Report

June 1959
1959-8

PUMPING TEST RESULTS FOR AN AQUIFER UNDER WATER TABLE CONDITIONS AT ANDREW, ALBERTA

By

E. G. LeBreton and G. M. Gabert

INTRODUCTION

A survey to determine the groundwater resources of the Andrew area was conducted by the Research Council of Alberta in 1958 (Farvolden et al, 1963). In conjunction with this program a pumping test was carried out during July 1960 on the Canadian Pacific Railway well located in the Village of Andrew. An analysis of the pumping test data was completed in November, 1960, but improved methods of analysis prompted a second analysis of the data during 1962. The results of the second analysis are included in this report.

A group of five wells were used in the pumping test conducted in 1958 (Fig.___). Water was discharged through the towns sewage system to a point about one-half mile from the test site. The effects of the pumping well (C.P.R. well) were measured in observation wells 1, 2, 3 and 4. Pumping commenced at 1:00 p.m. on July 5th at a constant rate of 27 imperial gallons per minute and continued until 11:40 a.m. July 12th.

GEOLOGY OF THE AQUIFER

The aquifer consists mainly of sand and gravel deposits which were laid down in glacial melt-water channels or stream trenches. The aquifer varies in thickness from 1 to 31 feet and lies directly on bedrock of low permeability. The aquifer material commonly extends to the surface but less permeable materials ranging up to 12 feet in thickness overlie a portion of the aquifer.

Evidence indicates the sand and gravel deposits have a westerly lineation (Fig.___). The width of the deposits most suitable for the development of groundwater at Andrew is approximately 2/3 of a mile.

ANALYSIS OF PUMPING TEST DATA

The analytical methods used to evaluate the aquifer have been outlined by Walton (1962).

The drawdown data was adjusted for decrease in the saturated thickness and therefore the coefficient of transmissibility of the aquifer by an equation devised by Jacob (1944). The adjusted values represent the drawdown that would occur in an equivalent artesian aquifer. Calculated future drawdowns in the aquifer were also adjusted with Jacob's equation.

Values of the aquifer constants, maximum safe pumping rate, and future drawdowns in the aquifer for given pumping rates at various distances from the center of the pumping well were calculated with the nonequilibrium formula developed by Theis (1935). (See Fig.___ & ___.) Values for the storage coefficient were also computed using an equation described by Ramsahoye and Lang (1961).

The natural percolation of water through a given cross-section of the aquifer has been derived from a useful form of Darcy's equation (Ferris and others, 1962).

RESULTS OF PUMPING TEST ANALYSIS

TABLE____. AQUIFER CONSTANTS CALCULATED FROM TIME-DRAWDOWN DATA

Well	Transmissibility gpd/ft	Storage Theis Curve	Coefficient Ramsahoye & Lang
Pumping	20,628	-	-
1	20,357	0.075	0.036
2	22,100	0.114	0.109
3	22,920	0.096	0.111
4	14,065	0.111	0.087

TABLE____. AQUIFER CONSTANTS CALCULATED FROM DISTANCE-DRAWDOWN DATA

Transmissibility gpd/ft	Storage Coefficient
21,488	0.054

MAXIMUM SAFE PUMPING RATE

The maximum safe pumping rate in imperial gallons permissable for the well can be calculated from the Theis nonequilibrium equation

$$Q_{max.} = \frac{T s'}{114.6\ W(u)}$$

where

$$u = \frac{1.56\ r^2 S}{T t}$$

r = nominal radius of well in feet

S = storage coefficient (dimensionless)

T = coefficient of transmissibility in gallons per day per foot

t = time in years

s' = adjusted drawdown in feet

W(u) = from standard tables

The Canadian Pacific Railway well at Andrew has a nominal radius of 8 feet. The average value of transmissibility for the aquifer in the vicinity of the well is 21,500 gpd/ft. A value of 0.11 is considered a characteristic storage coefficient for the aquifer. The total equivalent artesian drawdown available (s') is 2.5 feet. Based on a 20 year period the maximum safe pumping rate for the well is:

$$Q_{max.} = \frac{21,500 \times 2.5}{114.6 \times 20.5}$$

$$= 22.9 \text{ imperial gallons per minute}$$

FUTURE DRAWDOWN IN THE AQUIFER

TABLE____. PREDICTED FUTURE DRAWDOWN IN THE AQUIFER AFTER ONE DAY OF PUMPING

Distance from Center of Pumping Well in Feet	Pumping Rate in Imperial Gallons Per Minute		
	10	20	30
10	0.37	0.76	1.68
100	0.23	0.23	0.45
200	0.00	0.00	0.18
500	0.00	0.00	0.01
1000	0.00	0.00	0.01

TABLE____. PREDICTED FUTURE DRAWDOWN IN THE AQUIFER AFTER ONE WEEK OF PUMPING

Distance from Center of Pumping Well in Feet	Pumping Rate in Imperial Gallons Per Minute		
	10	20	30
10	0.47	1.01	2.40
100	0.21	0.44	0.91
200	0.14	0.29	0.60
500	0.05	0.10	0.20
1000	0.01	0.02	0.04

TABLE____. PREDICTED FUTURE DRAWDOWN IN THE AQUIFER AFTER ONE YEAR OF PUMPING

Distance from Center of Pumping Well in Feet	Pumping Rate in Imperial Gallons Per Minute		
	10	20	30
10	0.71	1.58	75.00
100	0.44	0.91	1.95
200	0.35	0.72	1.65
500	0.26	0.52	1.12
1000	0.17	0.36	0.76

TABLE____. PREDICTED DRAWDOWNS COMPARED WITH ACTUAL DRAWDOWNS FOR A WEEK LONG PUMPING PERIOD AT A RATE OF 27 IMPERIAL GALLONS PER MINUTE

Well	Predicted Drawdowns in Feet	Actual Drawdowns in Feet
Pumping	1.52	2.11
1	0.90	1.07
2	0.74	0.76
3	0.57	0.62
4	0.38	0.48

NATURAL MOVEMENT OF WATER THROUGH THE AQUIFER

The natural movement of water in imperial gallons per minute can be calculated from a form of Darcy's equation:

$$Q = \frac{TIL}{1440}$$

where

T = coefficient of transmissibility in gallons per day per foot

I = hydrolic gradient in feet per mile

L = width of cross-section in miles through which flow takes place

A cross-section of the aquifer 2/3 of a mile in width was considered at Andrew. A hydrolic gradient of 4 feet per mile was established from water level elevations at the Canadian Pacific Railway well and a point approximately two miles north-west of the Canadian Pacific Railway station. Using an average value of 21,500 gallons per day per foot for the coefficient of transmissibility of the aquifer, the natural movement of water through the cross-section of the aquifer is:

$$Q = \frac{21{,}500 \times 4 \times 2/3}{1{,}440}$$

$$= 40 \text{ imperial gallons per minute (rounded)}$$

RECHARGE OF THE AQUIFER

Groundwater replenishment of the aquifer is thought to be derived primarily from local precipitation.

OTHER PUMPING TESTS

A 33 3/4 hour long pumping test was conducted by the Research Council of Alberta during January, 1963, on one of two new wells completed west of the Canadian Pacific Railway well at Andrew to establish a safe pumping rate for the wells.

The pumping test results indicate that each of the two new wells should be pumped at a rate not exceeding 10 gallons per minute.

CONCLUSION

A week long pumping test was necessary before a reliable evaluation could be made of the shallow, water table aquifer at Andrew, Alberta.

The aquifer is of limited areal extent and is thought to be recharged by local precipitation. The future availability of water cannot be ~~assumed~~ assured if a groundwater supply exceeding 40 imperial gallons per minute is developed in the aquifer.

REFERENCES CITED

Farvolden, R.N., Meneley, W.A., LeBreton, E.G., Lennox, D.H., and Meyboom, P. (1963): Early contributions to the groundwater hydrology of Alberta; Res. Coun. Alberta Bull. 12, 123 pages.

Ferris, J.G., Knowles, D.B., Brown, R.H., and Stalman, R.W. (1962): Theory of aquifer tests; U.S. Geol. Surv. Water-Supply Paper 1536-E, 174 pages.

Jacob, C.E. (1944): Notes on determining permeability by pumping tests under water table conditions; U.S. Geol. Surv. mimeo rept.

Ramsahoye, L.E., and Lang, S.M. (1961): A simple method for determining specific yield from pumping tests; U.S. Geol. Surv. Water-Supply Paper 1536-C, 46 pages.

Theis, C.V. (1935): The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage; Trans. Am. Geophys. Union, Vol. 16, Pt. 2, p. 519-524.

Walton, W.C. (1962): Selected analytical methods for well and aquifer evaluation; Illinois State Water Surv. Bull. 49, 81 pages.

C.P.R. Well.

t = 10,000 MIN.

m = 5
2m = 10

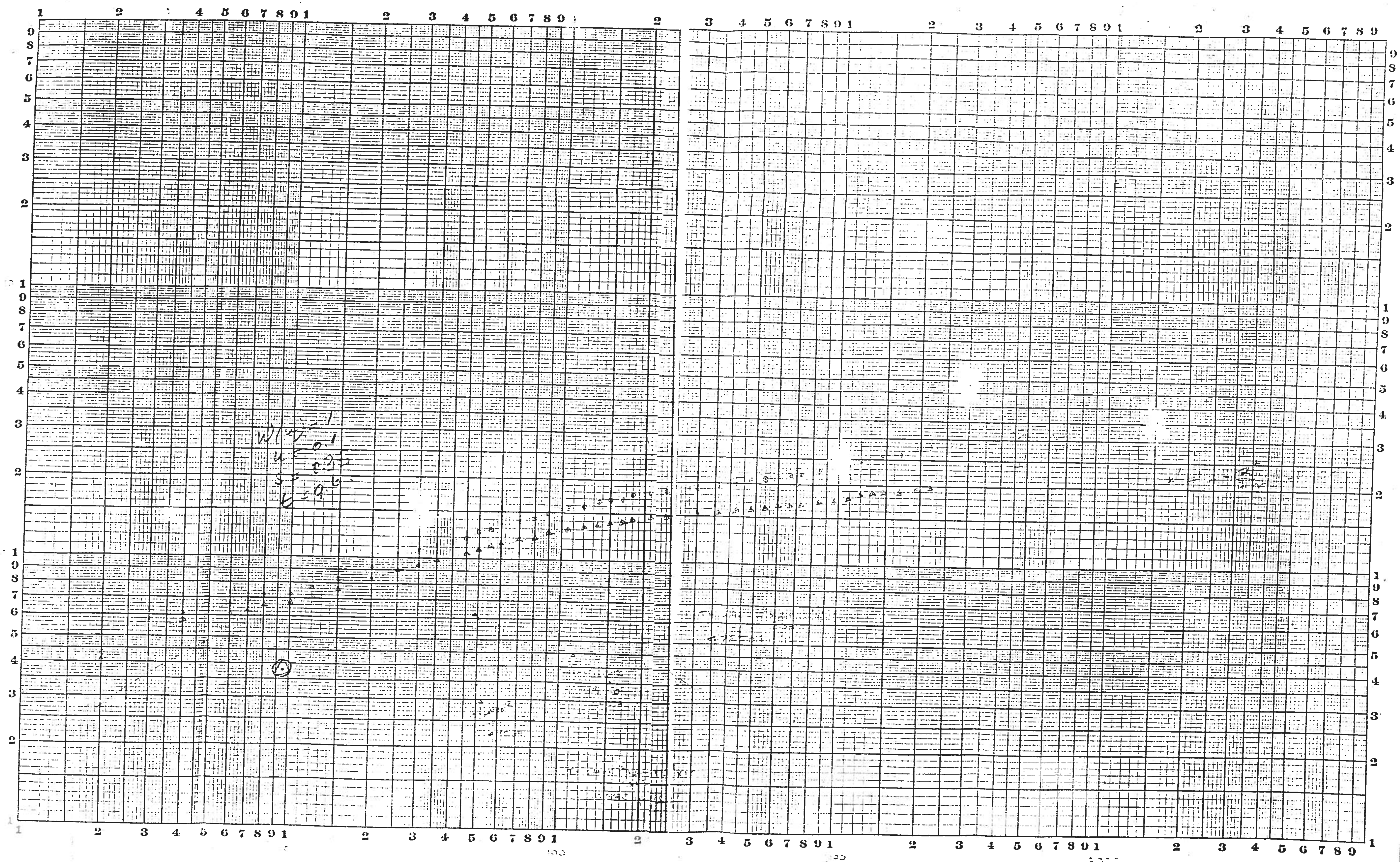
Well #	r	D.D. = s	u'	r^2
1	49' E.	1.07	.46	1.600×10^3
2	67' SW	0.76	.70	4.49×10^3
3	108' NSW	0.62	.58	1.164×10^4
4	202' NSW	0.48	.46	4.08×10^4

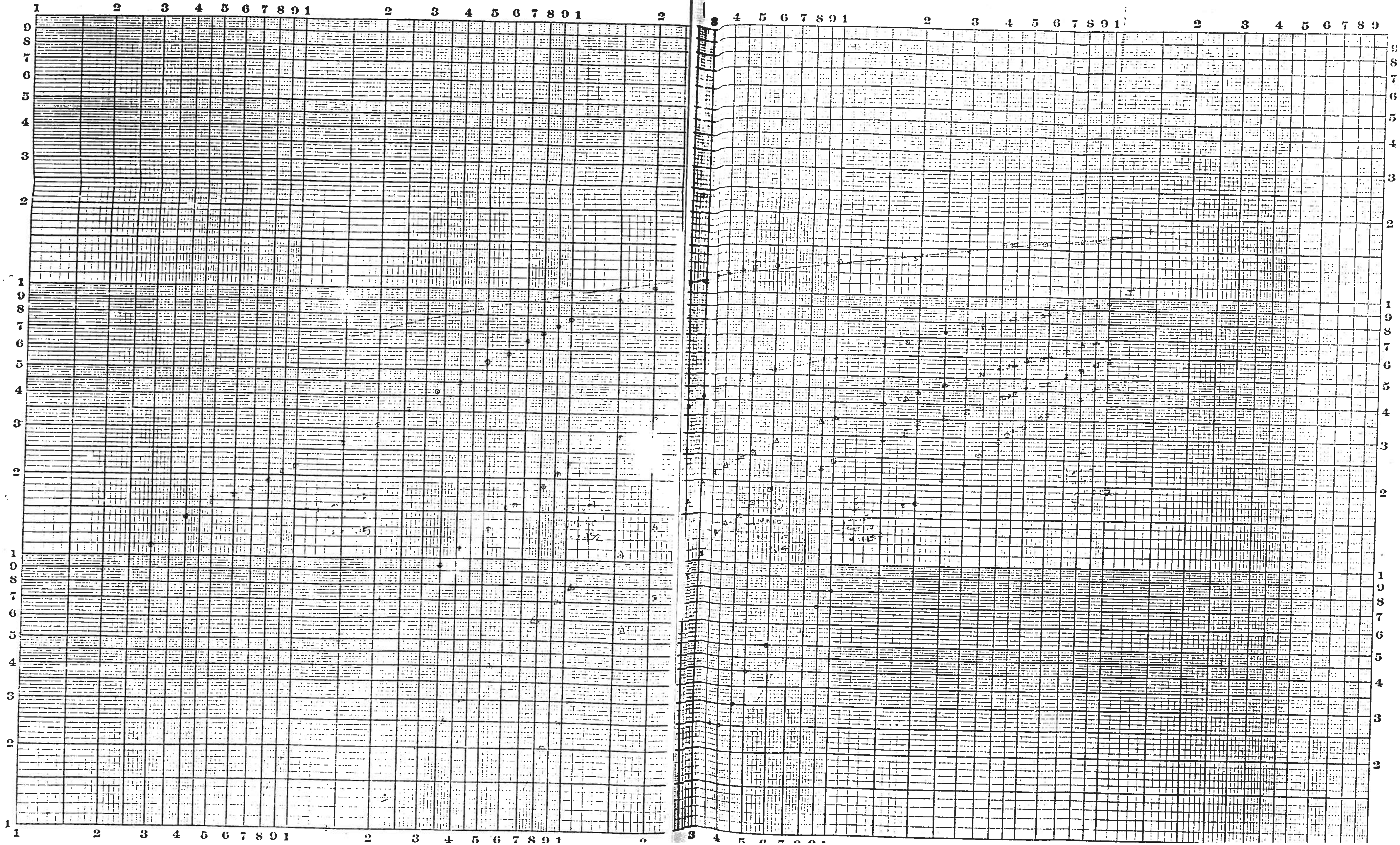
Well #	T gpd/ft	This Case S	Ramahorpsh USP - 1536 S
Pumping	20,628		0.036 (?
1	20,357	0.075	0.109
2	22,100	0.114	0.111
3	22,920	0.096	0.057
4	14,065	0.111	

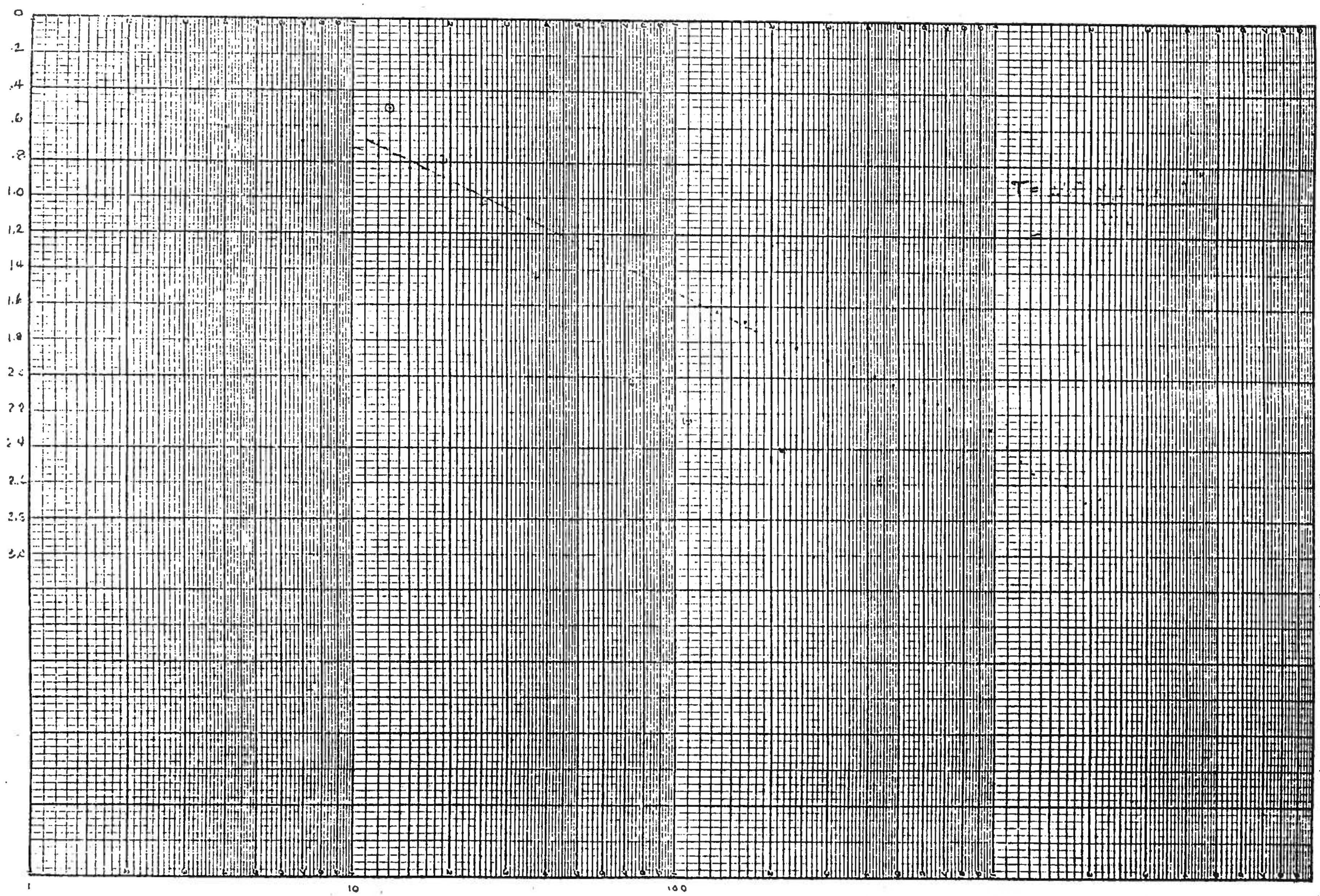
Ave. Summary	21,455	0.054
[illegible]	21,500	[illegible]

Use maximum value of field.

[illegible]







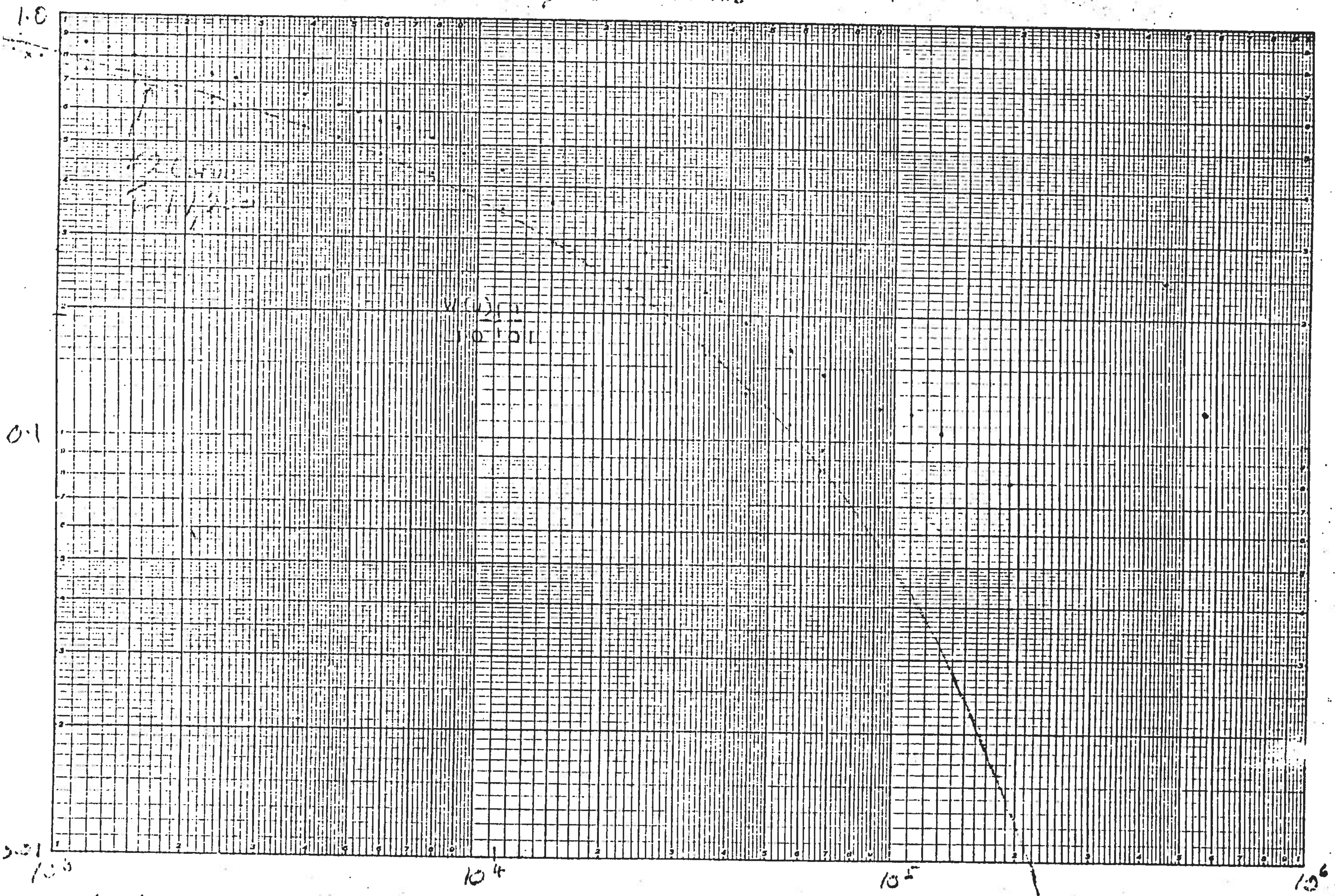
TIME IN MINUTES [illegible]

TIME-DRAWDOWN [illegible]

...40 ft East of C.P.R. Well   ANDREW   4 July 1960.

Field Calculations

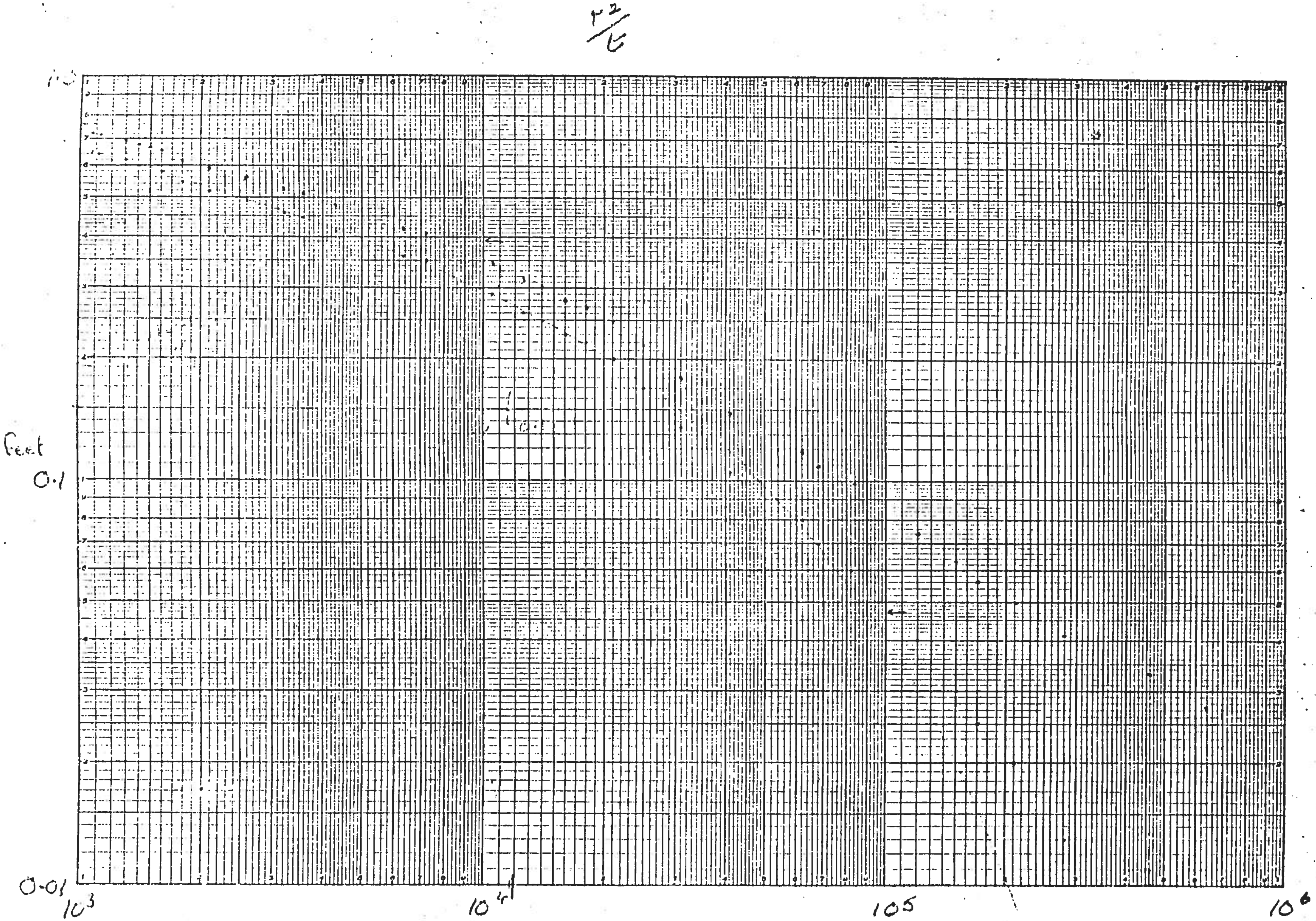
r^2/t in mins



T = 15,250

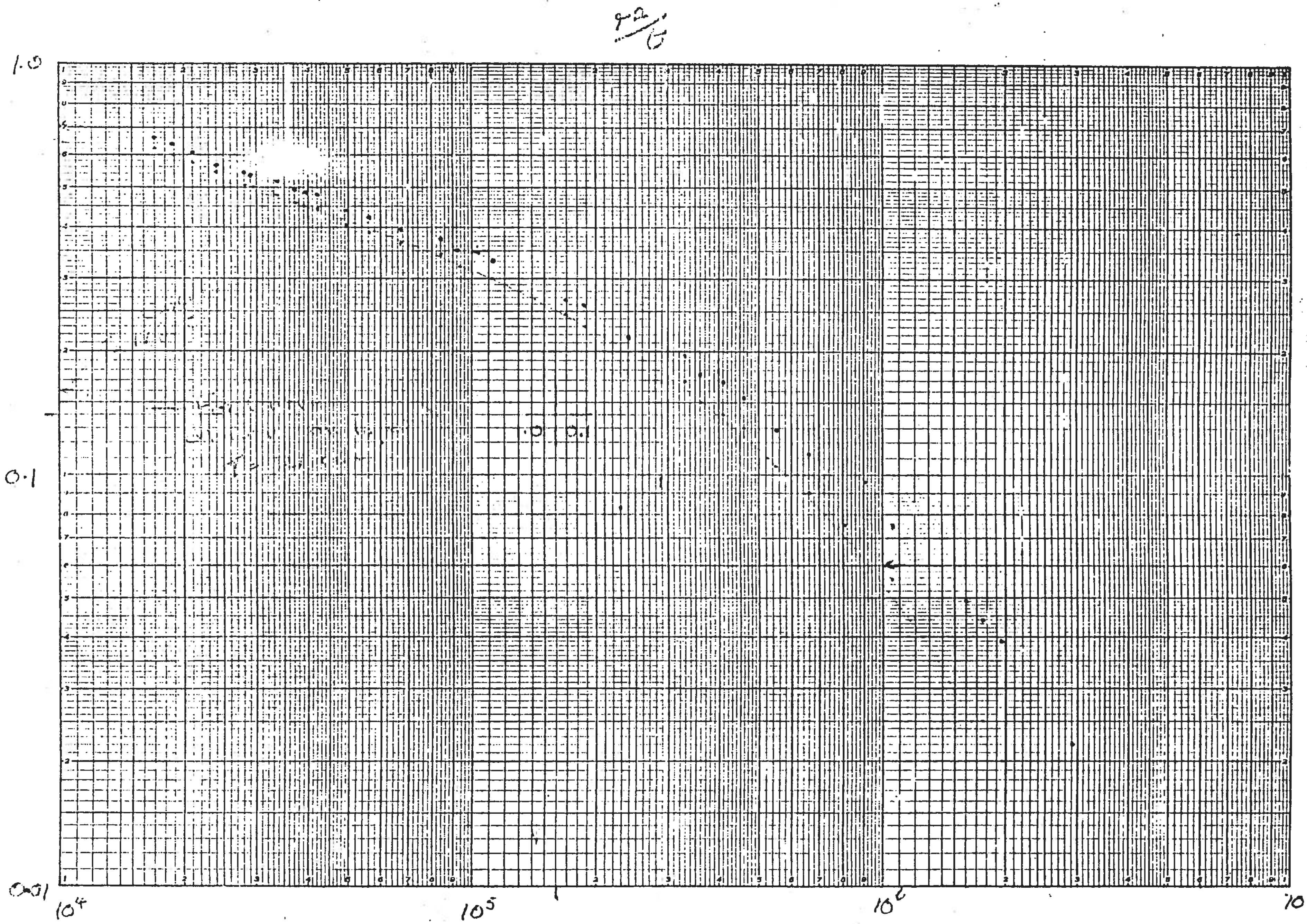
... 1.17 ...

Field Calculations



Observation Well 7 S.
108 ft West of C.P. Well.

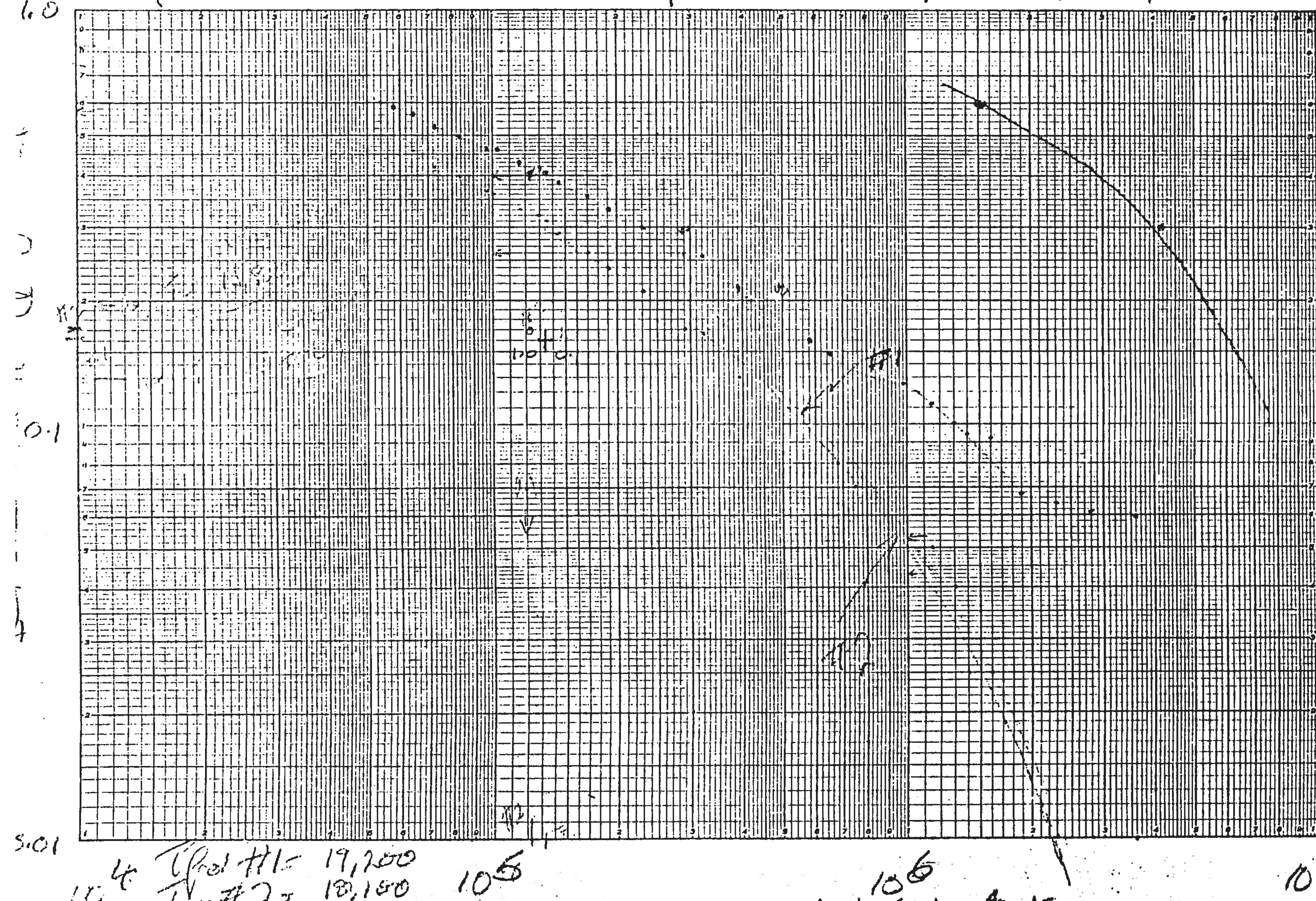
ANDREW 4th July 1960.



T = 22,100.
[illegible] 2 [illegible]

e.g. for Pulling Olivers' Well

For drawdown measurements plot diff. between S.L. & D.D. for the time of the pumping S.L. = 50 & D.D. = 51, 53, 56 =



Plot 3 6 sideways on graph. Fit Theory curve for Wu = & u =

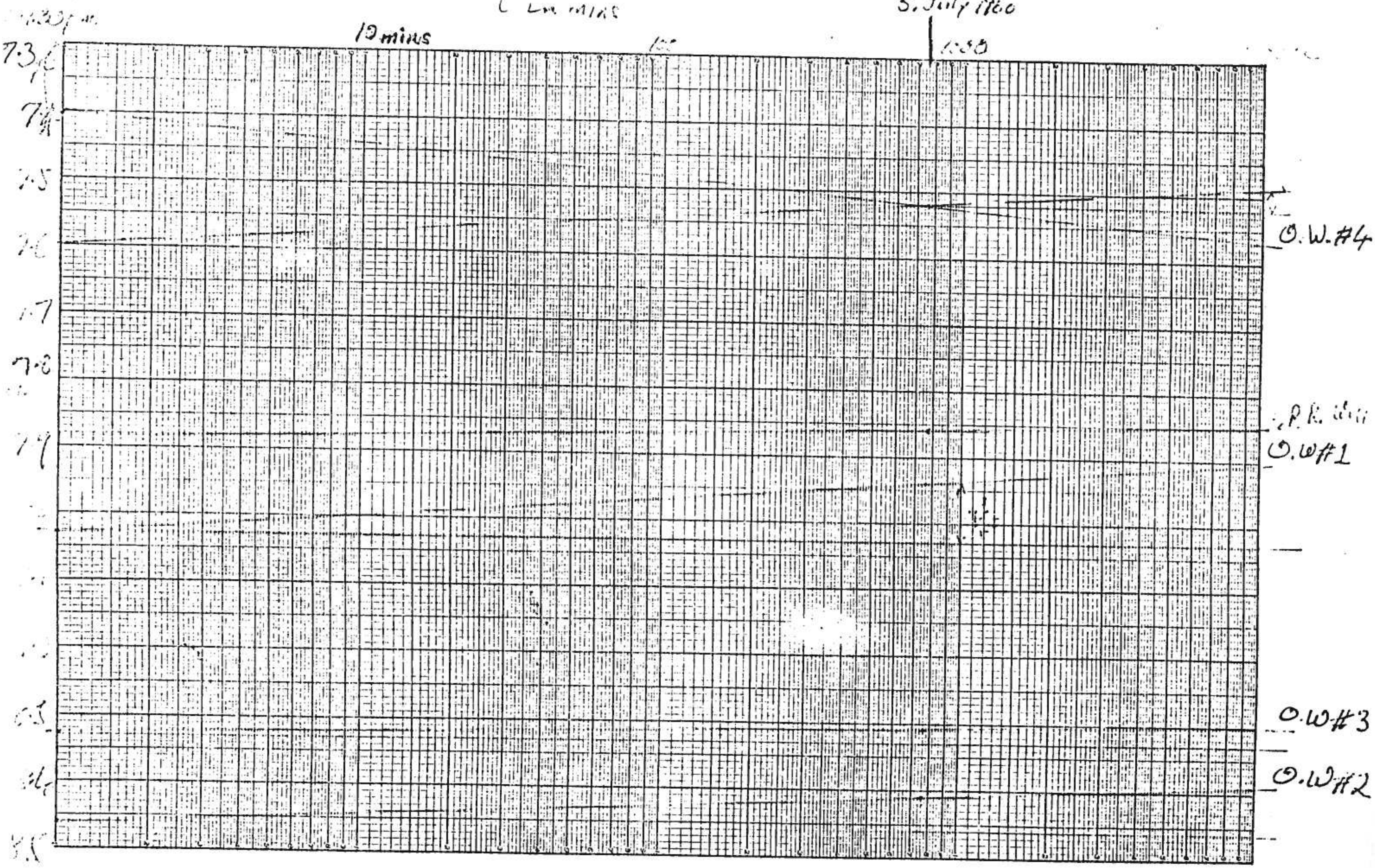
3.045
7.955

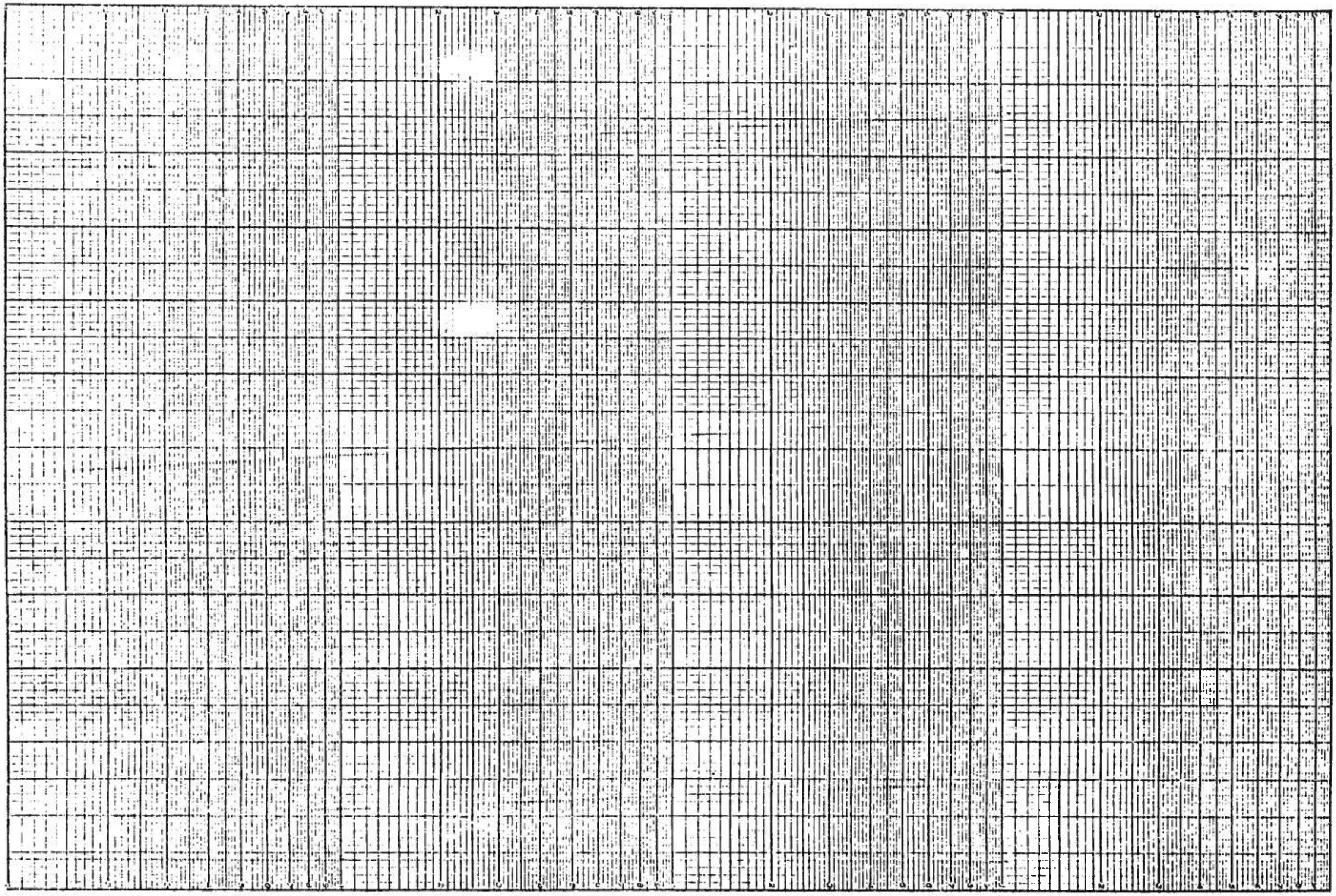
11.
3.4
7.6

T for #1 = 19,200
T .. #2 = 18,100

To get 10^4 ... in minutes

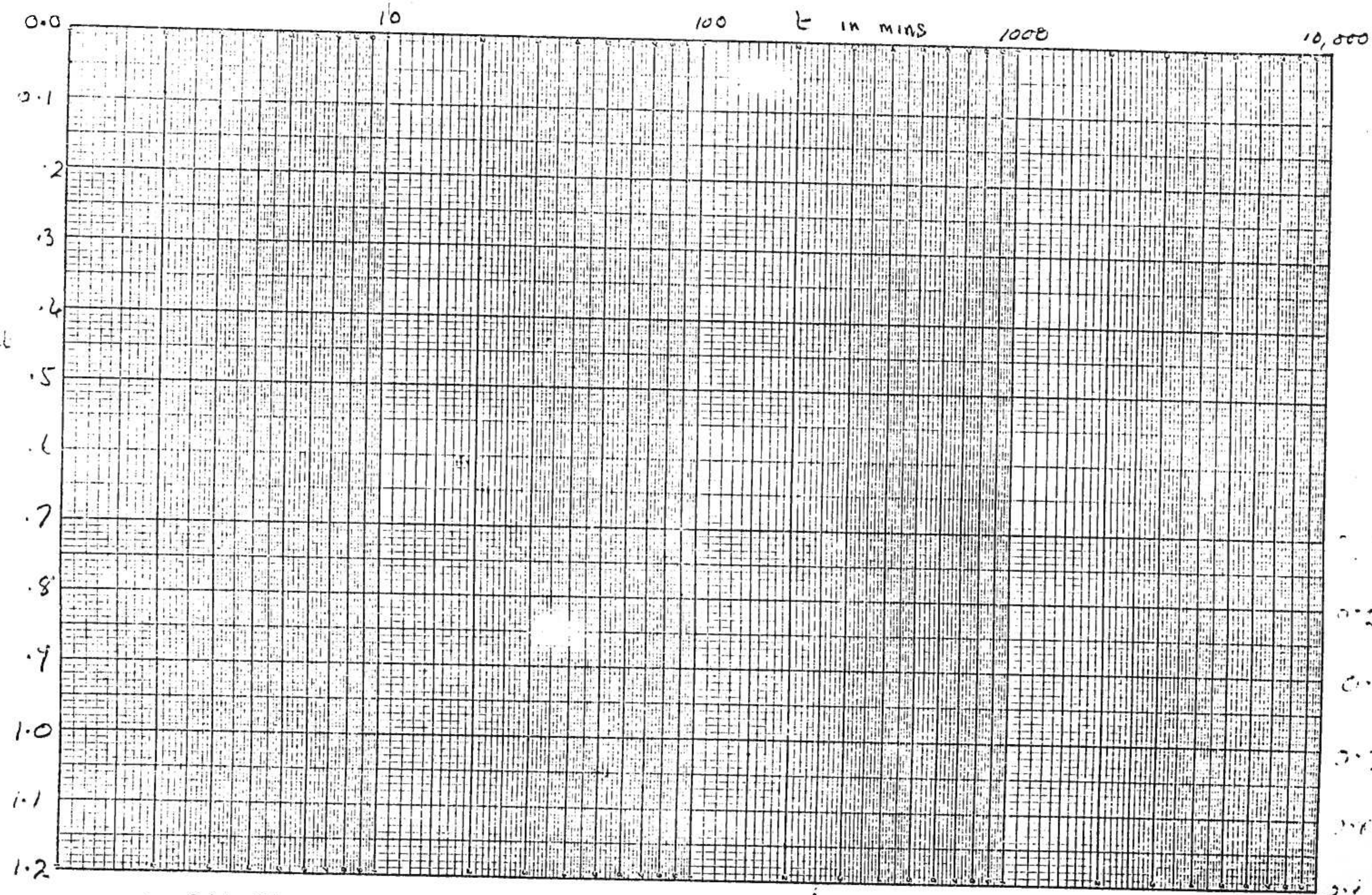
Observation Wells #1, #2, #3, #4.





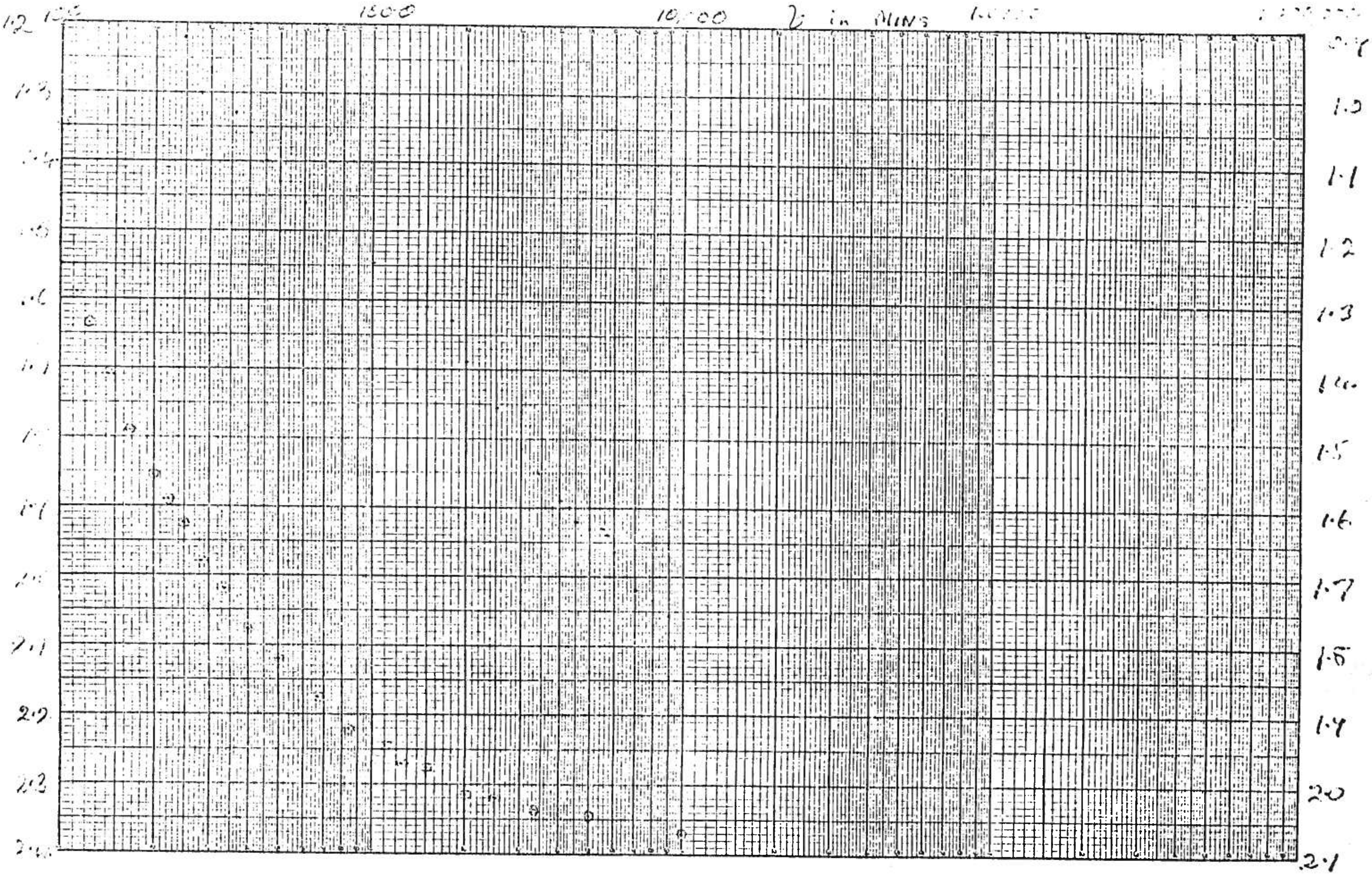
Loc:

Field Cal[illegible]ations



T = 264 x 2.5 = 6,442 min.

Field Calculations



C.P. Well	Obs. Well #1	Obs. Well #2	Obs. Well #3	Obs. Well #4
[illegible]	Distance from C.P. in feet = [illegible]	Dist. Well in feet = [illegible]	Dist. Well in feet = [illegible]	Dist. Well in feet = [illegible]
[illegible]	7:52 p.m. 12-3.17	7:49 p.m. 12-3.41	7:45 p.m. 11-3.77	7:55 p.m. 11-3.60
[illegible] 14.13 [illegible]	= 12.[illegible]	= 9.87 [illegible]	= 10.23 [illegible]	= 7.40
[illegible]	[illegible] 1.13	[illegible] 1.13	[illegible] 1.90	[illegible] 0.0
= 8.63	= 7.0[illegible] ft S.L	= 8.[illegible] S.L	= 8.33 ft S.L	= 7.40 ft S.L
[illegible]	8:3[illegible] 11-4.06	8:3[illegible] 13-4.46	[illegible]	[illegible]
12-[illegible]	= 11.94-3.0	= 11.54-1.13	= 10.21-1.90	11-[illegible]
= [illegible] 5	= [illegible]	= 8.41	= 8.[illegible]	= 7.[illegible]2
4				
1[illegible]-[illegible]=13.9	1[illegible]-[illegible]=[illegible]	14-4.46=9.54	14-[illegible]=10.21	11-3.[illegible]=7.5
	8.45 6.700			

[illegible]		Obs Well #1		Obs Well #2		Obs Well #3		Obs Well #4		Remarks
1.9[illegible] 5.5[illegible]	M.P.L. 15.90 ft		3.0[illegible] 8.92 ft		1.3 ft 9.56 ft		1.90 ft 10.22 ft		0.0 ft 7.52 ft	= 10.30 ... Top Reading
Time	Depth	Time	Depth	Time	Depth	Time	Depth	Time	Depth	
	13.90 ft		8.92 ft		9.55		10.20		7.53	
0	14–		14–		14–		14–			12.35 pm – 12.45 1.00 pm
1	[illegible]									
2	[illegible]									
3	-3.97									
4	-3.96									
5	-3.93									
6	-3.91									
7	-3.92									
8	-3.9[illegible]									
9	-3.89									
10	-3.88	12	-4.04	14	-4.46	17	-3.81			
15	-3.83	18	-4.02							30 g.p.m. approx
20	-3.78	21	-4.01	23	-4.44					
25	-3.735	25	-4.01	30	-4.45	28	-3.80			
23	-3.67	35	-3.995	37	-4.445					
40	-3.63	41	-3.97	43	-4.44	45	-3.805			25 g.p.m.
50	-3.[illegible]	[illegible]	-3.95	54	-4.43	58	-3.795			

	14		15 - 3.330		17		14		11.1	
200	-4.150	203	-3.330	202	-3.820	205	3.235	210	3.075	[illegible]
300	-4.300	298	-3.400	302	-3.870	307	3.265	306	3.085	[illegible]
400	18-3.4	401	-3.460	405	-3.900	403	3.290	408	3.090	[illegible]
500	-3.45	501	-3.500	503	-3.930	503	3.315	508	3.100	[illegible]
600	-3.49	602	-3.525	605	-3.960	610	3.330	610	[illegible]	7.40
700										11.20
800									[illegible]	7.00
900										2.10
1000	-3.60	[illegible]	-3.6[illegible]	1007	-4.0[illegible]	1005	3.400	1003	[illegible]	[illegible]
1500	-3.68	1503	-3.680	1505	-4.072	1507	3.450	1510	-3.4[illegible]	12.40
2000	-3.720	2001	-3.730	1996	-4.150	2000	-3.485	[illegible]	-3.500	9.00
2500	-3.760	2502	-3.760	2505	-4.18[illegible]	2497	-3.510	2494	[illegible]	5.25
3000	-3.785	2995	-3.785	2987	-4.200	2990	-3.530	2985	-3.250	[illegible]
3445	-3.8[illegible]	3448	-3.810	3450	-4.210	3455	-3.550	3452	-3.2[illegible]	10.00
4400	-3.800	4400	-3.825	4400	-4.260	4400	-3.590	4400	6.51	6.20
4500							10.515			2.40
5000										
6	-18.81									11.[illegible]
5500			11.71							
6000										

4.310
4.815
3.540
3.740
4.140
(1.13)

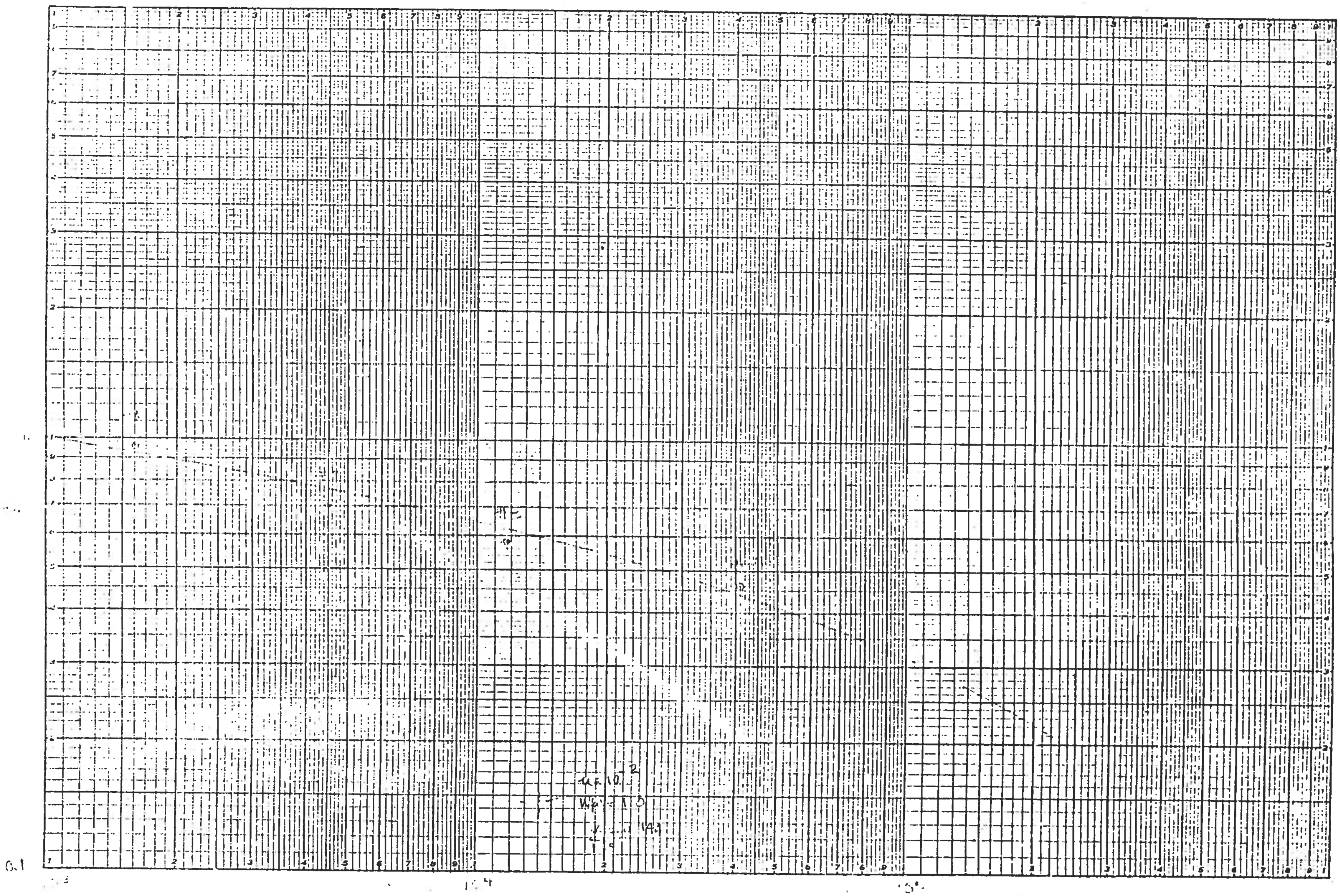
10.515
10.490
10.470
10.450
10.410
(1.90)
1.30
2.40

	5.9		3.0		1.83		1.89		2.0	
	18 —		16 —		14 —		14 —		11 —	
62	-3.17	60	-3.725	—	—	—	—	—	—	
70	-3.41	56	-3.92	78	-4.41	—	—	—	—	
80	-3.36	82	-3.87	—	—	—	—	—	—	
90	-3.305	72	-3.87	74	-4.40	85	-3.78	88	-3.47	
100	-3.25	101	-3.85	103	-4.37	105	-3.725	78	-3.47	
150	-4.08	153	-3.775	155	-4.365	157	-3.72	155	-3.44	
200	-3.95	205	-3.725	204	-4.335	208	-3.725	160	-3.44	
248	-3.87	250	-3.690	252	-4.30	254	-3.725	210	-3.44	
300	-3.835	297	-3.65	301	-4.27	305	-3.71	256	-3.46	
360	-3.77	356	-3.610	362	-4.25	367	-3.695	303	-3.45	
400	-3.74	398	-3.605	402	-4.24	404	-3.67	366	-3.44	
450	-3.70	447	-3.57	451	-4.22	455	-3.65	404	-3.44	
500	-3.67	478	-3.55	501	-4.21	506	-3.65	463	-3.44	
600	-3.64	600	-3.53	610	[illegible]	612	-3.63	527	-3.43	
700							-3.6?	626	-3.42	
800										
				907	-4.115	10?	-3.5??			
900	-3.5?0	910	-3.4?	912	-4.125	[illegible]	-3.5??	911	-3.4?	
1000	-3.5??	[illegible]	-3.??	10??	-4.110	[illegible]	-3.55?	[illegible]	-3.??	
1500	-3.417	[illegible]	-3.37	1???	-4.055	1498	-3.500	1503	-3.??	
[illegible]	-3.4?		-3.31		-4.0??		-3.4??		[illegible]	
[illegible]	[illegible]	[illegible]	-3.?1	2???	-3.???	2??9	-3.???	2??7	[illegible]	
3???	-3.285	3??2	-3.26	3009	-3.750	3007	-3.412	3005	-3.23	
3105	-3.25	3410	-3.23	3392	-3.725	3400	-3.395	3388	-3.21	
4???	-3.21	4005	-3.17	4017	-3.690	4015	-3.355	4010	-3.18	
4490	-3.180	4495	-3.17	4500	-3.675	4510	-3.340	4505	-3.15	8·00 a.m.
5???	-3.20	5000	-3.16	5000	-3.55?	5000	-3.32	5000	-3.14	
5???	-3.160	5100	-3.135	5100	-3.830	5???	-3.3??	5???	-3.11	
6???	-3.135	6000	-3.125	6000	-3.825	6000	-3.295	6000	-3.105	
7000	-3.08	7005	-3.08	7015	-3.785	7012	-3.255	7008	-3.?15	

	3.5		3.0		1.13		1.70		[illegible]	REMARKS
	14-1-		16-1-		14-		14-1-		11-1-	
8000	-3.065	8000	3.033	4000	3.[illegible]	[illegible]	3.230	[illegible]	3.0[illegible]	2.20 [illegible]
7000	-3.115	9000	3.130	7000	3.[illegible]	9000	3.300	[illegible]	3.110	[illegible]
10,000	-3.110	10,000	3.110	10,000	3.210	10,000	3.280	10,000	3.075	[illegible]
[illegible]	-3.10[illegible]		3.105						3.10[illegible]	[illegible]

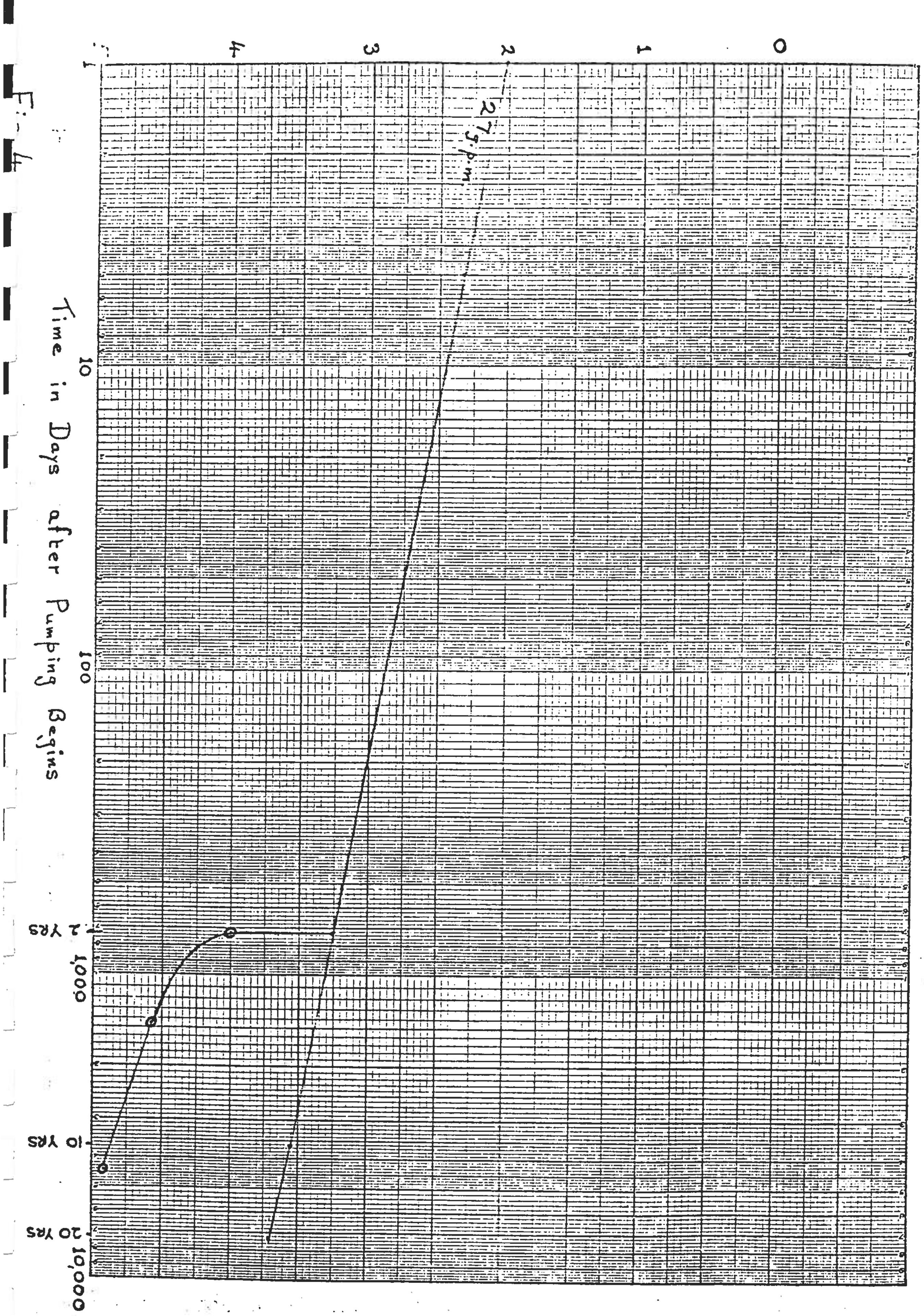
RECOVERY DATA

	[illegible]									
	-3.110	16-1-	-3.110	14-1-	3.210	14-1-	3.280	11-1-	3.110	[illegible]
1	-3.130									
2	-3.155									[illegible]
3	-3.163									[illegible]
[illegible]	-3.180									
[illegible]	-3.185									[illegible]
		6	-3.120							[illegible]
7	-3.225									[illegible]
[illegible]	-3.230									[illegible]
[illegible]	-3.245									
12	-3.2[illegible]0	10	-3.130	11	-3.210					[illegible]
15	-3.305	16	-3.145							1.[illegible]
[illegible]	-3.380	21	-3.155	22	-3.215					
25	-3.430	26	-3.165							[illegible]
30	-3.480	31	-3.176	32	-3.220					
35	-3.52	36	-3.175							[illegible]
40	-3.5[illegible]	41	-3.200	42	-3.223					
45	-3.610	47	-3.210	47	-3.225					[illegible]
50	-3.6[illegible]	51	-3.220	55	-3.230	[illegible]	-3.290			[illegible]
60	-3.710	[illegible]	-3.240	64	-3.240	62	-3.290	[illegible]	[illegible]	[illegible]
70	-3.785	71	-3.255	72	-3.240				-3.0[illegible]0	1.730
80	-3.850	82	-3.275	85	-3.260	84	-3.300			1.[illegible]
90	-3.910	91	-3.290	93	-3.260					[illegible]
100	[illegible]	101	-3.3[illegible]	[illegible]	-3.2[illegible]	[illegible]	-3.[illegible]			1.20



0.1

Predicted Water Levels 1 ft. from Pumping Well



ANDREW PUMP TEST No. 2

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RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water Level Measurements (field)

Location of project: ANDREW
Status: PUMPING (pumping or observation well)

Test conducted by: G.M. GABERT
Measured by: G.M.G. & CONTRACTOR
Well location: Lsd. or 1/4 ____ Sec. ____ Tp. ____ R. ____ Mer. ____
R = ____ (distance from pumping well in feet and direction)
Date: JAN. 29/63
Page: 1

Date	Time hrs. & mins.	Elapsed time in mins.	Tape Reading at Meas. Point	Tape Reading at Water level	Depth to water in feet	Draw-down	Q = discharge gals/min	[illegible]	Remarks (i.e. pump adjustments, water temp., static level, etc.)
JAN. 29	1900	0			9.30	.00		.00	NON PUMPING WATER LEVEL
	01	1			9.62	.32		.31	
	02	2			9.73	.43		.41	
	03	3			—	—		—	
	04	4			9.91	.61		.57	
	05	5			—	—		—	
	06	6			9.96	.66	24	.61	24 - 10 gal./25 sec.
	07	7			9.98	.68		.63	
	08	8			10.02	.72		.66	(.61)
	09	9			—	—		—	(.67)
	1910	10			10.03	.73		.67	
	1912	12			10.07	.77	24	.71	
	1915	15			10.13	.83		.72	
	[illegible]	20			10.22	.92		.83	
	1925	25			10.31	1.01		.90	
	1930	30			10.36	1.06		.94	
	1935	35			10.41	1.11		[illegible]	
	1940	40			—	—		—	
	1945	45			10.48	1.18	24	1.03	
	1950	50			10.55	1.25		[illegible]	WELL DIAMETER 8"
	1955	55			10.58	1.28		1.11	
	2000	60			10.62			1.13	
	2010	70			10.68	[illegible]		1.18	
	2020	80			10.71	1.41		1.20	
	2030	90			10.79	1.49		1.25	
	2045	105			10.84	1.54	24	1.29	
	2100	120			10.89	1.59		1.32	

RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water Level Measurements (field)

Test conducted by: G. M. GABERT   Measured by: GMG & CONTRACTOR

Location of project ANDREW   Well location: Lsd. or 1/4 ____ Sec. ____ Tp. ____ R. ____ Mer. ____

Status PUMPING   R = New Well   Date JAN.29/63   Page 2

(pumping or observation well)   (distance from pumping well in feet and direction)

Date	Time hrs. & mins.	Elapsed time in mins.	Tape Reading at Meas. Point	Tape Reading at Water level	Depth to water in feet	Draw-down in feet	Q = discharge gals/min	[illegible]	Remarks (i.e. pump adjustments, water temp., static level, etc.)
JAN.29	2115	135	15.00	4.07	10.93	1.63		[illegible]	
	2130	150	"	4.03	10.97	[illegible]		[illegible]	
	2145	165	"	4.01	10.99	1.69		[illegible]	
	2200	180	"	3.96	11.04	1.74		[illegible]	
	2230	210		3.91	11.09	1.79		[illegible]	
	2300	240	"	3.87	11.13	1.83		1.47	
	2400	300	"	3.80	11.20	1.90	24	[illegible]	
JAN.30	0100	360	"	3.77	11.23	1.93		[illegible]	
	0200	420	"	3.71	11.29	1.99		1.57	LOG OF WELL
	0300	480	"	3.66	11.34	[illegible]		[illegible]	0 - 6 SD.
	0400	540	"	3.62	11.38	2.08		[illegible]	6 - 13 GRAVEL & SD.
	0500	600	"	3.58	11.42	2.12		[illegible]	13 - 15 CLAY
	0600	660	"	3.56	11.44	2.14		[illegible]	
	0700	720	"	3.53	11.47	2.17		[illegible]	
	0900	840	"	3.46	11.54	[illegible]		1.71	
	1100	960	"	3.41	11.59	[illegible]	24	[illegible]	
	1300	1080	"	3.31	11.69	2.39		[illegible]	
	1500	1200	"	3.23	11.77	2.47		1.82	
	1700	1320	"	3.16	11.84	2.54		1.86	
	1900	1440	"	3.10	11.90	2.60		[illegible]	
	2300	1680	"	3.10	11.90	2.60		[illegible]	
JAN 31	0300	1920	"	3.00	12.00	2.70		[illegible]	
	0700	2160	"	2.90	[illegible]	2.80	24	1.97	STOP PUMPING

RESEARCH COUNCIL OF ALBERTA - Groundwater Division

Water Level Measurements (field)

Test conducted by: G.M. GABERT Measured by: CONTRACTOR

Location of project ANDREW Well location: Lsd. or 1/4 ____ Sec. ____ Tp. ____ R. ____ Mer. ____

Status PUMPING R = ____ Date JAN 31 Page 1

(pumping or observation well) (distance from pumping well in feet and direction)

Date	Time hrs. & mins.	Elapsed time in mins.	Tape Reading at Meas. Point	Tape Reading at Water level	Depth to water in feet	Draw-down in feet	Q = discharge gals/min	t'	Remarks (i.e. pump adjustments, water temp., static level, etc.)	t/t'
JAN.31	0700	2160	15.00	[illegible]	12.10	[illegible]	[illegible]	0	STOP PUMPING	
	0705	2165	"	3.[illegible]	11.88	[illegible]	[illegible]	5		4.33
	0710	2170	"	3.29	11.71	2.4[illegible]		10		217
	0720	2180	"	3.45	11.55	[illegible]		20		109
	0730	2190	"	367	11.33	2.0[illegible]		30		73
	0745	2205	"	398	11.02	1.7[illegible]		45		49
	0800	[illegible]	"	4.27	10.73	1.4[illegible]		60		37
	0830	2250	"	4.67	10.33	1.0[illegible]		90		25
	0900	2280	"	4.91	10.[illegible]	0.79		120		19
	1000	2340	15.00	5.70	9.[illegible]	[illegible]		180		13

1

RECHARGE OF THE AQUIFER

Replenishment of the aquifer is thought to be derived primarily from local precipitation. In order to determine the amount (surplus?) of water available for infiltration, comparison of water-need (evapotranspiration) and precipitation is necessary. Thornthwaite (1948) has outlined an empirical method for calculating potential evapotranspiration from meteorological data, in particular, from mean monthly temperature and total mean monthly precipitation. Since long term measurements of these climatic factors are not available at Andrew, measured values of temperature and precipitation at Vegreville, Alberta have been used to calculate potential evapotranspiration. A graph of the annual march (?) of precipitation and potential evapotranspiration (Fig. —) shows that only during the winter months from November to March, inclusive, is there a moderate surplus of water. This surplus falls as snow and is equal to 4.80

Andrew is topographically located in a flat, low area which is a catchment basin for surface runoff. Surface drainage from this area is very poorly developed. In the past, after periods of heavy precipitation, artificial drainage was necessary to lower the water level in Whitford Lake which is situated near Andrew. The granular material comprising the aquifer at Andrew either appear on the surface or underlie only a few feet of less permeable deposits. The aquifer is saturated to within a few feet of the surface.

Based on this information it is a reasonable assumption that a large part of the winter water surplus is not lost as runoff during the spring but remains in the area to infiltrate to the groundwater table. To obtain an estimate of the maximum potential recharge to the aquifer at Andrew, it is assumed that the entire 2.90 inches of winter water surplus infiltrates to the groundwater table. Test hole information suggests that the aquifer underlies an area at Andrew of at least one square mile. Distribution of the winter water surplus over this area would equal 153.6 acre feet (41,675,059 gallons) of water. On an annual basis this volume is equal to a recharge rate of 79.3 gallon per minute per square mile. An annual maximum safe rate of withdrawal of water from the aquifer at Andrew may be based upon an amount equal to the estimated annual maximum potential recharge to the aquifer or 79.3 gpm.

The maximum safe pumping rate calculated for each of the three wells at Andrew is based upon the withdrawal of water from storage in the aquifer for a continuous pumping period of 20 to pumping becomes more extensive the total maximum safe pumping rate can be increased by an amount equal to the volume of water that is recharged to the area influenced by the cone of depression of the pumping wells. The nonequilibrium formula and the aquifer coefficients used to calculate the maximum safe pumping rate for the Canadian Pacific Railway well can be used to calculate the radius at given times of the cone of influence for a well which is pumped continuously at a rate of 40 gallons per minute for 20 years. Table — gives values for the area of recharge influenced by the cone of depression at given times and expresses the intercepted volume of water available for recharge in gallons per minute.