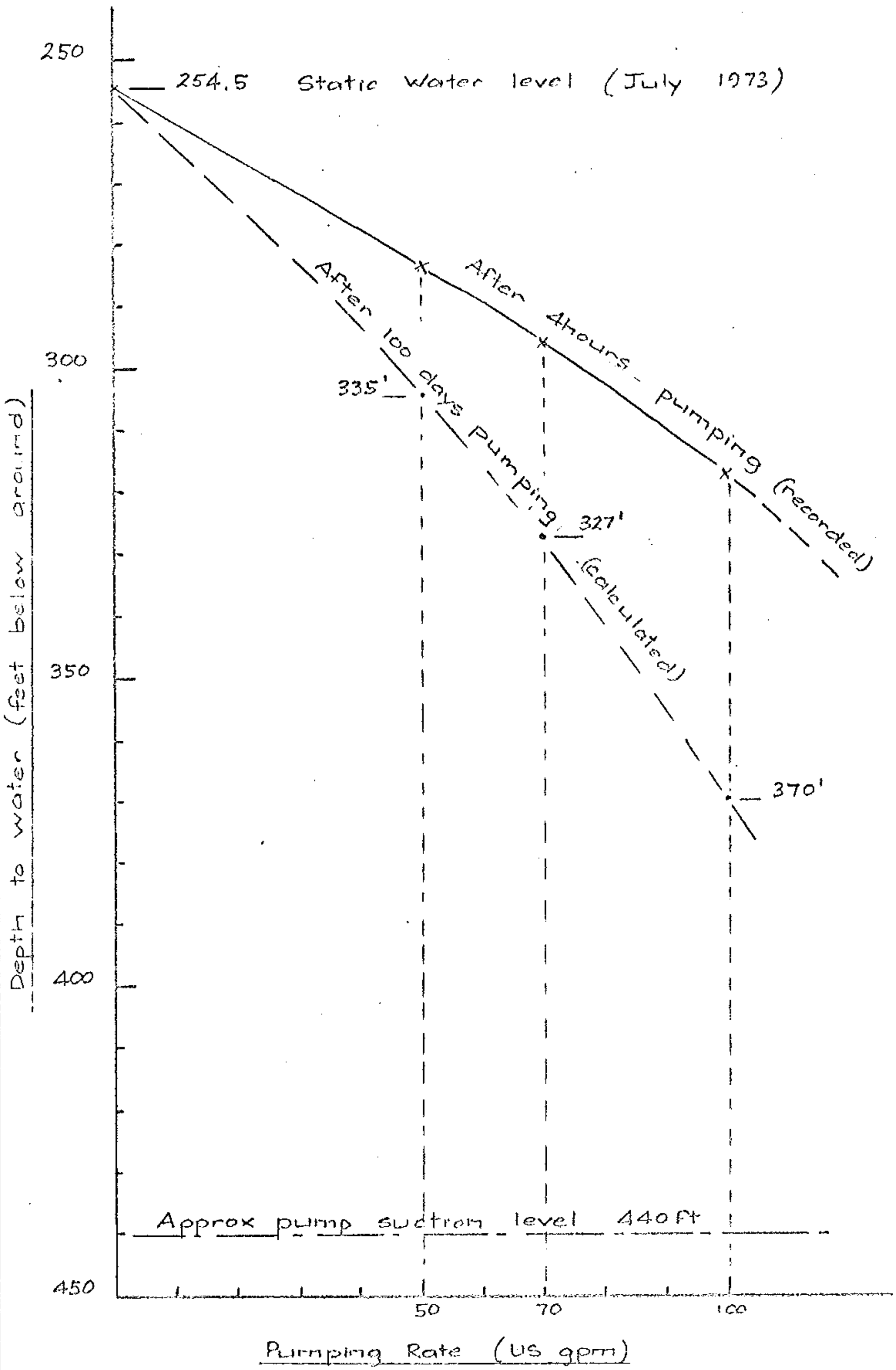
D. K. Dixon



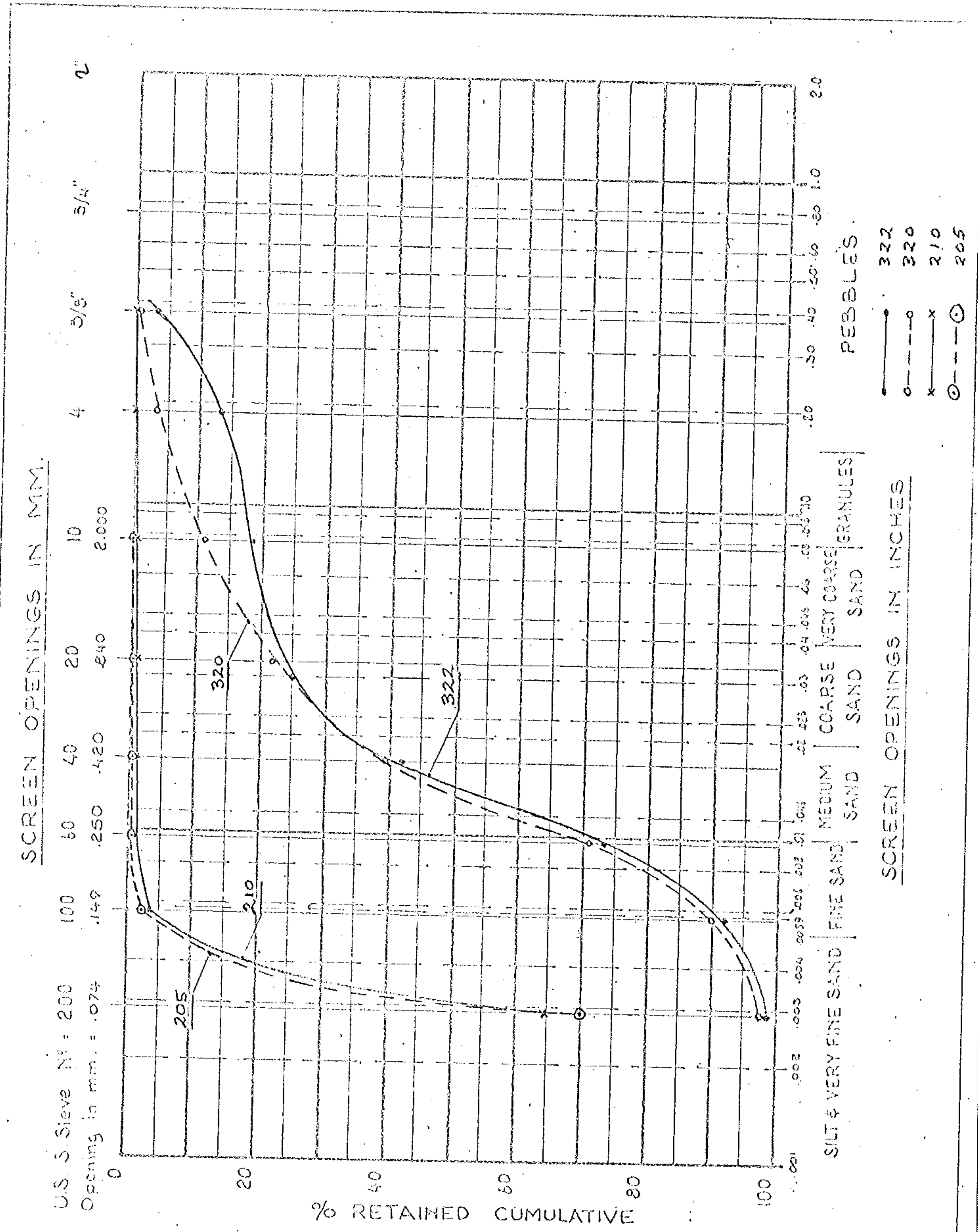
Morgan A. R. Stewart & Co.	LOCATION OF TEST HOLES	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
REDROOFS AREA SECHELT, B. C.		July 1973 — Fig: 1



Morgan A. R. Stewart & Co.	LOG TEST WELL No. 3	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA
REDROOFS AREA SECHELT, B. C.		July 1973 — Fig: 2



MORGAN A.R. STEWART & CO.	DRAWDOWN & PUMP RATE CURVE PRODUCTION WELL #1	ROBINSON, ROBERTS & BROWN LTD. CONSULTING GROUNDWATER GEOLOGISTS NORTH VANCOUVER, CANADA	
REDROOFS AREA SECHELT, B. C.		July 1973	Fig: 4

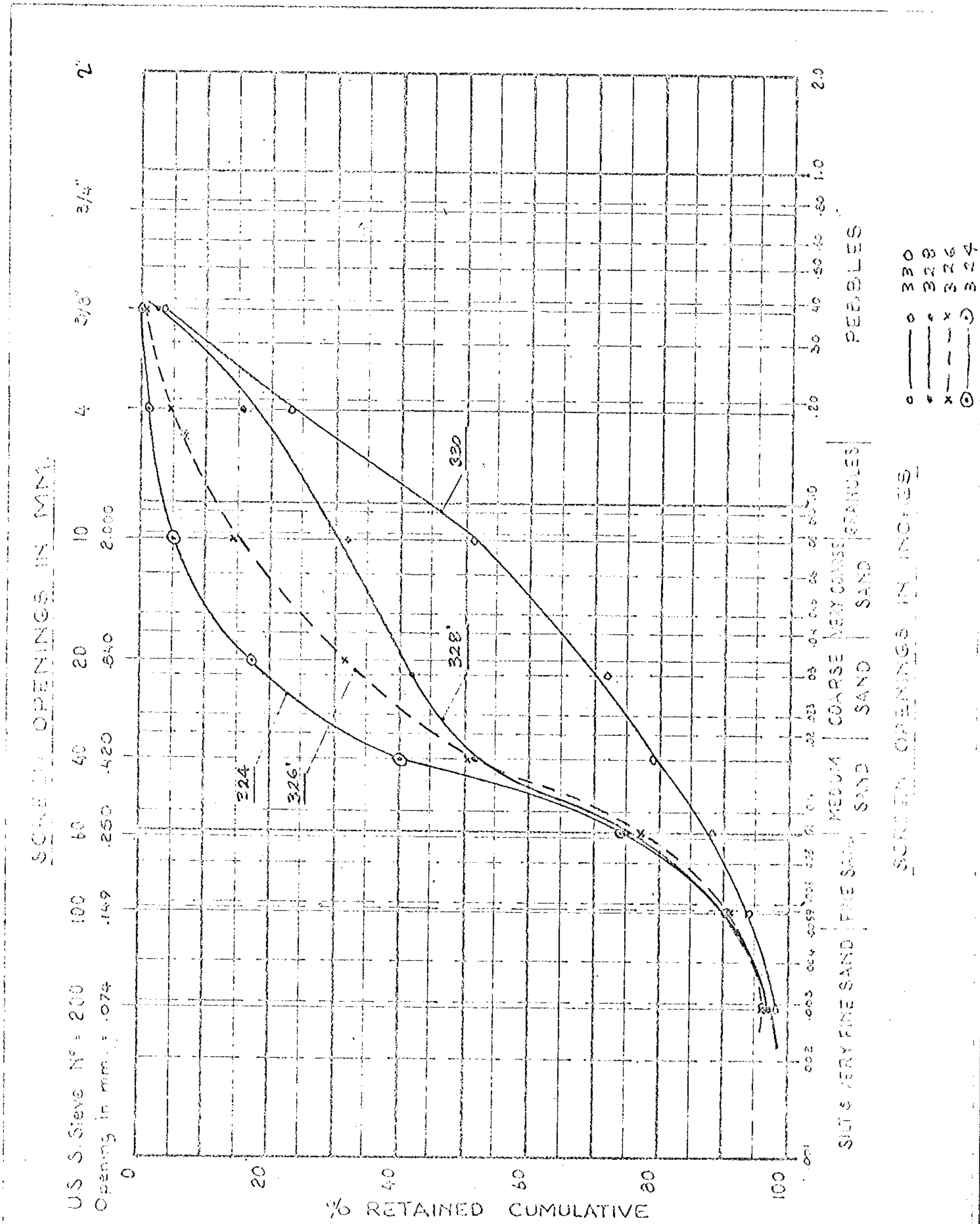


ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, B.C.

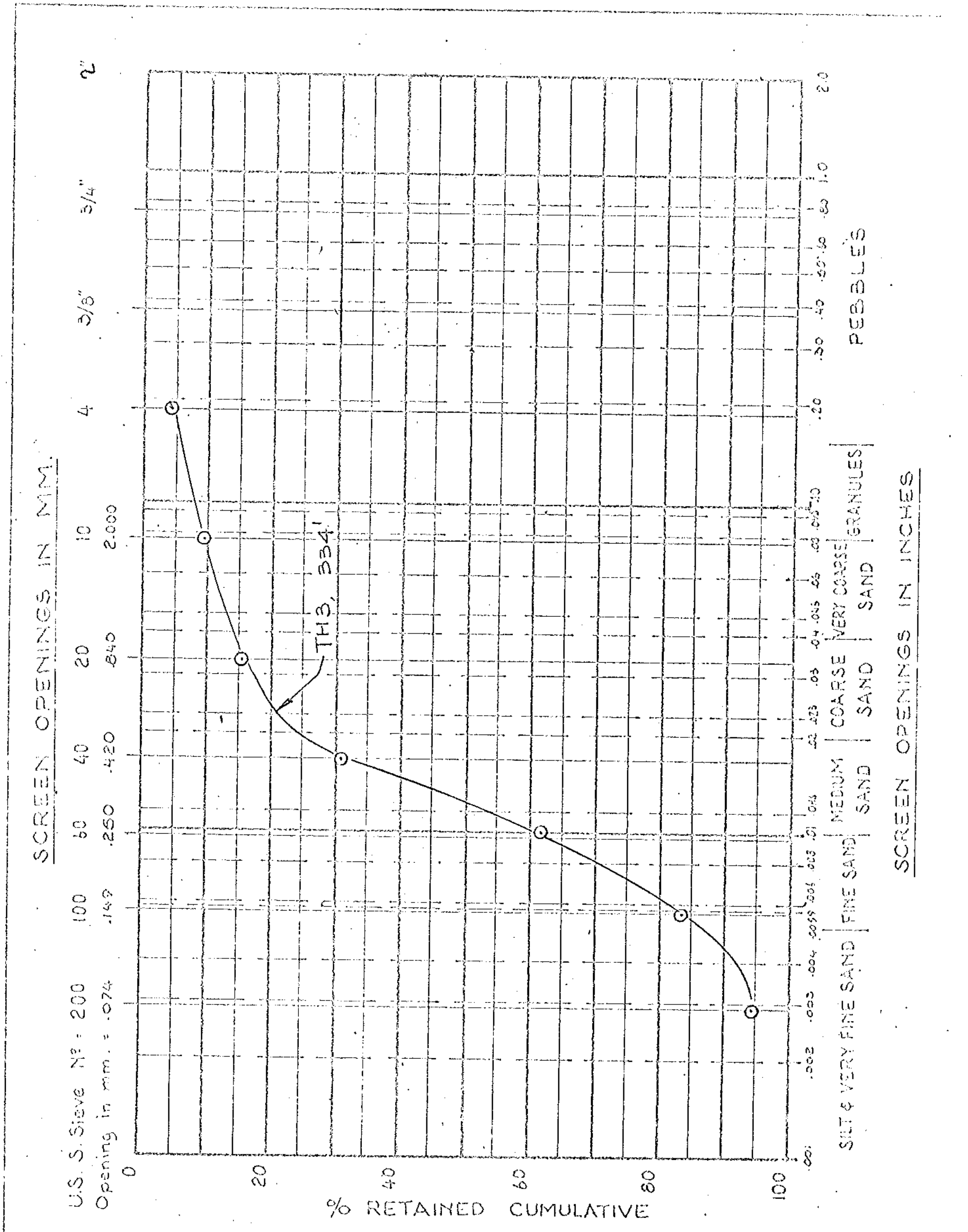
Morgan A. R. Stewart & Co.
Redroof Estates

SIEVE ANALYSIS
Test Hole: 3

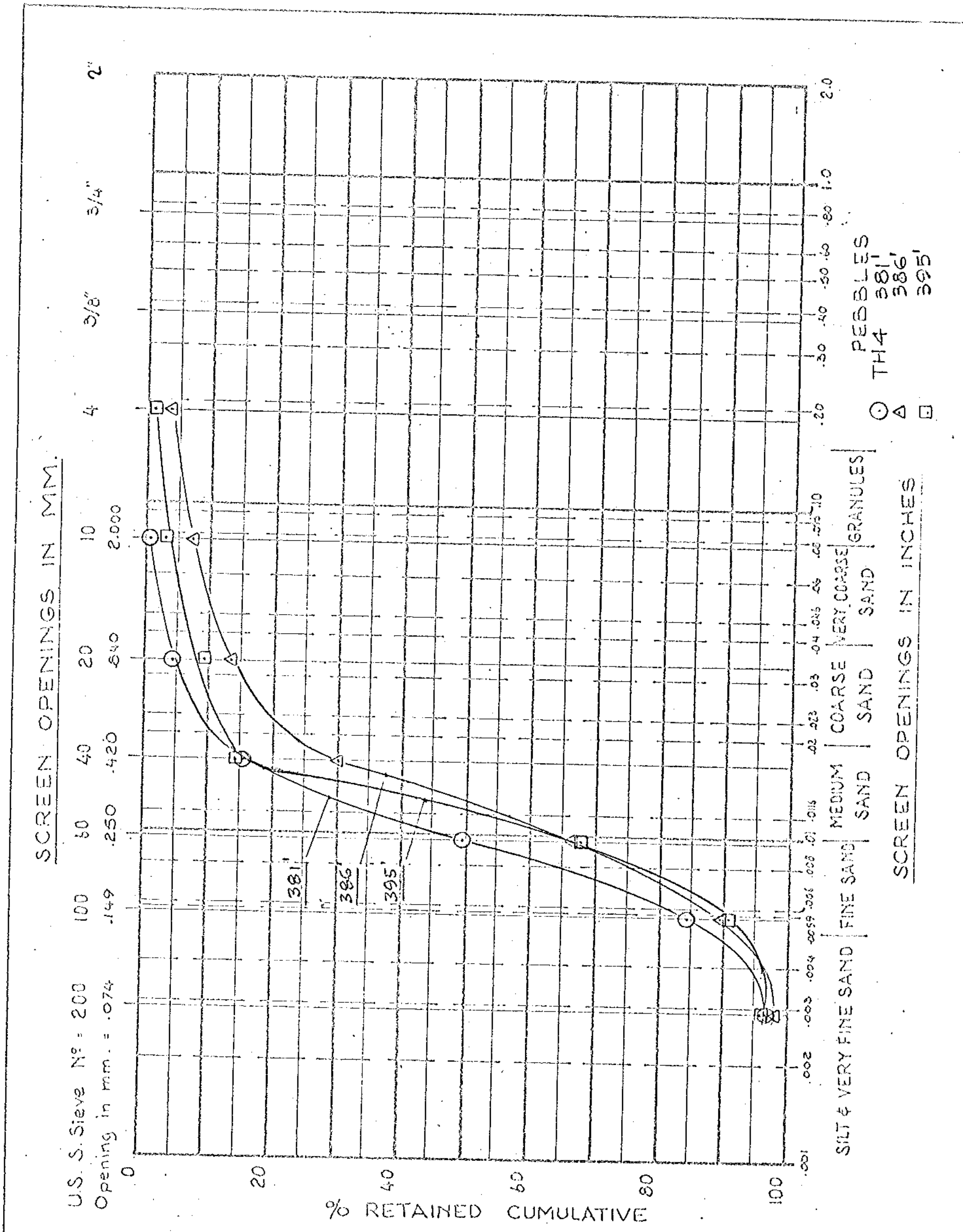
By: [illegible] | Date: Jun. 73
Job: B73-30 | Dwg: Fig. 5



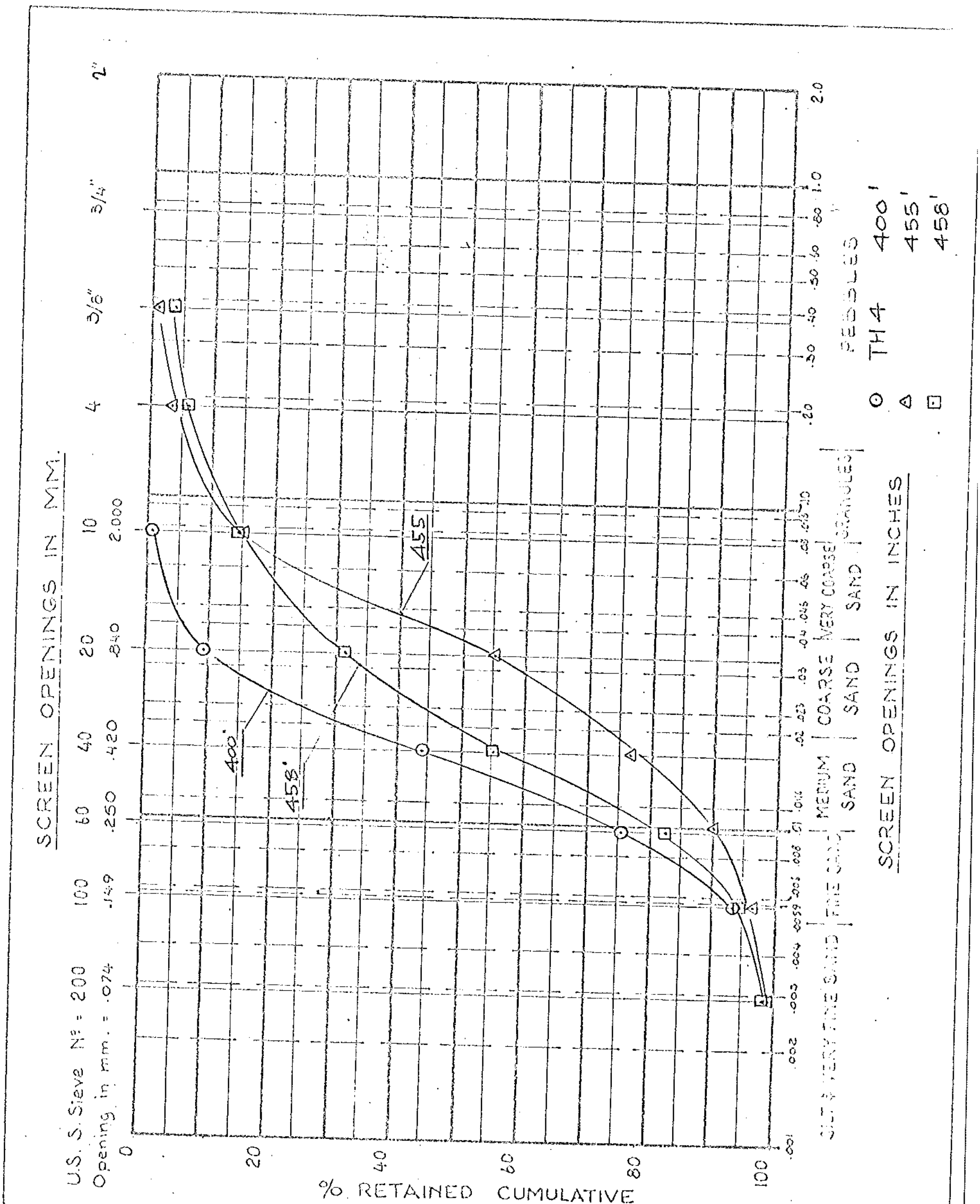
ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver
Morgan A. R. Stewart & Co. Redroofs Estates	SIEVE ANALYSIS Test Hole: 3
By:	Jun. 73
Job: B73-301	Fig. 6



ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, B.C.		
Morgan A. R. Stewart & Co. REDROOFS ESTATES	SIEVE ANALYSIS Test Hole: 3	By: JLC	Date: Jul. 6/73
		Job B73-301	Dwg: Fig: 7



ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, 1 - B.C.	
Morgan A. R. Stewart & Co. REDROOFS ESTATES	SIEVE ANALYSIS Test Hole: 4	By: [signature] / Date: Jul.6/73 Job: B73-301 / Dwg: Fig: 8



ROBINSON, ROBERTS & BROWN Ltd. Groundwater Geologists	R.A. SPENCE LTD - Consulting Engineers - Vancouver, 1 - B.C.		
Morgan A. R. Stewart, & Co. REDROOFS ESTATES	SIEVE ANALYSIS Test Hole: 4	By: JKL	Date Jul.6/73
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