

AQUIFER ANALYSIS
NEAR
OSHOTO RESERVOIR,
CROOK COUNTY, WYOMING.

for
Nuclear Dynamics, Inc.

by

Paul A. Manera

Geologist



September 6, 1977

Revised November 22, 1977



MANERA & ASSOCIATES
CONSULTANTS IN WATER RESOURCES

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GEOLOGIST • GEOPHYSICIST

September 6, 1977

Nuclear Dynamics, Inc.
200 South Lowell
Casper, Wyoming 82601

Attention: Mr. Al Stoick

Re: Aquifer Parameters

Gentlemen:

Enclosed is the report on the results of the aquifer test conducted August 1-4, 1977. The report answers questions 6a through 6f of the In-Situ Mining Application Supportive Information Handout, Wyoming DEQ, March 18, 1977.

The results are such that the aquifer parameters of the aquifer are valid within a radius of 1500 feet of the pumped well.

I will be happy to address any further questions you may have.

Sincerely,

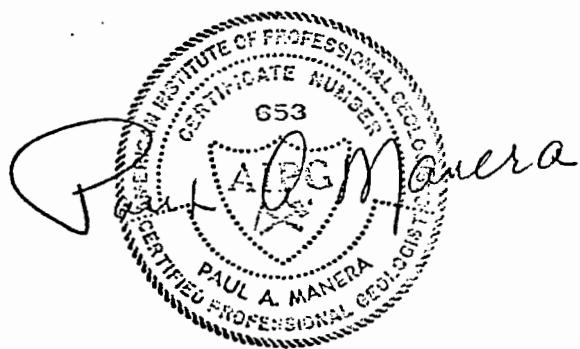
Paul A. Manera

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Summary

The 550 foot thickness of the Lance-Fox Hills formation overlying the Pierre shale in the Oshoto Reservoir study area is divided into three aquifers. The upper aquifer is under water table conditions while the middle and lower aquifers are under non-flowing artesian conditions. The static water levels and piezometric heads decrease with depth with the water table having an altitude range of 4137.24 to 4140.33 feet, Aquifer "A" (middle aquifer) having a piezometric head altitude range of 4127.50 to 4130.17 feet and Aquifer "B" (lower aquifer), the ore bearing aquifer, having a piezometric head altitude range of 4083.70 to 4087.10 feet. The water level varies from 36.54 to 80.46 feet in the water table aquifer, 58.73 to 80.00 feet in Aquifer "A" and 102.30 to 115.85 feet in Aquifer "B", depending upon the surface elevation of the well collars.

The pumping test results gave a production rate of ten gallons per minute with a range of transmissivity of 82 to 188 gallons per day per foot with an average T of 138, a range of hydraulic conductivity of 0.82 to 1.88 gallons per day per square foot with an average P of 1.38 and a range of coefficient of storage of 8.6×10^{-5} to 2.4×10^{-4} with an average S of 1.4×10^{-4} in the "B" aquifer.

Core analysis results from cores taken from the "B" aquifer gave a range of porosity of 19.6 percent to 37.8 percent.

Analysis of the pumping test data shows no leakage between Aquifer "A" and Aquifer "B" during the seventy-two hour pumping test.

The computed rate of flow in Aquifer "B" under natural conditions is less than one foot per year. ✓

Introduction

Nuclear Dynamics, Inc. is presently exploring the potential of "In Situ" mining of uranium ore in northeastern Wyoming. The concept of the process is to cause the ore to be dissolved in the groundwater, then extracted from the ore zone by pumping the groundwater. The determination of the aquifer parameters constitutes an important step in the "In Situ" process.

Purpose and Scope

The purpose of the aquifer test was to determine:

1. The degree of hydrologic isolation of the ore bearing aquifer;
2. The parameter's transmissivity (T), storage coefficient (S), and hydraulic conductivity (permeability P) of the aquifer; and
3. The potential of contamination of the water outside the mining zone and its rate of movement.

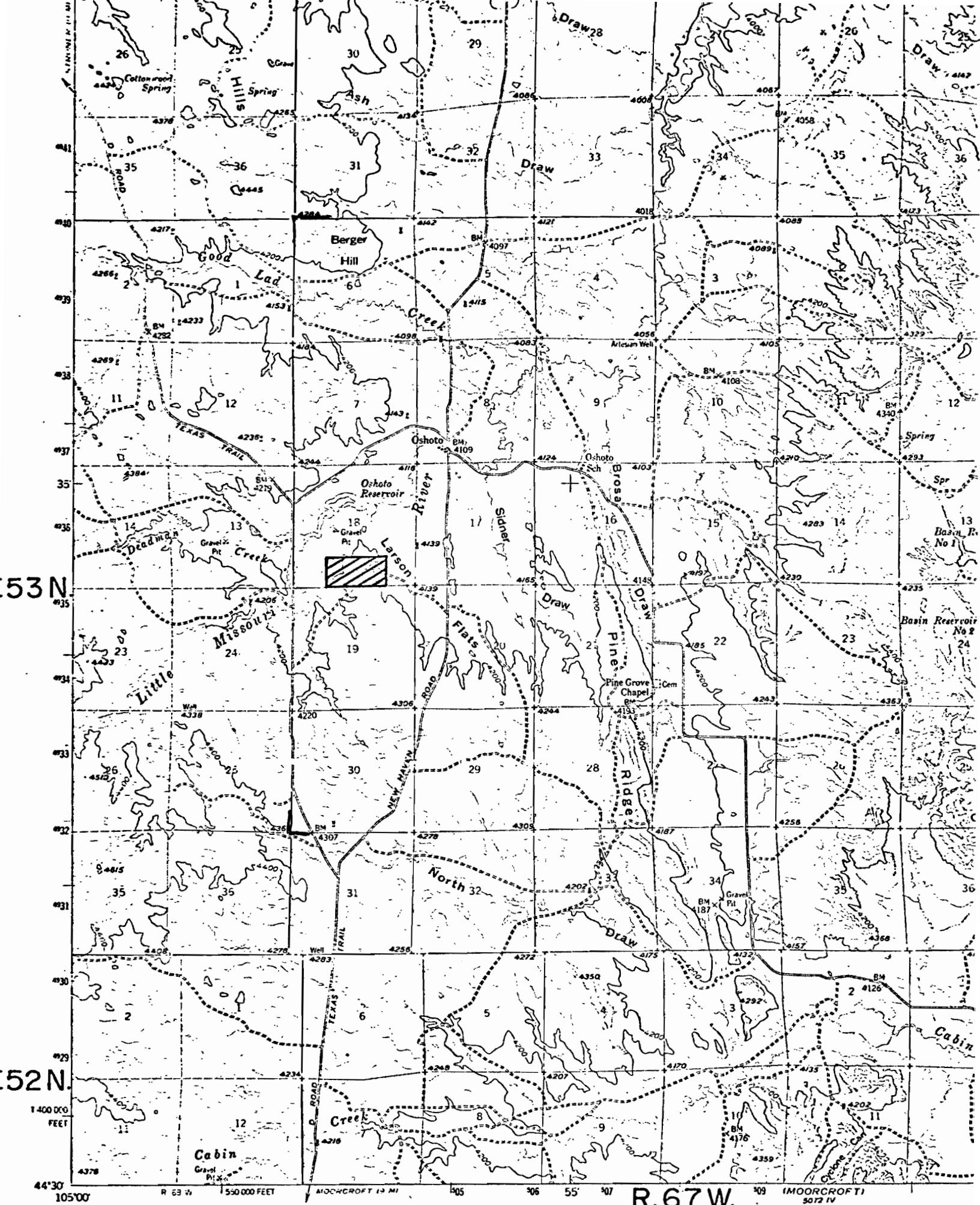
Location

The wells utilized in the aquifer test were all located in the S $\frac{1}{2}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ and the W $\frac{1}{2}$ S $\frac{1}{2}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ of Section 18, T. 53 N., R. 67 W., Kansas-Nebraska Boundary Base and Sixth Principal Meridian. The study area is one-half mile south of the Oshoto Reservoir and approximately 24 miles north of Moorcroft, Wyoming. The study area is delineated on Figure 1.

Field Work

The field work for this study included:

1. The construction of the required wells for monitoring the three aquifers and the production well;
2. Logging each of the wells;
3. Conducting a 72 hour pumping test and a 24 hour recovery test.



Mapped, edited, and published by the Geological Survey

Control by USGS, USC&GS, and Shell Oil Co.

Topography from 1:24 000-scale map of Missou Buttes

7.5-minute quadrangle surveyed 1954; and from aerial

MOORCROFT I
507 IV
SCALE 1:62500

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

FIGURE 1

Geologic Framework

The topography of the Oshoto Reservoir area is a gently rolling surface cut into the Lance-Fox Hills formation. The test hole data show this formation to consist of fine grained to very fine grained sands interbedded with layers of silts and clays. Correlation of the sands and clays indicates that the various layers are lenticular. Certain layers, particularly the clay layer between Aquifers "A" and "B", are laterally extensive and are traced across the study area. The Lance-Fox Hills formation is approximately 550 feet thick in the study area and thickens to 1200^{\pm} feet to the west. Eastward the Lance-Fox Hills formation is terminated by uplifting in a monocline and erosion of the upper materials.

There are no notable differences in the various portions of formation which form the water table aquifer, Aquifer "A" and Aquifer "B".

Underlying the Lance-Fox Hills formation is the Pierre Shale. In the 100^{\pm} feet penetrated by the drill in the study area, the Pierre formation consists of silts and clays with some calcareous cement.

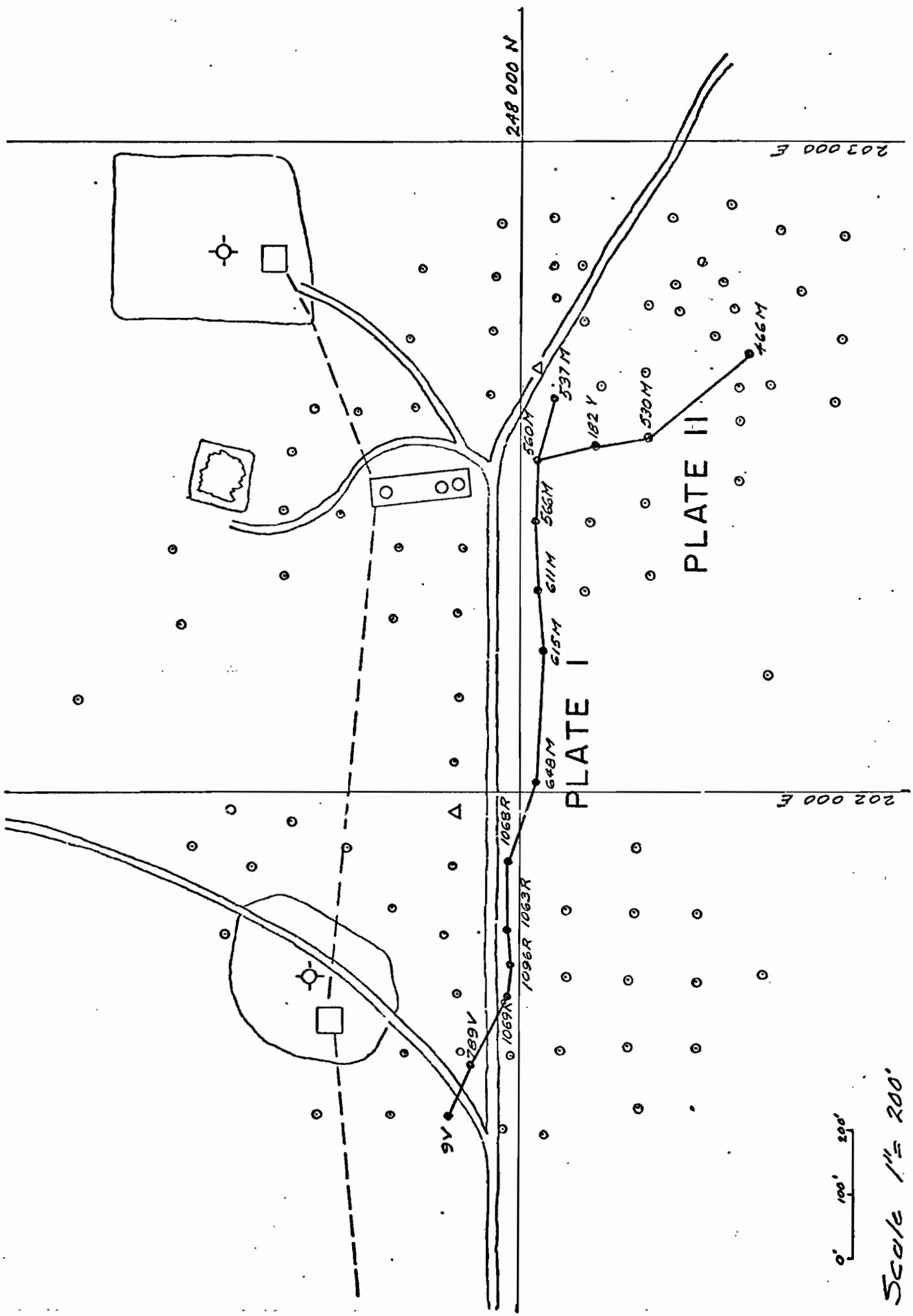
Plates I and II are a geologic cross section drawn from electric logs and drill cores or cuttings. The cross sections illustrate the above discussion. Figure 2 is an index map showing the location of the geologic cross sections.

Water Levels

Three separate aquifers are present in the Lance-Fox Hills formation. The uppermost, the water table aquifer, extends to a depth of approximately 150 feet. The exact confining bed underlying the water table aquifer was not delineated. The altitude of the water table ranges between 4137 feet to 4140 feet (rounded) with one anomaly.

FIGURE 2

Index to Geologic Cross Sections



The second aquifer, Aquifer "A", was perforated from approximately 250 feet to 430^+ feet. The head in Aquifer "A" caused the piezometric surface to rise to an altitude range of 4127 feet to 4130 feet (rounded).

The lower aquifer, Aquifer "B", is the ore bearing aquifer. The upper confining bed is a clay layer approximately 430 feet below the surface. The Pierre Shale forms the lower confining bed at approximately 550 feet. The piezometric surface of Aquifer "B" stands at an altitude range of 4084 feet to 4087 feet (rounded).

Although artesian, neither aquifer is a flowing artesian system in the study area. The water levels are illustrated on Plate III. The piezometric surface of Aquifer "A" stands approximately 50 feet higher than the piezometric surface of Aquifer "B".

There are diurnal variations in the piezometric heads of the aquifer caused by earth rotation and barometric pressure changes. Table 1 lists the water level altitudes in the three aquifers which appear most frequently.

Construction of Wells

Eleven wells were constructed expressly for the aquifer test. Seven of these wells were drilled to the top of the Pierre Shale and electric logged. Wells SP 789V, SP 788V, SP 791V and SP 797V were cased and cemented from the surface to the clay layer at approximately 440 feet. Well SP 789V was completed as a production well from the "B" aquifer by installing perforated 4 inch yellowine pipe from 440 feet to 555 feet. The remaining three wells were completed as observation wells in the "B" aquifer by installing perforated 2 inch pipe from 440^+ feet to 570 feet, 558 feet and 551 feet in Wells SP 788V, SP 791V and SP 797V, respectively.

TABLE 1
Water Levels

Well	Aquifer	Static Water Level Ground Level	Water Level Altitude
SP 790V	WT	36.54	4161.76
SP 794V	WT	49.17	4140.33
SP 795V	WT	80.46	4137.24
SP 796V	WT	74.12	4137.68
SP 3V	A	80.00	4127.50
SP 5V	A	68.04	4129.36
SP 9V	A	58.73	4130.17
SP 1067R	A	79.99	4129.01
SP 789V	B	112.8	4083.70
SP 788V	B	102.3	4087.10
SP 797V	B	113.85	4084.65
SP 791V	B	115.85	4084.65

Wells SP 3V, SP 5V and SP 9V were completed as observation wells in the "A" aquifer. The wells were cased and cemented from the surface to approximately 245 feet. The wells were then backfilled with cement to approximately 415± feet to seal off the "B" aquifer. Two inch perforated pipe was then installed in the "A" aquifer portion of each well.

The four wells, SP 790V, SP 794V, SP 795V and SP 796V, were completed as observation wells in the water table aquifer. The wells were drilled to 100 feet, cemented from the surface to 40 feet. The casing was perforated from 40 feet to 100 feet.

Plate III illustrates the cemented and perforated areas of each of the wells described above. Plate IV is a contour map of the study area showing the wells in the cross section, Plate III, in addition to the wells utilized in the aquifer test. The inset on Plate III illustrates the location and relationship of the pumped well and the observation wells.

Table 2 lists the characteristics of each well.

Aquifer Test Procedure

The water levels in all 10 observation wells were measured for 48 hours prior to the initiation of the test. Only the normal minor fluctuations occurred which indicated that the aquifers were in equilibrium at the initiation of the test.

The 72 hour pumping period was begun at 1145 hours August 1, 1977 for a total of 4320 minutes. Upon completion of the pumping period at 1145 hours August 4, 1977, the recovery period was initiated and continued to 2225 hours August 4, 1977, for a total of 640 minutes.

WELL CHARACTERISTICS

Hole No.	Coord.	Elev.	Cased Water Level Depth/Elev. 8/1/77	Purpose of Hole	Orig. T.D.	Present T.D. after deepening, cementing, etc.	Core Footage & sample interval 0-570'	Type of Casing U-3-9	Depth Bottom of Casing (423.6')	Location of Centralizers	Cement in Casing, Drill out Information	Well Screen Type	Location of Well Screen & Tubing 2" Yellowine Surface to 570', slotted @410'-570'
SP-788V	248,105N 201,487E	4189.4	102.30/4087.10	Hydrologic Monitor, Sand Zone "B"	570	570	5' samples, Kp + 250 High background	Yellowine 5½" 0.D. w/5'	423'7" (423.6') 5"-426' #1-25', #2-65', #3-165', #4-265', #5-365'	Distance from bottom of casing #1-25', #2-65', #3-165', #4-265', #5-365'	Cement top in casing 275', drilled out 6/13/77	Yellowine 2" 1.D. .025-.030" slots	2" Yellowine Surface to 570', slotted @410'-570'
SP-789V	248,087N 201,575E	4195.8	112.80/4083.00	Hydrologic Pump Well, Sand Zone "B"	566	Backfilled with gravel to 555' 6" 566'.	5' samples, Kp + 250 0-450' Core 450'-566'. 2.0'-0.019%	Yellowine 5½" 0.D. w/5'	440.85 9½"-442' 3" @ 442.3" to 566'	Same as above	Cement top in casing 390', drilled out 6/6/77	4" I.D. P.V.C. bottom 100' slotted .013"	Top Packers 427.7 bottom of screen 55.5'
SP-790V	248,087N 201,607E	4198.3	36.54/4161.76	Monitor Well for Upper Water Table	100	100	5' samples, No Mineral Air Drilled	No Mineral 4" 1.D. P.V.C. 20' Joints	100' 6½"-100'	None	None, Cement placed out-side top 20' of casing	Perforated 4" P.V.C.	Perforated 40-100-
SP-791V	248,135N 201,652E	4200.5	115.85/4084.65	Hydrologic Monitor, Sand Zone "B"	553' 6"	560	5' samples, Lo Kp + 250 0-450' Core 450'-553' 6" 553' 6"	Yellowine 5½" 0.D. w/5'	442.66 9½"-446' 5" @ 446' 566'	Same as 788V @ 789V	Cement top in casing 448', drilled out 6/15/77	Yellowine 2" 1.D. w/025-.030" slots	2" Yellowine Surface-@558', slotted @558-418'
SP-792V	248,089N 201,730E	4210.0	Not Determined	Monitor Hole for Upper Water Table	80	100	5' samples, No mineral Air Drilled	Not cased	-----	-----	-----	None	-----
SP-793V	248,088N 201,853E	4209.9	Not Determined	Monitor Hole for Upper Water Table	100	100	5' samples, No mineral Air Drilled	Not cased	-----	-----	-----	None	-----
SP-794V	248,093N 201,463E	4189.5	49.17/4140.33	Monitor Well for Upper Water Table	100	100	5' samples, No mineral Air Drilled	4" I.D. P.V.C. 20' Joints	100 6½"-100	None	None, Cement placed 4" P.V.C. placed out-side top 20' of casing	Perforated 40-100-	

WELL CHARACTERISTICS

Hole No.	Coord.	Elev.	Cased Water Level Depth/ Elev. 8/1/77 11:45 a.m.	Purpose of Hole	Present T.D. after deepening, cementing, etc.	Core Footage & Sample interval	% mineral U-3-0	Type of Casing	Depth Bottom of Casing	Location of Centralizers	Cement in Casing Drill out information	Well Screen Type	Perforated @ 4" P.V.C.,	Location of Well Screen & Tubing	
														Perforated @ 41-101, 43-103.	
SP-795V	248.085N 201.974E	4217.7	80.46/4137.24	Monitor Well for Upper water table	101	101	5' samples, 0'-100' Air Drilled	No mineral	4" I.D. P.V.C. 20' Joints	101	6 1/2" to 101'	None	None Cement placed outside top 20' of casing	Perforated @ 4" P.V.C.,	
SP-796V	248.090N 201.781E	4211.8	74.12/4137.68	Monitor Well for Upper water table	103	103	5' samples, 0'-100' Air Drilled	No mineral	4" I.D. P.V.C. 20' Joints	103.0	6 1/2" to 103'	None	None Cement placed outside top 20' of casing	Perforated @ 4" P.V.C.,	
SP-797V	248.036N 201.596E	4195.7	113.85/4081.85	Hydrologic Monitor Sand Zone "B"	580	580	5' samples, 0'-580'	Lo Kp + 250 @505' - 2.5' w/ 5% -1.0' - 151% Up Kp + 200' @529.5' - 2.0' -128%	Yellow lime 5%" 0.0	439	9 1/2" 5" 440' -580'	Same as SP-788V	Cement top in casing 350', drilled out 6/28/77	Yellow lime 2" 1.D. w/.025-.030" slots @414' - 551'	Slotted @414' 551', 2" blue- streak fiber- glass tubing @surface-414'
SP-1067R	248.119N 201.789E	4209.0	79.99/4129.01	Monitor Well for Sand Zone "A"	610	451	20' samples 0'-400'	Lo Kp + 250 @23.5' - .080%	4" I.D. P.V.C. 20' Joints	241	8 1/4" -241', 5" @241' -451'	Distance from bottom of casing #1-20', #2- 60', #3-160' 7/10/77	Cement top in casing 235', drilled out	None	None
SP- 3V	248.100N 201.590E	4207.5	80.00/4127.50	Monitor Well for Sand Zone "A"	610	432	20' samples 0'-400'	Kp + 250 @4.5' - tr Lo Kp + 250 @505' - 2.5' w/ 5% -7.0' - .06% @533.0' - 5.0' -tr	Yellow lime 5%" 0.0	243.75	9 1/2" 243.75 5" A 243.75- 432	Distance from bottom of casing #1-25', #2- 65', #3-165' 7/8/77	Cement top in casing 238', drilled out	Yellow lime 2" 1.D. w/.025-.030" slots	2" Yellow lime @surface -432- 432,
SP- 5V	248.096N 201.596E	4197.4	68.04/4129.36	Monitor Well for Sand Zone "A"	590	415	20' samples 0'-400'	Kp + 250 @475.5-1.5' -tr Lo Kp + 250 @508.5' 9.0' - .48% @522.0-2.0' -.02%	4" I.D. P.V.C. 20' joint-	248	8 1/4" 5" @250' -415'	Same as SP-1067R	Cement top in casing @232', drilled out	Yellow lime 2" 1.D. w/.025-.030" slots	2" Yellow lime @surface to 408', slotted @228' -408'

Table 2 (cont.)

WELL CHARACTERISTICS

Hole No.	Coord.	Elev.	Cased Water Level Depth/Elev. 8/1/77	Purpose of Hole T.D.	Orig. T.D.	Present T.D. after deepening, cementing, etc.	Core Footage & sample interval	%e	Type of Casing	Depth Bottom of Casing	Location of Centralizers	Cement in Casing, Drill Out Information	Well Screen Type	Location of Well Screen & Tubing
SP - 9V	248.120N 201.501E	4188.9	58.73/4130.17	Monitor Well for Sand Zone "A"	590	412	20' samples 0-100', 5' sample @400'-550'	lo kp + 250 @53.0'- 1.5'-tr	Yellowline 5½" O.D. 20' joints w/5' cementing shoe	242 5" @242'- 412'	Same as SP-3V	Cement top in casing @ 231', drilled out 7/10/77	Yellowline 2" I.D. w/ .025-.030" slots	2" Yellowline @surface-389'. Slotted @225'- -389'.

Water level measurements in all wells were made by sounder, except in the production well, SP 789V, where both sounder and airline pressure measurements were recorded. At 300 minutes into the test the sounder in the production well fouled. The airline measurements alone were recorded for the remainder of the test in Well SP 789V.

The periods of measurement in Aquifer "B" were:

Minutes	Interval in minutes
1 - 15	1
15 - 25	2
25 - 80	5
80 - 150	10
150 - 390	30
390 - 990	60
990 - 1575	120
1575 - 4320	180

Water level measurements in the "A" aquifer were made hourly from 1145 hours, August 1, 1977, to 0430 hours, August 2, 1977, then 8 times per day until the end of the test.

The observation wells in the water table aquifer were measured at odd periods throughout the test.

Water levels in all the wells have been measured on August 5, 8, 10, 15, 18 and 22, 1977.

Data Analysis

The pumping test data from each of the "B" aquifer observation holes were analyzed by three methods to allow a comparison of results. Analysis of data obtained from the production well was limited to one method.

(A) Jacob Method

In the Jacob Method the temporal distribution of the drawdown for each observation well or the production well is illustrated on semi-logarithmic paper. A straight line fit of the data gives a slope which can be used to solve the following equations in determining T and S.

$$T = \frac{264Q}{\Delta s} \quad (1)$$

$$S = \frac{0.3 T t_0}{r^2} \quad (2)$$

where:

T = transmissivity in gallons per day per foot

Q = discharge in gallons per minute

Δs = drawdown per log cycle in feet

S = storage coefficient (dimensionless)

t_0 = time at zero drawdown in days

r = distance between pumping well and observation well in feet

(B) Theis Method

In the Theis Method the temporal distribution of the drawdown for each observation well is illustrated on logarithmic paper. This relationship forms a curve which is then matched against a type curve formed by plotting $W(u)$. ($W(u)$ is read as the "well function for non-leaky isotropic artesian aquifers fully penetrated by wells and constant discharge conditions".)

W_u and u , a function, are obtained from tables in Wenzel (1942, facing page 89).

The coordinates of the match point W_u , $1/u$, s and t are substituted into the following equations to determine S and T .

$$T = \frac{114.6 Q W_u}{s} \quad (3)$$

$$S = \frac{Tut}{1.87 r^2} \quad (4)$$

where T , u , W_u , r , S , s are previously defined and t = time since pumping started in days.

(C) Recovery Method

The residual drawdown versus t/t' plotted on semi-logarithmic paper gives a straight line plot which can be used to satisfy Equation 1 to determine T

where

t = time since pumping started in minutes

t' = time since pumping stopped in minutes

Δs = residual drawdown per log cycle in feet.

Figure 3 illustrates the solution for T by the Jacob Method, Equation 1, for the data from the pumped well. The data utilized was the first 300 minutes of the aquifer test when the sounder was functional.

S and T determined by the Jacob Method, Equations 1 and 2, in Observation Wells SP 788V, SP 791V and SP 797V are illustrated in Figures 4, 5 and 6, respectively.

Water Level below Surface in Feet

100

125

150

175

200

225

10^4

10^3

10^2

10^1

1

NUCLEAR DYNAMICS, INC.

Jacob Method

Pumped Well SP 789V

August 1, 1977

Average pumping rate, $Q = 10$ gpm

$\Delta s = 21$ feet

$$T = \frac{264Q}{\Delta s} = \frac{264 \times 10}{21}$$

$T = 126$ gallons per day per foot

$\Delta s = 21$ ft

Time since pumping started in minutes

FIGURE 3

110

120

130

140

150

160

10^4

10^3

10^2

10^1

Time since pumping started, in minutes

$\Delta s = 16$ feet

$t_0 = 0.0183$ days

NUCLEAR DYNAMICS, INC.

Jacob Method

Observation Well SP 788V

August 1-4, 1977

Average pumping rate, $Q = 10$ gpm

$t_0 = 26.3$ minutes = 0.0183 days

$\Delta s = 16$ feet

$r = 94$ feet

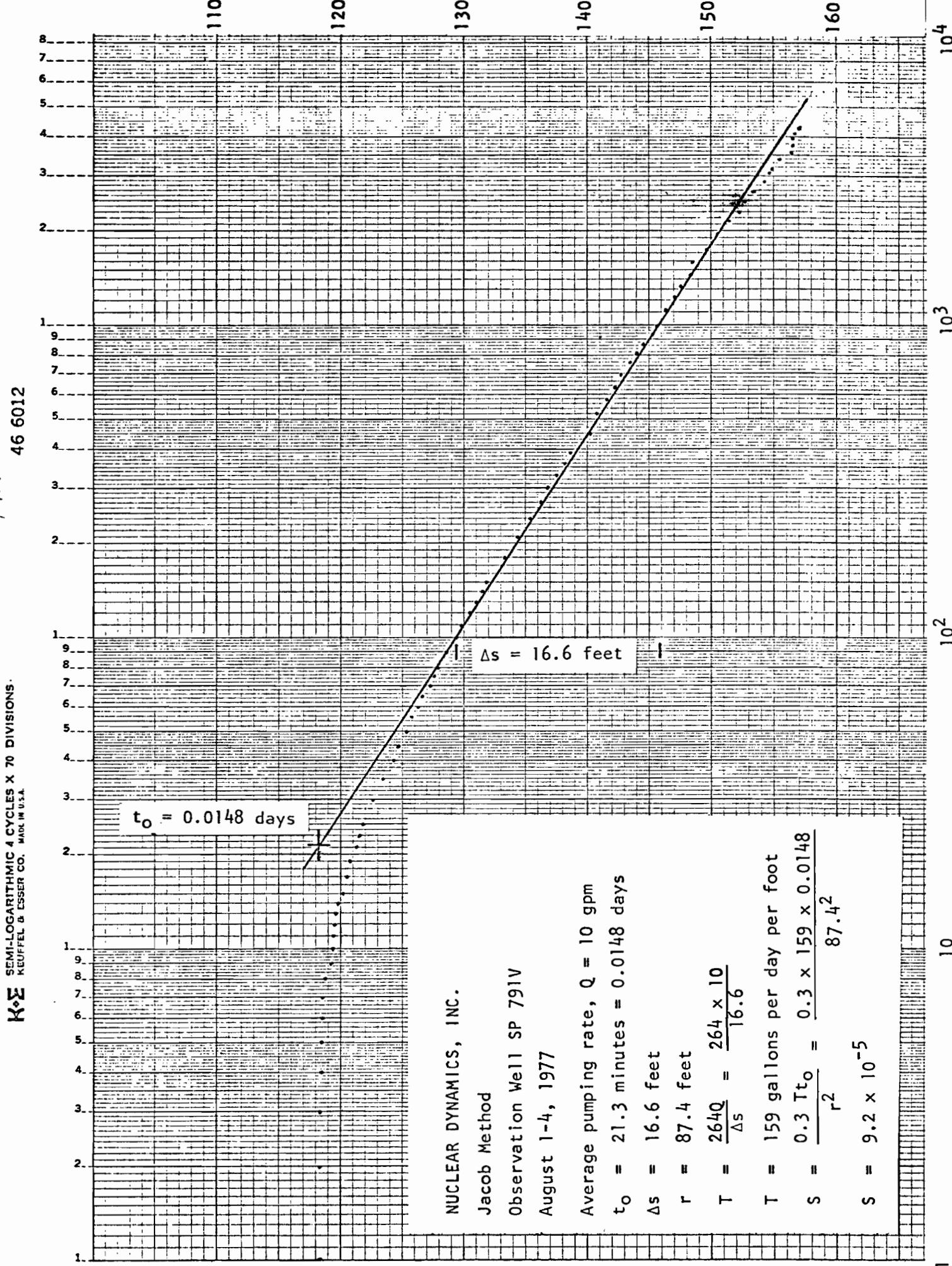
$$T = \frac{264Q}{\Delta s} = \frac{264 \times 10}{16}$$

$T = 165$ gallons per day per foot

$$S = \frac{0.3Tt_0}{r^2} = \frac{0.3 \times 165 \times 0.0183}{94^2}$$

$$S = 1.03 \times 10^{-4}$$

FIGURE 4

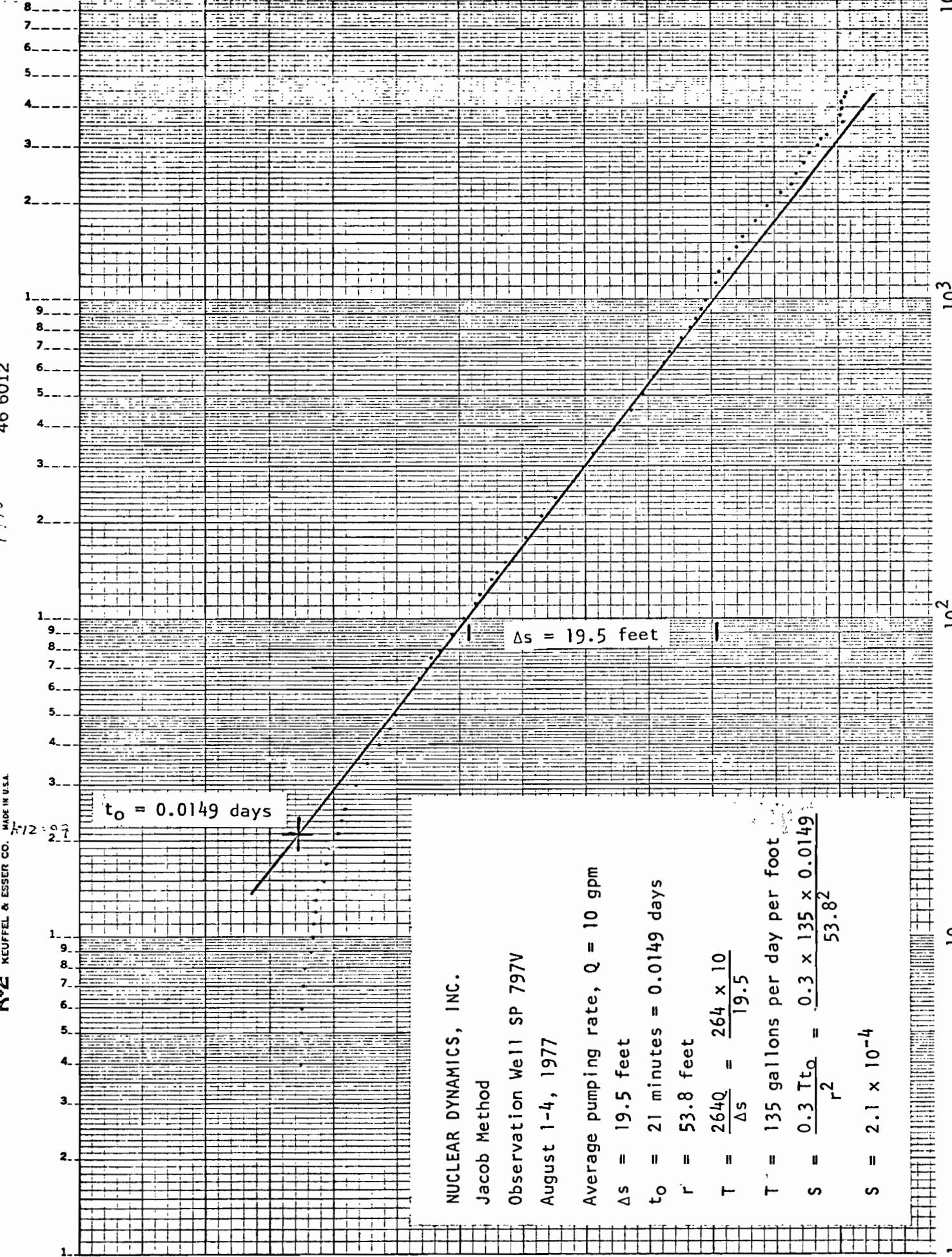


Time since pumping started, in minutes

FIGURE 5

K-E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

$\gamma \gamma \gamma \gamma$



Time since pumping started, in minutes

FIGURE 6

Figures 7, 8 and 9 illustrate the solution by the Theis Method, Equations 3 and 4 for S and T in the three observation wells. Figure 10 illustrates the non-leaky artesian, fully penetrating, constant discharge, time drawdown type curve used for this solution.

The recovery method solutions of Equation 1 for the three observation wells are illustrated as Figures 11, 12 and 13.

Table 3 compares the aquifer parameters obtained by the various methods and the different observation wells.

The Theis field curves closely matched the Theis type curve for a non-leaky artesian aquifer indicating that there is no leakage between Aquifer "A" and Aquifer "B". In addition, the observation wells SP 5V and SP 9V perforated against Aquifer "A" showed no signs of decline in the piezometric head during the 72 hour pumping period, as shown on Figure 14. The piezometric head on Observation Well SP 3V indicated a decline of 16 inches during the period 1080 minutes after pumping started until the cessation of pumping at 4320 minutes after pumping started, as shown on Figure 14. However, the decline in the piezometric head continued for an additional 98 hours before starting to rise. Although not to the same degree, the piezometric head declined in both Observation Well SP 5 V and Observation Well SP 9V during the 98 hour to 144 hour period following the cessation of pumping before starting to rise. These latter relationships are shown on Figure 15.

The continued decline for such a long period after pumping stopped leads to the conclusion that the changes which were measured in the observation wells in the "A" aquifer are the results of pressure adjustments on the aquifer and not a result of leakage from one aquifer to another.

VERNON
LINE

Logarithmic
3 x 5 Cycles

Drawdown (Δs) in Feet

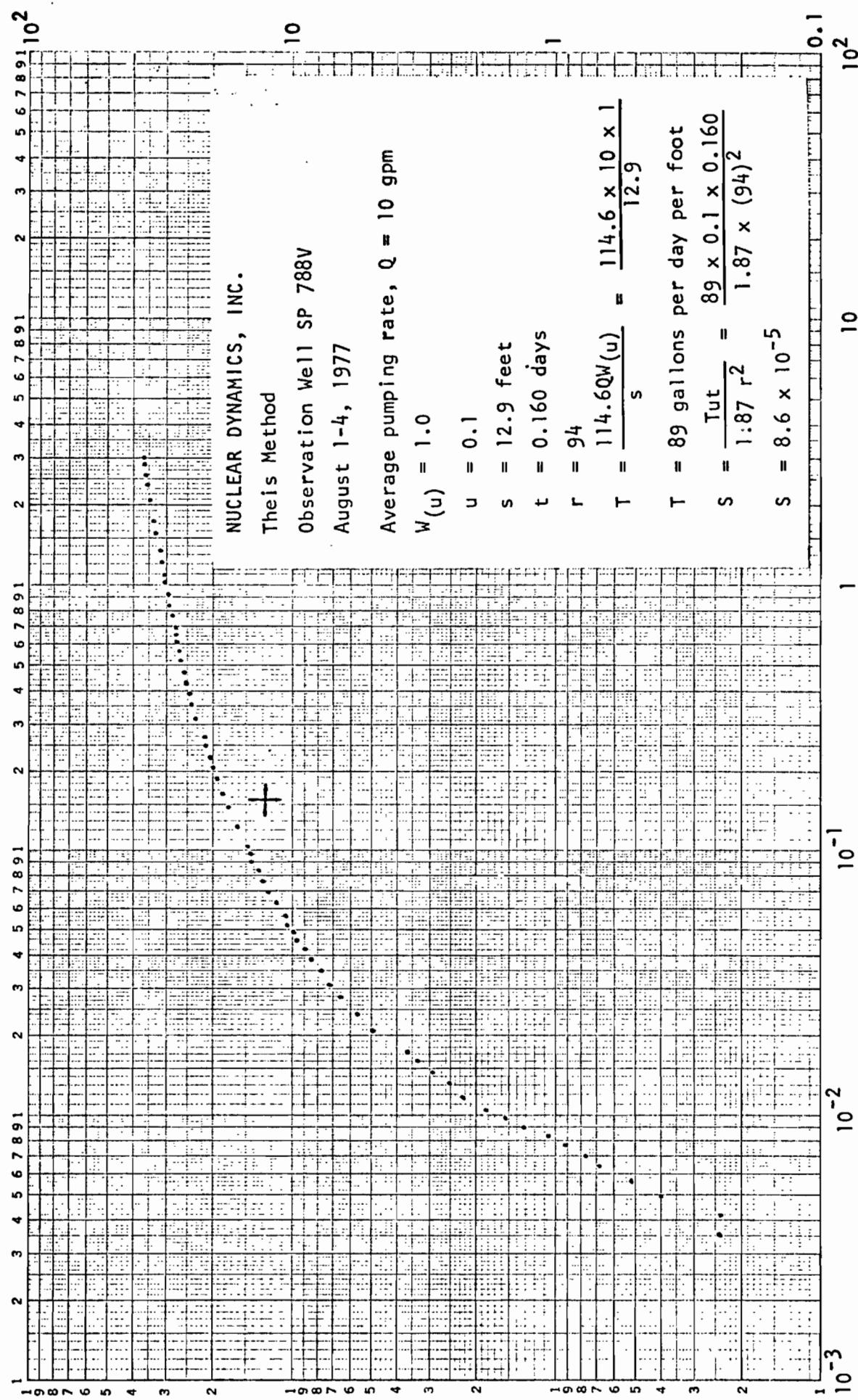


FIGURE 7

VERNON
R 24 LINE
MADE IN U.S.A.

Logarithmic.
3 x 5 Cycles

✓

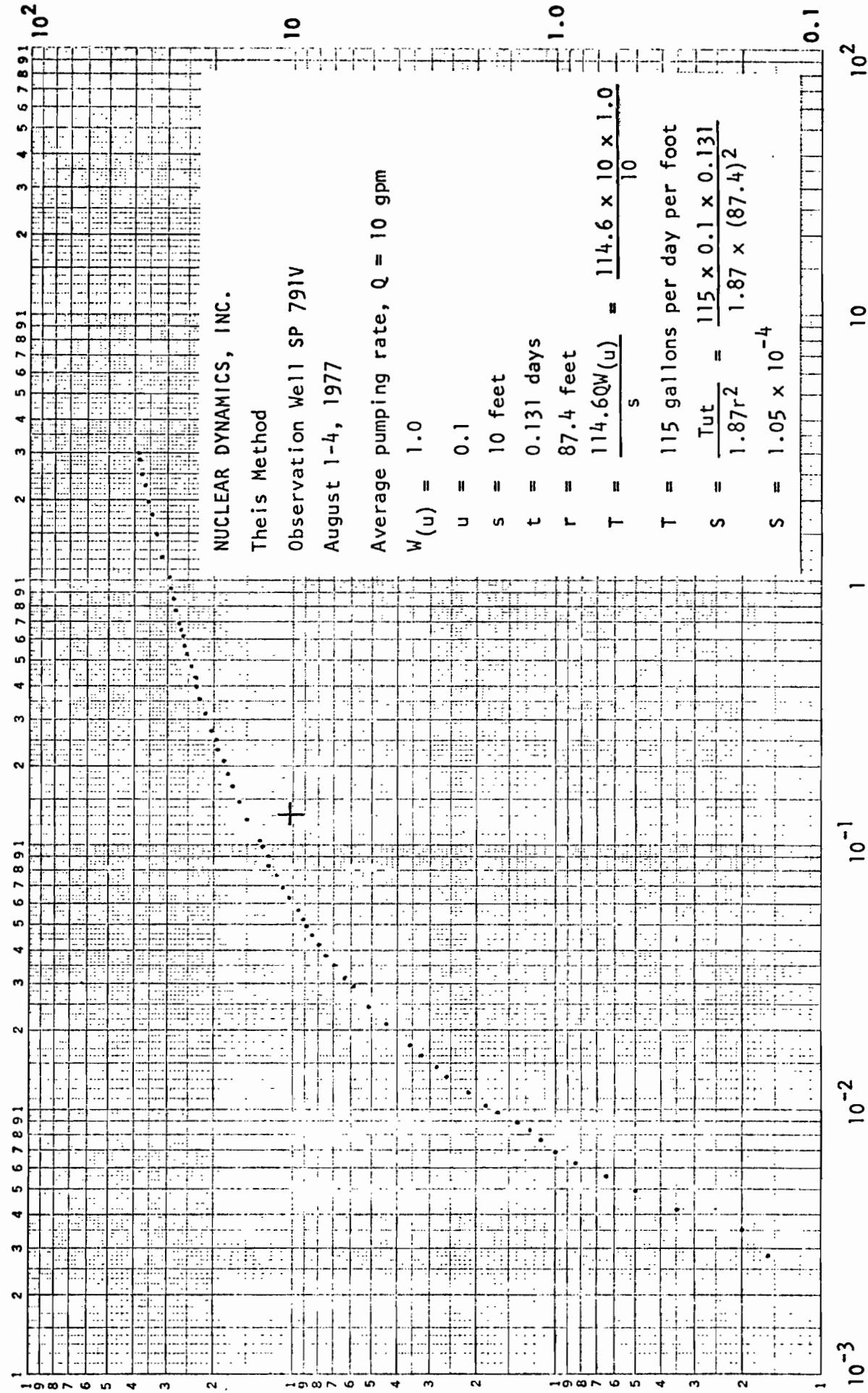
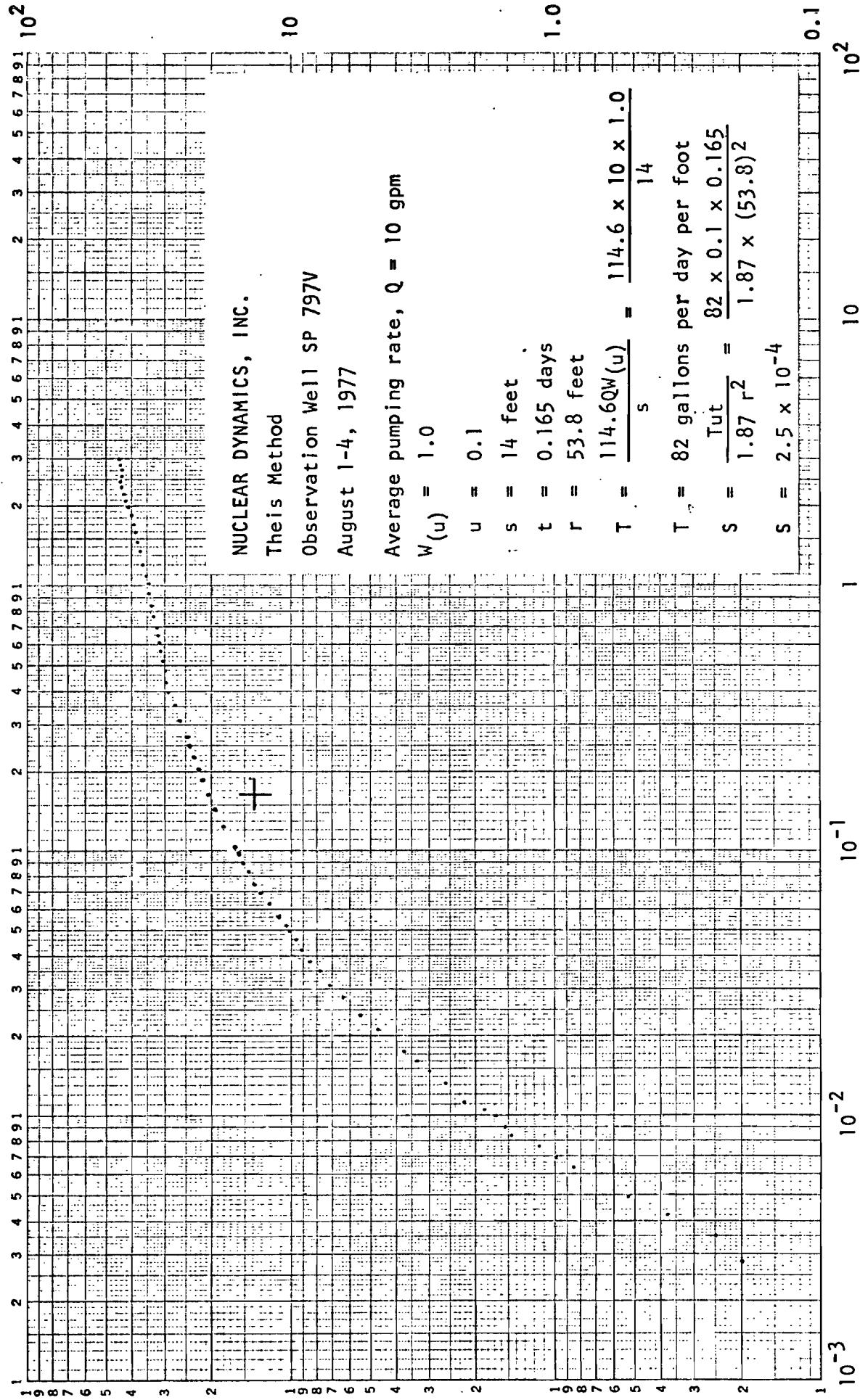


FIGURE 8

Drawdown (Δs) in Feet

VERNON BAY LINE R 24, L 5
Logarithmic
3 x 5 Cycles

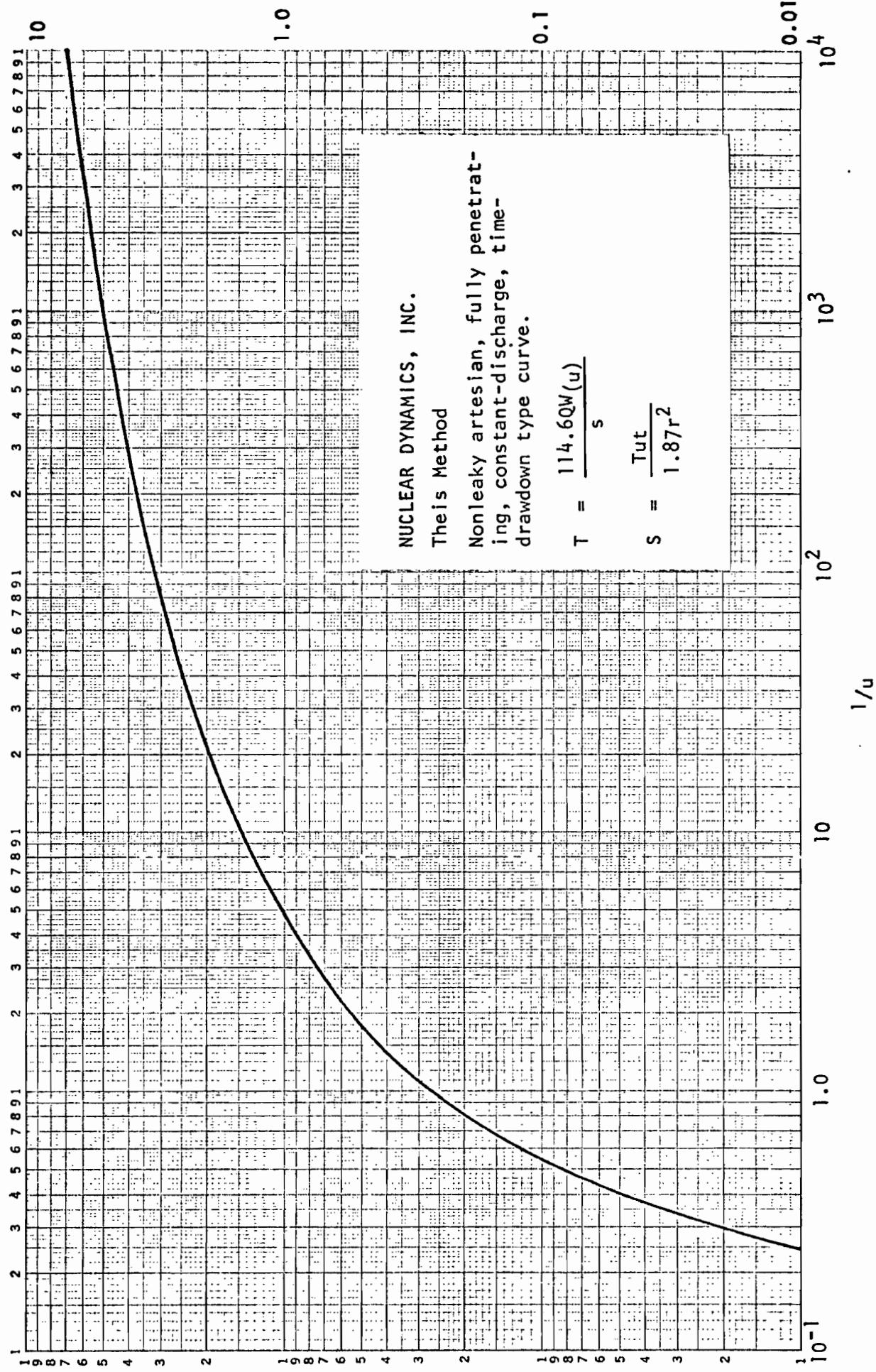
797



Time since pumping started, in days

FIGURE 9

FIGURE 10



$\log \Sigma$ SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSEN CO., MADE IN U.S.A.

46 6012

NUCLEAR DYNAMICS, INC.
Residual Drawdown Curve
Observation Well SP 788V
August 1-4, 1977

Average Pumping rate, $Q = 10$ gpm

$$\Delta s = 16.6 \text{ feet}$$

$$T = \frac{264Q}{\Delta s} = \frac{264 \times 10}{16.6}$$

$$T = 159 \text{ gallons per day per foot}$$

$\Delta s = 16.6 \text{ feet}$

Water level below surface in feet
 10^4
 10^3
 10^2
 10^1
Ratio t/t'

FIGURE 11

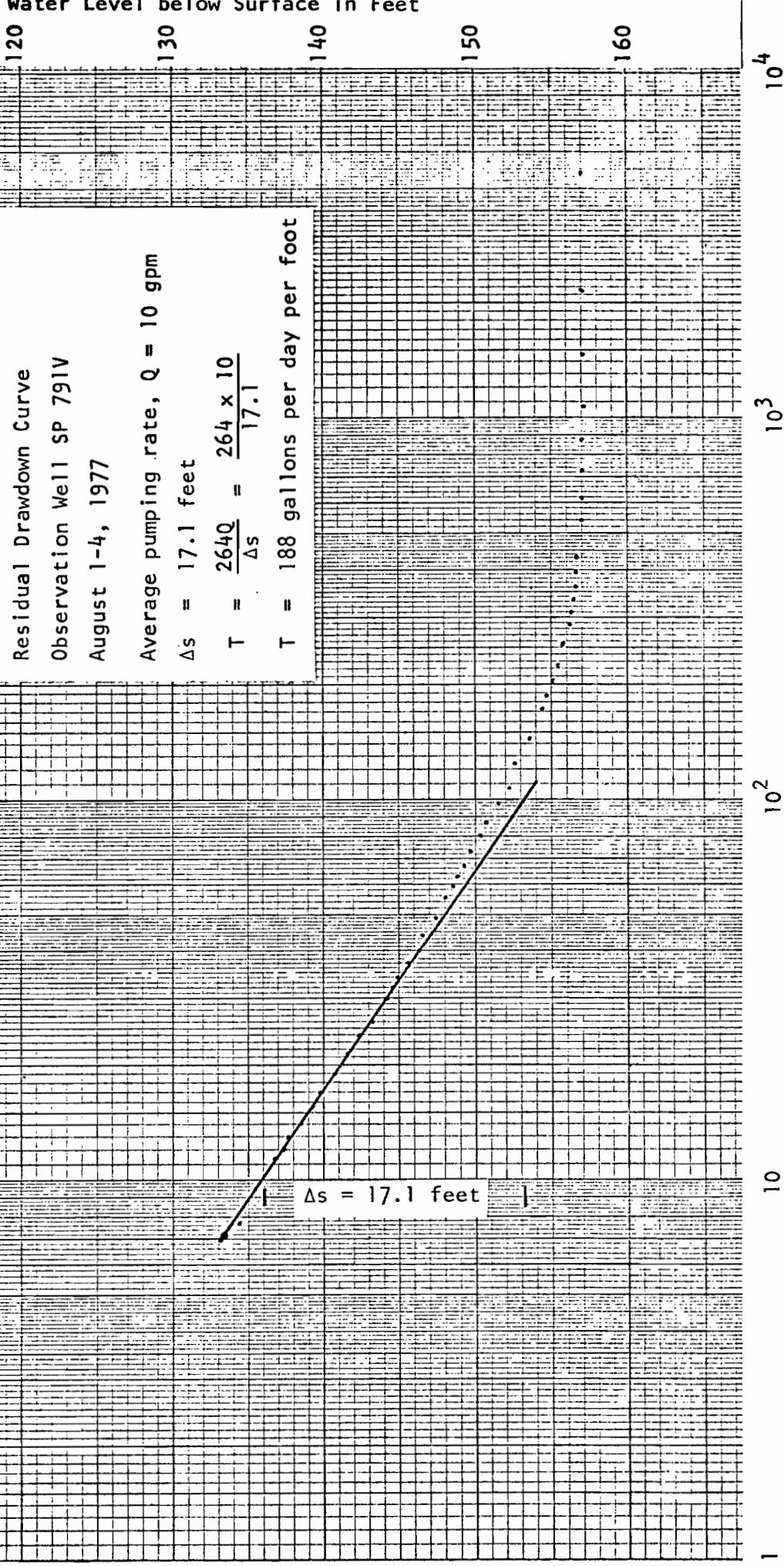


FIGURE 12

Water Level below Surface in Feet

100
110

120

130
140

150

160

10⁴

NUCLEAR DYNAMICS, INC.

Residual Drawdown Curve

Observational Well SP 797V

August 1-4, 1977

Average pumping rate, Q = 10 gpm

$\Delta s = 20.5$ feet

$$T = \frac{2640}{\Delta s} = \frac{264 \times 10}{20.5}$$

T = 129 gallons per day per foot

$\Delta s = 20.5$ feet

10²
10³
10⁴

Ratio t/t'

FIGURE 13

TABLE 3
Comparison of Aquifer "B" Parameters
Discharge 10 gpm

Well	Method of Solution	T gpd/ft	S dimensionless
SP 789V Pumped well	Jacob	126	--
SP 788V Obs. well	Jacob	165	1.03×10^{-4}
	Theis	89	8.6×10^{-5}
	Recovery	159	--
SP 791V Obs. well	Jacob	159	9.2×10^{-5}
	Theis	115	1.05×10^{-4}
	Recovery	159	--
SP 797V Obs. well	Jacob	135	2.1×10^{-4}
	Theis	82	2.5×10^{-4}
	Recovery	188	--

Range of T = 82 to 188 gallons per day per foot

Average T = 138 gallons per day per foot

Range of P* = 0.82 to 1.88 gallons per day per square foot

Average of P = 1.38 gallons per day per square foot

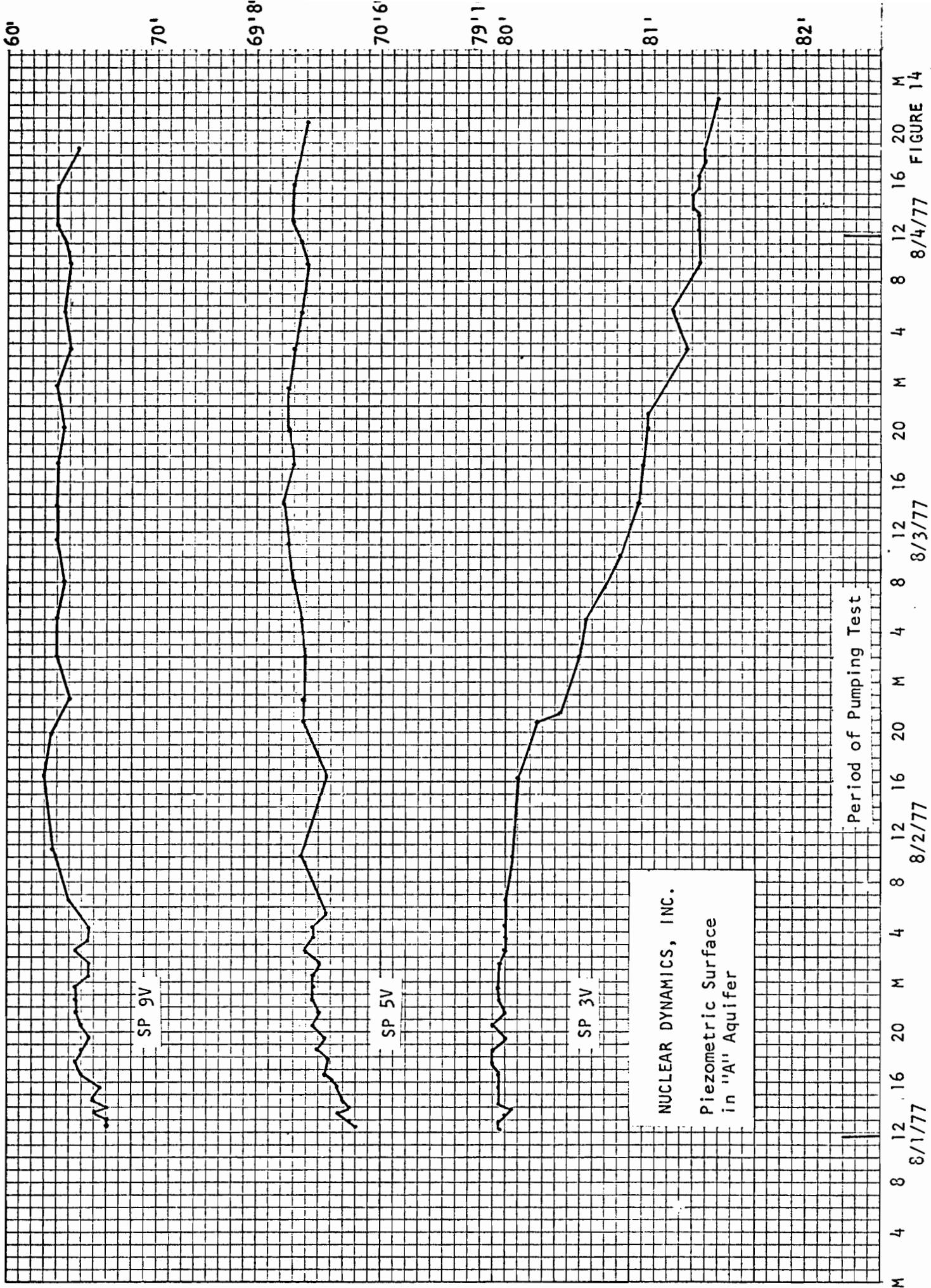
Range of S = 8.6×10^{-5} to 2.5×10^{-4}

Average of S = 1.4×10^{-4}

*P = the hydraulic conductivity

Ko 10 X 10 TO THE INCH • 7 X 10 INCHES
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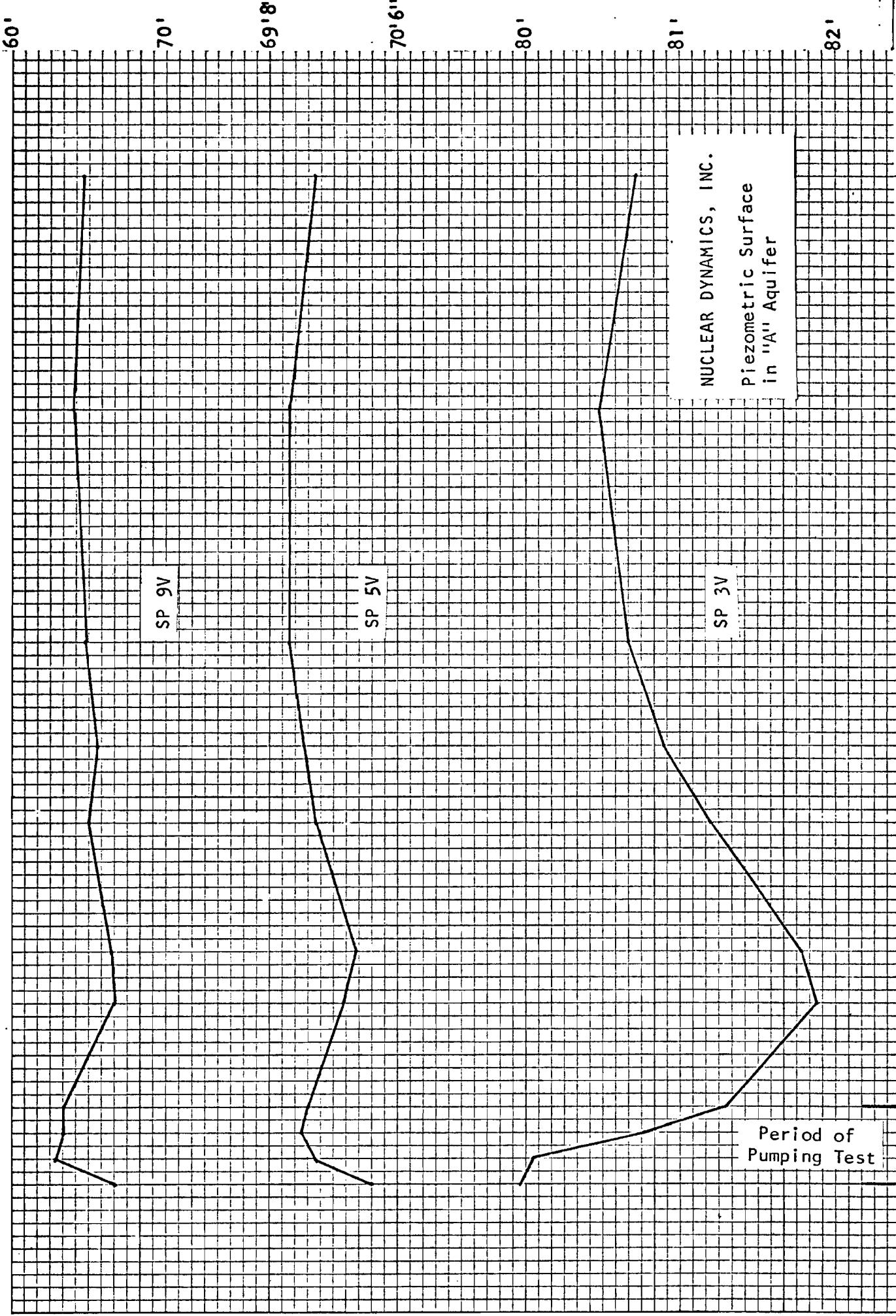
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DT 15'



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10
August 1977

FIGURE 15
September 1977

Table 4 is a tabulation of the static water levels in the water table aquifer, Observation Wells SP 790V, SP 794V, SP 795V and SP 796V.

Porosity of Aquifer "B"

Porosity analyses were made on cores from Aquifer "B" including the ore zone from Well SP 477V by Core Laboratories, Inc. Well SP 477V is located 162 feet east of Well SP 789V, the pumped well of the aquifer test as shown on Plate IV.

The porosity analyses were made by standard petroleum techniques.

Table 5 lists the results of the core analyses.

Area of Influence of Aquifer Test

Computation of the shape of the cone of depression illustrates that the area of influence of the aquifer test in the "B" aquifer extended to 1700 feet from the pumped well. Table 6 shows the computed drawdowns at various distances from the pumped well at 4320 minutes after pumping started at 10 gpm. Figure 16 graphically illustrates the data from Table 6. The method of computation is described by Bruin and Hudson (1955, page 13).

The field data curves indicate that no hydrologic boundaries were encountered by the expanding cone of depression during the pumping period and that lateral variations in the materials in Aquifer "B" are small.

The lack of interference in the cone of depression plus the uniformity of the "B" aquifer indicate that the aquifer is relatively consistent for a radius of 1300 or more feet around the pumped well, SP 789V.

TABLE 4
WATER TABLE AQUIFER ABOVE AQUIFER A

Static Water Levels
Feet Below Surface

<u>DATE AND TIME</u> <u>+15 min.</u>		<u>SP 790V</u> <u>TD 100 feet</u>	<u>SP 794V</u> <u>TD 100 feet</u>	<u>SP 795V</u> <u>TD 101 feet</u>	<u>SP 796V</u> <u>TD 100 feet</u>
7/29	1100	36.38	--	--	73.35
7/31	1000	36.38	49.01	79.94	73.69
	1700	36.54	48.96	79.90	73.61
8/1	1100	36.35	48.89	79.70	73.52
8/2	1000	36.88	49.29	80.63	74.37
	1630	36.67	49.25	80.48	74.07
	2000	36.67	49.21	80.54	74.17
	2245	--	49.23	--	74.16
	0500	36.67	49.29	80.50	74.12
8/3	1130	36.67	49.21	80.54	74.07
	1400	36.54	49.21	80.42	74.07
	1720	36.46	48.96	80.42	73.95
	2020	36.54	49.04	80.63	74.01
	2325	36.54	49.08	80.46	74.08
	0540	36.67	49.17	80.46	74.08
8/4	0925	36.92	49.29	80.58	74.20
	1530	36.85	49.34	80.50	74.08
	1835	36.75	49.29	80.54	74.08
	1330	36.75	49.21	80.54	74.20
8/10	1700	37.13	49.46	80.75	74.42
8/15	1000	37.05	49.21	80.58	74.25
8/18	1530	37.08	49.25	80.65	74.27

CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS

TABLE 5

Company	NUCLEAR DYNAMICS	Formation	UNKNOWN	Page	1	of	1
Loc.	477V	Cores	UNKNOWN	File	RP-4-3943		
Field	UNKNOWN	Drilling Fluid	UNKNOWN	Date Report	2-7-77		
County	UNKNOWN	State	UNKNOWN	Elevation	UNKNOWN	Analysts	
Location	UNKNOWN	Remarks					

CORE ANALYSIS RESULTS
(Figures in parentheses refer to footnote remarks)

SAMPLE NUMBER	DEPTH FEET	PERMEABILITY MILLIDARCY'S		POROSITY PERCENT	RESIDUAL SATURATION		PROBABLE PRODUCTION	REMARKS
		HORIZONTAL	VERTICAL		OIL % VOLUME	WATER % PORE		
1.	482.5	1.5	.01	24.1				
2.	490.6	38	5.0	27.8				
3.	500.0	1934	1915	34.0				
4.	506.5	2253	1239	37.8				
5.	507.0	1971	184	35.6				
6.	508.0	317	161	32.8				
	511.0	3380	2160	36.2				
8.	517.0	3944	2892	28.6				
9.	524.0	51	34	19.6				
10.	531.0	254	223	27.6				
11.	543.0	2629	2291	36.4				
12.	544.0	14	.90	29.8				
13.	557.0	1606	403	32.2				
14.	573.0	8.8	.01	25.9				

NOTE:

(*) REFER TO ATTACHED LETTER.

(**) INCOMPLETE CORE RECOVERY—INTERPRETATION RESERVED.

(2) OFF LOCATION ANALYSES—NO INTERPRETATION OF RESULTS

These analyses, opinions or interpretations are based on observations and materials supplied by the client to whom, and for whose exclusive and confidential use, this report is made. The interpretations or opinions expressed represent the best judgment of Core Laboratories, Inc. (all errors and omissions excepted); but Core Laboratories, Inc., and its officers and employees, assume no responsibility and make no warranty or representations, as to the productivity, proper operation, or profitability of any oil, gas or other mineral well or sand in connection with which such report is used or relied upon.

TABLE 6

The Computed Drawdown At Various
Distances From the Pumped Well
4320 Minutes After the Start of Pumping

$$\Delta s = \frac{114.6 Q}{T} = \frac{114.6 \times 10}{138} W(u) = 8.3 W(u)$$

$$u = \frac{1.87 r^2 S \times 1440}{Tt} = \frac{1.87 r^2 \times 1.4 \times 10^{-4} \times 1440}{138 \times 4320}$$

where $Q = 10$ gallons per minute

$T = 138$ gallons per day per foot

$S = 1.4 \times 10^{-4}$

$t =$ time since pumping started in minutes (4320)

$\Delta s =$ computed drawdown in feet

$r =$ distance from pumped well in feet

$u =$ a function

$W(u) =$ well function for a nonleaky isotropic artesian aquifer fully penetrated by wells and constant discharge conditions.

r feet	u	$W(u)$	Computed Δs feet
1	6.3×10^{-7}	13.7003	113.71
10	6.3×10^{-5}	9.0952	75.49
100	6.3×10^{-3}	4.4963	37.32
400	0.10	1.8229	15.13
700	0.31	0.8815	7.32
1000	0.63	0.4280	3.55
1500	1.42	0.1162	0.96

Illustrated on Figure 16

K-E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS.
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6012

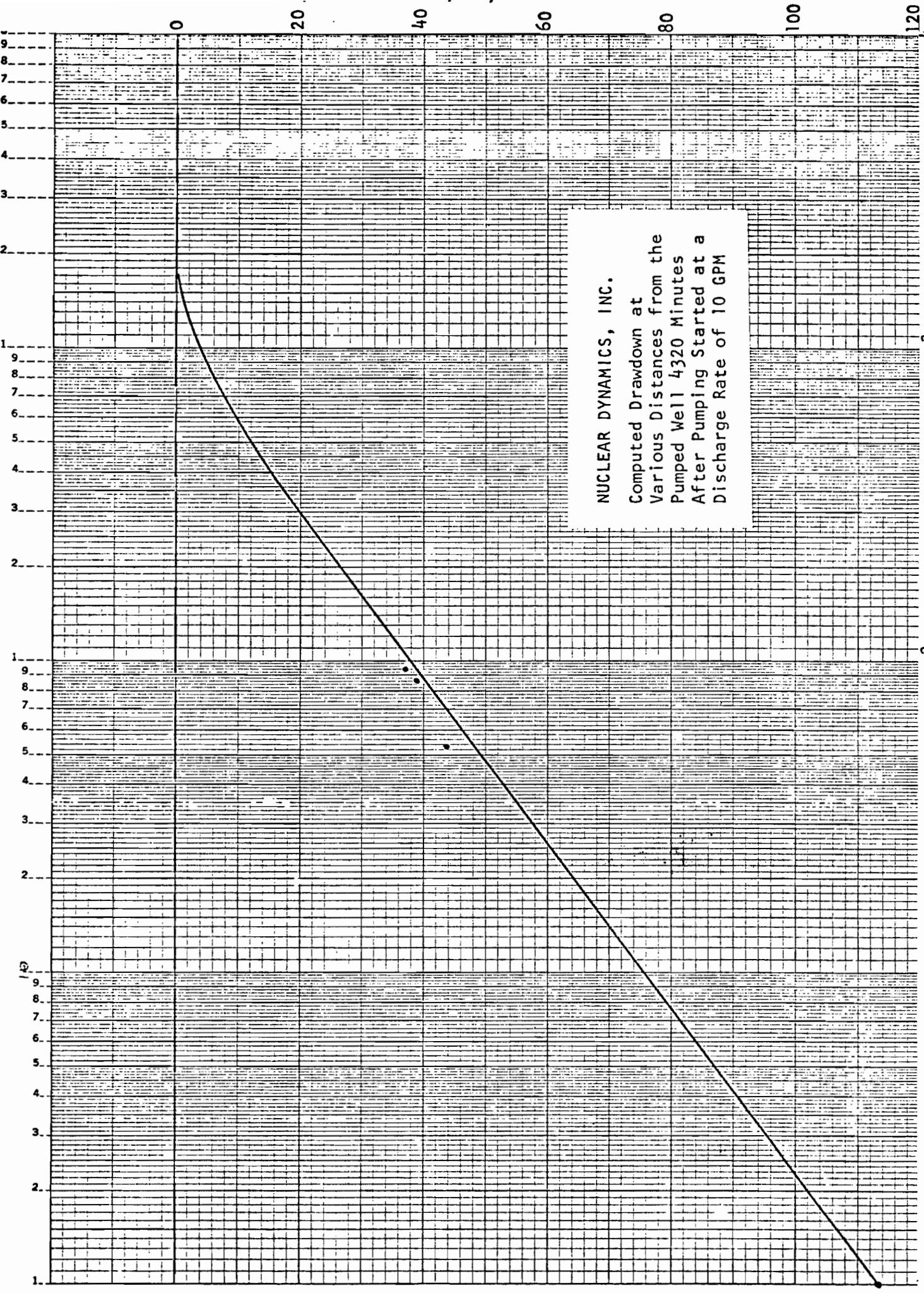


FIGURE 16
Distance, r , from pumped well, in feet

Rate of Flow in Aquifer "B"

The rate of flow in the aquifer is the result of the hydraulic conductivity times the gradient. The average hydraulic conductivity in the "B" aquifer is 1.38 gallons per day per square foot. The gradient appears to be 32 feet per mile to the west-northwest as the altitude of the piezometric head in Wells SP 789V, SP 2X and SP 19X are 4083.00 feet, 4084.29 feet and 4087.94 feet, respectively.

In an artesian aquifer the piezometric head within small areas should be similar, thus the gradient should approach zero which is not the case with these readings. Assuming that the apparent gradient of 32 feet per mile is correct, then the rate of flow in Aquifer "B" would be

$$\text{Velocity} = \text{hydraulic conductivity} \times \text{gradient}$$

$$V = \frac{1.38}{7.48} \times \frac{32}{5280} = 0.18449 \times 0.00606 = 0.00112 \text{ feet per day,}$$

or 0.40812 feet per year.

It is unlikely that the flow rate in the "B" aquifer under natural conditions exceeds one foot per year.

Additional wells are being drilled in the area as test holes and observation wells. Data collection will be continued and expanded as these wells are completed. Regional groundwater gradients will be refined periodically as this data becomes available.

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