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EXPLORATION AND TESTING OF AN UNCONFINED AQUIFER NEAR CADOGAN, ALBERTA

by

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Synopsis

This report contains the results of an aquifer exploration and testing program for an unconfined aquifer about 10 miles southwest of Cadogan. Four test holes were drilled and a 5-day constant-rate pump test and a step-drawdown test conducted. Two observation wells, at distances of 111 and 389 feet from the pumped well, were utilized during the constant-rate test.

The pumped well was especially designed and constructed for the purpose, using information gained during test drilling concerning size characteristics of the aquifer materials. The test-hole site at which the maximum saturated thickness of aquifer was observed was considered the most favorable one for the pumping test. The size characteristics of the aquifer material, which is also an important factor in choosing a pumping-test site, showed only minor variations at the four test-hole locations so that saturated thickness became the important criterion in site selection.

On the basis of the constant-rate and step-drawdown test results, it is predicted that the maximum 20-year safe yield for a single production well pumping continuously and completed at the base of the aquifer is about 42 imperial gallons per minute (igpm). This estimate is subject to the following limitations:

(a) available drawdown and aquifer size characteristics at any production well site must be the same as those at the test site

(b) construction and development of any production well must be the same as those for the test well

(c) it has not been possible to take into account either the limited extent of the aquifer or recharge of the aquifer by precipitation.

It is nevertheless believed that the 42 igpm figure is a reasonable working value on which to base initial estimates of well-field production. Some estimates are provided in this report for pairs of wells separated by specified distances. It is important to note that maximum 20-year safe yields are not doubled by doubling the number of wells. The total 20-year safe yields for the calculated examples range from 56 to 75 igpm (36 to 83 per cent production increases) for separations ranging from 1,000 to 6,000 feet. As the number of wells is increased, the effects of interference between wells will become even more serious.

The well pumped during the test was sold to the contractors. Development of this well, although adequate for testing purposes, was inadequate for its use on a steady production basis. This was evident from the gradual entry of appreciable amounts of sand into the well during the testing period. Before the well is used as a producer this sand should be removed and further development carried out.

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EXPLORATION OF AQUIFER MATERIALS, WELL DESIGN, AND WELL COMPLETION DETAILS

(July 11 to July 29, 1966)

By G. M. Gabert

The Aquifer

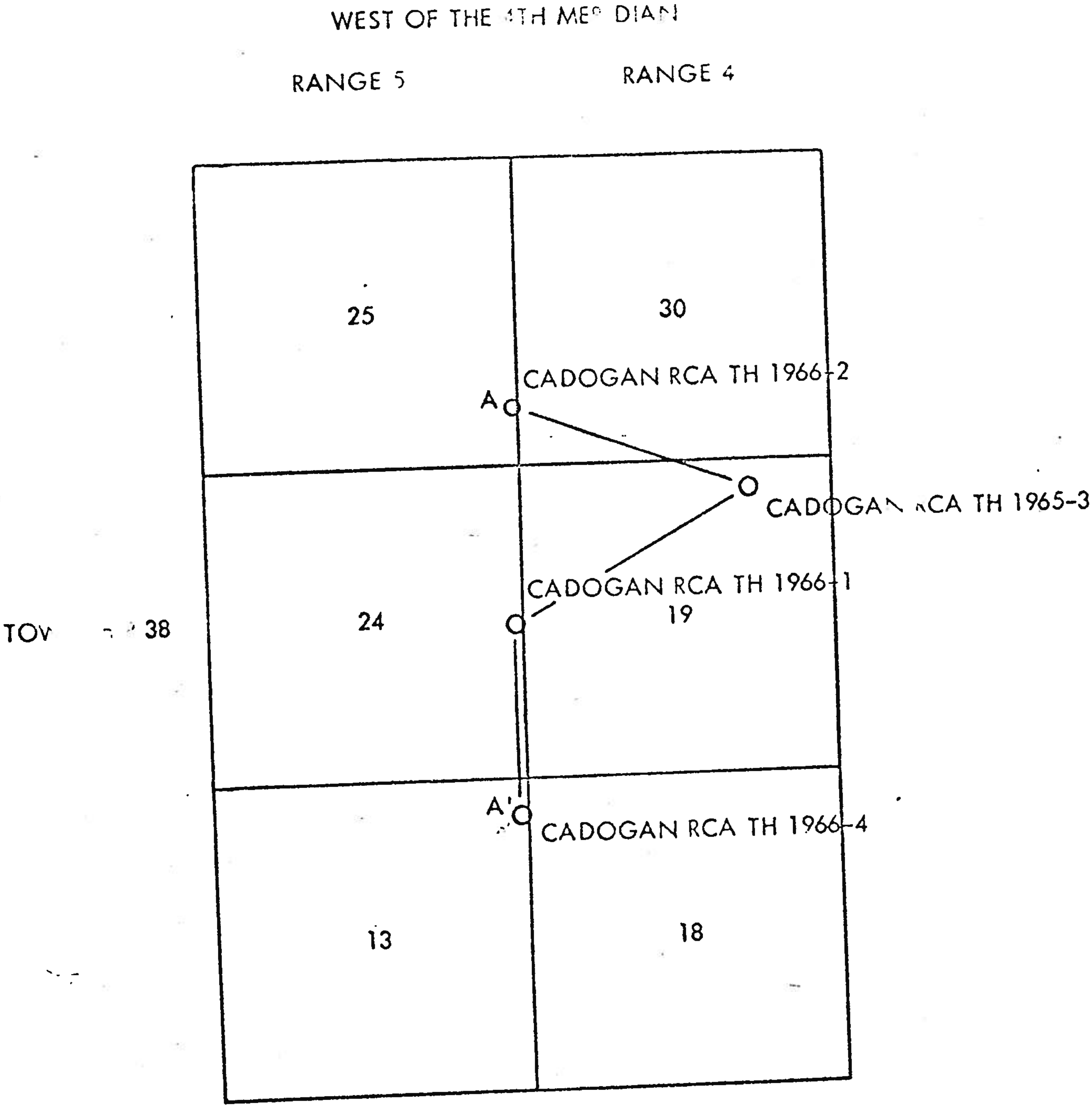
Water-well drillers' logs report partially saturated surficial sands in the area of investigation which is defined in figure 1. A study of aerial photographs shows that the entire area is covered with aeolian deposits which are mainly reworked glacial sands. Analysis of drillers' logs indicates that the surficial deposits overlie a bedrock surface with a regional slope of approximately 30 to 50 feet per mile towards the south.

Exploration of Aquifer Materials

Four test holes were drilled to examine the surficial materials at the locations shown in figure 1. Drilling was carried out with a Bucyrus-Erie 22W cable-tool rig. Drilling continued at each site until the surficial deposits and several feet of bedrock materials were penetrated. Samples of materials penetrated during drilling were obtained every five feet with a bailer. All the samples were washed and sand samples were dried in the field.

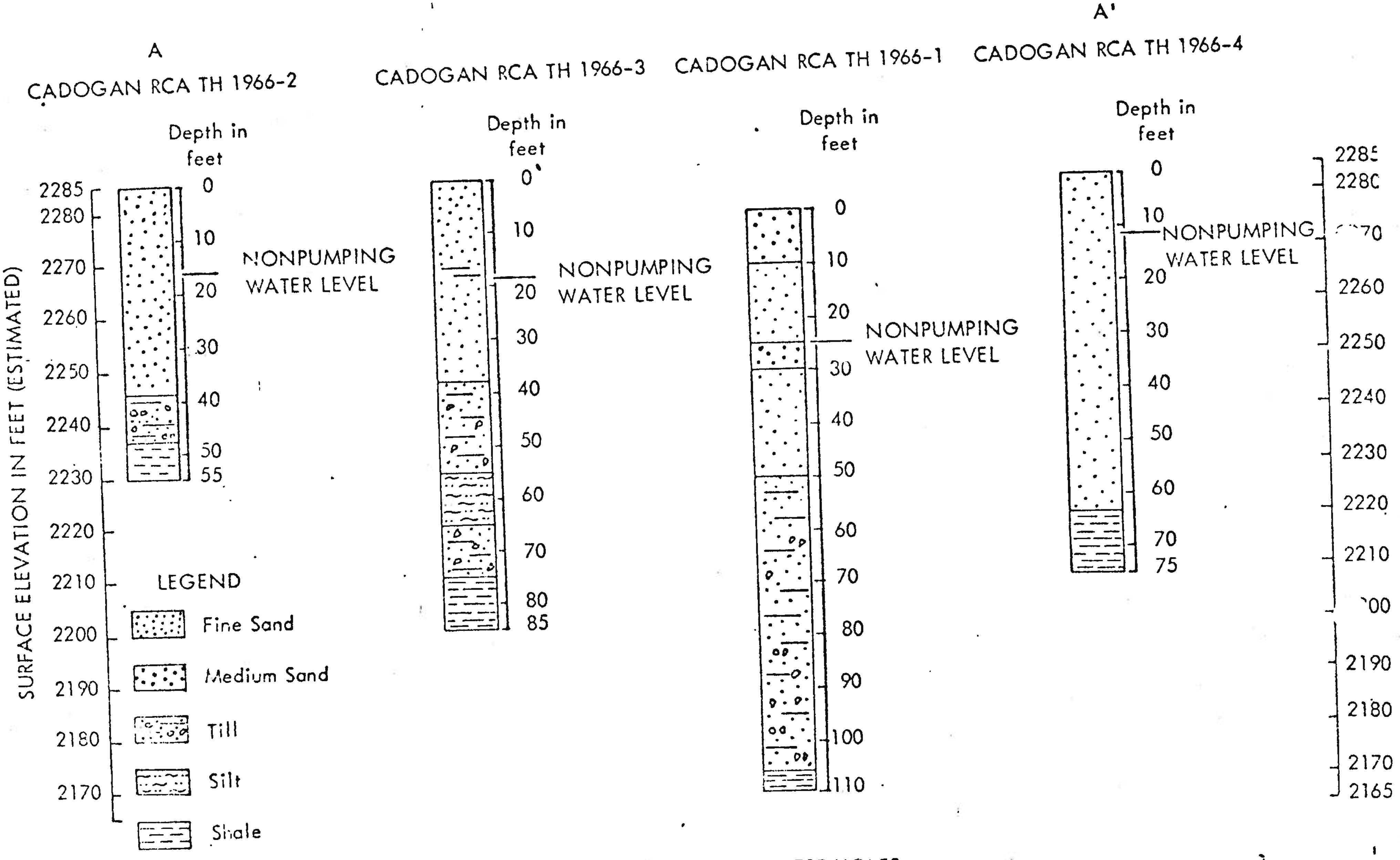
A descriptive log of the samples obtained from each of the four test holes is included in appendix A. Figure 2 is a graphic presentation of the lithologic logs. The common sequence of deposits encountered from the surface down was glacial sands, till, and shale. No till was encountered in Cadogan RCA TH 1966-4.

The nonpumping water level in figure 2 represents a point on the upper surface of the zone of saturation. The maximum thickness of saturated aquifer was encountered in Cadogan RCA TH 1966-4.



MAP OF TEST HOLE LOCATIONS AT CADOGAN, ALBERTA

FIGURE 1.



GRAPHIC LOGS OF CADOGAN TEST HOLES

FIGURE 2.

Justification for Choice of Aquifer Test Site

One of the critical factors in determining the maximum safe yield of a well for a given continuous pumping period is the total available drawdown. For a well completed in an unconfined aquifer this is defined as the height of the column of water from the nonpumping level to the top of the well screen.

Another critical factor in determining maximum yield is the size of the particles making up the aquifer materials. Coarser materials generally are more permeable and will yield more water than fine materials. Since the size range of the sands encountered in the four Cadogan test holes did not vary significantly, the important single criterion for choice of an aquifer test site was maximum saturated thickness of aquifer materials. On this basis, the site of Cadogan RCA TH 1966-4 was considered a suitable aquifer test site.

Pumping Well Design

Well design includes determination of screen diameter, screen length, screen slot size, and sand pack size. The well design was based on criteria outlined by Ahrens (1957), Smith (1961), and Walton (1962). The well was designed to produce 50 imperial gallons per minute (igpm) with a minimum of hydraulic head loss resulting from turbulent flow in the zone outside the well, through the well screen, and in the well casing. The pumping well was completed in the lower portion of the aquifer.

For the purpose of well design a mechanical analysis was completed for each of three samples of sand, representative of the intervals 45-50, 50-55, and 55-60 feet respectively in Cadogan RCA TH 1966-4. The results of the mechanical analysis are presented in appendix B. The dominant portion of each sample was fine sand. A plot of cummulative per cent sample retained versus particle size of the aquifer material is given for each of the above three intervals in figures 3a, 3b, and 3c respectively.

Well Diameter

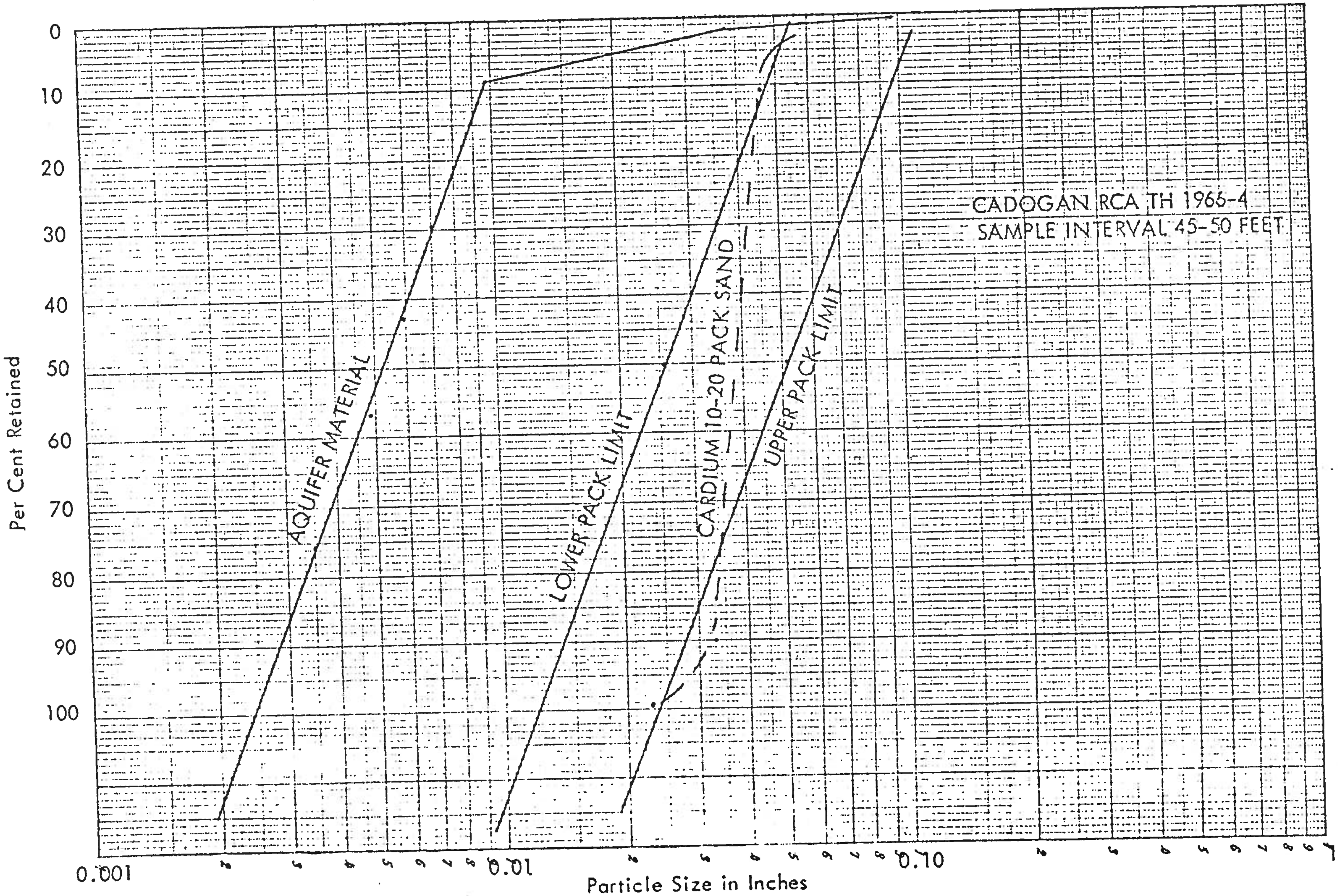
Well diameters are usually determined by the probable pump required. The casing diameter should be at least 2 inches larger than the nominal diameter of the pump bowls. A six-inch diameter well was chosen as optimum for the Cadogan pumping well for two main reasons; firstly, a smaller-diameter well would have required a longer length of screen and, therefore, a reduction in total available drawdown and well yield, in order to obtain sufficient open area to allow laminar flow of water through the formation and into the well; secondly, the increase in relative yeild, if well diameter is the only variable, is only 4 per cent for a diameter increase from 6 to 8 inches. An increase in diameter also results in a substantial increase in metal costs.

Screen Length

When the screen diameter and slot size to be used in a well are known, the length of the screen must be sufficient to provide the required open area to allow laminar flow through the formation and into the well. The length required for the Cadogan pumping well was calculated to be 10 feet, using manufacturer's tables of open area per foot of screen and assuming 50 per cent blockage by aquifer materials.

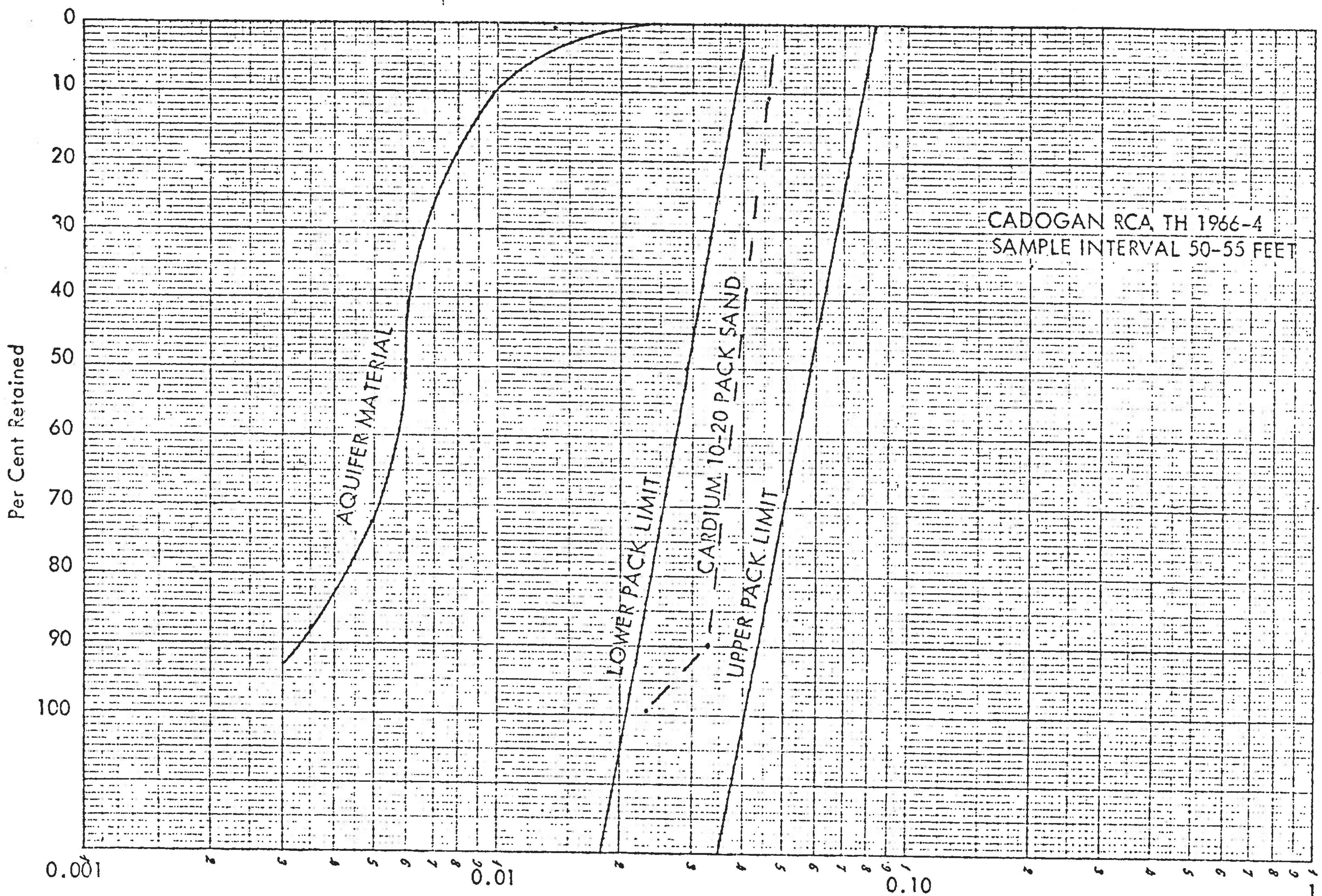
Sand Pack

On a basis of Ahren's criteria (1957) for choice of sand pack, a uniformly graded Cardium 10-20 pack of a size distribution falling within the pack limits in



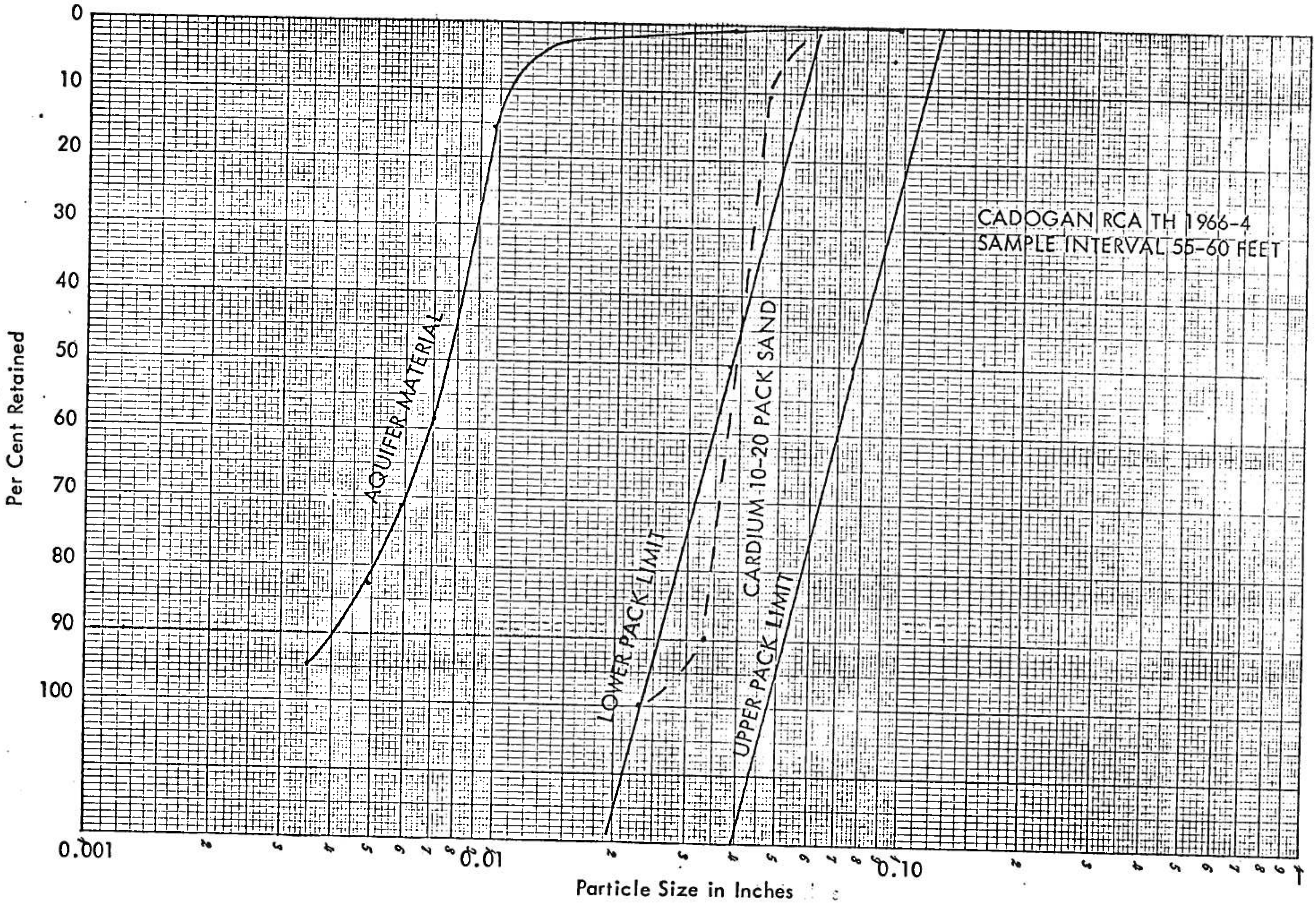
MECHANICAL ANALYSIS OF AQUIFER AND SAND PACK MATERIAL

FIGURE 3a



MECHANICAL ANALYSIS OF AQUIFER AND SAND PACK MATERIAL

FIGURE 3b



MECHANICAL ANALYSIS OF AQUIFER AND SAND PACK MATERIAL

FIGURE 3c.

figures 3b and 3c is the most satisfactory pack for the aquifer materials at the Cadogan RCA TH 1966-4 site. A pack is justified since it permits the use of a larger screen slot size which results in a correspondingly greater percentage of open area per foot of screen and, thus, in a greater yield and more efficient well. An acceptable sand pack will also stabilize uniformly graded aquifer sands having a large percentage of fine materials.

Screen Slot Size

Smith (1961) proposed that the screen openings be of a size that retains at least 90 per cent of the pack material. For a Cardium 10-20 pack sand this size is 0.025 inches or a No. 25 slot.

Observation Well Design

An observation well must be designed so that the water level in the well responds effectively to changes in head in the aquifer created by discharging water at the pumping well. To achieve this, elaborate well construction is generally not necessary. At the Cadogan aquifer test site a screen slot size that retained 30 to 50 per cent of the aquifer materials was chosen for the completion of two observation wells. This choice of screen slot size simplified construction of the observation wells and eliminated the need for development.

The distance an observation well is placed from a pumping well in order that the drawdown data be useful depends on the type of aquifer, and on the parts of the aquifer in which the pumped well and the observation well are completed. Both observation wells, like the pumped well, were completed in the lower portion of the aquifer. For the Cadogan unconfined aquifer at this site under these conditions, each observation well had to be at least 100 feet away from the pumped well. The actual locations were 111 feet south and 389 feet north of the pumped well.

Well Construction

The pumping well and observation wells were constructed at the locations shown in figure 4, on the west side of the road allowance between ranges 4 and 5 (Fig. 1).

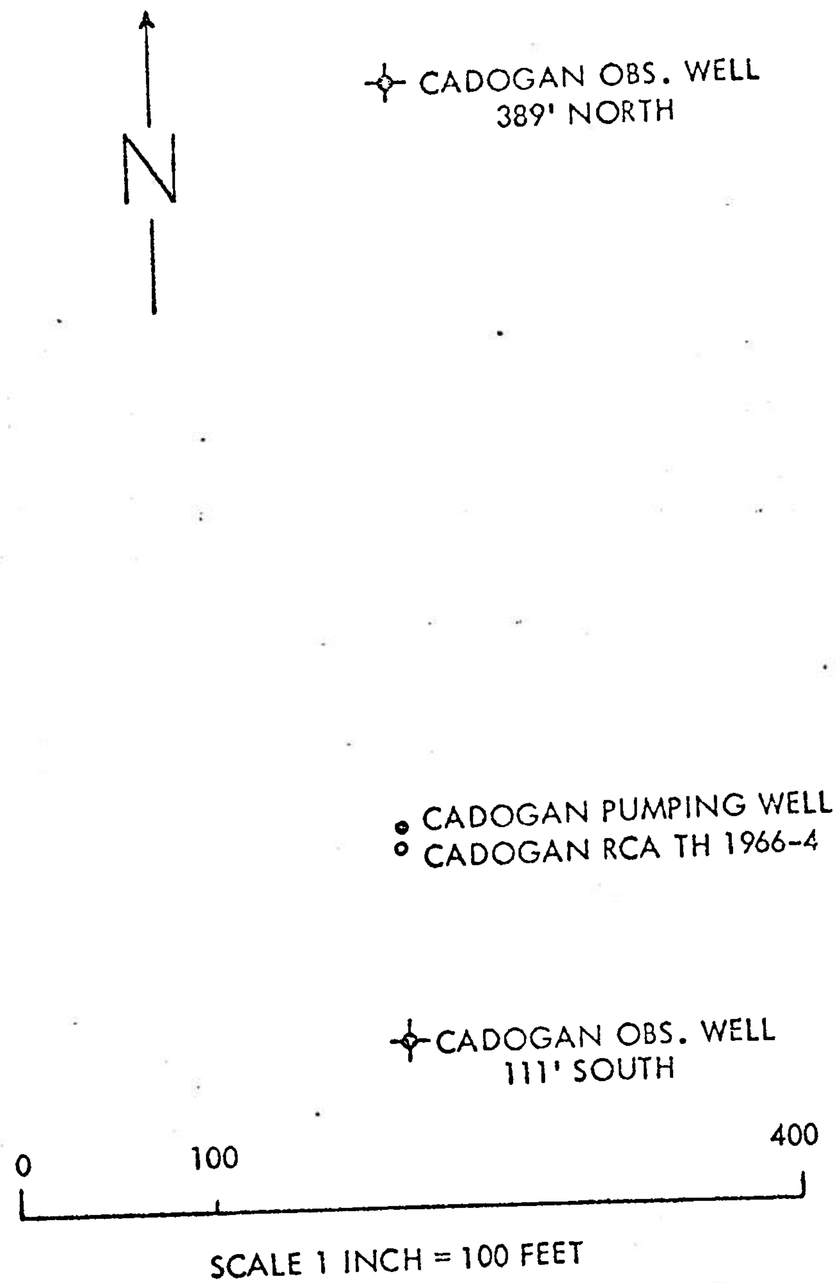
The pumping well was completed in the manner illustrated in figure 5. The screen was attached to the 7" O.D. casing and fitted with a 5-foot casing stub with a closed bottom. The 12" O.D. casing was set into the shale deposits. After the screen string was positioned and the sand pack placed in the annular space between the two casings, the 12" O.D. casing was pulled back until the full length of the screen was exposed to the aquifer.

The observation wells were completed in the manner illustrated in figure 6. The screens in both cases were fitted with closed bottoms and attached to 5 1/2" O.D. casing. The 5 1/2" O.D. casing was positioned inside the 7" O.D. casing which was set below the bottom of the fine sands. The 7" O.D. casing was then pulled back to expose the full length of screen to the aquifer.

Well Development

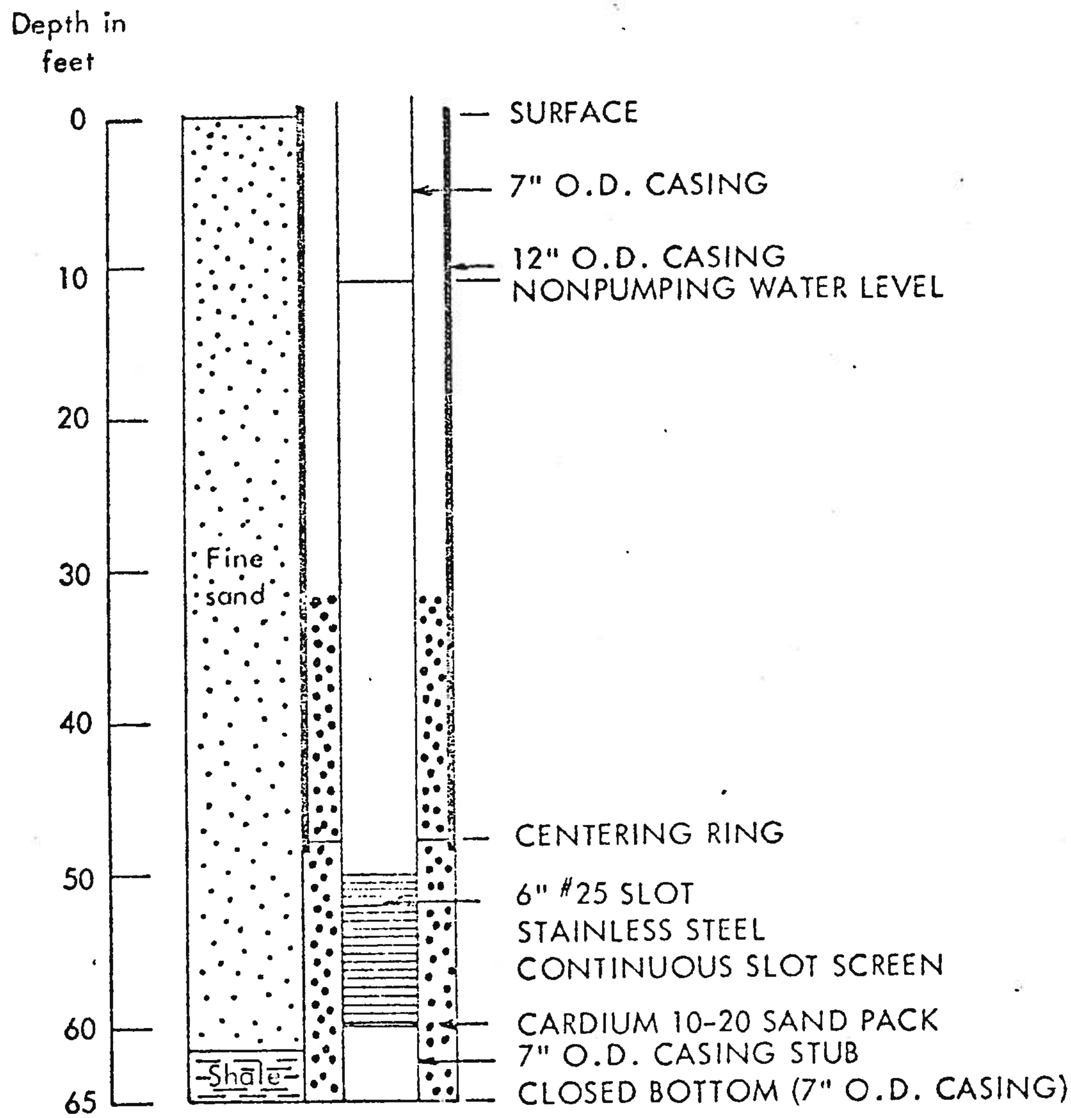
The purpose of well development is to increase the permeability of the materials surrounding and in the vicinity of the well screen in order to have a more efficient well. This is accomplished by removing fine materials from the volume surrounding the screen by "surging" water back and forth through the well screen openings.

Surging of the Cadogan pumping well was carried out by bailing and by use of a solid surge block. Vigorous surging with the surge block was premature at this point of development because an excessive amount of sand was moved through



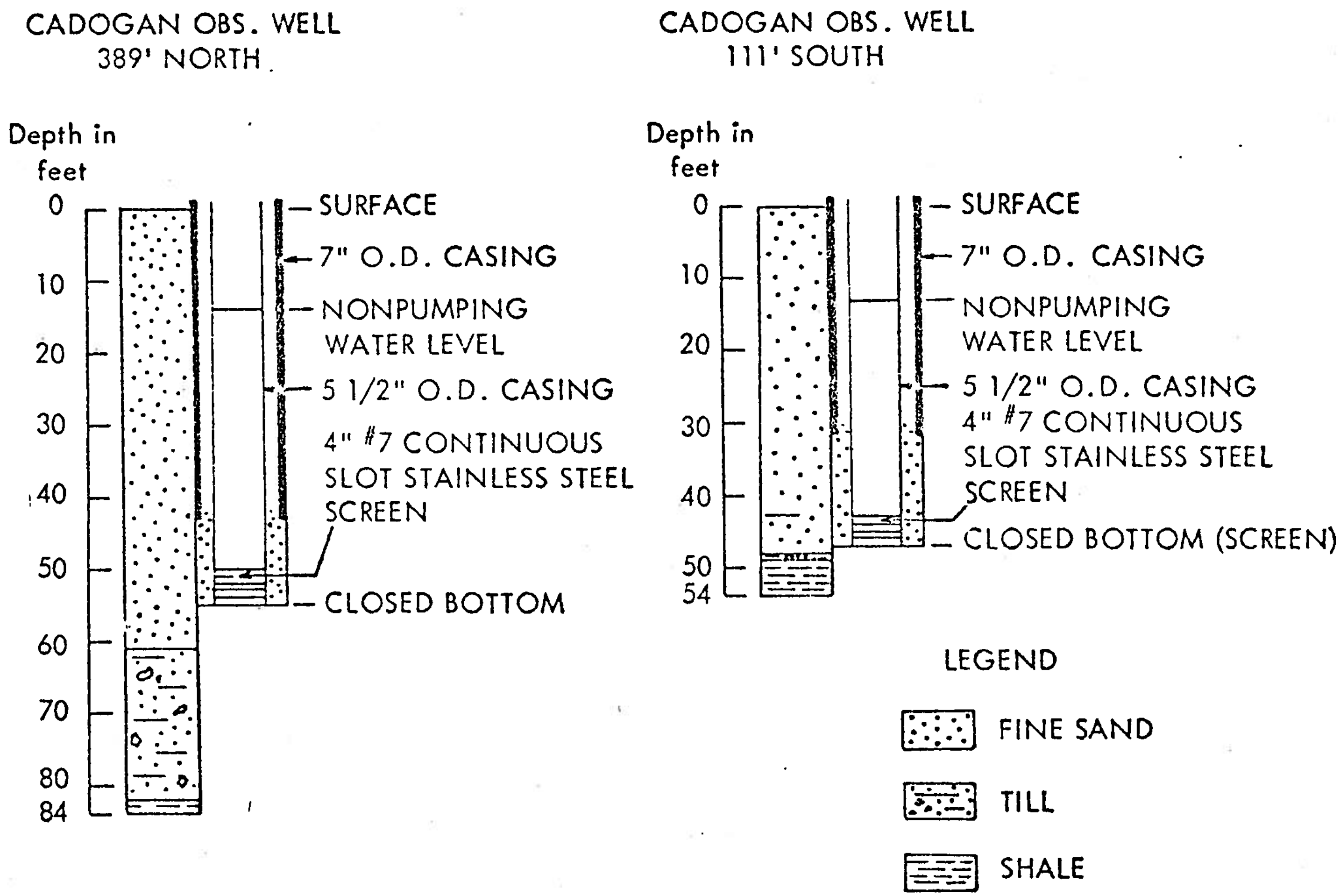
WELL SITE PLAN
CADOGAN, ALBERTA

FIGURE 4.



CADOGAN PUMPING WELL LITHIC LOG
AND COMPLETION DETAILS

FIGURE 5.



CADOGAN OBSERVATION WELLS LITHIC LOGS
AND COMPLETION DETAILS

FIGURE 6.

the pack sand. The development was therefore carried out mainly by bailing the well. A stabilized condition was not reached since a measureable amount of sand was still entering the well when development was stopped. However, it was considered that development was sufficient for the purpose of an aquifer test.

The two observation wells were not developed but each well was tested for response to head changes in the aquifer by suddenly injecting a "slug" or given quantity of water into the well and measuring the decline of the water level in the well as the artificially created head dissipated. The response in both cases was considered satisfactory.

Comments on Well Design and Development

The step-drawdown test, described in a later section, showed that the well design was successful for rates up to 50 igpm because laminar flow was maintained in and around the pumped well during this test, even for rates as high as 49 igpm.

At the conclusion of the step-drawdown test considerable sand had entered the pumped well. This is believed to be a consequence of insufficient development. Development, as remarked above, was adequate for test purposes only. If this well is to be put on a production schedule, it must be cleaned out and further developed, using approved methods. Development by bailing the well, by the use of compressed air, or with a solid surge block is recommended. Surging with a solid surge block must be gentle during early stages of development and build up to a maximum during final stages. Development is sufficient when only a minute amount of sand can be drawn into the well by surging for any length of time by any of the above methods.

Conclusions

All available information suggests that the aquifer materials are chiefly fine, glacial sands, the upper portion of which has been redeposited into dunes by wind action.

To obtain maximum yields from single well installations, elaborate well design is required.

The critical factor in the choice of a well site and the determination of a final production rate for a given well is the total available drawdown which is largely determined by the saturated thickness of the aquifer. Thus, the greater the saturated thickness, the greater the total available drawdown. The size characteristics of the aquifer materials play a minor part, since they appear to be relatively uniform for all the four sites at which test holes were drilled.

PUMP TEST

Test Procedures

Starting July 30, 1966 at 9.00 a.m., the test well was pumped at an average rate of 22.8 imperial gallons per minute (igpm). Discharge, measured with a 45-gallon drum, varied slightly during the test, particularly at sunrise and sunset, but the variations were not large enough to impair seriously the results of the test.

During the test water levels were measured in the test well and in two observation wells, located at 111 feet south and 389 feet north of the test well (Fig. 4). Pumping was continued for 125 hours, the test being ended on August 4 at 2.00 p.m. owing to engine failure; however, at this time the objectives of the test had been reached.

A step-drawdown test was run on August 8 to provide an estimate of well losses and well efficiency. Pumping rates were 15, 37.5 and 49 igpm.

Water-level measurements during bail testing, pump testing, recovery, and prior to testing are presented in appendix C, together with other pertinent data.

Analysis of Drawdown Measurements

The analysis of the drawdown measurements in the observation wells was based on the theory developed by Boulton (1963) describing the nonsteady-state time-drawdown relationship for pumping from a water-table aquifer. The type-curve method of solution – given by Prickett (1965) and based on Boulton's analysis – was the practical method utilized.

Drawdown measurements in the test well were plotted against the logarithm of time to establish the long-term trend of the water level in the test well. Boulton's method is not applicable to the test well.

The method developed by Rorabaugh (1953) was used in the analysis of the step-drawdown results.

Transmissibility and Storage Coefficients

In general, the response of a water-table aquifer to continuous pumping occurs in three stages: a first stage in which water is withdrawn from storage mainly by the compaction of the aquifer and by the expansion of the water as the pressure in the aquifer is lowered; a second transitional stage in which the influence of the actual drainage of the sediments becomes significant, resulting in a decrease of the slope of the time-drawdown curve; and a third stage in which gravity drainage is supplying practically all of the pumped water. During the first stage the response and the calculated storage coefficient of the aquifer are similar to those of an artesian aquifer; during the third stage the storage coefficient attains a water-table value and it is this storage coefficient that must be used in the calculation of the long-term effects of aquifer development.

From the pump test results the following coefficients were derived:

		T (igpd/ft)	S (artesian)	S (gr. drainage)
Observation well 389 feet north	Early data	1040	4.4×10^{-4}	-----
	Late data	930	--------	0.052
	Average	980		
Observation well 111 feet south	Early data	1240	3.7×10^{-4}	-----
	Late data	1240	--------	0.016
	Average	1240		
Average		1110	4.0×10^{-4}	0.034

Calculation of Safe Yield for a Single Well

The drawdown in a pumped well at any time is the sum of the formation losses, which can be calculated when the aquifer coefficients are known, and the well losses, which are due to flow conditions in the neighbourhood of and within the well. The step-drawdown test carried out after the main constant-rate pump test showed that for pumping rates up to 49 igpm – the maximum rate utilized during this test – well loss was proportional to the pumping rate. This indicates that flow in the vicinity of the pumped well never became turbulent for these rates.

The trend of the drawdown in the test well was calculated for the latter part of the constant-rate test as 1.00 feet per log cycle. This figure, however, is not too accurate, as there was much scatter to the measurements due to turbulence in the well bore and slight variations in the pumping rate. A better trend of 1.5 feet per cycle was obtained from the recovery measurements. Using this figure the expected drawdown at 10^7 minutes (20 years) can be calculated:

Drawdown at 10^7 min. = drawdown at 10^3 min. + 4 (drawdown per log cycle)

$$= 16.3 \qquad + 4 \times 1.15 \qquad = 20.9 \text{ feet.}$$

The total available drawdown is the elevation of the nonpumping level minus the elevation of the top of the screen = 50.0 - 11.8 = 38.2 feet. The safe pumping rate then becomes: $\frac{38.2}{20.9} \times 22.8 = 41.7$ igpm.

Systems of More than One Well

In case more than one well is producing from the same aquifer, the effects of all wells have to be taken into account at each well location. To calculate drawdowns at any point at a given distance from a given pumped well the transmissibility and storage coefficient of the aquifer must be known. In deriving the results listed in the table below, 1,100 igpd/ft (imperial gallons per day per foot) and .034 were assumed for the transmissibility and the storage coefficient respectively.

For a system of two wells at various distances apart the following values of the safe yield over periods of 20 years and 10 years were calculated:

Distance between wells (feet)	Drawdowns at Well No. 1 (feet): Self-caused due to unit discharge at Well No. 1	Drawdowns at Well No. 1 (feet): Due to unit discharge at Well No. 2	Total	Safe yield for each well (igpm)	Period (years)
1000	.908	.458	1.366	28.0	20
2000	.908	.315	1.223	31.2	20
3000	.908	.235	1.143	33.4	20
6000	.908	.109	1.017	37.6	20
1000	.898	.386	1.284	29.7	10
2000	.898	.247	1.145	33.3	10
3000	.898	.168	1.066	35.8	10
6000	.898	.058	0.956	40.0	10

For a system of three wells equally spaced along a straight line 6,000 feet long the maximum safe pumping rate for a period of 20 years would be 33 igpm for each of the two outer wells and 25.5 igpm for the center well.

Limitations of the Calculated Safe Yields

It is to be understood that the foregoing estimates of future water levels and safe pumping rates do not take into account that:

1) the aquifer is of limited areal extent

2) the aquifer does not necessarily have everywhere the same properties as encountered in the vicinity of the test well

3) the available drawdowns in other parts of the aquifer may be substantially different from that in the test well

4) The calculated well losses for the pumped well are characteristic of that well only.

It should therefore be kept in mind that the estimated yields should only be used as guide lines for aquifer development and not as an absolute guarantee that the quoted amounts of water can be safely withdrawn over a 10- or 20-year period.

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APPENDIX A. TEST-HOLE LOGS

CADOGAN RCA TEST HOLE 1966-1 DESCRIPTIVE LOG

Location: Lsd. 8, Sec. 24, Tp. 38, R. 5, W. 4th Mer.

Interval (feet)	Description
6- 10	Sand, quartz, medium grained, grey to light olive grey, subrounded
10- 15	Sand, quartz, fine grained, yellowish grey, subrounded
15- 20	Sand, quartz, fine grained, yellowish grey, subrounded
20- 25	Sand, quartz, fine to medium grained, yellowish grey, subrounded
25- 30	Sand, quartz, medium grained, yellowish grey, subrounded
32- 35	Sand, quartz, fine to medium grained, yellowish grey, subrounded
35- 40	Sand, quartz, fine grained, yellowish grey, subrounded
40- 45	Sand, quartz, fine grained, yellowish grey, subrounded
45- 50	Sand, quartz with silt, fine grained, yellowish grey to light olive grey, subrounded
50- 55	Clay, very silty, light olive grey
55- 60	Clay, very silty, light olive grey
60- 65	Clay with quartz grains, light olive grey
65- 70	Clay with quartz grains, light olive grey
70- 75	Clay, sandy, light olive grey
75- 80	Clay, sandy, light olive grey
80- 85	Clay with quartz grains, light olive grey
85- 90	Clay with quartz grains and shale chips, light olive grey
90- 95	Clay with shale chips, pale olive
95-100	Clay with quartz grains and shale chips, pale olive
100-106	Clay with quartz grains and shale chips, yellowish grey
106-110	Shale, yellowish grey

CADOGAN RCA TEST HOLE 1966-2 DESCRIPTIVE LOG

Location: Lsd. 1, Sec. 25, Tp. 38, R. 5, W. 4th Mer.

Interval (feet)	Description
5-10	Sand, quartz, fine to medium grained, yellowish grey, subrounded
10-15	Sand, quartz, fine-grained sand, yellowish grey, subrounded
15-20	Sand, quartz, fine grained, yellowish grey, subrounded
20-25	Sand, quartz, fine to medium grained, yellowish grey, subrounded
25-30	Sand, quartz, very fine to fine grained, yellowish grey, subrounded
30-35	Sand, quartz, very fine to fine grained, yellowish grey, subrounded
35-39	Sand, quartz, very fine to fine grained, yellowish grey to light olive grey, subrounded
39-45	Clay, olive grey with quartz grains and shale chips
48-50	Shale, yellowish grey.
50-55	Shale, yellowish grey

CADOGAN RCA TEST HOLE 1966-3 DESCRIPTIVE LOG

Location: Lsd. 15, Sec. 19, Tp. 38, R. 4, W. 4th Mer.

Interval (feet)	Description
0- 5	Sand, quartz, fine grained, yellowish grey, subrounded
5-10	Sand, quartz, fine grained, yellowish grey, subrounded
10-15	Sand, quartz, very fine to fine grained, yellowish grey to light olive grey, subrounded
15-20	Sand, quartz, fine to medium grained, yellowish grey to light olive gray , subrounded with thin clay layers
20-25	Sand, quartz, very fine grained, medium light grey, subrounded
28-30	Sand, quartz, very fine grained, medium light grey, subrounded
30-38	Sand, quartz, very fine to fine grained, yellowish grey, subrounded
38-40	Clay, sand with pebbles, light olive grey
40-45	Clay, sandy with pebbles, light olive grey
45-50	Clay, silty with pebbles and shale chips, light olive grey
50-55	Clay, sandy with pebbles, light olive grey
55-60	Silt, sandy, light olive grey
60-65	Silt, sandy, light olive grey
65-70	Clay, silty with pebbles and shale chips, light olive grey
70-75	Clay, silty with pebbles and shale chips, light olive grey
75-80	Shale, silty with carbonaceous fragments, light olive grey
80-85	Shale, carbonaceous fragments, yellowish grey

CADOGAN RCA TEST HOLE 1966-4 DESCRIPTIVE LOG

Location: Lsd. 16, Sec. 13, Tp. 38, R. 5, W. 4th Mer.

Interval (feet)	Description
5-10	Sand, quartz, fine grained, yellowish grey, subrounded
10-15	Sand, quartz, very fine to fine grained, yellowish grey, subrounded
15-20	Sand, quartz, fine grained, yellowish grey, subrounded
20-25	Sand, quartz, fine grained, yellowish grey, subrounded
25-30	Sand, quartz, fine grained, yellowish grey, subrounded
30-35	Sand, quartz, fine grained, yellowish grey, subrounded
35-40	Sand, quartz, very fine to fine grained, yellowish grey, subrounded
40-45	Sand, quartz, very fine to fine grained, yellowish grey, subrounded
45-50	Sand, quartz, very fine grained, yellowish grey, subrounded
50-55	Sand, quartz, fine grained, yellowish grey, subrounded
55-63	Sand, quartz, fine grained, yellowish grey, subrounded
63-75	Shale, silty, light olive grey

APPENDIX B. MECHANICAL ANALYSES

GROUNDWATER SIEVES

Location LSD 16-13-38-5-W 4M   Driller Forrester Drilling, Red Deer, Alberta

Sample interval 45-50feet   Date collected July 15/66   Collector R.C.A.

Depth of well ______   Date analysed July 18/66   Analyst G.M.Gabert & D. Roles

Description 0.53% coarse sand, 8.56% medium sand, 48.6 fine sand, 19.03 very fine sand, 23.27% silt and clay

Gross wt.	
Container wt.	
Net wt.	134.90 grams

Retained on Sieve Mesh No.	Size ins.	mm.	Sample + container	Container	Wt. (grams) ret.	Wt. % ret.	Cumulative % ret.	Wt. (grams) passed	% passed	Cumulative % passed
1/2"	.50	12.70								
1/4"	.25	6.35								
5	.157	4.00								
7	.111	2.83								
10	.0787	2.0								
18	.0394	1.0								
25	.0280	0.71								
35	.0197	0.50	2.07	1.37	0.70	.52	.52			
45	.0138	0.35	3.06	1.37	1.69	1.25	1.77			
60	.0098	0.25	11.04	1.37	9.67	7.17	8.94			
70	.0083	0.21								
80	.0070	0.177	29.69	1.37	28.32	20.99	29.93			
100	.0059	0.149	18.28	1.37	16.91	12.54	42.47			
120	.0049	0.125	20.66	1.37	19.29	14.30	56.77			
170	.0035	0.088	26.[illegible]	1.37	25.25	18.72	75.49			
Pan		.	32.26	1.37	30.89	22.90	98.39			
Total					132.72					

Location LSD 16-13-38-5-W 4M Driller Forrester Drilling, Red Deer, Alberta

Sample interval 50-55 feet Date collected July 15/66 Collector R.C.A.

Depth of well 75 feet Date analysed July 18/66 Analyst G.M. Gabert & D. Roles

Description 0.16% coarse sand, 9.83 % medium sand, 62.73% fine sand, 14.97% very fine sand, 12.31% silt & clay

Gross wt.	
Container wt.	
Net wt.	275.34 grams

Retained on Sieve Mesh No.	Size ins.	mm.	Sample + container	Container	Wt. (grams) ret.	Wt. % ret.	Cumulative % ret.	Wt. (grams) passed	% passed	Cumulative % passed
1/2"	.50	12.70								
1/4"	.25	6.35								
5	.157	4.00								
7	.111	2.83								
10	.0787	2.0								
18	.0394	1.0								
25	.0280	0.71								
35	.0197	0.50	1.81	1.37	0.44	.16	.16			
45	.0138	0.35	3.14	1.37	1.77	.64	.80			
60	.0098	0.25	26.66	1.37	25.29	9.19	9.99			
70	.0083	0.21								
80	.0070	0.177	91.36	1.37	89.99	32.68	42.67			
100	.0059	0.149	37.25	1.37	35.88	13.03	55.70			
120	.0049	0.125	48.23	1.37	46.86	17.02	72.72			
170	.0035	0.088	42.59	1.37	41.22	14.97	87.69			
Pan			35.26	1.37	33.89	12.31	100.00			
Total					275.34					

Location LSD 16-13-38-5-W M

Driller Forrester Drilling, Red Deer, Alberta

Sample interval 55-60 feet

Date collected July 15/66

Collector Research Council of Alberta, Groundwater Division,

Depth of well 75 feet

Date analysed July 18/66

Analyst G.M. Gabert & D. Roles

Description 0.18% coarse sand, 15.14% medium sand, 67.46% fine sand, 11.83% very fine sand, 5.39% silt and clay

Gross wt.	
Container wt.	
Net wt.	265.31 grams

Retained on Sieve Mesh No.	Size ins.	mm.	Sample + container	Container	Wt. (grams) ret.	Wt. % ret.	Cumulative % ret.	Wt. (grams) passed	% passed	Cumulative % passed
1/2"	.50	12.70								
1/4"	.25	6.35								
5	.157	4.00								
7	.111	2.83								
10	.0787	2.0								
18	.0394	1.0								
25	.0280	0.71								
35	.0197	0.50	1.84	1.37	0.47	.18	.18			
45	.0138	0.35	2.97	1.37	1.60	.60	.78			
60	.0098	0.25	39.95	1.37	38.58	14.54	15.32			
70	.0083	0.21								
80	.0070	0.177	116.46	1.37	115.09	43.38	58.70			
100	.0059	0.149	34.06	1.37	32.69	12.32	71.02			
120	.0049	0.125	32.57	1.37	31.20	11.76	82.78			
170	.0035	0.088	32.76	1.37	31.39	11.83	94.61			
Pan			15.66	1.37	14.29	5.39	100.00			
Total					265.31					

APPENDIX C. WATER-LEVEL MEASUREMENTS AND RELATED DATA

Water-Level Measurements In Nearby Wells Previous to and During the Test

Measurements with steel tape

RCA Test Hole No. 1	Curcio observation well	Date
24.50		July 13, 1966
24.70		July 14, 1966
24.72	30.71	July 15, 1966
24.97		July 18, 1966 9.00 a.m.
24.94		July 18, 1966 9.00 p.m.
24.87		July 19, 1966 8.00 a.m.
24.87		July 19, 1966 9.00 p.m.
24.96		July 20, 1966 8.00 a.m.
24.91		July 20, 1966 8.00 p.m.
25.03		July 21, 1966
24.95		July 25, 1966
25.03	30.76	July 30, 1966
25.07	30.77	July 31, 1966
25.08	30.73	Aug. 1, 1966
25.10	30.71	Aug. 2, 1966
25.10	30.71	Aug. 3, 1966

Bailed Well Recovery Data

Bail test July 29, 1966

Measurements with electric tape

Bailing rate: One bailer of 10 lgpm per 1/2 minute
Bailing period: One hour
Static (nonpumping level): 11.36 feet below top of casing

Time since bailing stopped (minutes)	Time since bailing started (minutes)	t/t'	Water level	Drawdown
1	61	61	25.51	14.15
2	62	31	18.03	6.67
3	63	21	15.75	4.39
4	64	16	14.71	3.35
5	65	13	14.26	2.90
6	66	11	13.97	2.61
7	67	9.6	13.72	2.36
8	68	8.5	13.52	2.16
9	69	7.7	13.39	2.03
10	70	7.0	13.29	1.93
12	72	6.0	13.10	1.74
14	74	5.3	12.94	1.58
16	76	4.8	12.80	1.44
19	79	4.2	12.64	1.28

Step Drawdown Test

Date: August 8, 1966

Nonpumping level: 11.39 feet below top of casing
Pumped at an initial rate of 15 igpm, after one hour rate increased to 37.5 igpm, after one hour increased to 49.1 igpm.
Measured with electric tape and steel tape

Drawdowns in pumped well:

Time since pumping started (minutes)	Drawdown (feet)	Time (min.)	Drawdown (feet)	Time (min.)	Drawdown (feet)
1	6.16	61	19.04	121	31.14
2	7.65	62	23.77	122	31.40
3	8.29	63	23.67	123	31.26
4	9.19	64	23.66	124	31.15
5	9.53	65	23.90	125	31.11
6	9.63	66	24.01	126	31.26
7	9.81	67	24.12	127	31.23
8	9.96	68	24.11	128	31.52
9	10.04	69	24.11	129	31.53
10	10.09	70	24.21	130	31.63
12	9.67	75	24.60	135	31.83
15	9.84	80	24.85	140	31.83
20	10.00	90	25.19	145	31.85
25	9.48	100	25.57	150	32.05
30	10.02	110	25.78	160	32.33
40	9.37	120	26.12	170	32.25
50	10.20			180	32.53
60	10.89				

Constant Rate Test

Drawdown in Pumped Well

Date: July 30 to August 4, 1966
Pumping rate: 22.8 Igpm
Nonpumping level: 11.30 feet below top of casing.
Measured with electric tape and steel tape

Time since pumping started (minutes)	Drawdown (feet)	Rate (Igpm)	Time since pumping started (minutes)	Drawdown (feet)	Rate (Igpm)
0	0.00	23.5	220	15.90	24.5
5	12.00	23.5	280	15.88	23.3
6	12.27	23.5	340	15.85	23.3
7	12.40	23.5	400	15.83	23.3
8	12.61	23.5	470	15.74	23.3
9	12.78	22.8	533	16.00	23.3
10	12.92	22.8	600	15.92	23.3
15	13.43	22.8	660	16.00	23.3
20	13.69	22.8	730	15.99	23.0
25	13.95	22.8	900	15.91	23.0
30	13.98	22.8	1103	15.90	21.6
35	14.40	22.8	1305	16.20	22.8
40	14.92	22.8	1500	16.11	22.8
50	15.17	22.8	1800	16.15	22.8
60	15.14	22.8	2100	15.93	21.9
70	15.14	22.8	2300	17.20	23.0
80	15.30	22.8	2830	16.85	22.8
90	15.44	22.8	3310	17.10	22.8
100	15.40	22.8	3548	16.80	22.8
130	15.50	22.8	4450	16.80	22.8
160	15.63	22.8	5710	16.96	22.8
190	15.66	22.8	7300.	17.25	22.8

Constant Rate Test Drawdown in Observation Well 111 Feet South
(Measurements with Stevens recorder, checked with steel tape)
(Static level 13.28 feet)

Time since pumping started (minutes)	Drawdown (feet)	Corrected drawdown $s-s^2/2m$ (feet)	Time since pumping started (minutes)	Drawdown (feet)	Corrected drawdown $s-s^2/2m$ (feet)
1.5	.01	.01	150	3.15	3.05
2.75	.04	.04	160	3.17	3.07
4.00	.09	.09	170	3.20	3.10
5.25	.15	.15	180	3.22	3.12
6.5	.22	.22	205	3.27	3.16
7.75	.29	.29	265	3.35	3.24
9.00	.37	.37	325	3.40	3.28
10.25	.46	.46	400	3.41	3.29
11.5	.55	.55	500	3.44	3.32
14.0	.73	.73	600	3.44	3.32
19.0	1.09	1.08	720	3.41	3.29
21.5	1.26	1.24	800	3.49	3.37
24	1.40	1.38	900	3.50	3.38
29	1.68	1.65	1100	3.51	3.39
34	1.90	1.86	1360	3.56	3.43
39	2.07	2.03	1640	3.57	3.44
44	2.22	2.17	1880	3.58	3.45
54	2.46	2.40	2100	3.56	3.43
60	2.57	2.51	2340	3.77	3.63
70	2.70	2.63	2580	3.77	3.63
80	2.81	2.73	2820	3.79	3.65
90	2.89	2.81	3000	3.79	3.65
100	2.96	2.87	3500	3.80	3.66
110	3.02	2.93	4360	3.84	3.69
120	3.07	2.93	5830	3.82	3.67
130	3.09	2.99	7300	3.93	3.73
140	3.12	3.02	7510	3.93	3.73

Constant Rate Test Drawdown in Observation Well 500 Feet North
(Measurements with Stevens recorder, checked with steel tape)
(Static level 14.20 feet)

Time since pumping started (minutes)	Drawdown (feet)	Time (min.)	Drawdown (feet)	Time (min.)	Drawdown (feet)
30	.01	210	.45	1640	.74
40	.02	220	.45	1870	.74
50	.04	300	.52	2100	.75
60	.07	350	.55	2240	.78
70	.11	380	.56	2580	.78
80	.14	420	.57	2820	.80
90	.17	440	.58	3100	.81
100	.20	500	.63	3540	.81
110	.24	600	.64	3720	.82
120	.26	720	.67	4260	.83
140	.31	800	.68	4360	.84
170	.36	900	.69	5830	.87
190	.39	1100	.70		
200	.44	1500	.71		

Recovery Data

Duration of pump test at 22.3 lpm = 7,516 minutes

t/t' = $\frac{\text{time since pumping started}}{\text{time since pumping stopped}}$

rd = residual drawdown

Recovery data for the producing well

t'	t/t'	rd	t'	t/t'	rd	t'	t/t'	rd
4	1880	3.20	47	161	2.02	202	37.8	1.29
6	1254	3.10	52	146	1.95	232	33.4	1.18
9	836	2.80	57	133	1.88	262	29.7	1.11
11	684	2.70	62	122	1.84	299	26.1	1.00
14	537	2.61	67	113	1.82	322	24.3	.94
16	471	2.54	72	105	1.81	457	17.4	.69
19	396	2.42	82	93	1.75	532	15.1	.53
22	343	2.32	87	87	1.70	592	13.7	.45
25	302	2.29	97	78.5	1.68	862	9.7	.14
28	270	2.25	112	68.0	1.59	982	8.6	.07
31	243	2.21	122	62.6	1.56	1492	6.0	.02
34	222	2.20	142	54.0	1.48			
37	204	2.13	162	47.4	1.37			
42	180	2.07	182	42.3	1.32			

Recovery data observation well 111 feet south; static level 13.28 feet

t'	t/t'	rd	t'	t/t'	rd	t'	t/t'	rd
5	1503	3.91	65	117	1.98	300	26.0	1.14
10	753	3.85	70	108	1.92	347	22.6	1.01
15	502	3.53	85	89	1.78	387	20.4	.94
20	377	3.19	100	76	1.71	427	18.6	.88
25	302	2.91	120	63.6	1.64	450	17.7	.84
30	251	2.75	140	54.7	1.55	465	17.3	.81
35	215	2.59	160	48.0	1.49	525	15.3	.73
40	189	[illegible]	180	42.8	1.43	585	13.2	.66
45	168	[illegible]	200	38.6	1.37	705	11.7	.57
50	151	2.19	220	35.2	1.32	825	10.1	.39
55	138	2.11	240	32.4	1.27	945	8.95	.28
60	126	2.03	260	29.9	1.22	990	8.5	.21

Recovery data observation well [illegible] feet north; static level 14.28 feet

t'	t/t'	rd	t'	t/t'	rd	t'	t/t'	rd
5	1508	.90	105	73	.77	400	19.8	.46
10	753	.89	111	69	.75	470	17.0	.42
15	502	.88	131	58	.72	530	15.2	.39
20	377	.87	151	51	.69	590	13.2	.37
30	251	.87	191	40.4	.64	710	11.6	.31
45	168	.86	231	33.5	.60	830	10.1	.24
60	126	.84	271	28.7	.57	950	8.95	.16
75	101	.83	311	25.2	.54	1010	8.5	.12
90	84	.80	320	24.5	.50			

CADOGAN UNCONFINED AQUIFER.

PUMP TEST

Test Procedures

Starting July 30, 1966 at 9.00 a.m., the test well was pumped at an average rate of 22.8 imperial gallons per minute (igpm). Discharge, measured with a 45-gallon drum, varied slightly during the test, particularly at sunrise and sunset, but the variations were not large enough to impair seriously the results of the test.

During the test water levels were measured in the test well and in two observation wells, located at 111 feet south and 389 feet north of the test well. Pumping was continued for 125 hours, the test being ended on August 4 at 2.00 p.m. owing to engine failure; however, at this time the objectives of the test had been reached.

A step-drawdown test was run on August 8 to provide an estimate of well losses and well efficiency. Pumping rates were 15, 37.5 and 49 igpm.

Analysis of Drawdown Measurements

The analysis of the drawdown measurements in the observation wells was based on the theory developed by Boulton (1963) describing the nonsteady-state time-drawdown relationship for pumping from a water-table aquifer. The type-curve method of solution — given by Prickett (1965) and based on Boulton's analysis — was the practical method utilized.

Drawdown measurements in the test well were plotted against the logarithm of time to establish the long-term trend of the water level in the test well. Boulton's method is not applicable to the test well.

The method developed by Rorabaugh (1953) was used in the analysis of the step-drawdown results.

Transmissibility and Storage Coefficients

In general, the response of a water-table aquifer to continuous pumping occurs in three stages: a first stage in which water is withdrawn from storage mainly by the compaction of the aquifer and by the expansion of the water as the pressure in the aquifer is lowered; a second transitional stage in which the influence of the actual drainage of the sediments becomes significant, resulting in a decrease of the slope of the time-drawdown curve; and a third stage in which gravity drainage is supplying practically all of the pumped water. During the first stage the response and the calculated storage coefficient of the aquifer are similar to those of an artesian aquifer; during the third stage the storage coefficient attains a water-table value and it is this storage coefficient that must be used in the calculation of the long-term effects of aquifer development.

From the pump test results the following coefficients were derived:

		T (igpd/ft)	S (artesian)	S (gr.drainage)
Observation well 389 feet north	Early data	1040	4.4×10^{-4}	-----
	Late data	930	--------	0.052
	Average	980		
Observation well 111 feet south	Early data	1240	3.7×10^{-4}	-----
	Late data	1240	--------	0.016
	Average	1240		
Average		1110	4.0×10^{-4}	0.034

Calculation of Safe Yield for a Single Well

The drawdown in a pumped well at any time is the sum of the formation losses, which can be calculated when the aquifer coefficients are known, and the well losses, which are due to flow conditions in the neighbourhood of and within the well. The step-drawdown test carried out after the main constant-rate pump test showed that for pumping rates up to 49 igpm – the maximum rate utilized during this test – well loss was proportional to the pumping rate.

The trend of the drawdown in the test well was calculated for the latter part of the constant-rate test as 1.00 feet per log cycle. This figure, however, is not too accurate, as there was much scatter to the measurements due to turbulence in the well bore and slight variations in the pumping rate. A better trend of 1.15 feet per cycle was obtained from the recovery measurements. Using this figure the expected drawdown at 10^7 minutes (20 years) can be calculated:

Drawdown at 10^7 min. = drawdown at 10^3 min. + 4 (drawdown per log cycle)

$$= 16.3 \quad + 4 \times 1.15 \quad = 20.9 \text{ feet}$$

The total available drawdown is the elevation of the nonpumping level minus the elevation of the top of the screen = 50.0 - 11.8 = 38.2 feet. The safe pumping rate then becomes: $\frac{38.2}{20.9} \times 22.8 = 41.7$ igpm.

Systems of More than One Well

In case more than one well is producing from the same aquifer, the effects of all wells have to be taken into account at each well location. To calculate drawdowns at any point at a given distance from a given pumped well the transmissibility and storage coefficient of the aquifer must be known. In deriving the results listed in the table below, 1,100 igpd/ft (imperial gallons per day per foot) and .034 were assumed for the transmissibility and the storage coefficient respectively.

For a system of two wells at various distances apart the following values of the safe yield over periods of 20 years and 10 years were calculated:

Distance between wells (feet)	Drawdowns at Well No. 1 (feet): Self-caused due to unit discharge at Well No. 1	Drawdowns at Well No. 1 (feet): Due to unit discharge at Well No. 2	Total	Safe yield for each well (igpm)	Period (years)
1000	.908	.458	1.366	28.0	20
2000	.908	.315	1.223	31.2	20
3000	.908	.235	1.143	33.4	20
6000	.908	.109	1.017	37.6	20
1000	.898	.386	1.284	29.7	10
2000	.898	.247	1.145	33.3	10
3000	.898	.168	1.066	35.8	10
6000	.898	.058	0.956	40.0	10

For a system of three wells equally spaced along a straight line 6,000 feet long the maximum safe pumping rate for a period of 20 years would be 33 igpm for each of the two outer wells and 25.5 igpm for the center well.

Limitations of the Calculated Safe Yields

It is to be understood that the foregoing estimates of future water levels and safe pumping rates do not take into account that:

1) the aquifer is of limited areal extent

2) the aquifer does not necessarily have everywhere the same properties as encountered in the vicinity of the test well.

3) the available drawdowns in other parts of the aquifer may be substantially different from that in the test well.

It should therefore be kept in mind that the estimated yields should only be used as guide lines for aquifer development and not as an absolute guarantee that the quoted amounts of water can be safely withdrawn over a 10- or 20-year period.

Water-Level Measurements in Nearby Wells Previous to and During the Test

Measurements with steel tape

RCA Test Hole No. 1	Curcio observation well	Date
24.50		July 13, 1966
24.70		July 14, 1966
24.72	30.71	July 15, 1966
24.97		July 18, 1966 9.00 a.m.
24.94		July 18, 1966 9.00 p.m.
24.87		July 19, 1966 8.00 a.m.
24.87		July 19, 1966 9.00 p.m.
24.96		July 20, 1966 8.00 a.m.
24.91		July 20, 1966 8.00 p.m.
25.03		July 21, 1966
24.95		July 25, 1966
25.03	30.76	July 30, 1966
25.07	30.77	July 31, 1966
25.08	30.78	Aug. 1, 1966
25.10	30.71	Aug. 2, 1966
25.10	30.71	Aug. 3, 1966

Bailed Well Recovery Data

Bail test July 29, 1966

Measurements with electric tape

Bailing rate: One bailer of 10 igpm per 1/2 minute
Bailing period: One hour
Static (nonpumping level): 11.36 feet below top of casing

Time since bailing stopped (minutes)	Time since bailing started (minutes)	t/t'	Water level	Drawdown
1	61	61	25.51	14.15
2	62	31	18.03	6.67
3	63	21	15.75	4.39
4	64	16	14.71	3.35
5	65	13	14.26	2.90
6	66	11	13.97	2.61
7	67	9.6	13.72	2.36
8	68	8.5	13.52	2.16
9	69	7.7	13.39	2.03
10	70	7.0	13.29	1.93
12	72	6.0	13.10	1.74
14	74	5.3	12.94	1.58
16	76	4.8	12.80	1.44
19	79	4.2	12.64	1.28

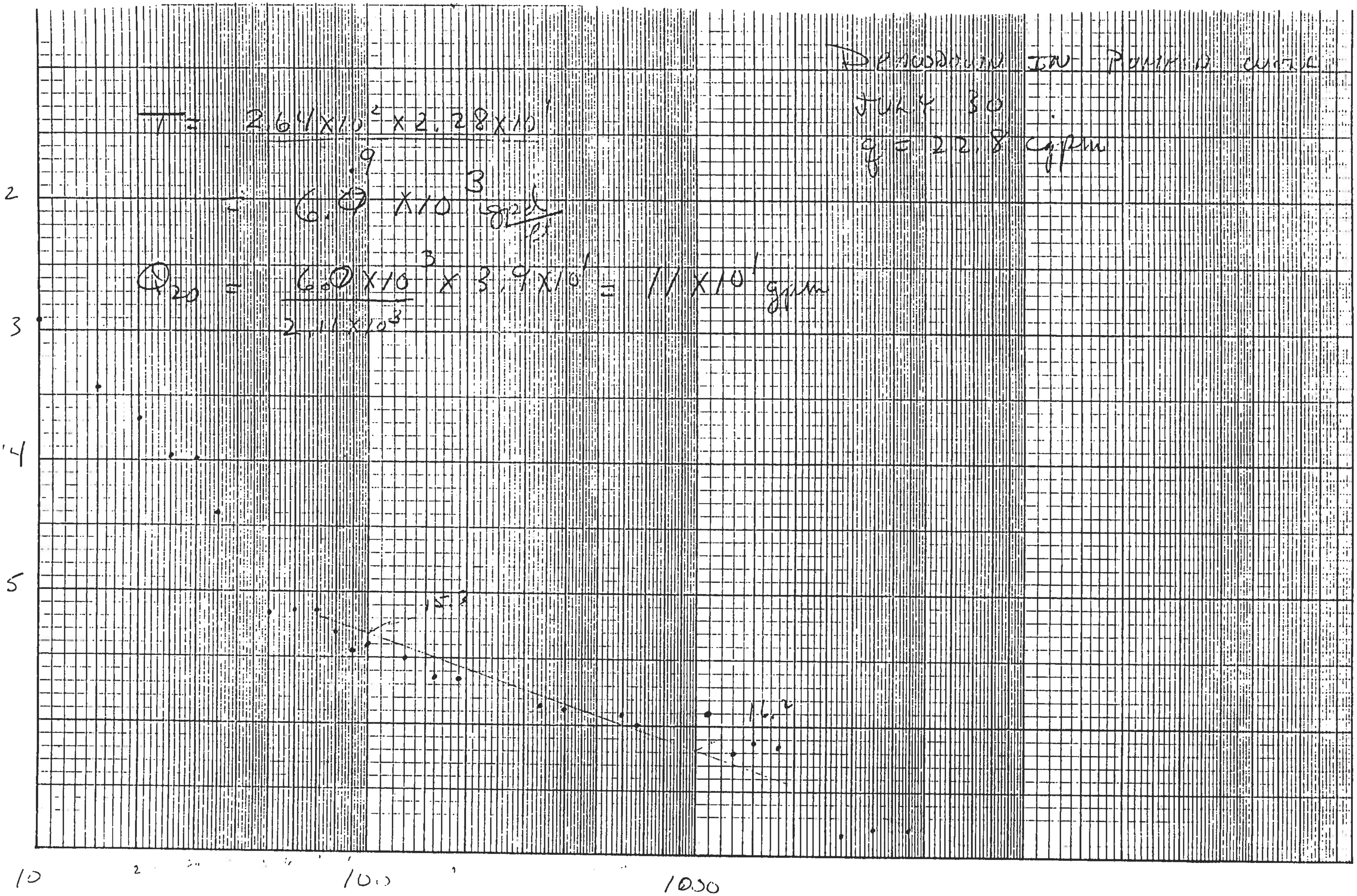
Step Drawdown Test

Date: August 8, 1966

Nonpumping level: 11.39 feet below top of casing
Pumped at an initial rate of 15 igpm, after one hour rate increased to 37.5 igpm, after one hour increased to 49.1 igpm.
Measured with electric tape and steel tape

Drawdowns in pumped well:

Time since pumping started (minutes)	Drawdown (feet)	Time (min.)	Drawdown (feet)	Time (min.)	Drawdown (feet)
1	6.16	61	19.04	121	31.14
2	7.65	62	23.77	122	31.40
3	8.29	63	23.67	123	31.26
4	9.19	64	23.66	124	31.15
5	9.53	65	23.90	125	31.11
6	9.63	66	24.01	126	31.26
7	9.81	67	24.12	127	31.28
8	9.96	68	24.11	128	31.52
9	10.04	69	24.11	129	31.53
10	10.09	70	24.21	130	31.68
12	9.67	75	24.60	135	31.83
15	9.84	80	24.85	140	31.88
20	10.00	90	25.19	145	31.86
25	9.48	100	25.57	150	32.05
30	10.02	110	25.78	160	32.38
40	9.37	120	26.12	170	32.25
50	10.20			180	32.53
60	10.89				


DRAWDOWN IN PUMPED WELL
JULY 30
q = 22.8 gpm
T = 2.64 x 10^2 x 2.28 x 10^1 / 9
= 6.Ø x 10^3 gpd/ft
Q20 = 6.0 x 10^3 / 2.11 x 10^3 x 3.9 x 10^1 = 11 x 10^1 gpm
2
3
4
5
15.3
16.2
10
100
1000

Constant Rate Test

Drawdown in Pumped Well

Date: July 30 to August 4, 1966
Pumping rate: 22.8 igpm
Nonpumping level: 11.80 feet below top of casing.
Measured with electric tape and steel tape

Time since pumping started (minutes)	Drawdown (feet)	Rate (igpm)	Time since pumping started (minutes)	Drawdown (feet)	Rate (igpm)
0	0.00	23.5	228	15.90	24.5
5	12.00	23.5	280	15.88	23.3
6	12.27	23.5	340	15.85	23.3
7	12.40	23.5	400	15.88	23.3
8	12.61	23.5	478	15.74	23.3
9	12.78	22.8	533	16.00	23.3
10	12.92	22.8	600	15.92	23.3
15	13.43	22.8	660	16.00	23.3
20	13.69	22.8	780	15.99	23.0
25	13.95	22.8	900	15.91	23.0
30	13.98	22.8	1108	15.90	21.6
35	14.40	22.8	1306	16.20	22.8
40	14.92	22.8	1500	16.11	22.8
50	15.17	22.8	1800	16.15	22.8
60	15.14	22.8	2100	15.93	21.9
70	15.14	22.8	2300	17.20	23.0
80	15.30	22.8	2830	16.85	22.8
90	15.44	22.8	3310	17.10	22.8
100	15.40	22.8	3548	16.80	22.8
130	15.50	22.8	4450	16.80	22.8
160	15.63	22.8	5710	16.96	22.8
190	15.66	22.8	7300	17.25	22.8

Constant Rate Test Drawdown in Observation Well 111 Feet South
(Measurements with Stevens recorder, checked with steel tape)
(Static level 13.28 feet)

Time since Pumping started (minutes)	Drawdown (feet)	Corrected drawdown $s-s^2/2m$ (feet)	Time since pumping started (minutes)	Drawdown (feet)	Corrected drawdown $s-s^2/2m$ (feet)
1.5	.01	.01	150	3.15	3.05
2.75	.04	.04	160	3.17	3.07
4.00	.09	.09	170	3.20	3.10
5.25	.15	.15	180	3.22	3.12
6.5	.22	.22	205	3.27	3.16
7.75	.29	.29	265	3.35	3.24
9.00	.37	.37	325	3.40	3.28
10.25	.46	.46	400	3.41	3.29
11.5	.55	.55	500	3.44	3.32
14.0	.73	.73	600	3.44	3.32
19.0	1.09	1.08	720	3.41	3.29
21.5	1.26	1.24	800	3.49	3.37
24	1.40	1.38	900	3.50	3.38
29	1.68	1.65	1100	3.51	3.39
34	1.90	1.86	1360	3.56	3.43
39	2.07	2.03	1640	3.57	3.44
44	2.22	2.17	1800	3.58	3.45
54	2.46	2.40	2100	3.56	3.43
60	2.57	2.51	2340	3.77	3.63
70	2.70	2.63	2580	3.77	3.63
80	2.81	2.73	2820	3.79	3.65
90	2.89	2.81	3000	3.79	3.65
100	2.96	2.87	3500	3.80	3.66
110	3.02	2.93	4360	3.84	3.69
120	3.07	2.98	5830	3.82	3.67
130	3.09	2.99	7300	3.93	3.78
140	3.12	3.02	7510	3.93	3.78

Constant Rate Test Drawdown in Observation Well 389 Feet North
(Measurements with Stevens recorder, checked with steel tape)
(Static level 14.23 feet)

Time since pumping started (minutes)	Drawdown (feet)	Time (min.)	Drawdown (feet)	Time (min.)	Drawdown (feet)
30	.01	210	.45	1640	.74
40	.02	220	.45	1870	.74
50	.04	300	.52	2100	.75
60	.07	350	.55	2340	.78
70	.11	380	.56	2580	.78
80	.14	420	.57	2820	.80
90	.17	440	.58	3100	.81
100	.20	500	.63	3540	.81
110	.24	600	.64	3720	.82
120	.26	720	.67	4260	.83
140	.31	800	.68	4360	.84
170	.38	900	.69	5830	.87
180	.39	1100	.70		
200	.44	1300	.71		

Recovery Data

Duration of pump test at 22.8 igpm = 7,516 minutes

$t/t' = \frac{\text{time since pumping started}}{\text{time since pumping stopped}}$

rd = residual drawdown

Recovery data for the producing well

t'	t/t'	rd	t'	t/t'	rd	t'	t/t'	rd
4	1880	3.20	47	161	2.02	202	37.8	1.29
6	1254	3.10	52	146	1.95	232	33.4	1.18
9	836	2.80	57	133	1.88	262	29.7	1.11
11	684	2.70	62	122	1.84	299	26.1	1.00
14	537	2.61	67	113	1.82	322	24.3	.94
16	471	2.54	72	105	1.81	457	17.4	.68
19	396	2.42	82	93	1.75	532	15.1	.53
22	343	2.32	87	87	1.70	592	13.7	.45
25	302	2.29	97	78.5	1.68	862	9.7	.14
28	270	2.25	112	68.0	1.59	982	8.6	.07
31	243	2.21	122	62.6	1.56	1492	6.0	.02
34	222	2.20	142	54.0	1.48			
37	204	2.13	162	47.4	1.37			
42	180	2.07	182	42.3	1.32			

Recovery data observation wellI111 feet south; static level 13.28 feet

t'	t/t'	rd	t'	t/t'	rd	t'	t/t'	rd
5	1503	3.91	65	117	1.98	300	26.0	1.14
10	753	3.85	70	108	1.92	347	22.6	1.01
15	502	3.53	85	89	1.78	387	20.4	.94
20	377	3.19	100	76	1.71	427	18.6	.88
25	302	2.91	120	63.6	1.64	450	17.7	.84
30	251	2.75	140	54.7	1.55	465	17.3	.81
35	215	2.59	160	48.0	1.49	525	15.3	.73
40	189	2.45	180	42.8	1.43	585	13/2	.66
45	168	2.29	200	38.6	1.37	705	11.7	.57
50	151	2.19	220	35.2	1.32	825	10.1	.39
55	138	2.11	240	32.4	1.27	945	8.95	.28
60	126	2.03	260	29.9	1.22	990	8.5	.21

Recovery data observation well 389 feet north; static level 14.23 feet

t'	t/t'	rd	t'	t/t'	rd	t'	t/t'	rd
5	1503	.90	105	73	.77	400	19.8	.46
10	753	.89	111	69	.75	470	17.0	.42
15	502	.88	131	58	.72	530	15.2	.39
20	377	.87	151	51	.69	590	13.2	.37
30	251	.87	191	40.4	.64	710	11.6	.31
45	168	.86	231	33.5	.60	830	10.1	.24
60	126	.84	271	28.7	.57	950	8.95	.16
75	101	.83	311	25.2	.54	1010	8.5	.12
90	84	.80	320	24.5	.50			

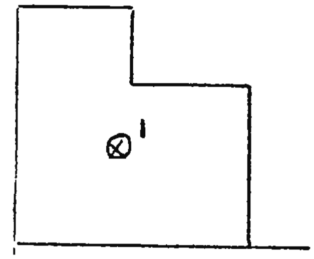
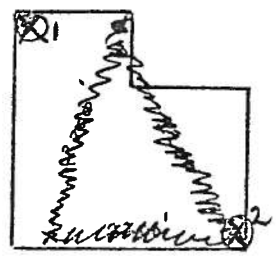
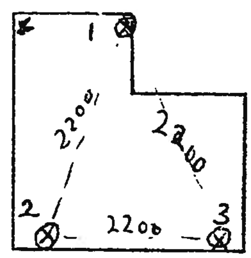
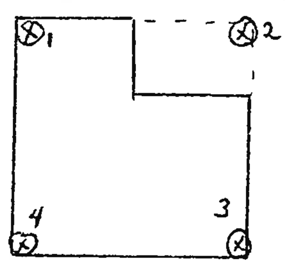
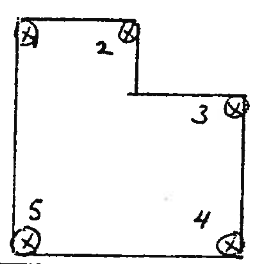
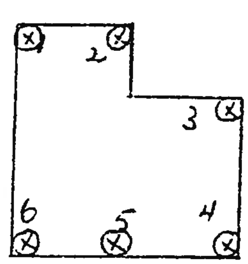
CALCULATION OF THE YIELD OF A MULTIWELL FIELD IN AN UNCONFINED AQUIFER NEAR CADOGAN

Results

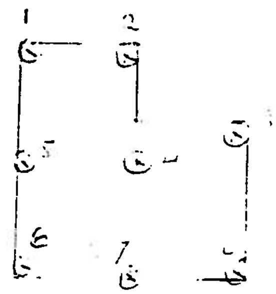
This report contains the results of a study of the behavior of the aquifer described in "Exploration and Testing of an Unconfined Aquifer near Cadogan, Alberta,"(unpublished internal report on Groundwater Division files), when water is pumped from the aquifer by means of a number of equally spaced wells in a prescribed area of 534 acres. The manner of pumping is in a complex cycle of from 12 to 18 hours pumping per day over periods of from 6 to 8 weeks per year, as prescribed by the envisaged use of the water in an irrigation project.

On the basis of the calculations the following figures for safe pumping rates were calculated.

Safe Yields for a 20-year Pumping Period

	Number of wells	Cyclic pumping hours/day	Cyclic pumping weeks/year	Safe yields (gpm) total of all wells	Location of well	Safe yield of each well for the 12 hrs/day, 6 weeks/year cycle
1	1	continuous pumping		41.7		#1 50.7
2	1	12	6	50.7		
3	1	12	8	50.5		
4	1	18	6	49.1		
5	1	18	8	46.7		
6	2	continuous		68.6		#1 40.1
7	2	12	6	80.2		#2 40.1
8	2	12	8	79.8		
9	2	18	6	78.2		
10	2	18	8	75.0		
11	3	continuous		75.9		#1 28.5
12	3	12	6	85.4		#2 28.5
13	3	12	8	85.0		#3 28.5
14	3	18	6	83.6		
15	3	18	8	81.4		
16	4	continuous		94.6		#1 25.6
17	4	12	6	102.4		#2 25.6
18	4	12	8	102.1		#3 25.6
19	4	18	6	100.8		#4 25.6
20	4	18	8	98.2		
21	5	12	6	101.1		#1 21.8
						#2 14.3
						#3 17.6
						#4 23.1
						#5 24.3
22	5	12	6	102.1		#1 21.3
						#2 13.8
						#3 16.7
						#4 19.8
						#5 9.6
						#6 20.9

Continued

	Number of wells	Cyclic pumping hours/day	Cyclic pumping weeks/year	Safe yields (gpm) total of all wells	Location of well	Safe yield of each well for the 12 hrs/day, 6 weeks/year cycle	
23	8	12	6	104.2		#1	15.4
						#2	19.0
						#3	14.1
						#4	1.4
						#5	7.8
						#6	19.6
						#7	8.7
						#8	18.2

From the table it is apparent that:

(1) The safe yield* of a single well pumped cyclicly in the manner prescribed is only slightly higher than the safe yield of a single well pumping continuously.

(2) The maximum amount of water to be withdrawn from the prescribed area is in the neighborhood of 100 gpm if pumping is only for 12 hours/day and 6 weeks/year.

(3) No substantial gain in total production is obtained by increasing the number of wells over 4.

The estimates are subject to the following limitations:

(a) Available drawdown and aquifer size characteristics at any production well site must be the same as those at the test site.

(b) Construction and development of any production well must be the same as those for the test site.

(c) It has not been possible to take into account either the limited extent of the aquifer or recharge of the aquifer by precipitation.

(d) It has not bee possible to take into account the effect of cyclic pumping on the interference between wells. The calculated safe yields are therefore slightly on the low side.

(e) The assumption had to be made that, where cyclic pumping is indicated, all wells in the well field are pumped simultaneously at the indicated rates, and are shut in simultaneously.

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*By "safe yield" is meant the maximum rate at which the well or wells can be pumped during the pumping periods.

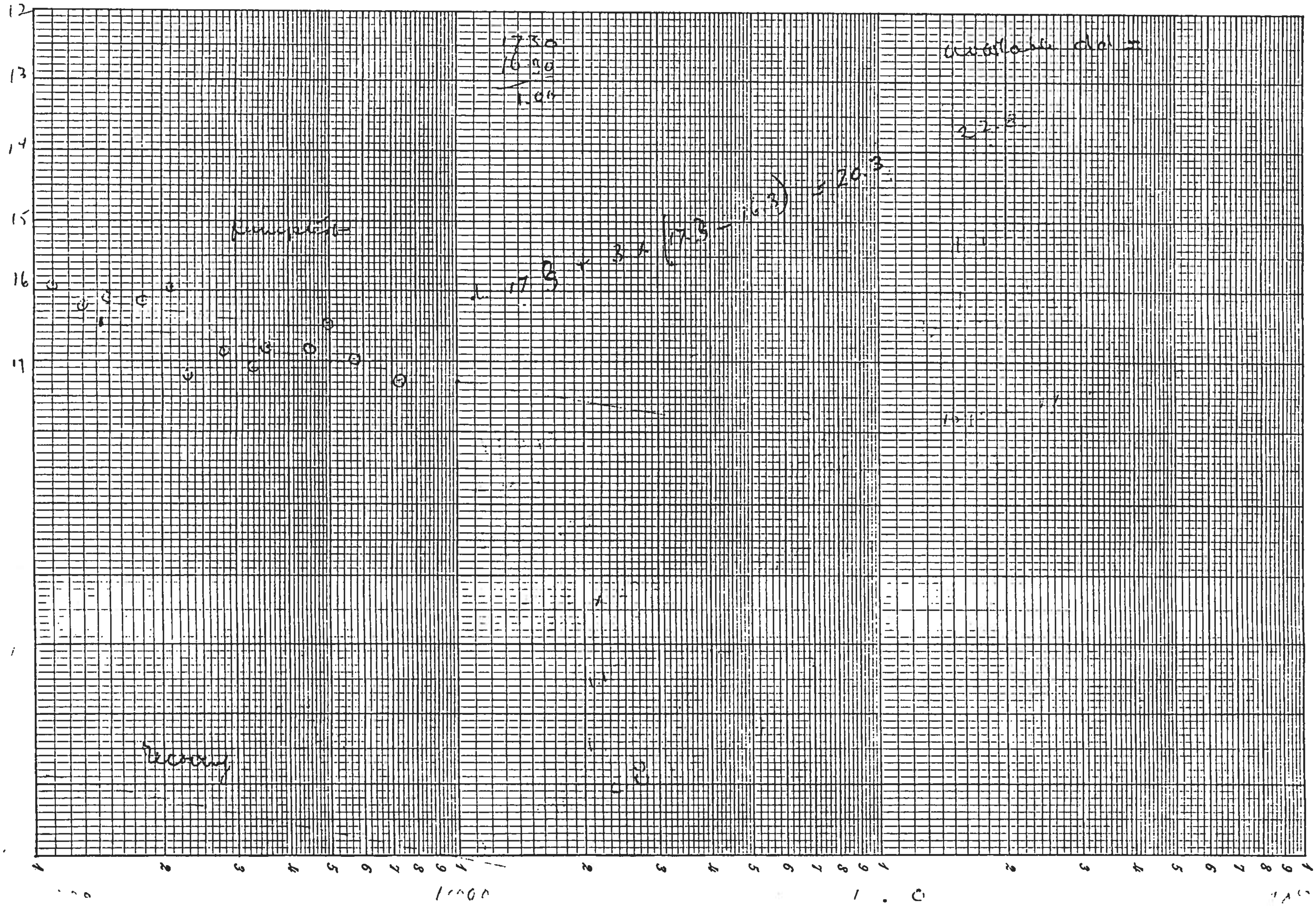
50.00
11.80
39.20

3920

Pumping well.

16.45

Cadogan 20.3R July 30 - Aug 4. 66

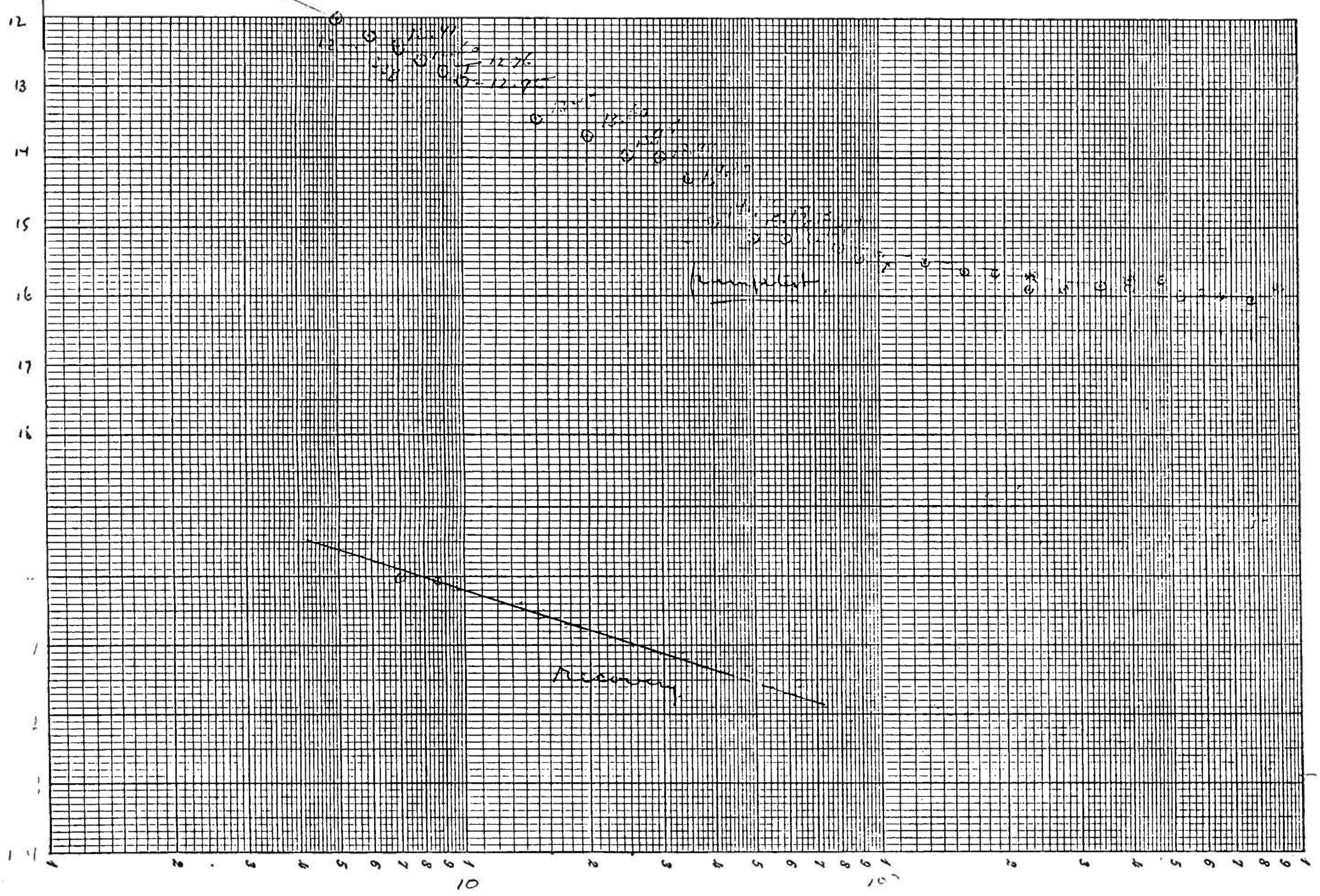


Chalagam

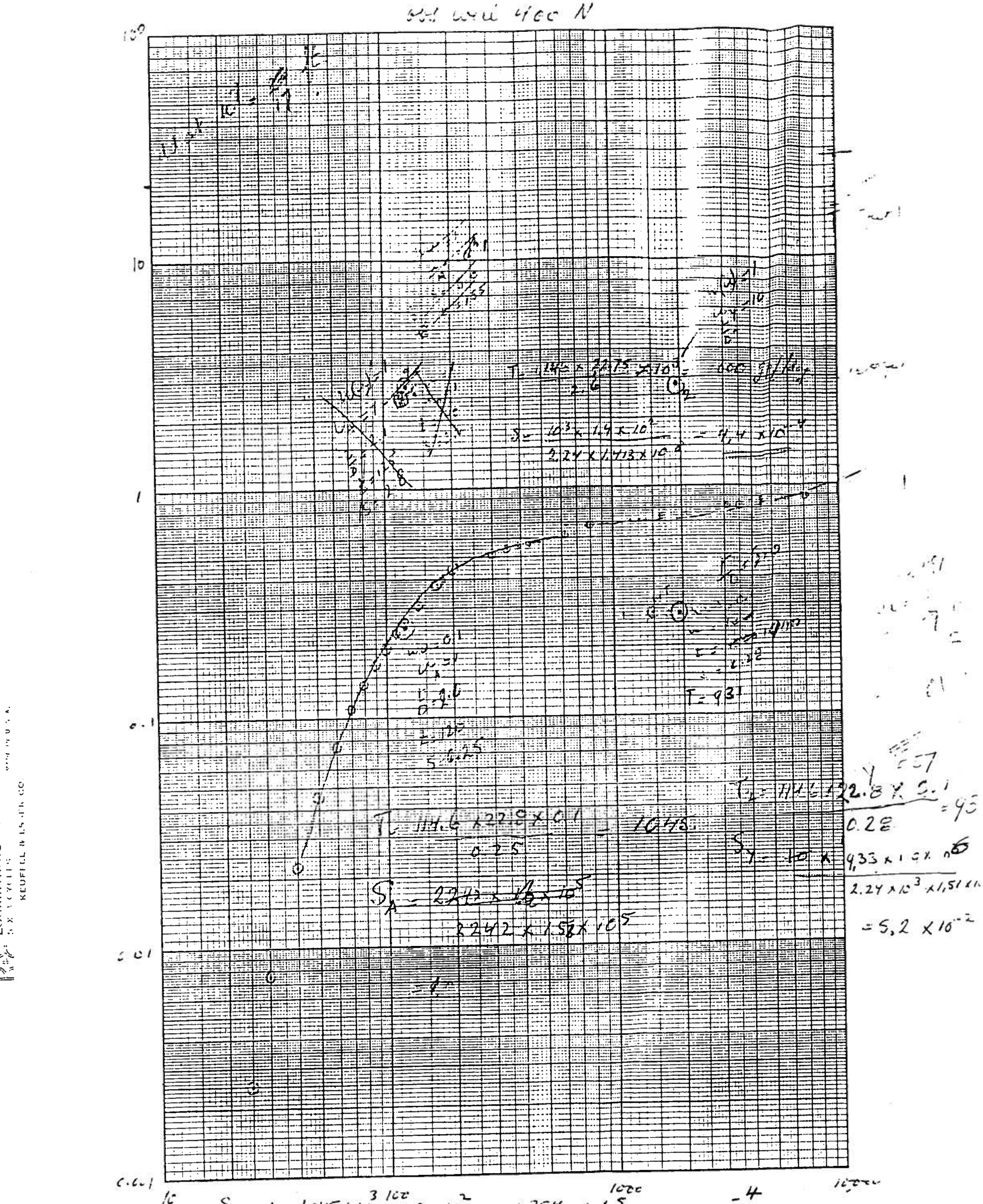
July 30 - Aug 4 1966

15.64
12.88
2.76

$T = \frac{264 \times 23}{2.76} = 2200$ gpd/ft

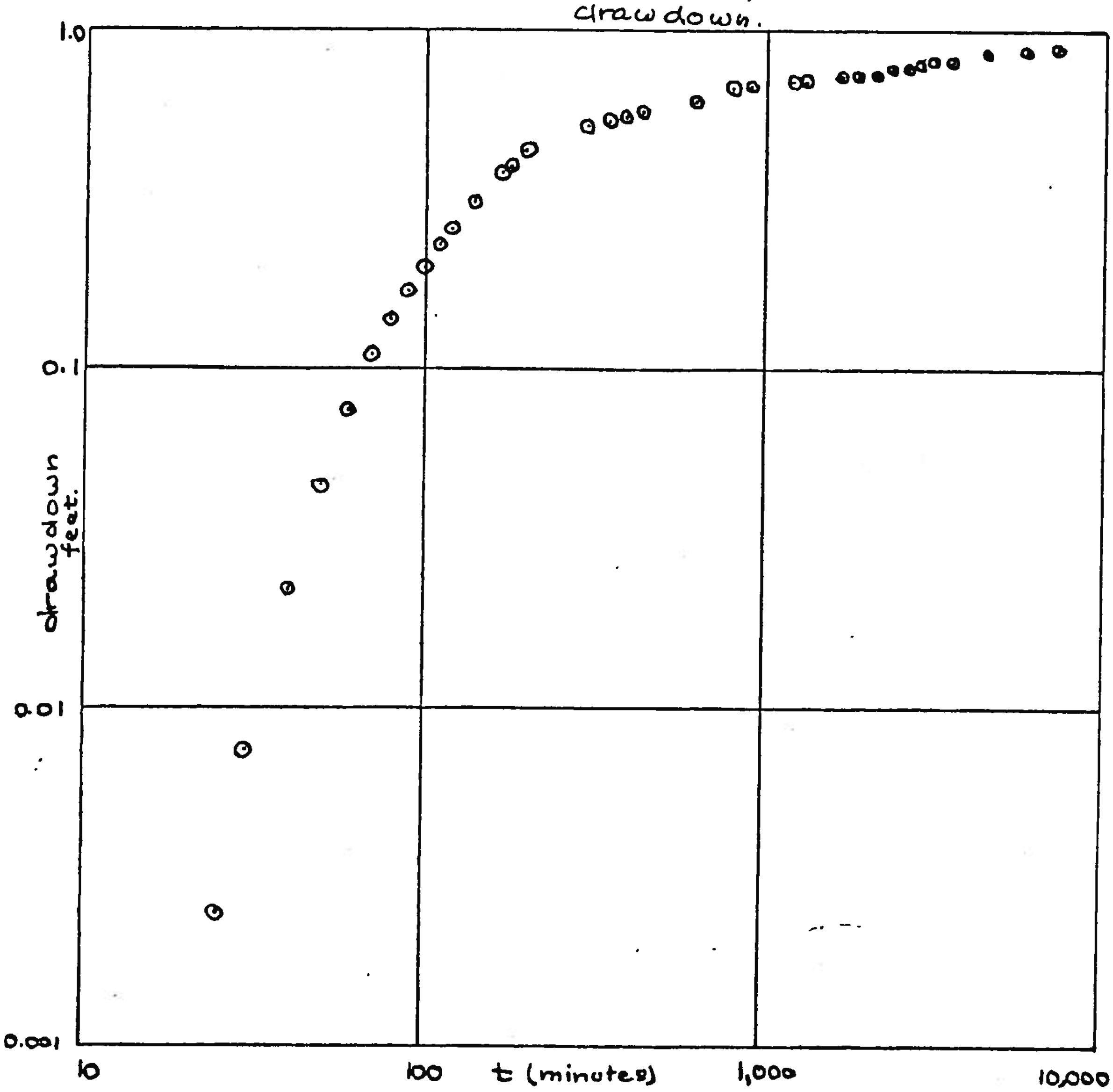


pumptest.



$$S_A = \frac{1 \times 1.045 \times 10^3 \times 1.2 \times 10^2}{2.24 \times 10^3 \times 1.51 \times 10^5} = \frac{1.254 \times 10^5}{0.338 \times 10^9} = 3.7 \times 10^{-4}$$

Cadogan Pumptest July 30 - Aug 4, 1966
Obs. well 389 feet North.
drawdown.



Cadogan Pumptest July 30 - Aug 4, 1966
Obs. wel 111' S. Q = 22.8 gpm.
Drawdown.