MANCHESTER WATER DISTRICT #4 AQUIFER TEST

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December 1973

Open-File Technical Report 73-01

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MANCHESTER WATER DISTRICT #4 AQUIFER TEST

Introduction

A request was made by the Northwest Regional Office of the Washington State Department of Ecology to conduct a 24-hour aquifer test on the Manchester Water District Well #4 in Kitsap County. This well is located in Township 24 North, Range 2 East, W.M. Section 29P along the Bulman Road near Port Orchard. The well, cased and screened down to 257 feet, provides water for numerous homes in the Manchester Water District area.

Four other wells were monitored during the testing to determine effects of the pumping of the Manchester well. The Mrs. C.W. Leonard well is located 280 feet west of the pumped well and is cased down to 173 feet. A 263-foot well owned by Royce M. Stockwell is 763 feet northwest of the Manchester well. It is cased and open at the bottom with perforations the last 6 feet. This well provides water for four other houses besides the Stockwell residence. The Ock well, north of the Manchester well, and an open-cased artesian well approximately 1/4 of a mile to the north were also monitored throughout the test. The Ock well and the artesian well were sounded to depths of about 70 feet and 35 feet, respectively. The 78-foot Endsley well and the shallow 22-foot Dotson well, also in the area, were not measured.

Topography and Geology

The wells are located in a valley running approximately north-south; Bulman Road transects the floor of the valley. The north end of Bulman Road stops at the approximate surface-water divide within the valley, while the high ground to the east and west provide runoff from these areas.

The valley is underlain by glacially derived materials. Sands and gravels interbed with clays and silts and the beds pinch-out at differing intervals. The clay units are thought to act as impermeable or semi-permeable barriers in the horizontal and vertical directions. The wells derive most of their water from the more permeable sands and gravels found at various depths. The deepest units probably consist of pre-Salmon Springs deposits. It appears that the valley itself is a glacial outwash channel probably of Vashon age created by the glacial erosion with subsequent fluvial deposition of gravels, sands, and clays. (Figure #1 depicts the geology of the Stockwell and Manchester wells as recorded by drillers' logs.)

Aquifer Test

The drawdown part of the test was to start at 1200 hours on April 26, 1977. In preparation the Stockwell domestic well and the Leonard well were hooked to the Manchester Water District #4 system at approximately 1500 hours April 22, 1977 so that the observation wells would be off for some period prior to pumping, and would not be used during the test.

The Manchester well was turned off at 0900 on April 25. This would allow the water level within the well to recover to static level or apparent static level before the beginning of the test. The pre-pumping water levels in the Stockwell and Leonard wells were 112.39 feet and 68.90 feet below land surface, respectively. The Manchester well water level was 71.8 feet below land surface prior to test pumping. The Ock water level was 6.3 feet below the top of the casing and the artesian well had a static level 2.10 feet above land surface (the casing in this well stood 3.65 feet above land surface). The difference in elevation between the Stockwell, Leonard and Manchester wells would place the water level in the Leonard well approximately 10 feet higher than that of the Manchester well while the Stockwell static level is nearly 17 feet lower than the Manchester static level.

The differences in the static water levels of the Stockwell, Leonard and Manchester #4 wells are explained by the physical construction differences of the individual wells. The Leonard well is 173 feet deep (see Figure #2) and is open to a sand/gravel aquifer which shall be called the "upper aquifer" in this report. The Stockwell well is 263 feet deep and is perforated the final 6 feet thus tapping the "lower aquifer." The Manchester #4 well is screened from approximately the 190-212 foot and 240-250 foot levels of its total depth of 257 feet. Thus the Manchester well draws water from both the "upper" and "lower" aquifers, and the static water level is a composite of both the "upper" and "lower" water levels. According to the report on construction of Manchester Well #4 by Robinson and Noble, Inc., consultants, the upper aquifer is the better producer (Robinson and Noble, 1973). The final pumping and recovery data would have to be considered carefully and the discrepancies in well construction taken into account.

Although the Manchester #4 well was to begin pumping at 1200 hours on April 26, it was not until 12:08 that the actual pumping started. Throughout the test, discharge was maintained between 90 and 100 gallons per minute (gpm) and averaged 94.34 gpm. Twelve minutes after the beginning of the test, effects were noted in the Leonard well. Another 6 minutes elapsed before drawdown occurred in the Stockwell water level. The Ock and artesian wells were never affected by the pumping.

After 24 hours the water levels had declined 7.92 feet and 8.93 feet in the Leonard and Stockwell wells, respectively. The maximum drawdown in the pumped well was 35.38 feet. The wells were measured frequently the first few hours of testing and then at hourly intervals after 5 hours. The pump was turned off at 1200 hours on April 27, and recovery measurements were maintained for 26 hours. (See Data Sheets)

Results

After 29 minutes of pumping the Manchester Water District #4 well, the water level in the Leonard well declined at a rate faster than the initial decline; this is shown by the semi-log plot of drawdown (s in feet) versus time (t in minutes). See Figure #3. The t_o shown is the time of initial drawdown while t_1 and t_2 are the times of slope decline changes. The increased drawdown is thought to be the result of boundaries when the cone of depression from the pumping well encounters impermeable or less permeable units. In the Stockwell well, boundary conditions appear after 48 (55) and 122 (132) minutes of pumping (Figure #4). The second increase could be due to reflection or a second barrier. The data from the Manchester well does not show a change until after 92 (100) minutes of pumping (Figure 5) which would indicate the closest barrier is probably in the direction of the observation wells (procedure described in Johnson's Ground Water and Wells, 1972 and Bruin and Hudson, Selected Methods for Pumping Test Analysis, 1955). Logs of the Manchester and Stockwell wells imply that the upper aquifer pinches out somewhere between the two wells. Therefore, the barrier for the Leonard well could be the lensing-out of the gravel and sand aquifer which supplies this well. Similar conditions may exist for the lower aquifer. Figure #6 is a representation of possible boundary reflection loci for the Stockwell and Leonard wells using a method described by Edward A. Moulder in Shortcuts and Special Problems in Aquifer Tests (1963). Only the first boundaries were evaluated from the information available. There is a possibility of more than one or two boundaries present, and the case for the use of leaky parallel-channel aquifer equations is strong. However, since the Manchester well is to be pumped at a cyclic rate of 200 gpm for 2 hours with a 6 hour idle period, it is sufficient to calculate a transmissivity (T) and storage coefficient (S) using equations for single boundary conditions with constant discharge from a confined aquifer as described by Lohman in Ground-Water Hydraulics, 1972. A logarithmic curve is drawn of drawdown (s_o) versus time (t in days) for each of the observation wells (Figures 7 and 8). The plot of the observed data is then superposed on the family of type curves devised by R. W. Stallman in 1963 (plot of $\Sigma W(u)$ versus $1/U_p$). The points $\Sigma W(u) = 1$ and $1/U_p = 1$ are chosen to simplify the calculations and then $t_{days} = 2.8 \times 10^{-2}$ and $S_o = 3.6$ feet for the Stockwell well. A K factor may be obtained from the graph to determine r_i or distance from the observation well to the image well. The "upper aquifer" image well is approximately 700 feet from the Leonard well, the "lower aquifer" image well is nearly 1070 feet from the Stockwell well. The method of boundary reflection loci may then be used as shown in Figure #6.

Since part of the flow to the Manchester well is coming from both the "upper" and "lower" aquifers, and the recharge potential of the "upper aquifer" is perhaps two times greater than that for the lower "aquifer," the Q_o for the Leonard well would be $\frac{2Q}{3}$ where Q is the average rate of discharge of the pumped well, 94.34 gpm. Then Q_o would be 63 gpm (90,720 gpd) for the "upper aquifer" and 31.5 gpm (45,360 gpd) for the "lower aquifer." The equations $T = \frac{Q_o \; W(u)}{4\pi \; S_o}$ may be used to calculate transmissivity and $S = \frac{4 \; T \; t \; u_i}{{r_i}^2}$ may be used to determine Storage where $u_i = K^2 \; U_p$. The transmissivity and storage coefficient for the Leonard well then becomes 4,250 gallons per day/ft (568 ft^2/day) and 8.1×10^{-4}, respectively. The "lower" aquifer transmissivity is 1,000 gpd/ft (134 ft^2/day) and the storage coefficient is then 7.3×10^{-5}.

The straight-line solution methods may also be used to solve for T and S. Figures 3 through 5 are examples of the Jacob straight-line method using drawdown versus time. However, to calculate the slope of the curve when boundary conditions are present one must choose between the data plotted during the early part of the pumping test before barriers are encountered or the later data which reflect the actual boundary effects. For this test, the later data were chosen. The possibility of parallel-channel aquifer conditions or at the minimum, several boundaries would justify the use of the more conservative figures. The Leonard observation well would then have a transmissivity of 3,540 gpd/ft (473 ft^2/day) and a storage coefficient of 6.2×10^{-4}. The "lower" aquifer would have a T of 1,100 gpd/ft or 147 ft^2/day and an S of 3.8×10^{-5}. In both cases the figures are quite comparable to the curve-matching method. The T for the pumping (Manchester #4) well is 2,200 gpd/ft (294 ft^2/day) using the straight-line method. A plot of the straight-line recovery curve, shown in Figure #9, also gives a T of 2,200 gpd/ft which would verify the results of the drawdown curve and eliminates the factor of discharge fluctuation in the former. The figures for the pumping well allow some control of the calculations for the other wells since, at least, discharge from the combined aquifers is a substantiated quantity.

Figures 10A, 11A, and 12A represent the individual drawdown and recovery curves as well as the residual drawdown for the Manchester, Leonard and Stockwell wells, respectively. The Figures 10B, 11B and 12B illustrate the resultant straight-line residual drawdown curves. It should be emphasized that certain problems are inherent with these last curves. The recovery curve as shown in Figure 9 for the Manchester well is dependent on an equilibrium or near-equilibrium drawdown situation. If subsequent boundary conditions are encountered during the period of extrapolation, the slope of the drawdown curve would increase rather than level-off as shown by the graph: the recovery data would be in error. Likewise, if water levels as originally measured, immediately prior to pumping of the Manchester well, were not static levels as originally thought, but rather rising levels, the residual drawdown data would be in error. For these reasons the T and S values from the pumping data will be used in evaluation of aquifer conditions in proximity to Bulman Road. A transmissivity of 4,000 gpd/ft. and a storage coefficient of 7.1×10^{-4} for the "upper" aquifer provide intermediate values for the straight-line and Stallman matching-curve methods. A T of 1,050 gpd/ft. and an S of 5.5×10^{-5} should be sufficient in the "lower" aquifer. A value of 2,200 gpd/ft. represents the combined aquifer transmissivity.

CONCLUSIONS

It is apparent that the geohydrologic conditions in the Bulman Road area are very complicated. The boundary conditions as well as the separate aquifer and combined aquifer situations confuse the calculations and results. However, some conclusions may be made from the available data.

Figure 13 demonstrates the probable drawdown within the Manchester well if allowed to pump 200 gpm for 2 hours and recover for 6 hours. The n shown is the number of 8 hour cycles and p (= 0.25) is the fraction of the total cycle in which pumping is taking place. The column on the right margin represents drawdown for a well pumping 200 gpm from an aquifer with a T of 2,200 gpd/ft. After one cycle (pumping 2 hours and recovering 6 hours), the drawdown within the well will be 2.4 feet, after 100 cycles the drawdown will be 14+ feet and after 1000 cycles the drawdown will be 20+ feet. The resultant lowering of water level after

1, 5 and 9 years would be 20.4, 24.5 and 26.2 feet, respectively. The Manchester well will never recover fully, but will pump from a depressed water level.

The Leonard well will be drawn down 2.24 feet by the Manchester well pumping 200 gpm over a period of 2 hours; the well will then probably recover to within a foot of static water level after the pump has been off for 6 hours. The water level will have been lowered 7-1/2 feet after 1 year and 9-1/2 feet after 9 years (see Figure #14). Figure 15 shows a similar reaction for the Stockwell observation well. It must be mentioned that these figures are based on the equations derived by R. H. Brown in USGS Water Supply Paper 1536-I. The procedure is designed for a pumping well only. However, it has been applied to the two observation wells to give a rough idea of the possible drawdowns which might occur. The observation wells should approximate the Manchester well, with variations occurring due to boundary effects.

The pumping of the Manchester well will not allow full recovery of the water levels in either the Leonard or Stockwell wells. However, drawdown should not be excessive in either well. The Ock, Dotson, Endsley and unused artesian wells should not be influenced.

RECOMMENDATIONS

If a permit is granted it is recommended that the following be required:

1. A further test be conducted under the actual conditions of pumpage. The water will be discharged at the rate of 200

gpm over a 2 hour period after which recovery will be measured for 6 hours. This will be repeated over a 48 hour period.

2. Throughout the year, measurements shall be made of the pumping and static water levels when all wells are pumping during normal usage.

A general trend of ground-water decline can then be observed and a new withdrawal pattern designed to accommodate the conditions if changes are necessary.

3. A meeting of the various well owners and the Manchester Water District be held to discuss possibilities.

If the Manchester Water District can provide water for the various homes along Bulman Road, perhaps this would be the best solution.

REFERENCES

1) Bentall, Ray, ed., 1963, Methods of Determining Permeability, Transmissibility and Drawdown, Geol. Survey WSP, 1536-I, pp. 324-330

2) ___________ 1963, Shortcuts and Special Problems in Aquifer Tests, USGS WSP 1545-C, pp. C33-C37, C45-C47, C62-C68, C110-C112.

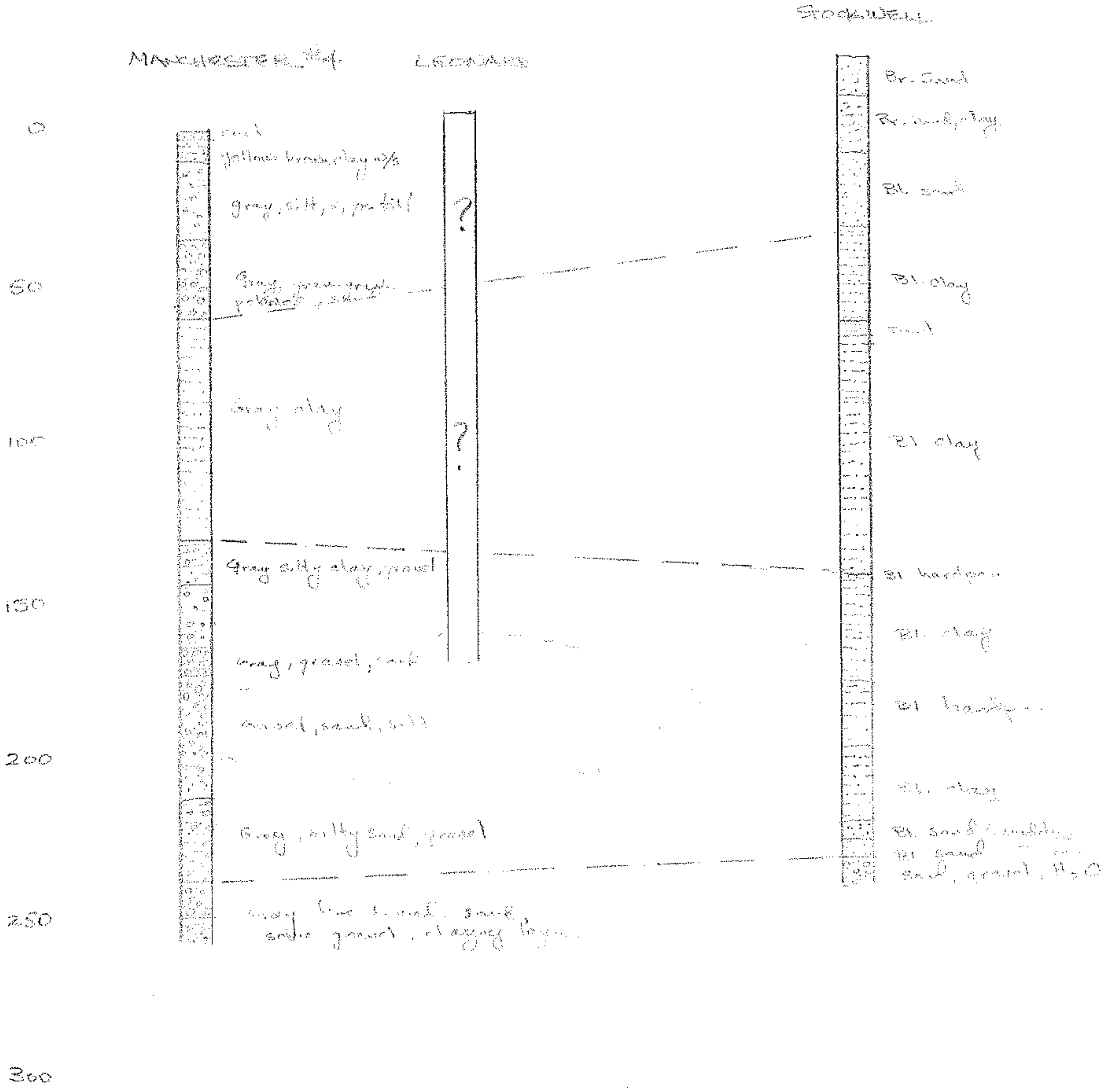
3) Bruin, Jack and Hudson, H.E., Jr., 1955, Selected Methods for Pumping Test Analysis, State of Illinois, pp. 22-37.

4) Johnson, Edward E., 1972, Ground Water and Wells, Universal Oil Products Co., pp. 108-144.

5) Lohman, S.W., 1972, Ground-Water Hydraulics, USGS Professional Paper 708, pp. 57-61 and plate 9.

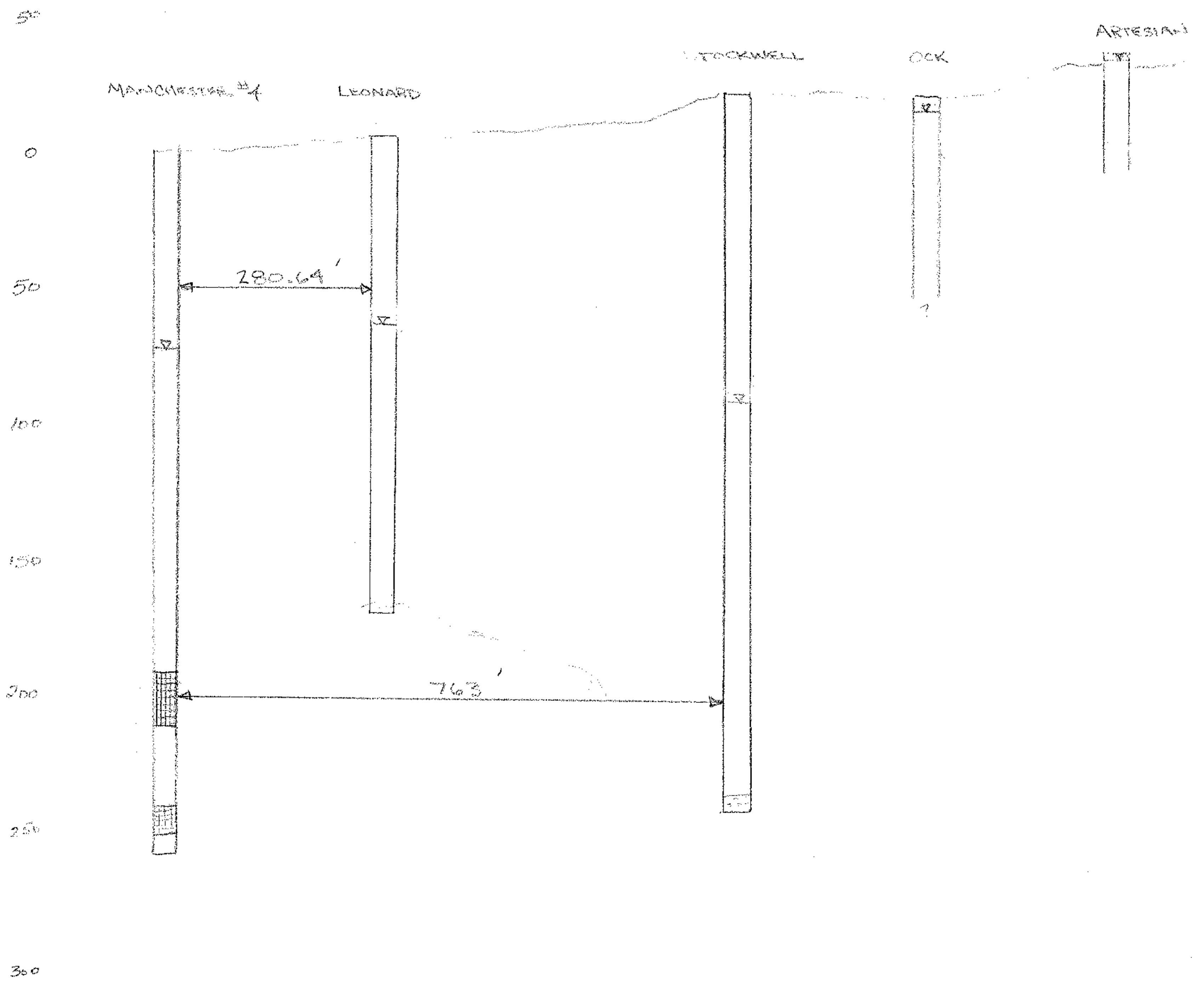
6) Robinson & Noble, Inc., 1973, Construction Report Well 4 (24/2E-29Q) Manchester Water District Kitsap County, Washington.

7) ___________ Oct. 1973, Report of Findings Re: Interference between Manchester Water District Well No. 4 and Stockwell Community Well



MANCHESTER #4
LEONARD
STOCKWELL
0
50
100
150
200
250
300
Gray silty clay, gravel
Gray clay
Gray, silty sand, gravel
?
?
Br. Sand
Bl. clay
Bl. clay
Bl. clay
sand, gravel, H_2O

FIGURE 1



50
0
50
100
150
200
250
300
MANCHESTER #4
LEONARD
TOCKWELL
OCK
ARTESIAN
280.64'
763'

FIGURE 2

NO. 340-L410 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
4 CYCLES X 10 DIVISIONS PER INCH

DIETZGEN CORPORATION
MADE IN U.S.A.

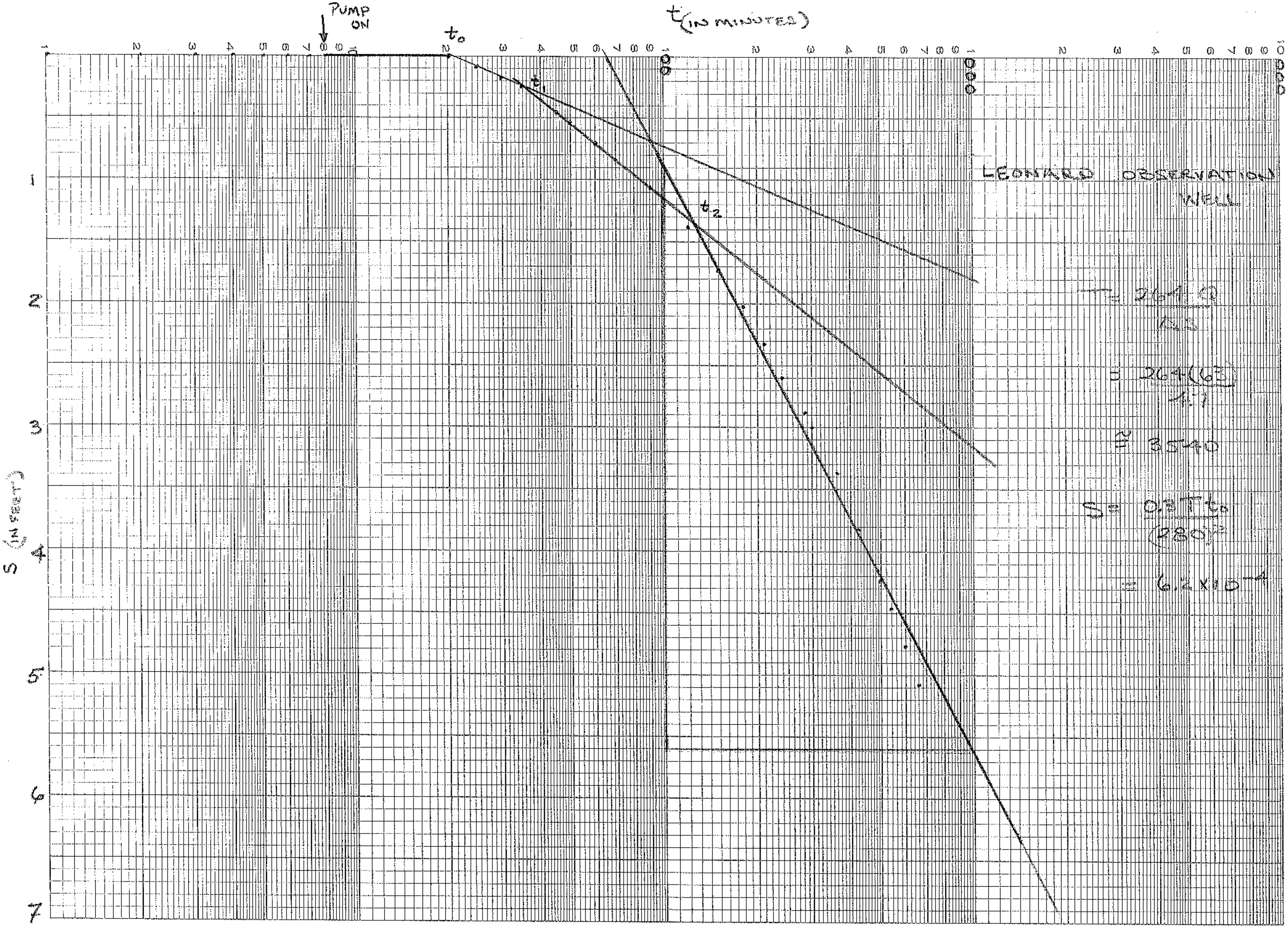


FIGURE 3

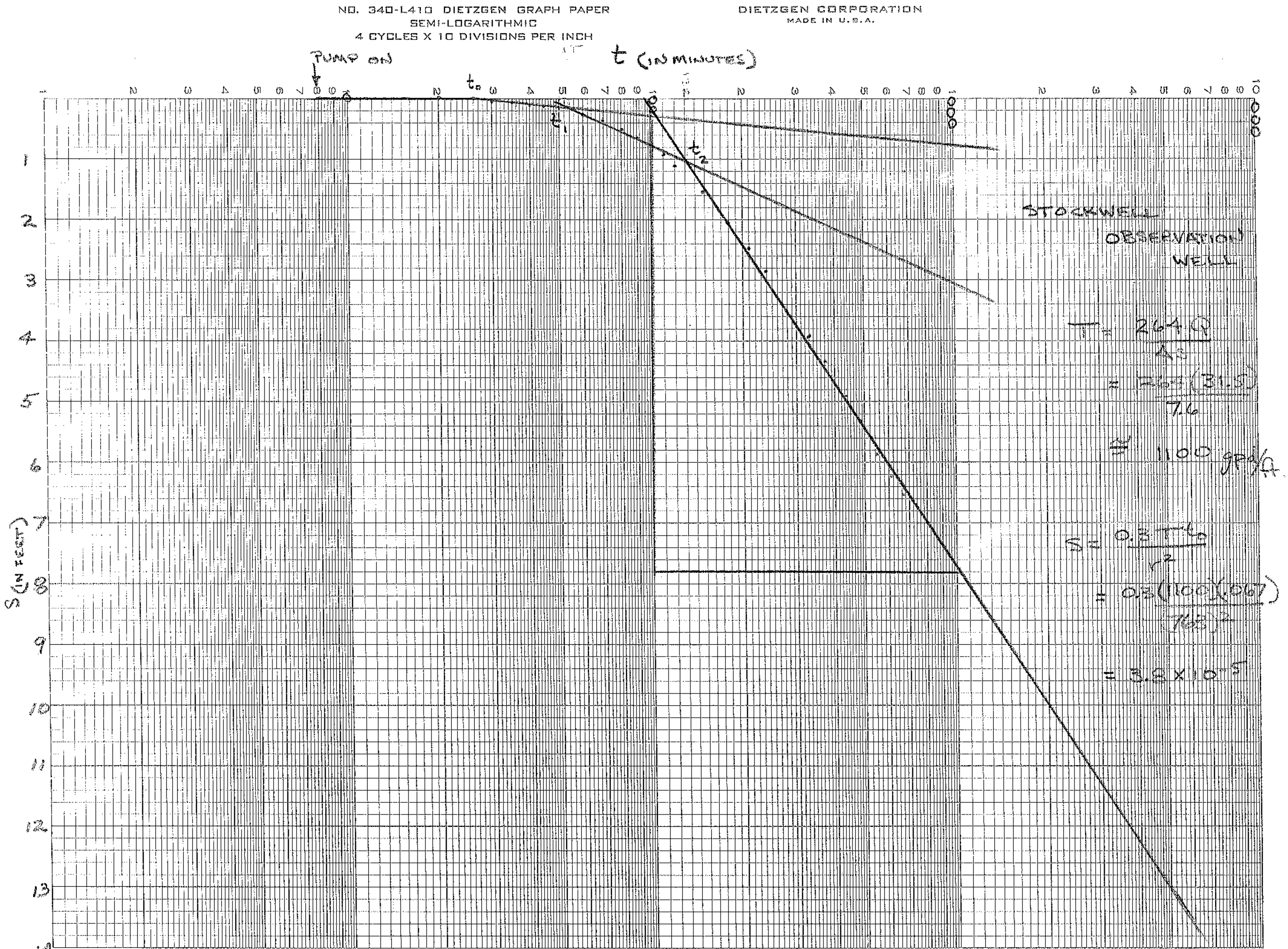

NO. 340-L410 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
4 CYCLES X 10 DIVISIONS PER INCH
DIETZGEN CORPORATION
MADE IN U.S.A.
PUMP ON
t (IN MINUTES)
S (IN FEET)
STOCKWELL OBSERVATION WELL
T = 264 Q / Δs
= 1100 gpd/ft
S = 0.3 T t₀ / r²
= 3.8 X 10⁻⁵

FIGURE 4

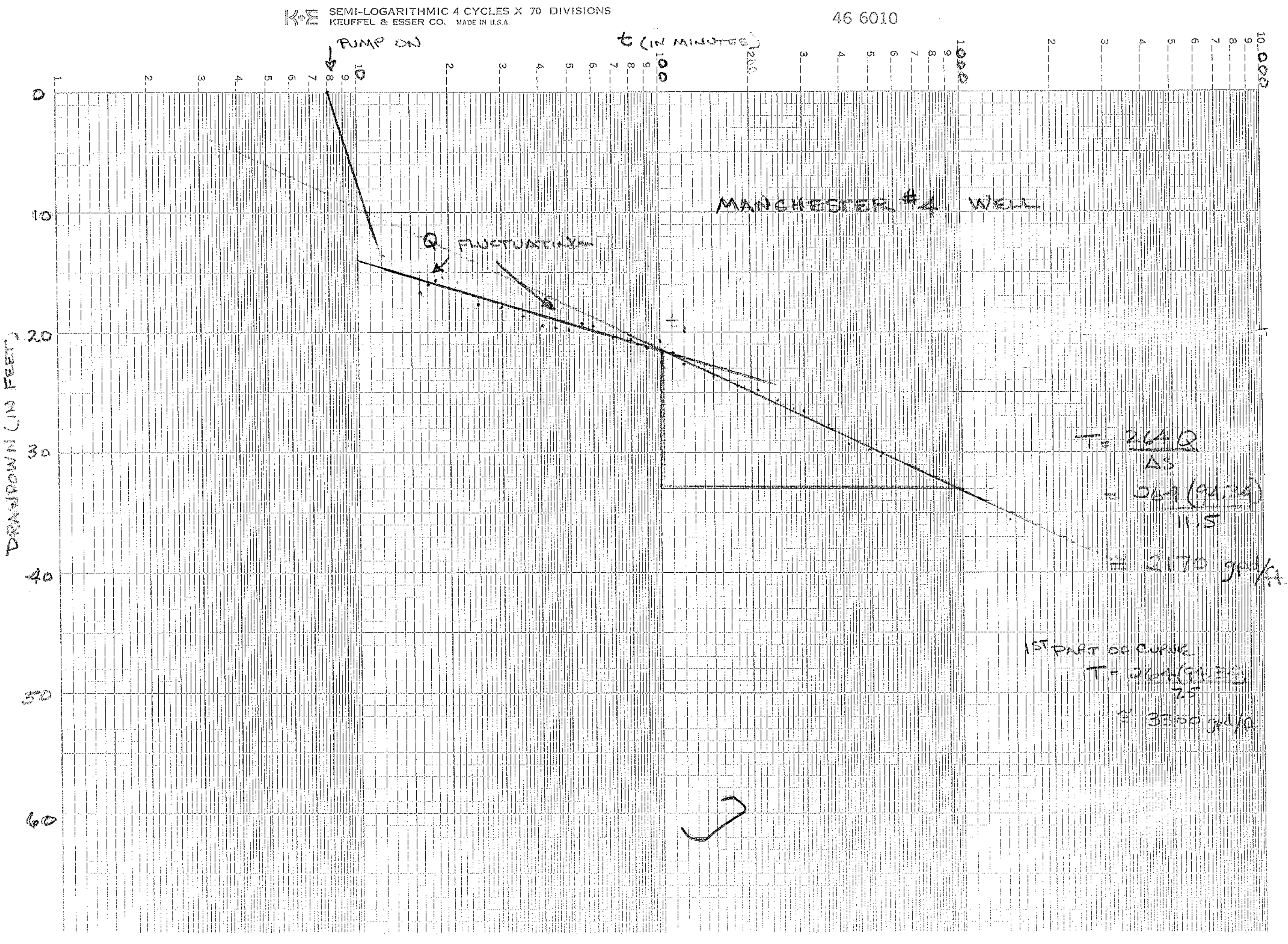
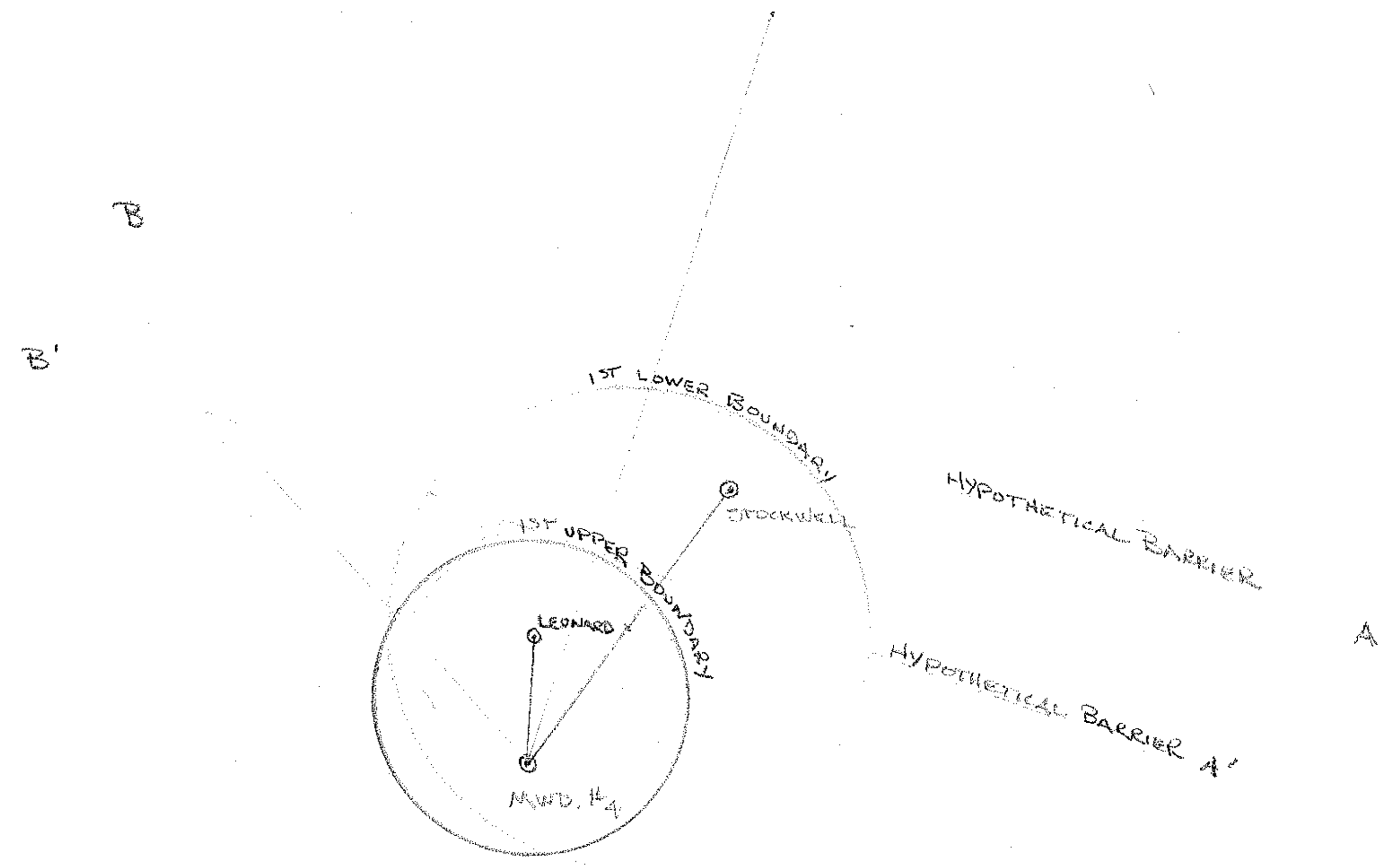

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6010
t (IN MINUTES)
DRAWDOWN (IN FEET)
PUMP ON
Q FLUCTUATION
MANCHESTER #4 WELL
T = 264 Q / Δs
= 264 (94.74) / 11.5
= 2170 gpd/ft
1ST PART OF CURVE
T = 264 (91.33) / 7.5
= 3300 gpd/ft

FIGURE 5



POSSIBLE BOUNDARY REFLECTION LOCI

MANCHESTER WATER DISTRICT AQUIFER TEST   FIGURE 6

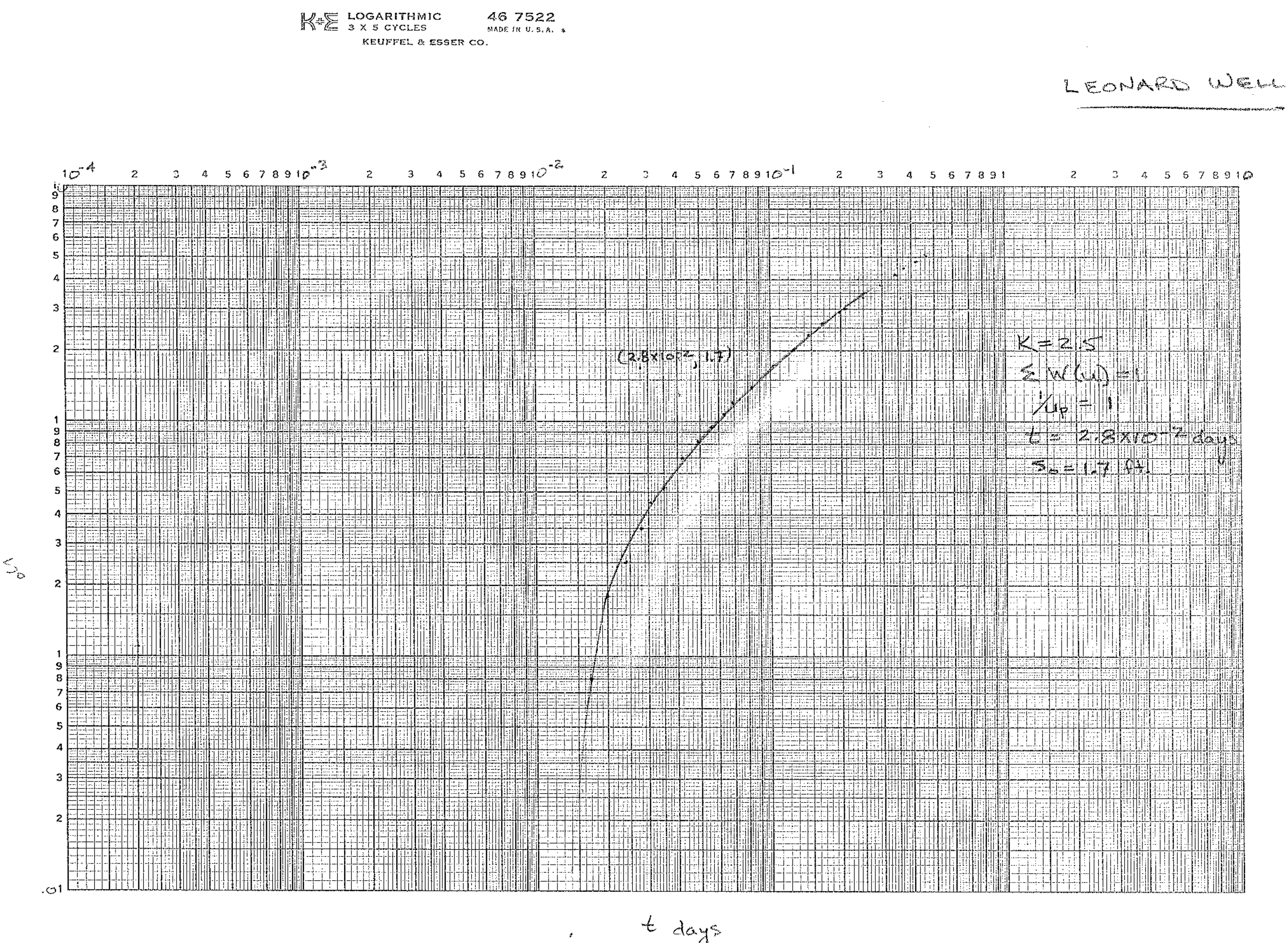

K+E LOGARITHMIC 3 X 5 CYCLES KEUFFEL & ESSER CO. 46 7522 MADE IN U.S.A.
LEONARD WELL
(2.8x10⁻², 1.7)
K = 2.5
Σ W(u) = 1
1/up = 1
t = 2.8x10⁻² days
s₀ = 1.7 ft.
s₀
t days

FIGURE 7

STOCKWELL WELL

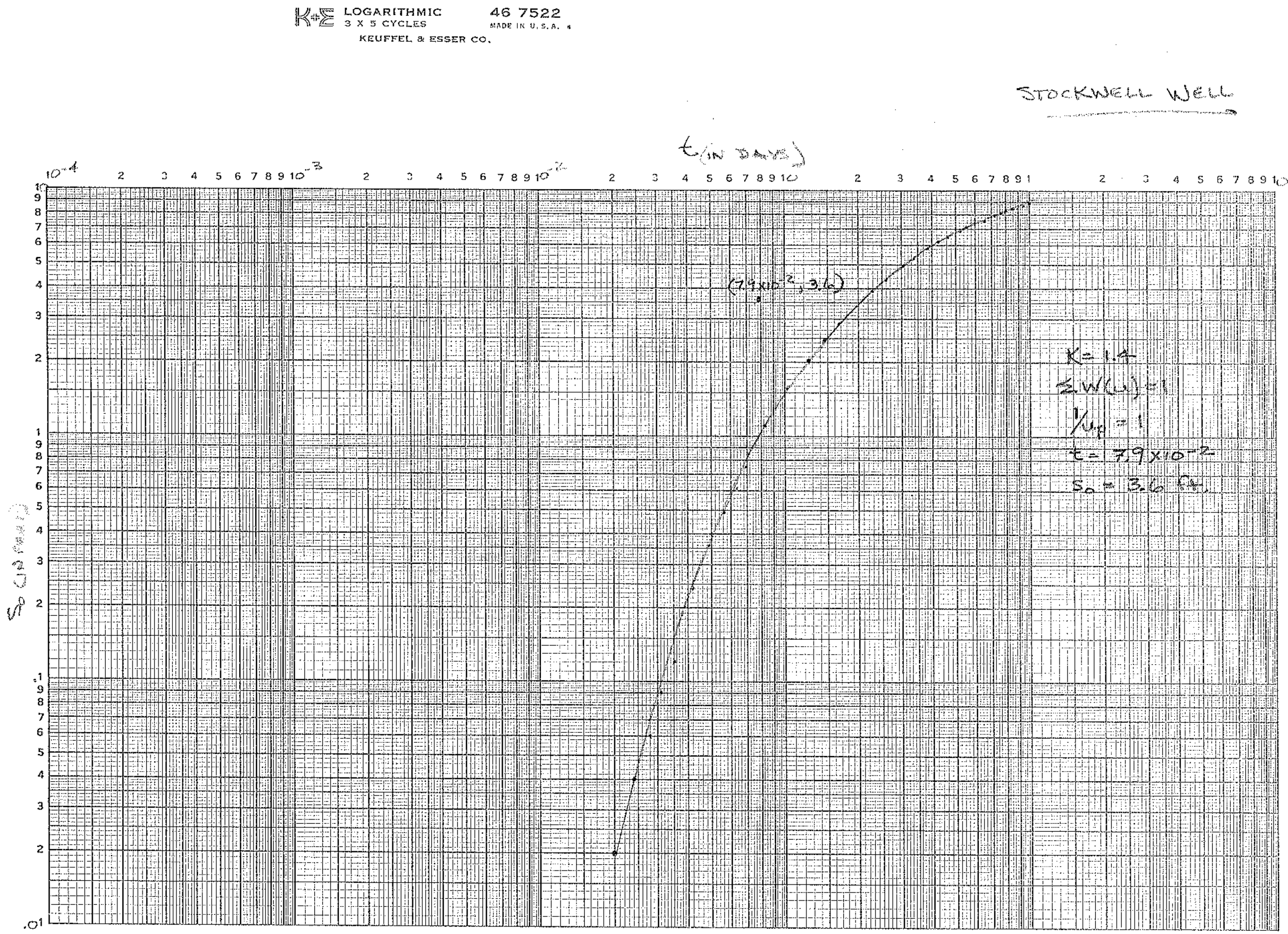
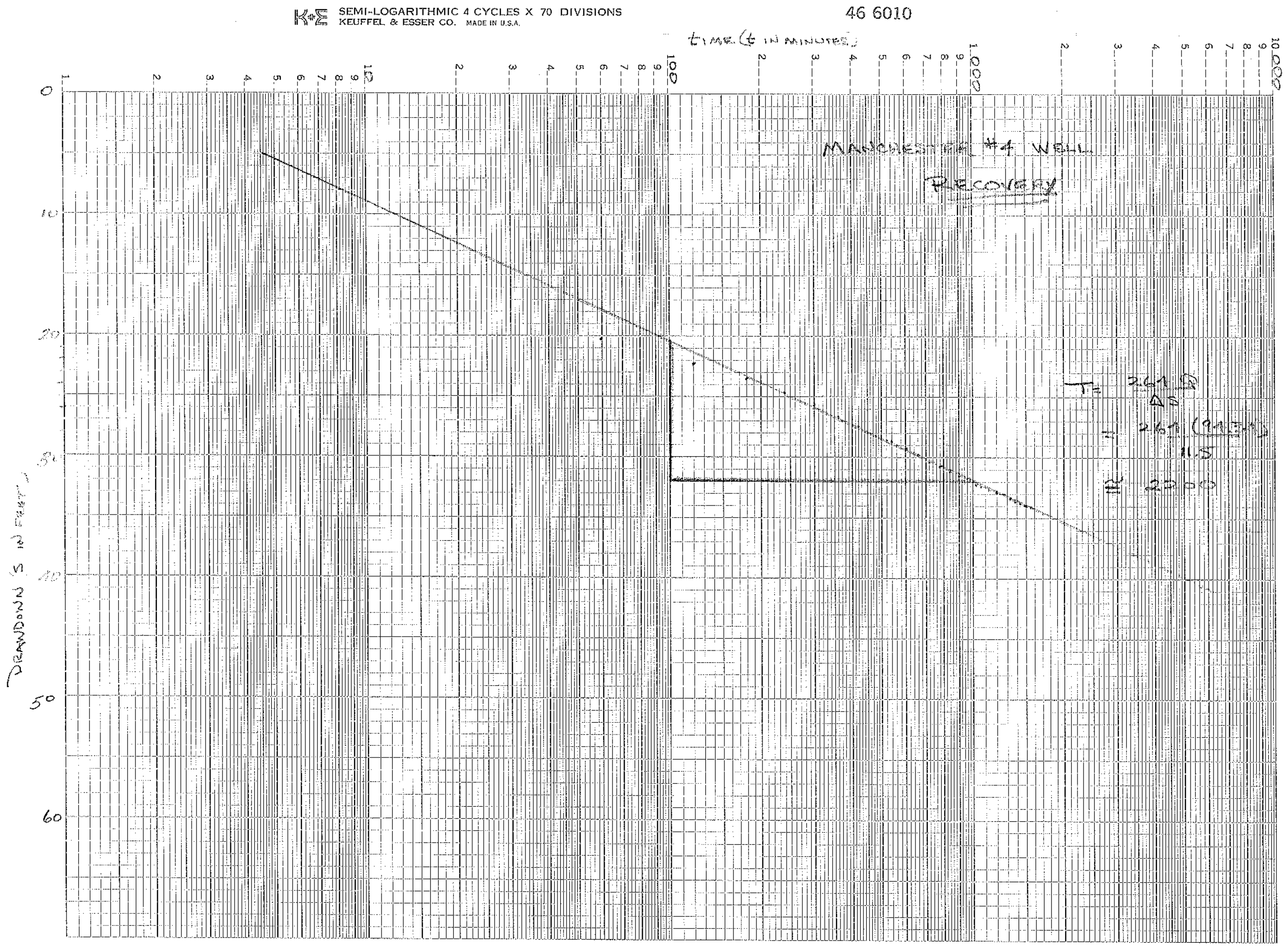
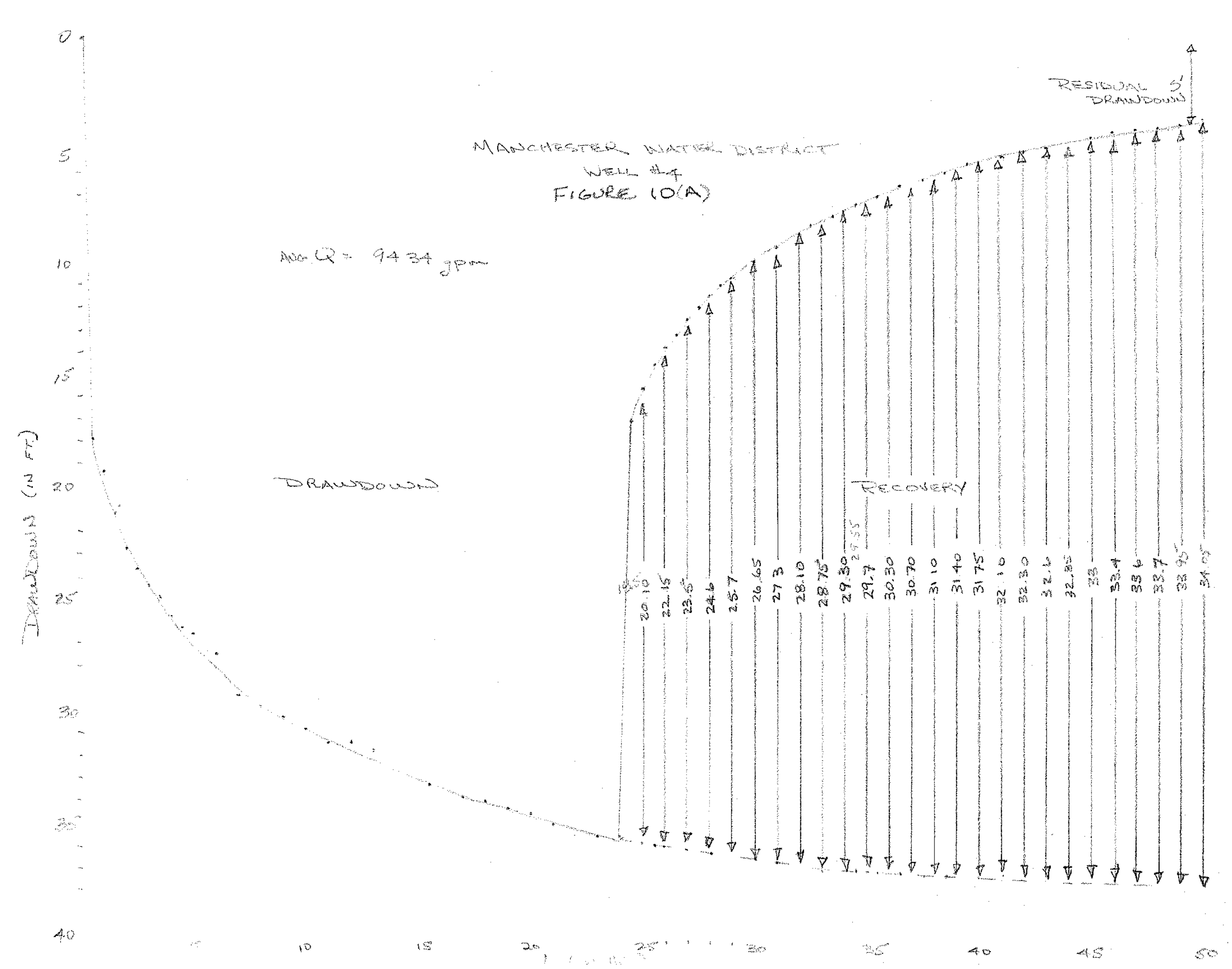


FIGURE 8



K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6010
time (t in minutes)
DRAWDOWN (s in feet)
MANCHESTER #4 WELL
RECOVERY

FIGURE 9


MANCHESTER WATER DISTRICT
WELL #4
FIGURE 10(A)
AVG. Q = 94 34 gpm
DRAWDOWN
RECOVERY
RESIDUAL 5'
DRAWDOWN
DRAWDOWN (IN FT.)
0
5
10
15
20
25
30
35
40
45
50
18.55
20.10
22.15
23.5
24.6
25.7
26.65
27.3
28.10
28.75
29.30
29.55
29.7
30.30
30.70
31.10
31.40
31.75
32.10
32.30
32.6
32.85
33
33.4
33.6
33.7
33.95
34.05

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MANCHESTER #4 WELL

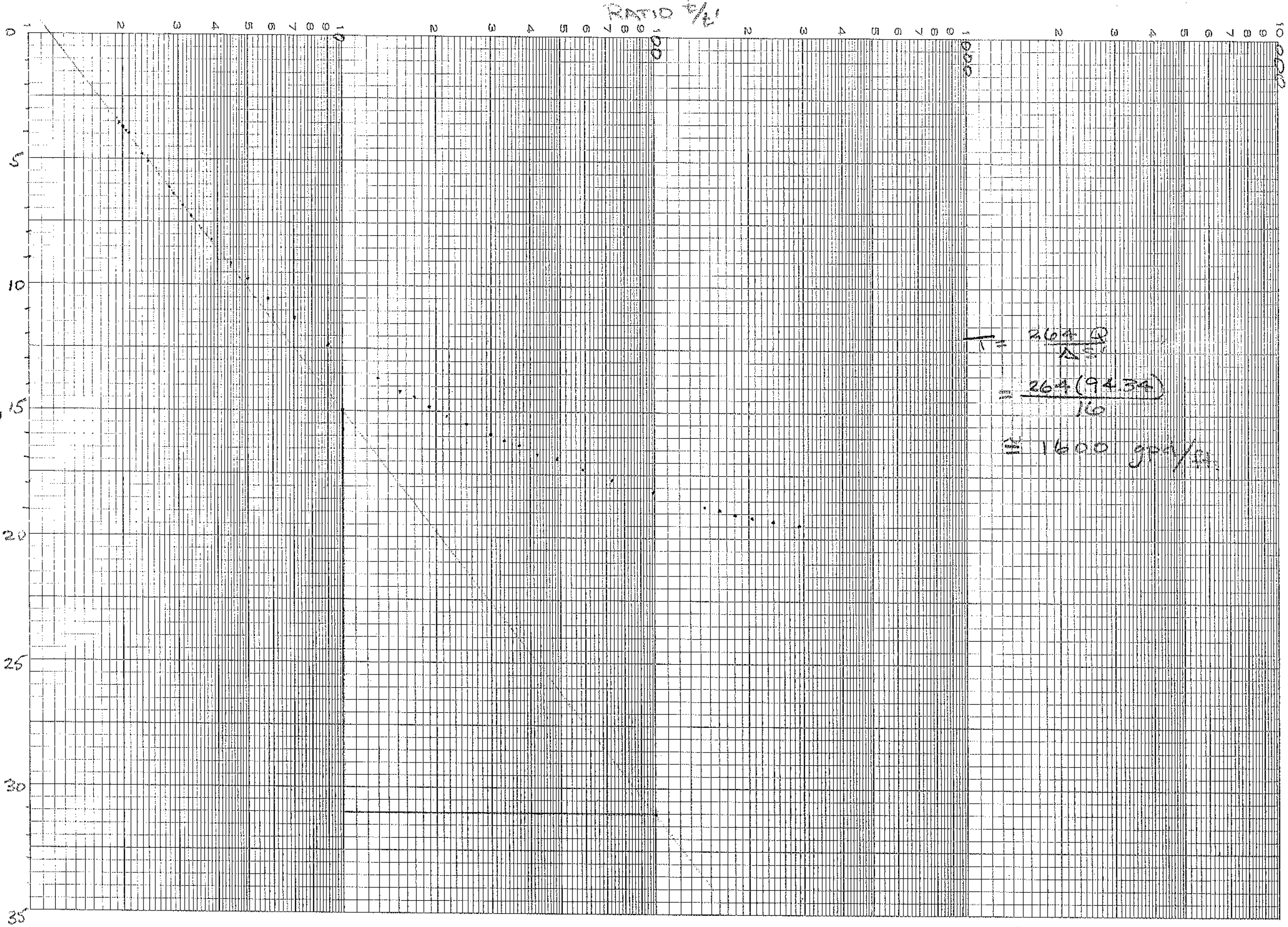
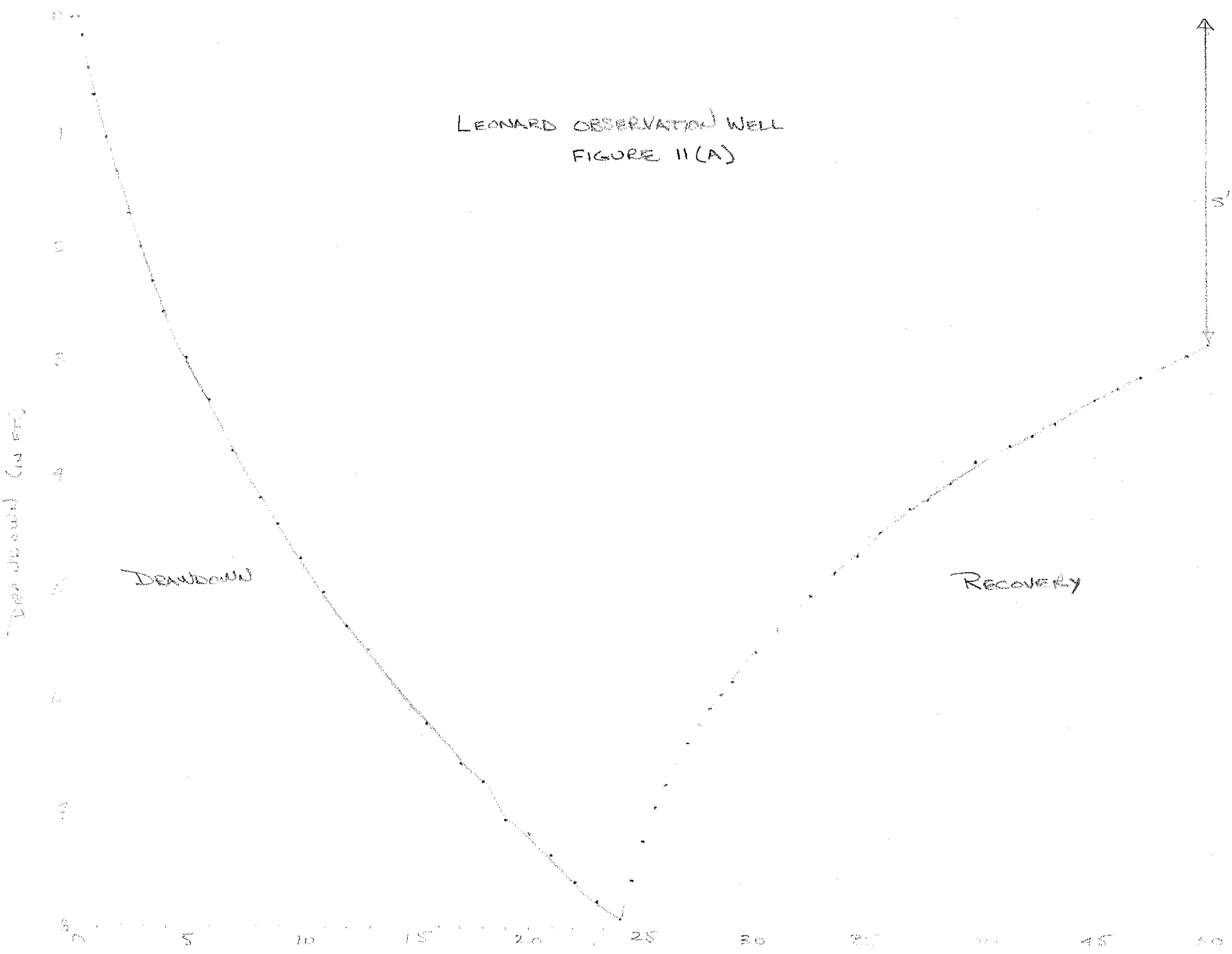


FIGURE 10 (B)


LEONARD OBSERVATION WELL
FIGURE 11(A)
DRAWDOWN
RECOVERY
S'
5
10
15
20
25
30
45

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LEONARD OBSERVATION WELL

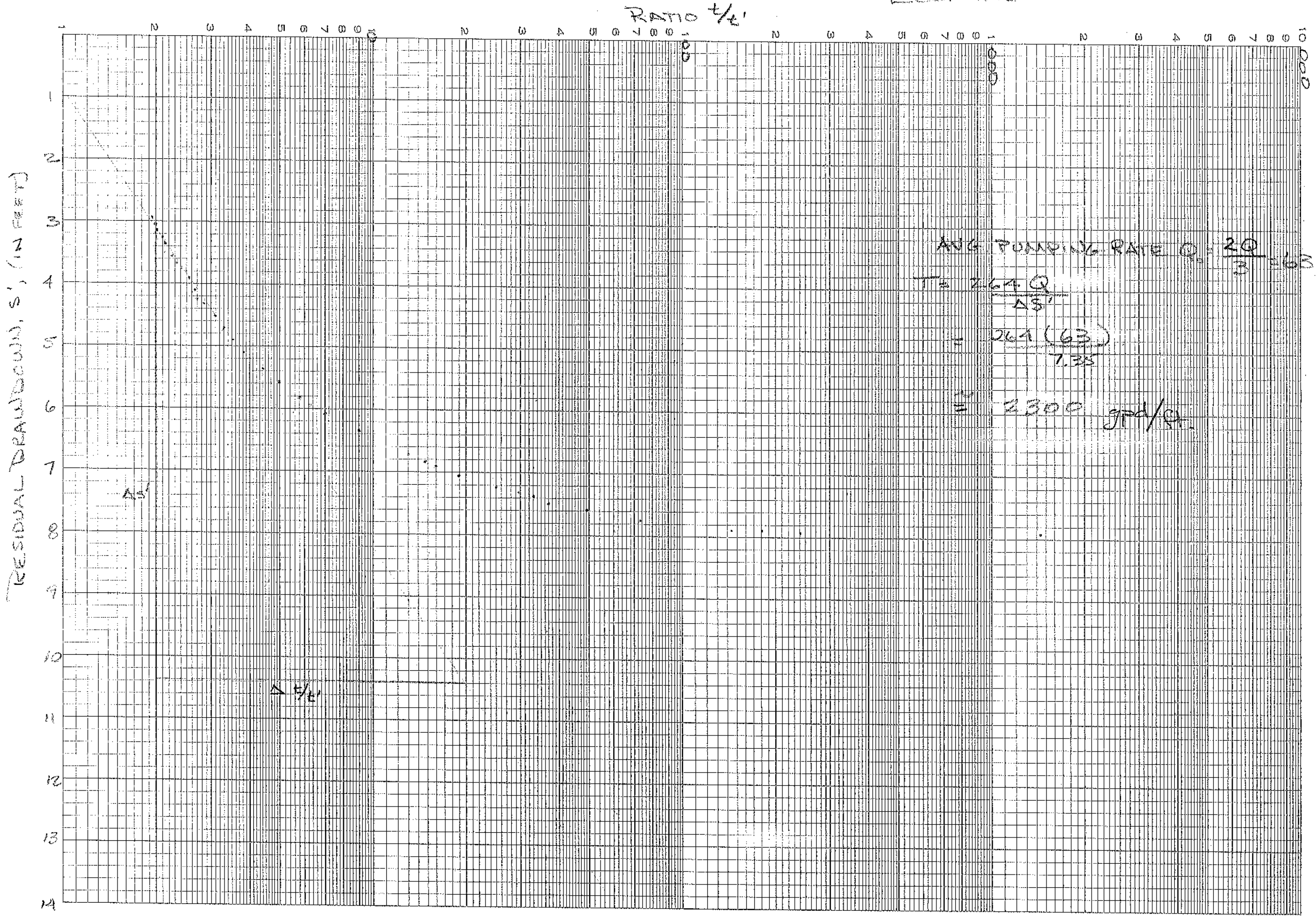
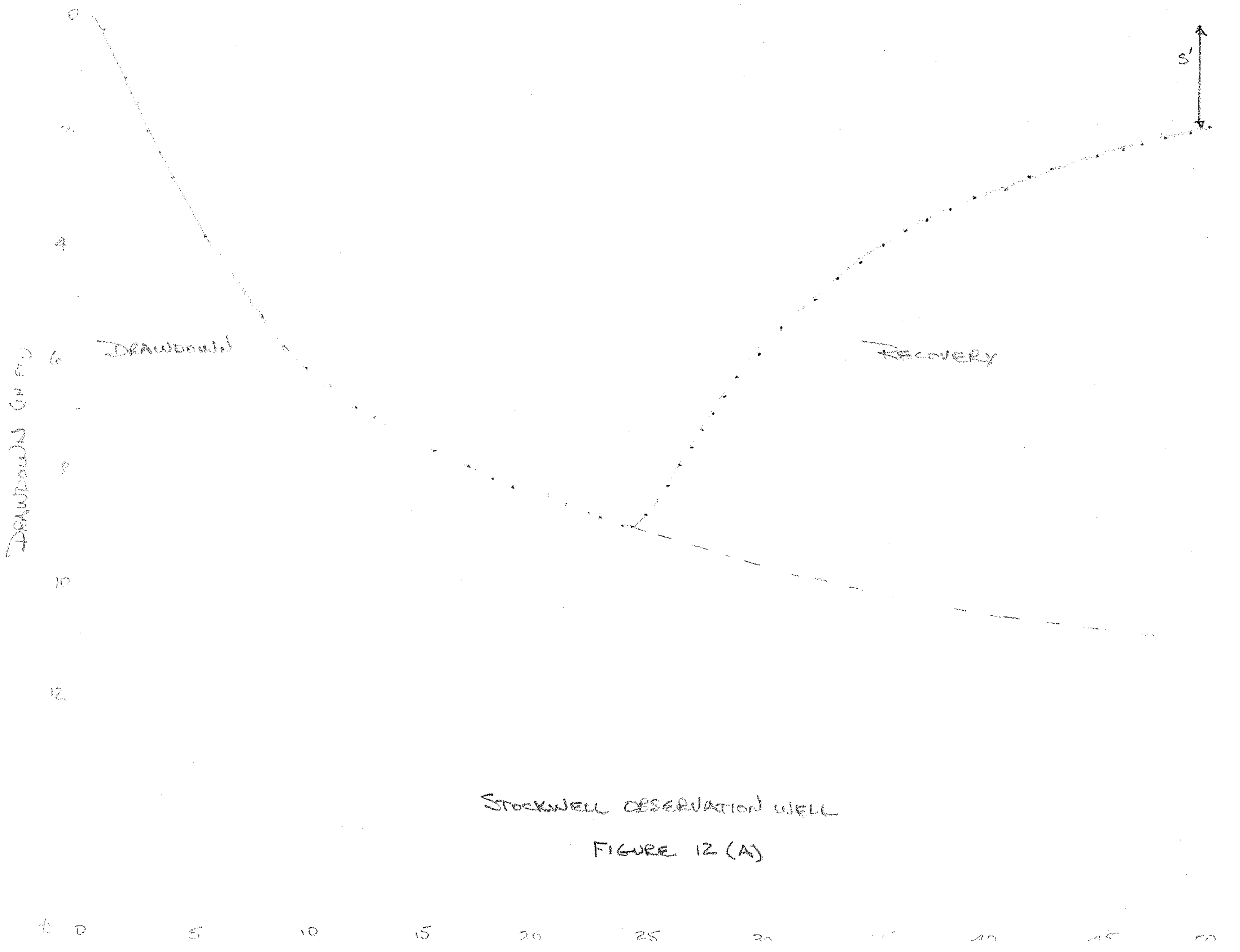


FIGURE 11(B)



STOCKWELL OBSERVATION WELL

FIGURE 12 (A)

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STOCKWELL OBS. WELL

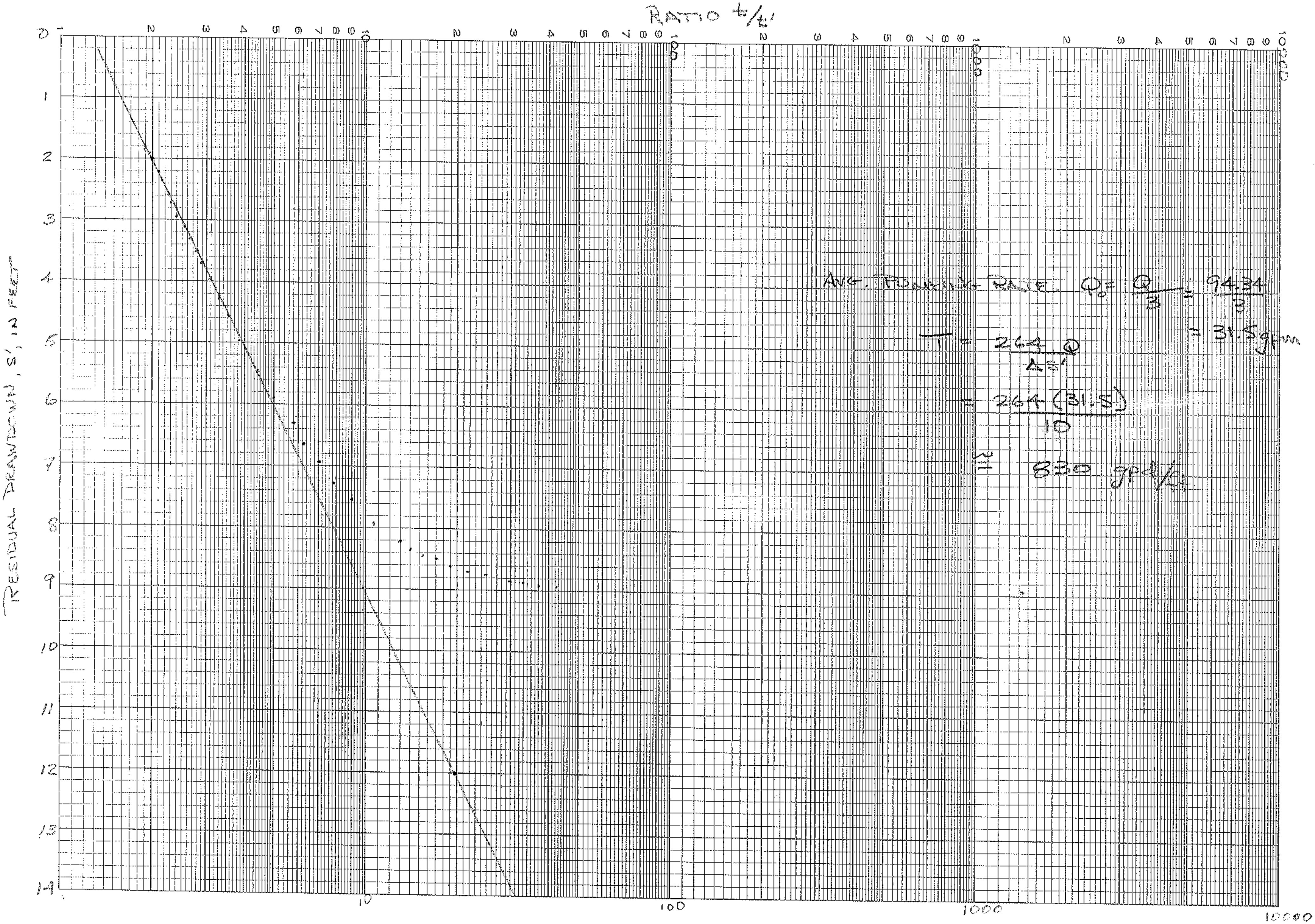

FIGURE 12(B)

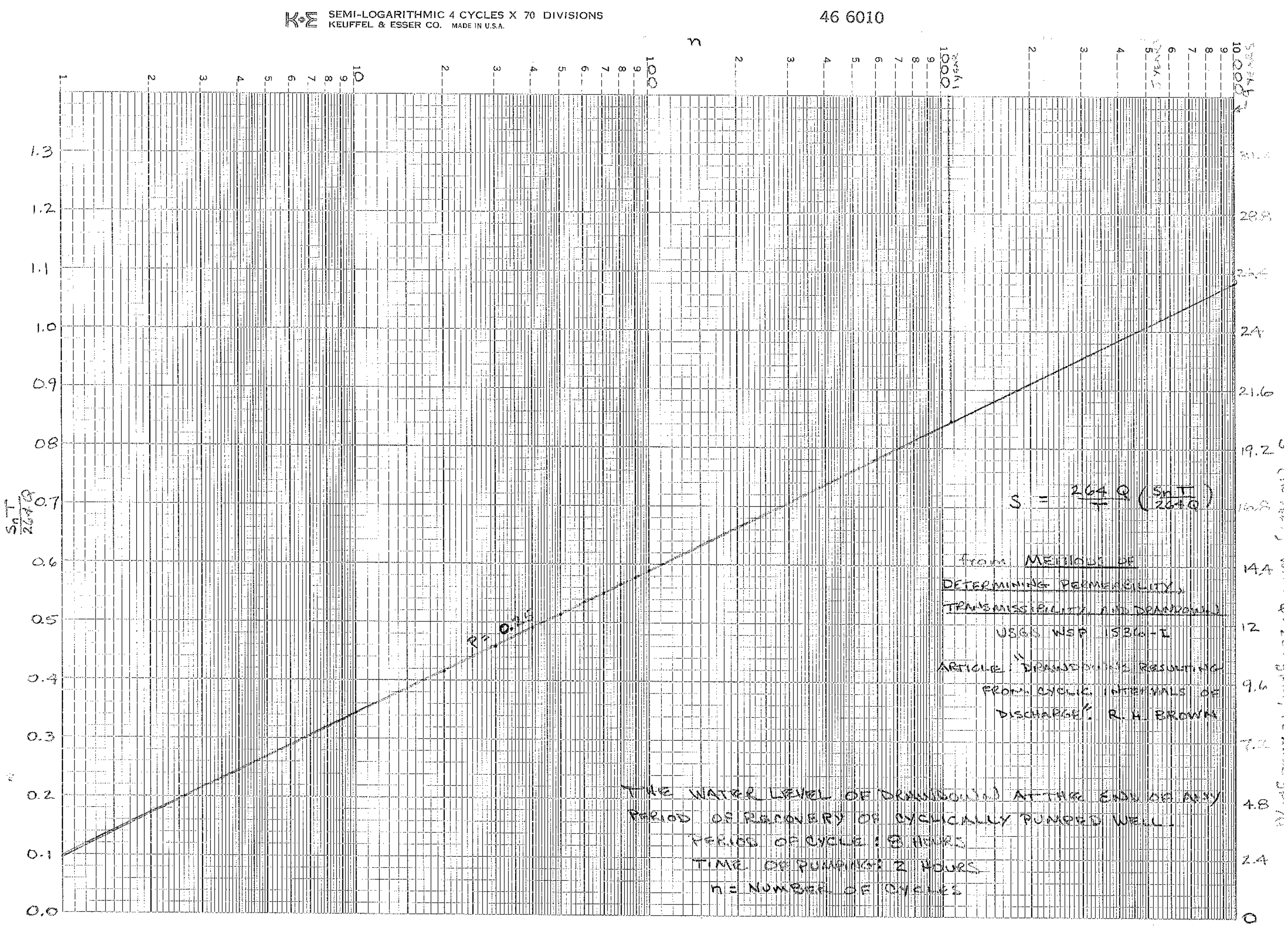
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6010
n
$\frac{S_n T}{264 Q}$
P = 0.25
$S = \frac{264 Q}{T} \left(\frac{S_n T}{264 Q} \right)$
from METHODS OF DETERMINING PERMEABILITY, TRANSMISSIBILITY, AND DRAWDOWN
USGS WSP 1536-I
ARTICLE: "DRAWDOWNS RESULTING FROM CYCLIC INTERVALS OF DISCHARGE". R. H. BROWN
THE WATER LEVEL OF DRAWDOWN AT THE END OF ANY PERIOD OF RECOVERY OF CYCLICALLY PUMPED WELL.
PERIOD OF CYCLE: 18 HOURS
TIME OF PUMPING: 2 HOURS
n = NUMBER OF CYCLES
1 YEAR
5 YEARS

FIGURE 13

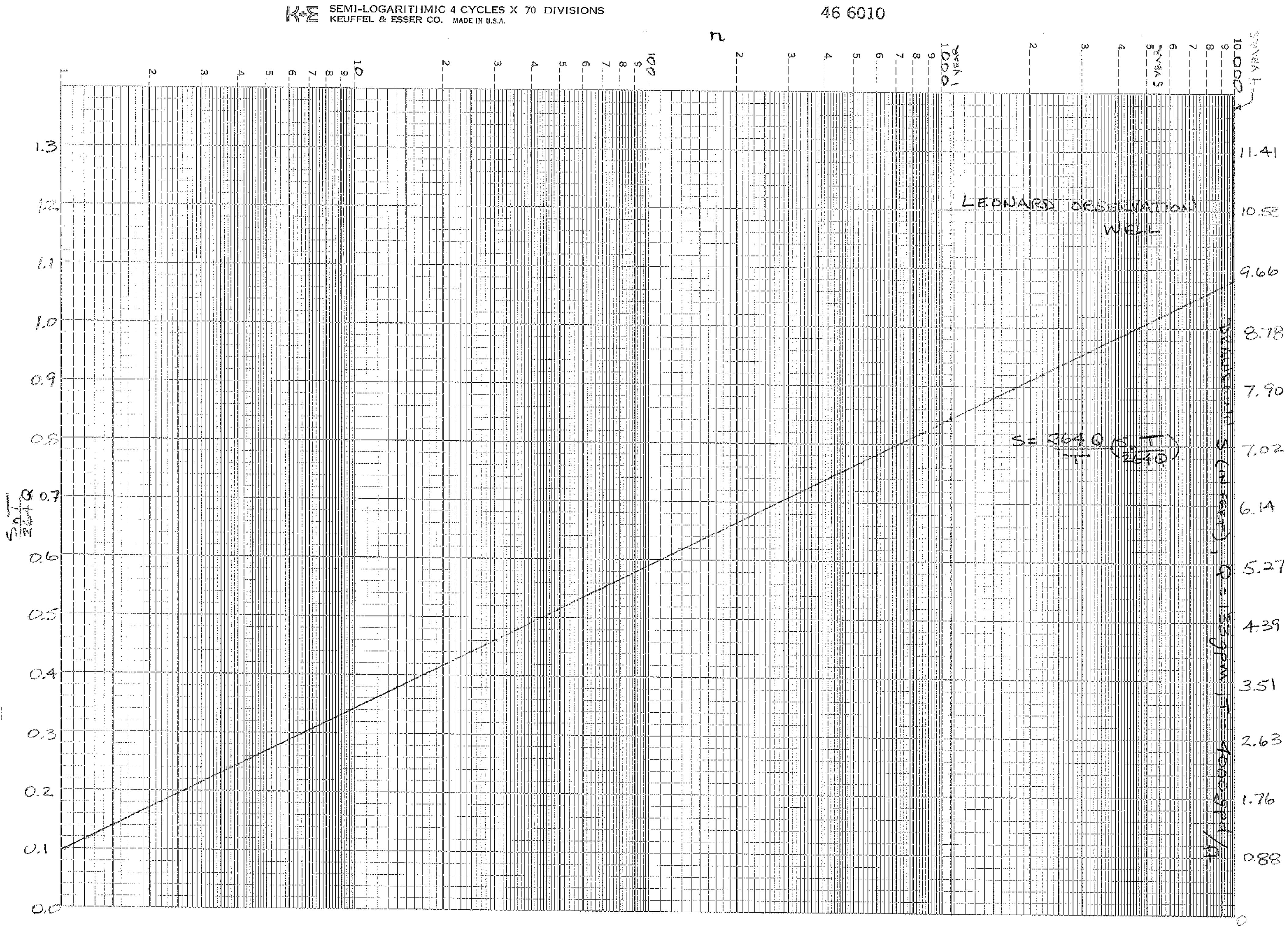
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6010
n
1 YEAR
5 YEARS
10 YEARS
LEONARD OBSERVATION WELL
S= 264 Q / T (S, T / 264 Q)
DRAWDOWN S (IN FEET), Q = 133 gpm, T = 4000 gpd/ft
S, T / 264 Q
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
0
0.88
1.76
2.63
3.51
4.39
5.27
6.14
7.02
7.90
8.78
9.66
10.53
11.41

FIGURE 14

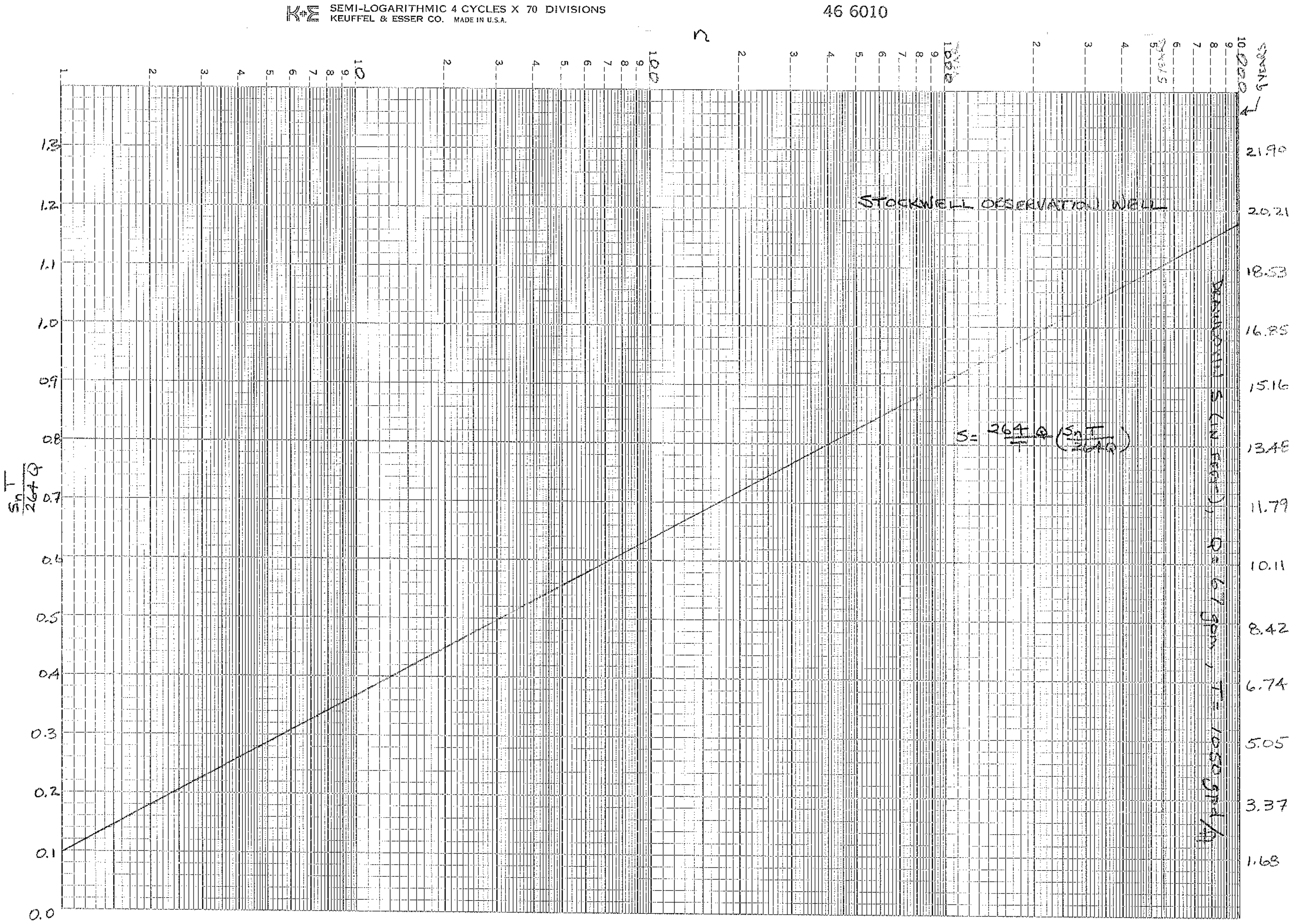
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6010
n
1 YEAR
5 YEARS
9 YEARS
$\frac{S_n T}{264 Q}$
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.68
3.37
5.05
6.74
8.42
10.11
11.79
13.48
15.16
16.85
18.53
20.21
21.90
STOCKWELL OBSERVATION WELL
$S = \frac{264 Q}{T} \left(\frac{S_n T}{264 Q}\right)$
S (IN FEET), Q= 67 gpm, T= 1050 gpd/ft

FIGURE 15