APT REANALYSIS

SITE: Highland Beach West Wellfield
Section 32, Township 46S, Range 43E

REPORT: Camp, Dresser, & McKee, Aquifer Performance Test at Town of Highland Beach, FL, October 19-21, 1978.

GEOLOGIC DATA:

Drilling logs to 104' BGL (poor descriptions).
Logs show sand from 0-30' and white rock from 30-104'.
Assumed aquifer thickness of 220'.

WELL DESCRIPTIONS:

Well	Diam. (in)	Total Depth	Cased Depth	Screen /Open	r	~~State Plane Coords.~~	
						~~X~~	~~Y~~
No. 4	8	105'	85'	screen	pump		
No. 5	8	105'	85'	screen	238'		
4"Obs.	8	105'	45'	open	135'		

INFLUENCING FACTORS:

1) Production well No. 1 which is located 1,300 ft. from well No. 4.

2) A canal near well No. 1 (no further location or description of the canal is given.

APT:

Started:	10/20/78 at 0915
Duration:	1484 min. (24.7 hrs.)
Discharge:	322 GPM
Recovery:	measured for 4 hrs.

Comments:

1) All pumping wells were turned off at 2000 hrs. on 10/19.

2) Pump test data were corrected for trend noted between 2000 hrs on 10/19 and the start of the pump test. Trend assumed due entirely to aquifer recovery. Looks reasonable.

3) At 1330 hrs. on 10/20 (t = 239 min.) well No. 1 was turned on at 393 GPM. It remained on at this rate for the remainder of the test. No corrections were made for this.

4) Wells 4 and 5 were measured with an unweighted steel tape which makes the accuracy of the data there questionable. The 4" observation well was measured with a Stevens Type F recorder.

CONSULTANT'S ANALYSIS:

Method: Boulton Analysis - Jacob Analysis

Results:
T = 131,480 GPD/FT
Early S = .0000569
Late S = .00646
Delay Index = 873 min.
n = 122

Comments:

1) Recent data indicate that the base of the Surficial Aquifer is -290' NGVD at the test site. Land surface there is about 15' NGVD. DTW is about 15', so the initial saturated aquifer thickness is probably 290', instead of 220' as assumed.

2) Partial penetration of the wells is not accounted for. The pumping well is open to only 7% of the aquifer.

3) A nearby canal is mentioned but is not further described or accounted for.

REANALYSIS:

Method: Neuman (1975)

Rerun w/ $K_D = .1$
$K_D = .01$

Results:

Well	T Ft2/Day	S	K_D
4" Obs.	49,400	.00025	.005

Comments:

1) The canal was neglected since there is insufficient data to account for it.

2) Aquifer bottom elevation of -290' NGVD assumed based on Miller (198~~4~~7).

3) Data from wells 4 and 5 was not used due to questionable measuring techniques.

4) Given the computed T and estimated aquifer thickness, hydraulic conductivity at the site is about 170 FT/DAY. The computed anisotropy ratio, .005, is quite low. This could result from treating the site as a homogeneous system, when it is more likely a series of layers with varied permeabilities.

Jacob

RECOMMENDED VALUES:

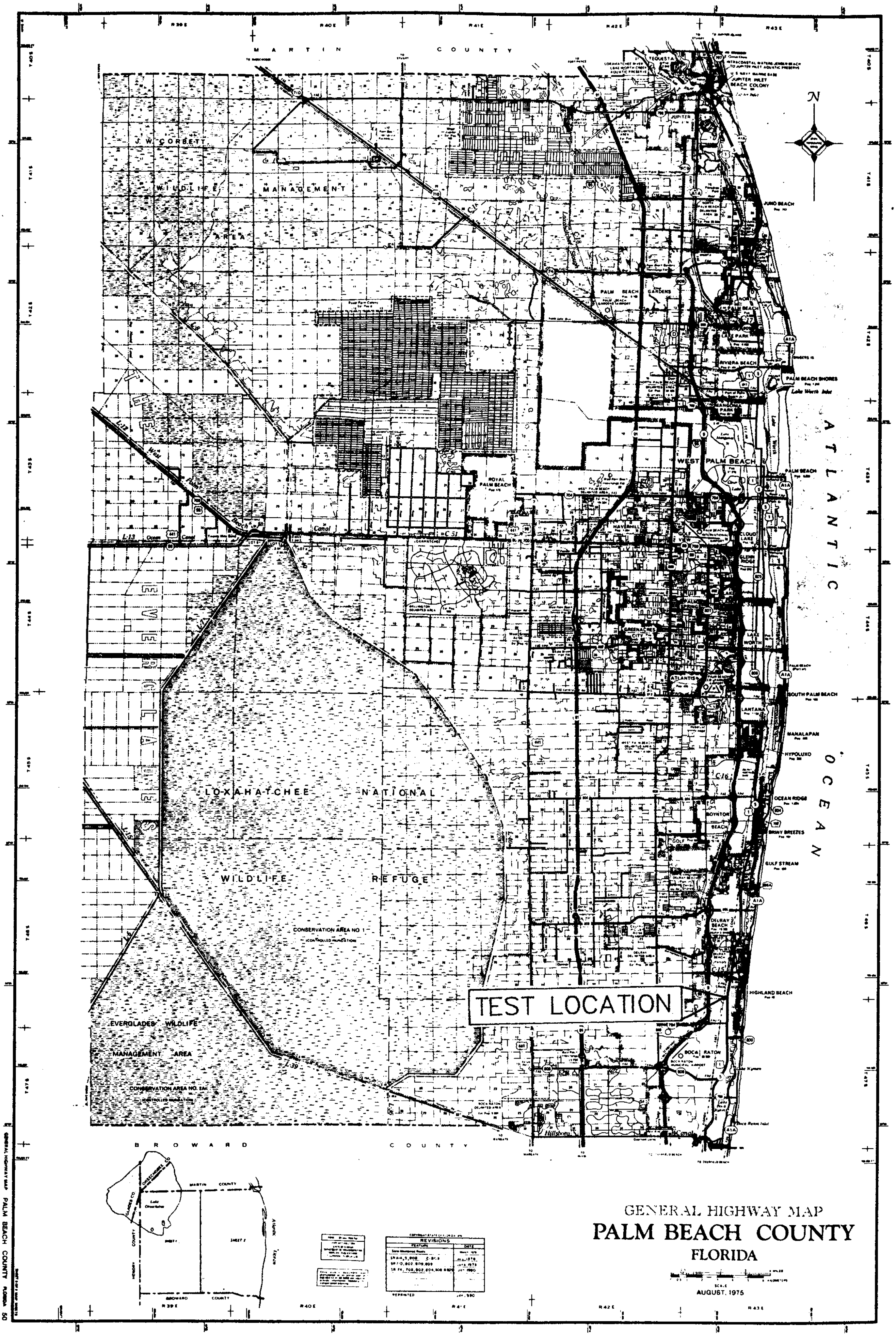
Comments:

REFERENCES:

Miller, W.L., 198~~4~~7. ~~Draft of Map of Base of Surficial Aquifer System in Palm Beach County, FL, USGS.~~ Lithology and base of the surficial aquifer system, Palm Beach County, Florida. USGS Water-Resources Investigations Report 86-4067.

Neuman (1975), Analysis of Pumping Test Data from Anisotropic Unconfined Aquifers Considering Delayed Gravity Response. Water Resources Res., V. II, No. 2.

Water Use Permit 50-00346, Staff Report


MARTIN COUNTY
J. W. CORBETT
WILDLIFE MANAGEMENT AREA
TEQUESTA
JUPITER
JUNO BEACH
PALM BEACH GARDENS
NORTH PALM BEACH
LAKE PARK
RIVIERA BEACH
PALM BEACH SHORES
Lake Worth Inlet
MANGONIA PARK
WEST PALM BEACH
PALM BEACH
ROYAL PALM BEACH
CLOUD LAKE
GLEN RIDGE
HAVERHILL
LOXAHATCHEE
GREENACRES CITY
LAKE WORTH
ATLANTIS
SOUTH PALM BEACH
LANTANA
MANALAPAN
HYPOLUXO
OCEAN RIDGE
BOYNTON BEACH
BRINY BREEZES
GULF STREAM
DELRAY BEACH
HIGHLAND BEACH
BOCA RATON
ATLANTIC OCEAN
EVERGLADES
LOXAHATCHEE NATIONAL WILDLIFE REFUGE
CONSERVATION AREA NO. 1
EVERGLADES WILDLIFE MANAGEMENT AREA
CONSERVATION AREA NO. 2A
BROWARD COUNTY
TEST LOCATION
N
R 39 E
R 40 E
R 41 E
R 42 E
R 43 E
GENERAL HIGHWAY MAP
PALM BEACH COUNTY
FLORIDA
REVISIONS
AUGUST, 1975
GENERAL HIGHWAY MAP PALM BEACH COUNTY FLORIDA 50

AQUIFER PERFORMANCE TEST, PROCEDURES, AND DATA

Highland Beach presently has two well fields. The east well field consists of three wells and the west well field has two. The east field is relatively near salt water canals (about 600 feet to the nearest canal) and therefore is susceptable to salt-water encroachment. This fact dictated that pumpage should be moved westward wherein two wells (numbers 4 and 5) were drilled at a distance of about 1600 feet from the nearest salt-water canal. Pumpage has recently been shifted to these two new western wells. The eastern well field is used only occasionally when either Well Number 4 or 5 needs maintenance.

Highland Beach has requested an increase in allowable pumpage from the SFWMD. That increased pumpage would come from Wells Number 4 and 5 and from additional wells drilled in the west field. The APT was therefore conducted in the west field.

Highland Beach is contemplating requesting an increase in allowable pumpage from the SFWMD. That increased pumpage would either come from Wells Number 4 and 5 or from an additional well drilled in the west field. The APT was therefore conducted in the west field.

The overall procedure for the APT therefore involved measuring water level fluctuations in the west field due to prescribed changes in pumpage rates from the wells there. These fluctuations and the subsequent analyses provide the means for determining aquifer properties of interest.

Three wells were used in the APT. Well Number 4 was used as the pumped well and Well Number 5 and a nearby 4-inch test well were used as observation wells. Logs of these wells are given in Appendix A of this report.

A. Calibration Of Pumping Rates.

Well Number 4 was chosen as the pumped well for the APT. First, the pumping rate from Well Number 4 was determined by shutting off all Highland Beach wells and then pumping number 4 alone into the treatment plant ground level reservoir. The dimensions of the treatment plant reservoir were known and several water level measurements, with time, were taken to give a pumping rate of 322 gpm. In addition, an in-line flow meter was calibrated to this flow rate so that further flow rates could be directly read from this meter.

Next, the flow of Well Number 1 was measured by the same method as above and indicated that well number 1, by itself, pumped 393 gpm.

It was expected that the ground plus elevated storage capacity of Highland Beach would not be adequate to maintain fire protection without, sometime during the APT, turning Well Number 1 on in addition to Number 4. To calibrate the the in-line flow meter and to assure that pumpage from one well would not effect the other (due to common piping connections at the treatment plant) both Wells 1 and 4 were calibrated, as above, when pumping together. This calibration run showed that Wells 1 and 4 running together did not discernibly affect one anothers individual pumping rate.

It should be mentioned that all Highland Beach wells pump their waters to the ground level reservoir beneath the treatment plant at atmospheric pressure. Water is then discharge from this open reservoir to the distribution system via separate transfer pumps. Therefore, changes in distribution system pressure in no way affects the pumping rates from the wells.

B. Water Levels Prior To Pumping.

All pumpage at Highland Beach was stopped at 8:00 PM on the evening of October 19, 1978. A Stevens Type F water level recorder was set up to record water levels in an existing 4-inch diameter, 105 foot deep test well located between Well Number 4 and 5. This 4-inch diameter observation well measured 135 feet north of Well Number 4 and 103 feet south of Well Number 5. All three wells are west of and on a line parallel with the Florida East Coast Railroad tracks.

The recorder operated overnight and provided the trend to water levels in the aquifer prior to pumping Well Number 4. The water level data taken from that recorder are given in Table 1.

During the morning of October 20,1978 additional nonpumping water levels were measured in Wells Number 4 and 5 to further establish prepumping aquifer conditions. Water levels in Wells 4 and 5 prior to pumping can be found in Tables 2 and 3 respectively. Water levels before pumping were plotted on semilog paper using 8 PM October 19, 1978 as the beginning time. The trend listed in Tables 2 and 3 came from that plot extended over the entire time of pumping of Well Number 4. The implication of this trend extention is that the prepumping water level fluctuations are solely attributable to recovery due to turning pumpage off in the west field.

Water levels corrected for recovery trend

C. Prodution Test Of Well Number 4.

Well Number 4 was turned on at 9:31:15 (9 hours, 31 minutes, and 15 seconds) AM EDST on October 20, 1978 at a constant pumping rate of 322 gpm for a period of 1484 minutes. At 1:30 PM on October 20, 1978 Well Number 1 was needed at that time and was turned on at the

24.7 hrs

t= 239 min

4" obs WELL

TABLE 1
WELL PRODUCTION TEST — TREND ANALYSIS

Engineer: Prickett--CDM Test by: Prickett, Herzog
Sturtz, Arney
Owner: Highland Beach Location: Observation well ✓
Measuring point: 2.77' above cement slab at land surface
Measuring equipment: Stevens Type F recorder

Pumpage Stops

Date	Hour	Time (min)	Water level depth (ft)	Recovery (ft)
10/19	8:00 pm	0	14.380	0
	10:00	120	14.250	0.130
	12:00	240	14.180	0.200
10/20	2:00 am	360	14.145	0.235
	4:00	480	14.107	0.273
	6:00	600	14.083	0.297
	7:45	705	14.073	0.307
	~~9:31~~	~~811~~	~~11.832~~	~~.442~~

lowest WT

Different Reference? well 5 not obs well

Obs — pump well #4

TABLE 2
WELL PRODUCTION TEST — PUMPING

Engineer: Prickett--CDM Test by: Prickett, Herzog, Sturtz, Arney
Owner: Highland Beach Location: Pumping well (#4)
Measuring point: 1' 11½" above land surface
Measuring equipment: airline or steel tape (inches and feet) and chalk

Date	Hour	Time (min)	Held (ft)	Water level	Depth (ft)	Draw-down (ft)	Trend (ft)	Corrected drawdown (ft)	Remarks
				Wet					
10/20	8:58 am	0	17	1' 4 7/8"	15.59				
	9:00	0	17	1' 4 5/8"	15.61	0			
	9:31:15	0							pump started
	9:48:30	17.25	17	5'	--				invalid) tape
	9:51:00	19.75	22	--	--				readings) stuck
	10:08	37			27	11.39	0.003	11.393	airline
	10:17	46	20	--	--				tape wet, no readi
	10:34	63			27	11.39	0.007	11.397	airline
	11:10	99			27	11.39	0.011	11.401	airline
	11:56	145			27	11.39	0.017	11.407	airline
	12:57 pm	206			27	11.39	0.023	11.413	airline
	1:59	268			26½	10.89	0.030	10.920	airline
	3:08	337			27	11.39	0.035	11.425	airline
	4:06	395			26½	10.89	0.041	10.931	airline
	5:12	461			27	11.39	0.048	11.438	airline
	5:28	477			27	11.39	0.049	11.439	airline
	6:18	527			27	11.39	0.053	11.443	airline
	7:02	571			27	11.39	0.053	11.443	airline
	8:36	633			27	11.39	0.059	11.449	airline
	9:55	744			27	11.39	0.066	11.456	airline
	11:52	861			26½	10.89	0.075	10.965	airline
10/21	2:09	998			27	11.39	0.082	11.472	airline
	3:55	1104			27½	11.89	0.087	11.977	airline
	5:33	1202			27½	11.89	0.091	11.981	airline
	7:08	1297			27½	11.89	0.097	11.987	airline
	9:01	1410			28	12.39	0.101	12.491	airline
	9:44	1453			27	11.39	0.103	11.493	airline

TABLE 3
WELL PRODUCTION TEST — PUMPING

Obs WELL 238' to pumping

Date: October 20, 1978 Engineer: Prickett--CDM Test by: Prickett, Herzog, Arney, Sturtz, Cotter

Owner: Highland Beach Location: Well #5

Measuring point: 1' 11½" above land surface Measuring equipment: steel tape & chalk

Hour	Time (min)	Held (ft)	Water level Wet	Depth (ft)	Draw-down (ft)	Trend (ft)	Corrected drawdown (ft)	Remarks
8:40 pm	0	18	3' 1¼"	14.90				
8:43	0	17	2' 1 3/4"	14.85				
	0	17	2' 1 3/4"	14.85				
	0	17	2' 2"	14.83				
	0	17	2' 3/4"	14.94				
	0	18	3' 1 3/4"	14.85				
9:02:40		17	2' 1 7/8"	14.84	0	0	0	
9:31:15					14.84			pump started 811 min Recovery
9:32:30	1.25	17	1' 8"	15.33	0.49	0	0.49	
9:33:00	1.75	17	1' 6"	15.50	0.66	0	0.66	
9:34:00	2.75	17	1' 5 7/8"	15.51	0.67	0	0.67	
9:35:00	3.75	17	1' 5"	15.58	0.74	0	0.74	
9:36:00	4.75	17	1' 4 7/8"	15.59	0.75	0	0.75	
9:37:00	5.75	17						reading missed
9:38:00	6.75	17	1' 4½"	15.62	0.78	0.001	0.78	
9:39:00	7.75	17	1' 4 3/8"	15.64	0.80	0.001	0.80	
9:40:00	8.75	17	1' 4 3/8"	15.64	0.80	0.001	0.80	820 min Recovery
9:42:00	10.75	17	1' 4½"	15.62	0.78	0.002	0.78	
9:45:00	13.75	17	1' 3 3/4"	15.69	0.85	0.002	0.85	
9:54:00	22.75	17	1' 3¼"	15.73	0.89	0.003	0.89	
9:56:00	24.75	17	1' 3 3/8"	15.72	0.88	0.004	0.88	Dan Cotter read
10:01	29.75	17	1' 3¼"	15.73	0.89	0.004	0.89	
10:13	41.75	17	1' 3"	15.75	0.91	0.004	0.91	
10:27:00	55.75	17	1' 2 3/4"	15.77	0.93	0.006	0.94	
10:31:00	59.75	17	1' 2 3/4"	15.77	0.93	0.007	0.94	
10:40:00	68.75	17	1' 2½"	15.79	0.95	0.008	0.96	
10:50:00	78.75	17	1' 2 3/8"	15.80	0.96	0.009	0.97	
11:05:00	93.75	17	1' 2 3/8"	15.80	0.96	0.010	0.97	
11:54	143	17	1' 2 1/8"	15.80	0.96	0.016	0.98	
12:55 pm	204	17	1' 2¼"	15.81	0.97	0.023	0.99	
1:55	264	17	1' 2 3/8"	15.80	0.96	0.030	0.99	
3:05	334	17	1' 2 3/8"	15.80	0.96	0.035	1.00	
4:03	392	17	1' 2 7/16"	15.80	0.96	0.041	1.00	
5:06	455	17	1' 2 7/16"	15.80	0.96	0.047	1.01	
5:23	472	17	1' 1 7/8"	15.84	1.00	0.048	1.05	
6:18	527	17	1' 1 3/4"	15.85	1.01	0.053	1.06	
6:50	559	17	1' 1 3/8"	15.89	1.05	0.054	1.10	
8:32	629	17	1' 1 1/8"	15.91	1.07	0.059	1.13	
10:02	751	17	1/ 1 3/8"	15.89	1.05	0.066	1.12	
11:48	857	17	1' 1¼"	15.90	1.06	0.073	1.13	
2:06 am	995	17	1' 1½"	15.88	1.04	0.082	1.12	date change to 10/21
3:42	1091	17	1' 1 1/8"	15.91	1.07	0.086	1.16	
5:40	1209	17	1' ½"	15.96	1.12	0.092	1.21	
7:14	1303	17	1' 1/8"	15.99	1.15	0.097	1.25	
9:40	1449	17	10 3/4"	16.10	1.26	0.103	1.36	820+720 = 1540

constant rate of 393 gpm. Well Number 1 remained on at that rate until after the completion of the remainder of the total APT.

Table 4 gives values of the in-line flow-rate meter readings taken during the test. These readings are accurate only to the nearest 100 gallons since that is the smallest division that can be read. Small apparent variations in pumpage rate from this meter may not be meaningful. All wells are electric motor driven with free discharge at the treatment plant. Therefore, there is no reason to believe that pumpage rates significantly changed during the entire APT.

D. Water Level Fluctuations During The Pumping Of Well Number 4.

Pumping of Well Number 4 began at 9:31:15 AM Eastern Daylight Savings Time (9 hours, 31 minutes and 15 seconds) on October 21, 1978. Two watches were used while mwasuring water levels. One watch (#1) was used in measuring levels at Wells Number 4 and 5. The second watch (#2) was used solely at the 4-inch test well where the recorder was operating. Since split second timing was necessary to synchronize water level measurements, these two watches were necessary. As it turned out, the SFWMD requested a record of the original data collected during the test. Table 5 is the water level flucturation observed at the 4-inch observation well with the recorder and watch #2. The beginning of pumping on watch #2 was 9:31:00. If one focuses attention on the time after pumping started column for all wells, this difference in watch settings is not relevant.

The trend listed in Table 5 was constructed in the same manner as Tables 2 and 3.

TABLE 4
WELL PRODUCTION TEST - PUMPING RATES

715

Date: October 20,1978 Owner: Highland Beach Location: Well #4 Engineer: Prickett--CDM
Test by: Prickett, Herzog, Arney, Sturtz Measuring equipment: flow meter at water plant

Time since pumping began (minutes)	Meter reading (gallons)	Apparent pumpage (gallons)	Time interval (minutes)	Apparent pumping rate (gal/min)	Remarks
0	63979900	0			Pump #4 on at 9:31:15 a.m. October 20, 1978
15	63984450	4550	15	303	
30	63989100	4650	15	310	
45	63993500	4400	15	293	
60	63998000	4500	15	300	
75	64002600	4600	15	307	
90	64007200	4600	15	307	
105	64011700	4500	15	300	
120	64016200	4500	15	300	
218	64046000	29800	98	304	
		66100	218	303	flow meter Average
				322	actual bypassing treatment plant reservoir Calibrated
239					Wells #1 and 4 on
278	64082000				
347	64133000	51000	69	739	Wells 1 & 4
540	64277000	144000	193	746	well located at
674	64377200	100200	134	748	Treatment plant
764	64444900	67700	90	752	not west wellfield
1007	64627200	182300	243	750	October 21, 1978
1225	64792000	164800	218	756	
1314	64859000	67000	89	753	
1441	64955000	96000	127	756	
		873000	1163	751	Average
				715	Calibrated

obs well 135' to pumpin
4" obs. well

TABLE 5
WELL PRODUCTION TEST — PUMPING

Engineer: Prickett--CDM   Test by: Prickett, Herzog, Sturtz,
Arney, Fisher, Cotter
Owner: Highland Beach   Location: Observation well ✓
Measuring point: 2.77' above cement slab (≈ ground surface)
Measuring equipment: Stevens Type F recorder

			Water level						
Date	Hour	Time (min)	Held (ft)	Wet	Depth (ft)	Draw-down (ft)	Trend (ft)	Corrected drawdown (ft)	Remarks
0/20	8:45pm		18	3' 20"	14.83	0	0	0	steel tape measurement to set recorder
	9:31:00	0.0			14.822	0	0	0	
	:01				14.822 ✓			0	
	:02				14.838	0.015		0.015	
	:03				14.879	0.057		0.057	
	:04				14.950	0.128		0.128	
	:05			15.039	~~15.138~~	~~0.316~~	.217	0.316	
	:06	0.1		15.128	~~15.150~~	~~0.328~~	.306	0.328	
	:07				15.213	0.391		0.391	
	:08				15.267	0.445		0.445	
	:09				15.290	0.468		0.468	
	:10				15.300	0.478		0.478	
	:11				15.306	0.484		0.484	
	→ :12	0.2			15.325	0.503		0.503	
	:13				15.350	0.528		0.528	
	:14				15.381	0.559		0.559	
	:15				15.420	0.598		0.598	
	:16				15.456	0.634		0.634	
	:17				15.480	0.658		0.658	
	:18	0.3			15.496	0.674		0.674	
	:19				15.498	0.676		0.676	
	:20				15.500	0.678		0.678	
	:21				15.502	0.680		0.680	
	:22				15.506	0.684		0.684	
	:23				15.513	0.691		0.691	
	:24	0.4			15.521	0.699		0.699	
	:25				15.530	0.708		0.708	
	:26				15.535	0.713		0.713	
	:27				15.542	0.720		0.720	
	:28				15.549	0.727		0.727	
	:29				15.550	0.728		0.728	
	:30	0.5			15.556	0.734		0.734	
	:31				15.558	0.736		0.736	
	:32				15.567	0.745		0.745	
	:33				15.582	0.750		0.750	
	:34				15.592	0.760		0.760	
	:35				15.609	0.787		0.787	
	:36	0.6			15.618	0.796		0.796	
	:37				15.630	0.808		0.808	
	:38				15.640	0.818		0.818	
	:39				15.650	0.828		0.828	
	:40				15.658	0.836		0.836	
	:41				15.663	0.841		0.841	
	:42	0.7			15.668	0.846		0.846	
	:43				15.674	0.852		0.852	

TABLE 5 (CONTINUED)
WELL PRODUCTION TEST — PUMPING (Continued)

4" obs-well
r= 135'

Date	Hour	Time (min)	Water level			Draw-down (ft)	Trend (ft)	Corrected drawdown (ft)	Remarks
			Held (ft)	Wet	Depth (ft)				
10/20	9:31:44				15.680	0.858	0	0.858	
	:45				15.684	0.862		0.862	
	:46				15.692	0.870		0.870	
	:47				15.697	0.875		0.875	
	:48	0.8			15.701	0.879		0.879	
	:49				15.705	0.883		0.883	
	:50				15.709	0.887		0.887	
	:51				15.713	0.891		0.891	
	:52				15.719	0.897		0.897	
	:53				15.725	0.903		0.903	
	:54	0.9			15.730	0.908		0.908	
	:55				15.733	0.911		0.911	
	:56				15.742	0.920		0.920	
	:57				15.746	0.924		0.924	
	:58				15.750	0.928		0.928	
	:59				15.758	0.936		0.936	
	9:32	1.0			15.765	0.943		0.943	
		1.1			15.790	0.968		0.968	
		1.2			15.808	0.986		0.986	
		1.3			15.827	1.005		1.005	
		1.4			15.840	1.018		1.018	
		1.5			15.854	1.032		1.032	
		1.6			15.869	1.047		1.047	
		1.7			15.880	1.058		1.058	
		1.8			15.890	1.068		1.068	
		1.9			15.899	1.077		1.077	
	9:33	2.0			15.909	1.087		1.087	
		2.2			15.922	1.100		1.100	
		2.4			15.931	1.109		1.109	
		2.5			15.936	1.114		1.114	
		2.6			15.941	1.119		1.119	
		2.8			15.944	1.123		1.123	
	9:34	3.0			15.958	1.136		1.136	
	9:35	4			16.004	1.182		1.182	
	9:36	5			16.030	1.208		1.208	
	9:37	6			16.048	1.226	0.001	1.227	
	9:38	7			16.062	1.240	0.001	1.241	
	9:39	8			16.076	1.254	0.001	1.255	
	9:40	9			16.085	1.263	0.001	1.264	
	9:41	10			16.092	1.270	0.002	1.272	
	9:43	12			16.107	1.285	0.002	1.287	
	9:45	14			16.118	1.296	0.002	1.298	
	9:47	16			16.128	1.306	0.003	1.309	
	9:49	18			16.135	1.313	0.003	1.316	
	9:51	20			16.140	1.318	0.003	1.321	
	9:56	25			16.153	1.331	0.004	1.335	
	10:01	30			16.168	1.346	0.004	1.350	
	10:06	35			16.175	1.353	0.004	1.357	
	10:11	40			16.184	1.362	0.004	1.366	
	10:16	45			16.190	1.368	0.005	1.373	

TABLE 5 (CONCLUDED)
WELL PRODUCTION TEST – PUMPING (Concluded)

4" obs well.
r = 135'

			Water level				ok		
te	Hour	Time (min)	Held (ft)	Wet	Depth (ft)	Draw-down (ft)	Trend (ft)	Corrected drawdown (ft)	Remarks
/20	10:21am	50			16.197	1.375	0.005	1.380	
	10:21:30	51					0.005		big train comes
	10:23:45	53					0.005		train leaves
	10:26	55			16.204	1.382	0.006	1.388	
	10:31	60			16.205	1.383	0.007	1.390	
	11:07	96	18	1' 9¼"	16.227	1.405	0.010	1.415	replaced chart after removing to read
	11:19	108			16.234	1.412	0.013	1.425	
	11:21	111			16.227	1.405	0.013	1.428	train stops on inside track
	11:23	113					0.013		engine alone passes
	11:31	120			16.233	1.411	0.014	1.425	
	11:32	121					0.014		another train passes part way
	11:34	123			16.227	1.405	0.014	1.419	second train stops
	11:37	126					0.015		train 3 passes (unseen)
	11:39	128					0.015		first train leaves
	11:40	129			16.249	1.427	0.015	1.442	
	11:49	138					0.016		second train pulls out
	11:51	140			16.267	1.445	0.016	1.461	second train gone
	12:01 pm	150			16.248	1.426	0.017	1.443	
	12:59	208			16.243	1.421	0.023	1.444	
	1:30	239			16.225	1.403	0.027	1.430	pump 1 on
	2:01	270			16.211	1.389	0.030	1.419	breeze appears to move drum
	3:09	338			16.218	1.396	0.035	1.431	
	3:12	341					0.036		train passes for 2 min
	4:06	395					0.041		train passes for 5 sec
	4:11	400			16.235	1.413	0.042	1.445	
	5:08	457			16.254	1.432	0.047	1.479	
	6:17	526			16.273	1.451	0.053	1.504	
	7:03	572			16.284	1.462	0.054	1.516	
	8:25	654			16.298	1.476	0.060	1.536	
	9:58	747			16.310	1.488	0.066	1.554	
	11:40	849			16.311	1.489	0.072	1.561	
0/21	2:00 am	989			16.311	1.489	0.081	1.570	big train scenario here
	3:46	1095			16.314	1.492	0.086	1.578	train approaches
	3:47:00	1096					0.086		start clock
	3:47:43	1097			16.253	1.431	0.086	1.517	43 sec-low point
	3:47:50	1097					0.086		second low, starts oscillating
	3:48:40	1098					0.086		train gone
	3:48:45	1098			16.354	1.532	0.086	1.618	top of rebound
	3:50	1099			16.320	1.498	0.086	1.584	
	5:42	1211			16.340	1.518	0.092	1.610	
	7:01	1290					0.097		heard big train from treatment plant
	7:16	1305			16.359	1.537	0.097	1.634	
	8:56	1405			16.382	1.560	0.102	1.662	
	9:44	1453			16.384	1.562	0.103	1.665	

Water-level fluctuations in Wells Number 4 and 5 during pumping of Well Number 4 are given in Tables 2 and 3.

Measurement problems @ wells 4 & 5

Some difficulties in measuring water levels were encountered during the entire APT and concerned mainly those at Wells Number 4 and 5. Rapid measurements could not be taken in either one of these wells because of column pipe couplings blocking easy access. One had to be careful and feed the tape into the available space. Wetness of the casing and column pipe continually fouled accurate readings in the pumped well and occasionally in Well Number 5. There was no room through the pump base to lower anything other than an unweighted steel tape. Furthermore, the float used on the recorder in the 4-inch observation well had a characteristic damped sine-wave oscillation when water levels moved rapidly as when nearby locomotives and heavy truck traffic passed by. This oscillation was not present to any great extent during other times of the test.

Local train traffic affected water levels momentarily throughout the APT. The water levels listed in Tables 2,3, and 5 do not show this frequent occurrence. Heavy trucks passing on Route 811 also had momentary effects on water levels. In both of these cases, measurements were delayed until these disturbances passed.

E. Water Level Fluctuations During the Recovery Period After Pumping Stopped.

Well Number 4 was turned off at 10:15 AM EDST on October 21, 1978 and water levels were measured as they recovered. Tables 6,7, and 8 give water level measurements taken in Wells Number 4 and 5 and the

Production well

TABLE 6
WELL PRODUCTION TEST – RECOVERY ✓

Date: October 21, 1978   Engineer: Prickett--CDM   Test by: Prickett, Herzog, Arney
Owner: Highland Beach   Location: #4   Measuring point: 1' 11½" above land surface
Measuring equipment: steel tape and chalk and 40' air line

Hour	Time (min)	Held (ft)	Water level		Draw-down (ft)	Remarks
			Wet	Depth*		
10:15 am	0			27/19.75	0	test started
11:00	45			23/15.75	4.0	air line #4/
11:04	49					tape reading
11:48	93			23/15.75	4.0	
11:54	99	17	9 3/4"	16.19	3.56	
11:57	102	18	1' 11"	16.09	3.67	
12:18 pm	123	18	2' 3½"	15.71	4.04	
12:20	125	17	1' 3"	15.75	4.00	
12:21	126			23/15.75	4.00	
12:31	136	17	10½"	16.12	3.63	
1:05	170	17	1' 2 3/8"	15.80	3.95	
1:47	212	17	1' 3½"	15.71	4.04	
2:14	239	17	1' 3 7/8"	15.68	4.07	322/4 = 80

T= 120,000 to 160,00

*depth figures assume airline meausrements are 7.25' high, which is the discrepancy noted between airline and tape measurements taken at the same time

238' from
Production well

TABLE 7

WELL PRODUCTION TEST – RECOVERY

Date: October 21, 1978 Engineer: Prickett--CDM Test by: Prickett, Herzog, Arney
Owner: Highland Beach Location: Well #5 Measuring point: 1' 11½" above land surface
Measuring equipment: steel tape (inches and feet) and chalk

Hour	Time (min)	Held (ft)	Water level Wet	Water level Depth (ft)	Recovery (ft)	Remarks
10:10 am	0	17	1'	16.00	0 14.84 DD	ref t/t'
10:15	0					pump off 1484 min
10:17	2	17	1' 6¼"	15.48	0.52 .64	742
10:20	5.25	17	1' 6½"	15.46	0.54 .62	282
10:21	6	17	1' 7"	15.42	0.58 .58	247
10:23	8	17	1'	16.00	0	stuck tape
10:24	9	17	10"	16.17	-0.83	
10:25	10	18	2"	17.83	-1.83	questionable readings (tape may have stuck)
10:26	11	18	6 5/8"	17.45	-1.45	
10:27	12	18	1' ½"	16.96	-0.96	
10:28	13	18	5 3/4"	17.52	-1.52	
10:30	15	18	4 7/8"	17.59	-1.59	
10:31	16	18	6¼"	16.48	-0.48	
10:32	17	18	1' ½"	16.96	-0.96	
10:34	19	17	1' 4½"	15.625	0.375 .785	78
10:38	23	16	9"	15.25	0.75 .41	64.5
10:40	25	16	8"	15.33	0.67 .49	59.4
10:42	27	16	8 3/4"	15.27	0.73 .43	54.9
10:45	30	16	1' 1"	14.92	1.08 .08	49.5
10:46	31	16	10½"	15.12	0.88 .28	47.9
10:47	32	16	8 1/8"	15.32	0.68 .48	46.4
10:49	34	16	11½"	15.04	0.96 0.20	43.6
10:55	40	16	11¼"	15.06	0.94 0.22	37.1
10:59	44	16	7"	15.42	0.58 0.58	33.7
11:15	60	16	11 3/4"	15.02	0.98 0.18	24.7
11:25	70	16	1'	15.00	1.00 0.16	21.2
11:35	80	16	1' 1/8"	14.99	1.01 0.15	18.6
11:45	90	16	1' ¼"	14.96	1.04 0.12	16.5
11:50	95	16	7¼"	15.40	0.60 0.56	15.6
12:00 pm	105	16	1' 5/8"	14.95	1.05 0.11	14.1
12:15	120	16	1' 3/4"	14.94	1.06 0.10	12.4
12:32	137	17	2' 7/8"	14.93	1.07 0.09	10.8
12:39	144	17	2' 7/8"	14.93	1.07 0.09	10.3
1:25	190	16	1' ½"	14.06	1.04 0.78	7.8 ✓
1:44	209	16	1' 1"	14.92	1.08 0.08	7.1
2:24	249	16	1' 1 5/8"	14.86	1.14 0.02	5.95
2:26	251	16	1' 1 3/4"	14.85	1.15 0.01	5.91

135' [illegible]
Production Well

TABLE 8
WELL PRODUCTION TEST — RECOVERY ✓

Date: October 21, 1978 Engineer: Prickett--CDM Test by: Prickett, Herzog, Arney
Owner: Highland Beach Location: Observation Well ✓
Measuring point: 2.77' above cement slab (≈ 2.77' above land surface)
Measuring equipment: Stevens Type F Recorder

Hour (h:m:s)	Elapsed Time (min)	Water level depth (ft)	Recovery (ft)	Remarks
10:15 am	0	16.380	0 DD	1/2 Well Number 4 off
10:15:05	0.0833	16.245	0.135 1.42	17,808
:10	0.1667	15.992	0.338 1.17	8904
:15	0.25	15.910	0.470 1.09	5936
:20	0.33	15.796	0.584 0.974	4452
:25	0.416	15.733	0.647 0.911	3562
:30	0.50	15.675	0.705 0.853	2968
:35	0.583	15.639	0.741 0.817	2544
:40	0.667	15.600	0.780 0.778	2226
:45	0.750	15.561	0.819 0.739	1979
:50	0.833	15.536	0.844 0.714	1781
:55	0.916	15.510	0.870 0.688	1619
10:16:00	1	15.490	0.890 0.668	1484
10:16:05	1.08	15.469	0.911 0.647	1370
:10	1.17	15.452	0.928 0.63	1272
:15	1.25	15.437	0.943 0.615	1187
:20	1.33	15.419	0.961 0.597	1113
:25	1.42	15.408	0.972 0.586	1048
:30	1.50	15.397	0.983 0.575	989
:35	1.58	15.390	0.990 0.568	937
:40	1.67	15.380	1.000 [illegible]	890
:45	1.75	15.370	1.010 0.548	848
:50	1.83	15.361	1.019 0.539	809
:55	1.92	15.352	1.028 [illegible]	774
10:17:00	2	15.343	1.037 0.521	742
10:17:20	2.33	15.312	1.068 0.49	636
:30	2.50	15.300	1.080 0.478	594
:45	2.75	15.286	1.094 0.464	540
10:18:00	3	15.275	1.105 0.453	495
10:19:15	4.25	15.228	1.152 0.406	349
10:20	5	15.209	1.171 0.387	297
10:21	6	15.187	1.193 0.365	247
10:22	7	15.170	1.210 0.348	212
10:23	8	15.153	1.227 0.331	186
10:24	9	15.143	1.237 0.321	165
10:25	10	15.134	1.246 0.312	10:45 train here, 12:30 train gone (min:sec)
10:28	13	15.118	1.262 ?	114
10:32	17	15.089	1.291 0.267	87
10:37	22	15.068	1.312 0.246	67.5
10:43	28	15.048	1.332 0.226	53
10:49	34	15.034	1.346 0.212	43.6
10:55	40	15.022	1.358 0.20	37.1
11:09	54	15.001	1.379 0.179	27.5
11:22	67	14.986	1.394 0.164	22.1

1484 min
Ref = 14.822

TABLE 8 (CONCLUDED)
WELL PRODUCTION TEST — RECOVERY (Concluded)

Hour	Time (min)	Water level depth (ft)	Recovery (ft)	Remarks
11:32 am	77	14.975	1.405 0.153	19.27 train here 78:37
11:45	90	14.963	1.417 0.141	16.5
11:58	103	14.953	1.427 0.131	14.4
12:15 pm	120	14.940	1.440 0.118	12.4
12:39	144	14.926	1.454 0.104	10.3
1:03	168	14.912	1.468 0.09	8.8
1:25	190	14.900	1.480 0.078	7.8
1:40	205	14.890	1.490 0.066	7.2
1:59	224	14.879	1.501 0.057	6.6
2:09	234	14.872	1.508 0.05	6.3
2:09:45	234.75			train scenario (see Fig. 5)
2:25	250	14.866	1.514 0.044	end of test 5.9

4-inch diamter observation well respectively. Recovery measurements were taken for a period of about four hours at the completion of which was the end of the APT.

F. Inventory of Nearby Pumpage, Barometic Pressure, and Tidal Variations.

Water levels in the Highland Beach wells could possibly be affected by items other that their own pumpage. Information on nearby pumpage from other wells, barometric pressure changes, and tidal fluctuations were therefore collected.

The nearest groundwater pumpage found was at Boca Teeca Golf Course where 6 wells (350 gpm each) are operated 8 hours daily between 7 PM in the evening and 3 in the morning. The nearest of these wells is about 0.5 miles southwest of Well Number 4.

Other wells were found at Boca Raton Country Club, but these wells were not used due to moist conditions during the period October 19-21, 1978.

The next nearest pumpage is at Boca Raton, a distance of about 1.5 miles. This pumpage would not be expected to complicate a short term test such as this APT.

A tidal table is included in Appendix B to indicate ocean level change effects that have a bearing on the Highland Beach water levels.

Rather large barometric pressure changes were noted during the period of the APT. Appendix C includes hourly data on barometric pressures at West Palm Beach, Fort Lauderdale (International Airport), and Fort Lauderdale (Executive Airport) during the APT. A plot of pressures versus water levels during the APT reveals some apparent correlation--but it is believed to be only apparent (not real), as will be pointed out later.

ANALYSIS OF APT DATA

The hydrogeologic conditions at Highland Beach bring to mind several possible ways to interpret water-level fluctuations. According to the logs and well construction features in Appendix A, the classic delayed yield from storage theory probably best fits the conditions at Highland Beach in their west field. One could also argue for such theories as leaky artesian, storage from confining layers, or vertical to horizontal permeability difference effects in a partially penetrating water-table system. However, the two-layer systems (fine sand-rock) with apparent high permeability contrast does not fit any of these later mentioned cases. The theory finally chosen for calculating aquifer coefficients was the delayed yield concept developed by Boulton (1963). The type-curve method by Prickett (1965) was used in the matching process of logarighmic plots of drawdown and recovery data.

A. Analysis Of Time-Drawdown Data

Logarithmic and semilogarithmic plots of time-drawdown data were constructed from the measurements given in Tables 2, 3, and 5. Plots of both uncorrected and corrected drawdowns were made.

Figures 1 and 2 show logarithmic plots of corrected time-drawdown data from the 4-inch diameter observation well and Well Number 5. Both plots give consistent results on all aquifer parameters calculated. The type curves available from theory, however, do not allow a choice of values of r/D any finer than the 0.1 and 0.2 values used. A closer agreement in parameters could have resulted if smaller r/D increment curves were available.

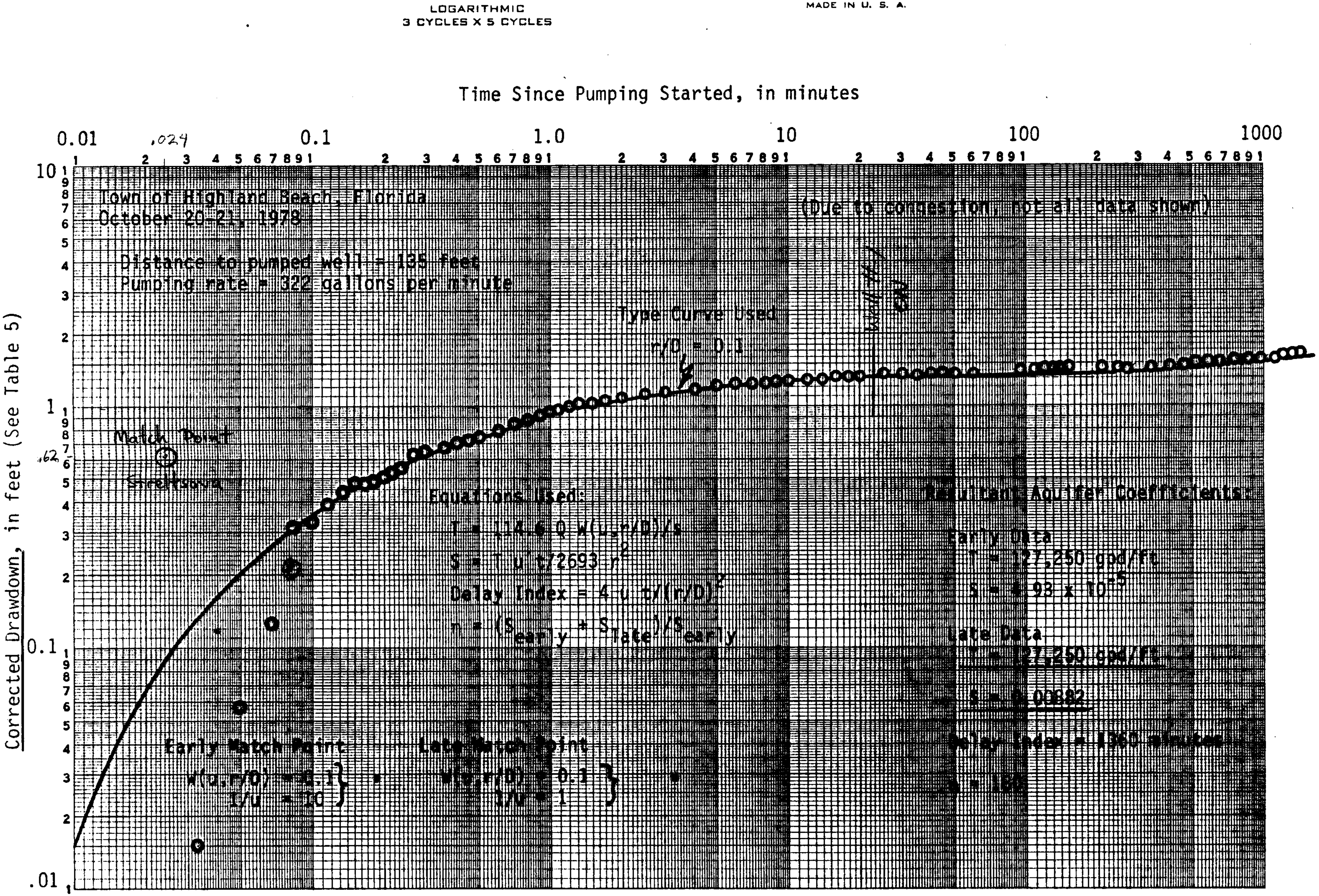


Figure 1. Time-drawdown graph for 4-inch diameter test well used as an observation well during pumping of Well Number 4

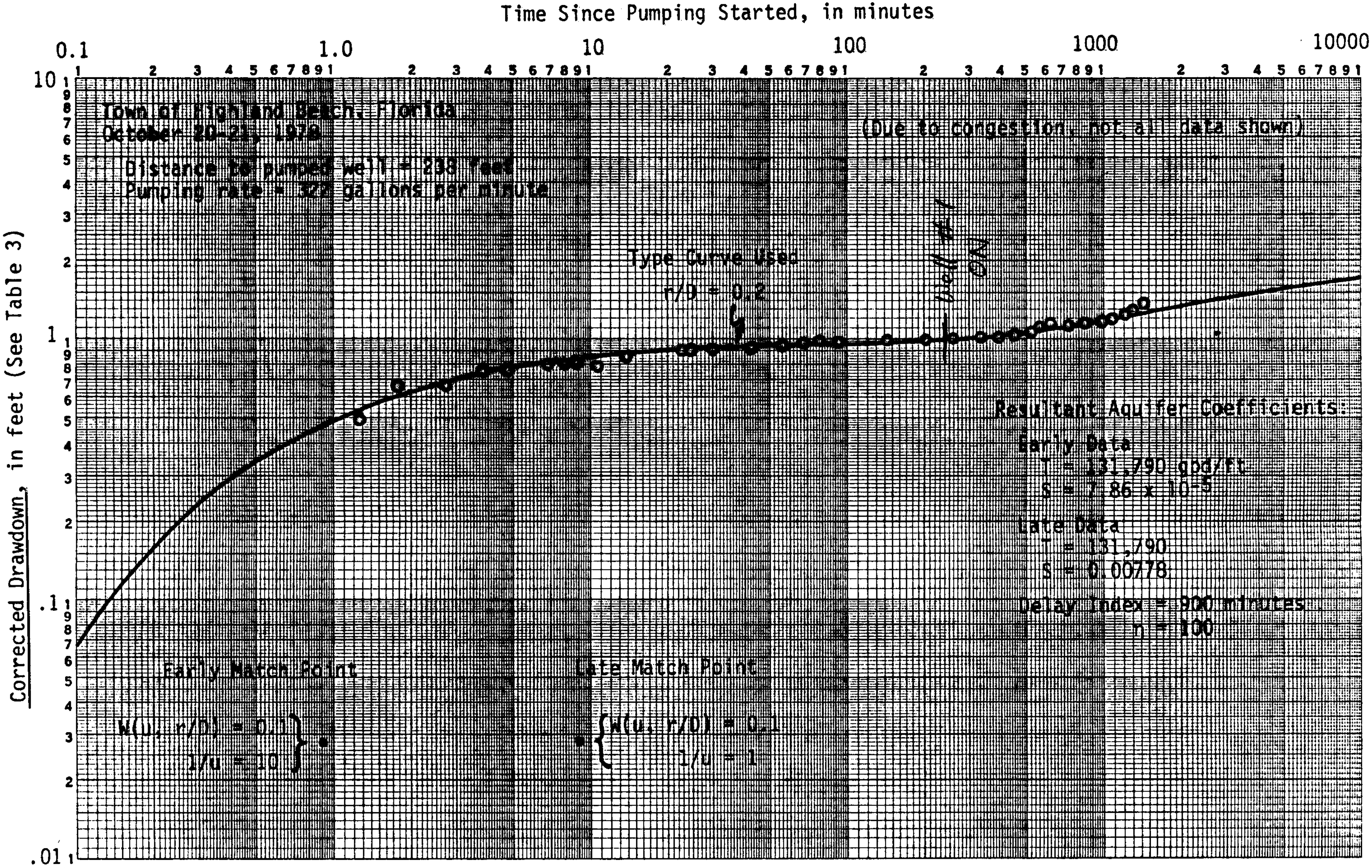


Figure 2. Time-drawdown graph for Well Number 5 used as an observation well during pumping of Well Number 4

One will note that the drawdown data prior to 0.1 minutes in Figure 1 are below the type curve. We believe this is delayed observation well response due to inertia, frictional loss in the casing, float damping, and storage of casing water effects.

One will also notice, in both Figure 1 and 2, that the drawdown data is rising slightly above the type curves near the end of the test, generally in the time region greater than 600 minutes after pumping started. We believe this deviation is due to the additional drawdown effects of Highland Beach Well Number 1.

No Correction for Well #1 ??

In actuality, there are several small water-level fluctuations taking place in the observation wells that are not greatly apparent in Figures 1 and 2.

Figure 3 shows a semilogarithmic plot of time-drawdown data in the 4-inch observation well. This plot is shown at an enlarged scale to illustrate the deviations of interest. For purposes of discussion, we have labeled portions of the curves shown in Figure by the letter A through D. Curve A is a straight line wherein Jacob's modified nonequilibrium formula was used to calculate early time-drawdown data unaffected by delayed yield (see Cooper and Jacob, 1946). The oscillations around this straight line apparently are due to the float characteristics. Note that the resultant transmissivity and early storage coefficient reasonably matches those calculated in Figure 2.

$u < 0.01$ at 1.75 for S_E 4.9×10^{-5} and at 322 min for $S_2 = 0.$

$u = \frac{r^2 S}{4Tt} < 0.1$

Curve B (the dashed curve) represents the average time-drawdown data around which water levels fluctuate due evidently to tidal phenomena. First, note that there is an apparent sinusoidal variation

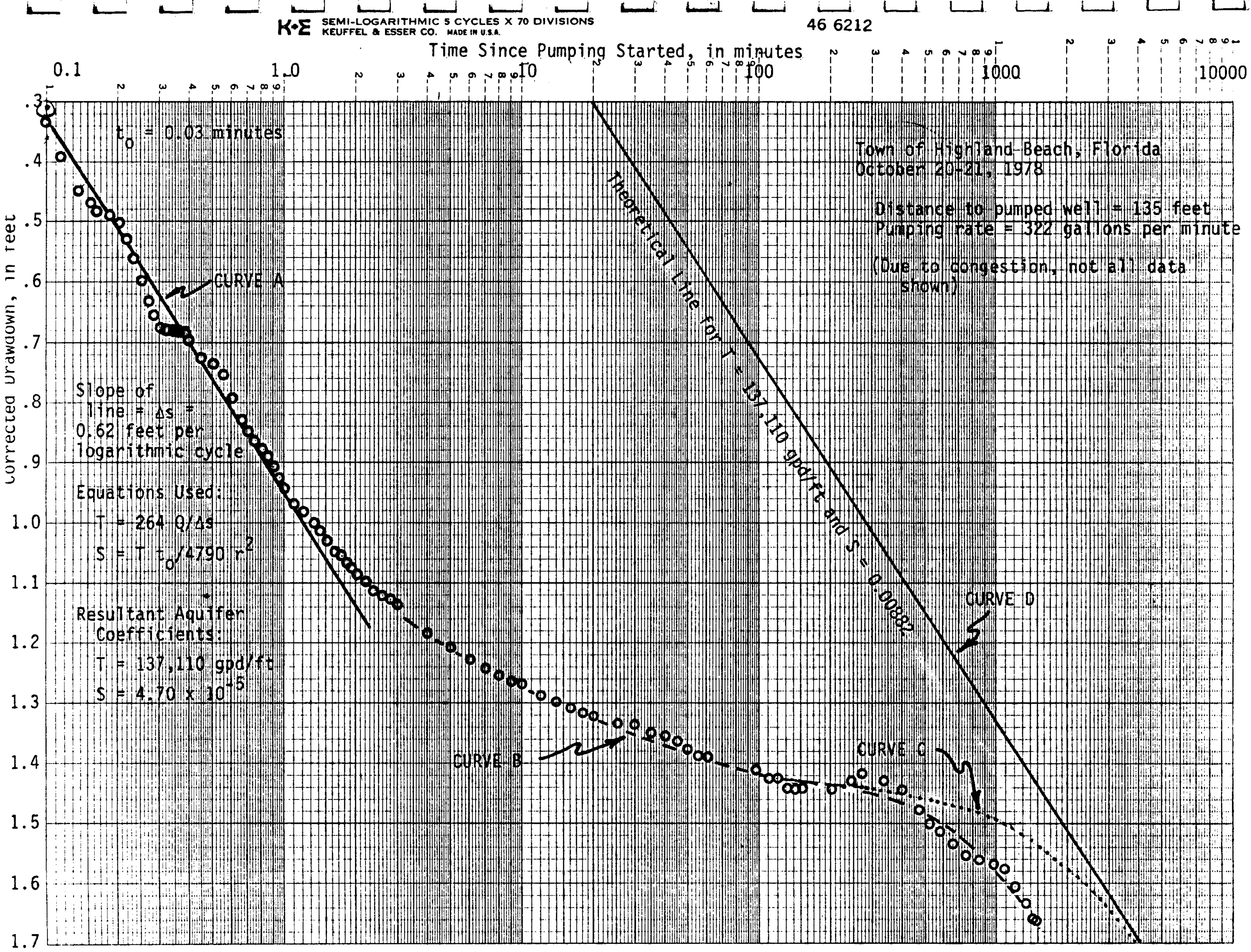


Figure 3. Time-drawdown graph for 4-inch test well used as an observation well during pumping of Well Number 4

around the average Curve B in the time range greater than about 150 minutes. The maximum deviations from the average (Curve B) occur at about 300, 760, 1050, and 1400 minutes. The high and low tides, as shown in Appendix B, have time differences that are in synchronization with the Figure 3 variations about the average. The lag time (see Todd, 1959) of the water-level fluctuation behind the tide fluctuations was calculated to be about 26.5 hours, using an effective distance to the tidal source (approximate centroid of canals, intercoastal and ocean system) of about 3800 feet from the observation well, and the transmissivity and late storage coefficient of Figure 1. The range of tidal fluctuations at the observation well (about 0.05 feet) was in the proper range using the same above coefficients and realizing that the nearest tidal effects are coming from canals as close as 1,600 feet away.

Upon examination of the barometric pressure readings (see Appendix C), one may expect that there may be some barometric efficiency effects causing the oscillating deviations about the average Curve B line of Figure 3. This is not the case. Plots of barometric pressure changes were plotted against the deviations and, although there is some correlation, the fluctuations are about 2 hours out of phase. Barometric pressure changes cause immediate water level changes in observation wells in artesian cases and no changes in water-table cases. Thus the atmospheric pressure changes are not directly the cause of the oscillations noted.

No corrections made as a result of these

Barometric pressure changes, however, are known to affect the height of ocean tides. There may thus be some indirect pressure change effects on the observation well water levels via their effects on ocean tides (see Vacher, 1978).

Curve D illustrates the line parallel to which the type curve of Figure 1 would approach. Curve C illustrates, beginning at about 250 minutes, where the approximate time-drawdown curve should have gone in the absence of pumping from Highland 322 + 393 = 715 gpm at 240 min Beach Well Number 1. The vertical difference between Curves B and C represents the effects due to Well Number 1. An analysis of the difference between Curves B and C indicates that the canal system near Well Number 1 is also involved. Separating canal related effect (at least as a partial image well type of constant head boundary analysis) near Well Number 1 complicates the analysis.

A final word is necessary concerning the effects of partial penetration in the analyses. According to the construction features of the wells involved in Appendix A, Wells Number 4 and 5 have 20 feet of strainer, the bottoms of which are set at 104 feet below land surface. The 4-inch observation well is believed to be open hole construction from a depth of 45 feet to the bottom at 105 feet below land. Little is know about the thickness of the shallow aquifer at Highland Beach. However, based upon Schroeder, et al. (1954), we have assumed an aquifer thickness of about 220 feet. This would make Wells Number 4 and 5 partially penetrating to the extent of about 9 percent and the 4-inch observation well at about 30%.

No corrections made as a result of this

Despite these small penetrations, distortions in the magnitudes of drawdowns at the observation wells were not apparent (essentially the same T and S). All wells terminating at the same depth may be the reason why this is so. It would be possible to analyze this test on the basis of partially penetrating wells in a water-table aquifer. However, one would then face the complicating two-layer sand and rock situation.

B. Analysis Of Time-Recovery Data.

Well Number 4 was shut off at 10:15 AM EDST on October 21, 1978. Recovery of water levels were plotted from Tables 6, 7, and 8 on both logarithmic and semilogarithmic paper. One such plot is shown in Figure 4. Uncorrected recovery (the difference in the water level at the end of pumping and the water levels thereafter) were used in this illustration. Not a great deal of difference in calculated aquifer properties is noted from this plot as would be calculted from corrected (for trend) recovery. The deviation of recovery above the chosen r/D=0.1 type curve after about 100 minutes is due to the continuing tidal effects which were rising in this time interval also.

C. Railroad Traffic Nearby APT Site.

Water levels in all wells in the Highland Beach well field are affected by passing trains on several tracks east of the well field. Numerous trains passed throughout the APT with resulting short term effects. Figure 5 illustrates typically one of the water level

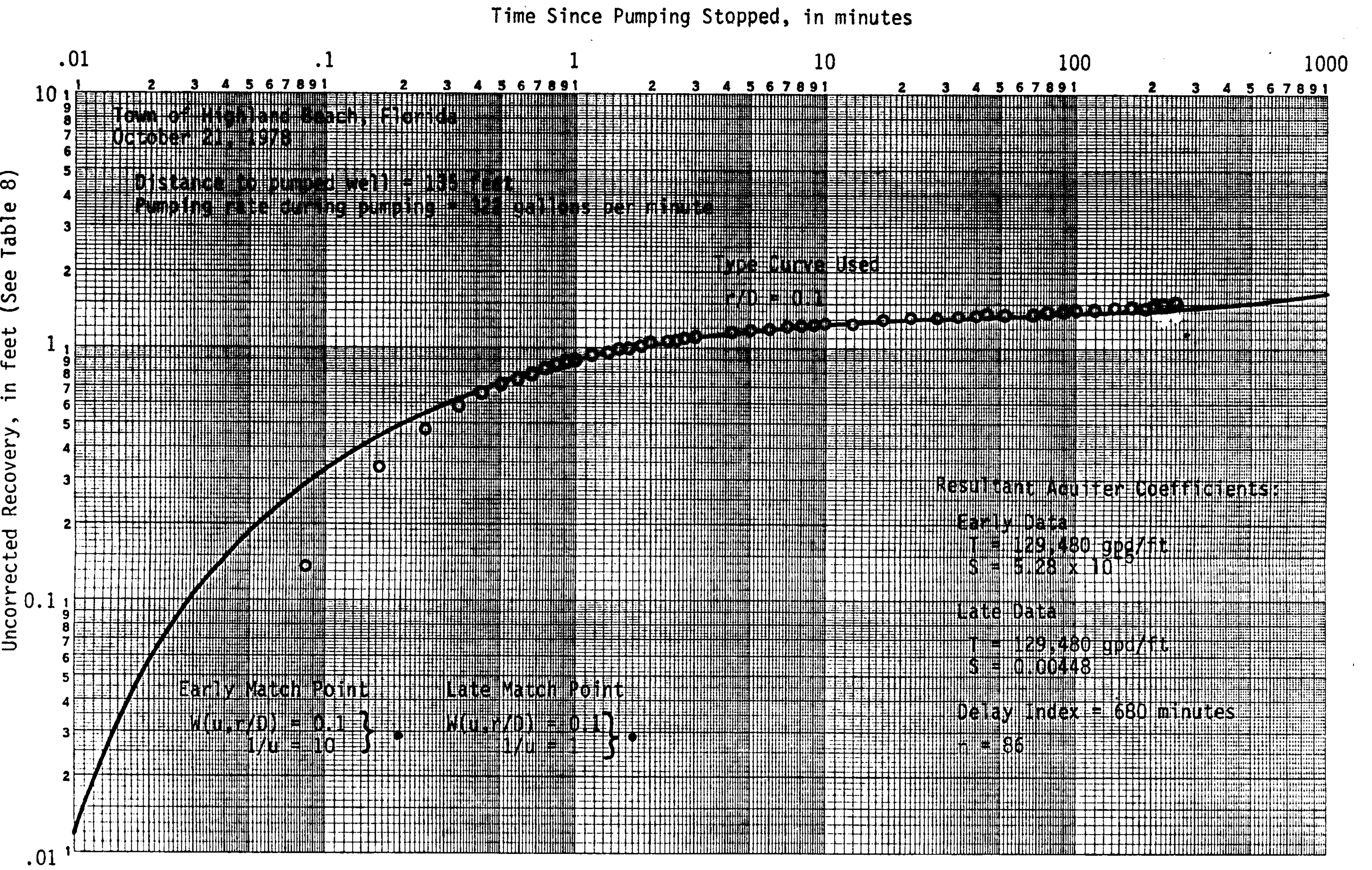


Figure 4. Time-recovery graph for 4-inch diameter test well used as an observation well after pumping at Well Number 4 stopped

fluctuations due to a passing train during the recovery portion of the APT at about 2:09 PM on October 21, 1978.

Figure 5 is a classical example of an artesian aquifer response near a railroad with a passing train. The only unusual added characteristic of the water level response is the damped oscillations of the float-counterweight-recorder system. One should make special note of oscillations being greater as water levels rise as opposed to when they fall.

The water levels of Tables 2, 3, 5, 6, 7, and 8 contain data taken only when trains were not present, with one exception as noted near the 129 minute mark in the pumping portion of the APT.

The long-term implication of the Florida East Coast Railroad upon salt-water encroachment should be investigated.

D. Summary Of Calculated Aquifer Coefficients And Final Discussion Of Results.

Table 9 lists the aquifer coefficients calculated. We did not list hydraulic conductivity as one of the coefficients, as we feel the aquifer thickness is not adequately defined. If one assumes the 220 foot thickness mentioned previously and the average transmissivity of 131,480 gpd/ft of Table 9,the hydraulic conductivity calculates to be about 600 gpd/ft^2, a rather low value. Not knowing the actual aquifer thickness severely hampers an analysis of the entire test and the basis of any partially penetrating theory. When this information becomes available, the test should be reevaluated.

The average delay index of 873 minutes fits with a scenario of the water table varying within very fine to fine sand and is

Table 9 Summary of Aquifer Coefficients

	Data From Well Number	Transmissivity (gpd/ft)	Early Storage Coefficient	Late Storage Coefficient	Delay Index (minutes)	n	Type of Analysis	
	4-inch	127,250	4.93×10^{-5}	0.00882	1360	180	Time-drawdown (log-log plot)	} Boulton
? Readings	5	131,790	7.86×10^{-5}	0.00778	900	100	Time-drawdown (log-log plot)	
	4-inch	137,110	4.70×10^{-5}	---	---	---	Time-drawdown (semilog plot)	
	4-inch	129,480	5.28×10^{-5}	0.00448	680	86	Time-recovery (log-log plot)	
? Readings	5	131,790	----	0.00475	550	---	Time-recovery (log-log plot)	
		131,480	5.69×10^{-5}	0.00646	873	122	AVERAGE OF ABOVE	

No partial penetration correction

Town of Highland Beach, Florida
Aquifer Performance Test of October 19-21, 1978

IL BORING
CORE DRILLING
TEST DRILLING
ALSAY DRILLING, Inc.
WATER WELLS
A NAME TO REMEMBER
INDUSTRIAL — PUMPS — RESIDENTIAL
O. BOX 1226
LAKE WORTH, FLORIDA 33460

DRILLING LOG HIGHALND BEACH *wells 4 & 5*

8" WELL #5
5/28/71

DEPTH	DESCRIPTION
0- 5	Top Soil, white sand
5-10	Brownish sand
10-15	Brownish sand
15-20	Brownish sand
20-25	Brownish sand
25-30	Brownish sand
30-35	White layers rock
35-40	White layers rock
40-45	" " " "
45-50	" " " "
50-55	" " " "
55-60	" " " "
60-65	" " " "
65-70	" " " "
70-75	" " " "
75-80	" " " "
80-85	" " " "
85-90	" " " "
90-95	" " " "
95-100	" " " "
100-104	" " " "

NOTE: Casing installed to 54' depth and 20' well screen added.

An interview by T.A. Prickett with the drilling company indicates that 85 feet of casing and 20 feet of strainer is installed in this well. The above information was an estimate by the driller at the time the well was drilled and does not match the final construction. The size of the strainer is unknown.

PB 85

ORING CORE DRILLING TEST DRILL

'ALSAY DRILLING, Inc.

WATER WELLS

A NAME TO REMEMBER

INDUSTRIAL—PUMPS—RESIDENTIAL

OX 1226 LAKE WORTH, FLORIDA 33460

May 11, 1971

HIGHLAND BEACH DRILLING LOG 4" TEST WELL

DEPTH	DESCRIPTION
0 - 5	Top Soil
5 - 10	Brown Sand
10 - 15	Brown Sand
15 - 20	Brown Sand
20 - 25	White sand some shell
25 - 30	White sand some shell
30 - 35	White sand some shell
35 - 40	White Layers rock
40 - 45	" " "
45 - 50	" " "
50 - 55	" " "
55 - 60	" " "
60 - 65	" " "
65 - 70	" " "
70 - 75	" " "
75 - 80	" " "
80 - 85	" " "
85 - 90	" " "
90 - 95	" " "
95 -100	" " "
100 -105	" " "

An interview with the well driller indicates that no record exists for the construction features of this well---however, the driller believes the casing length is about 40 feet in length below land surface and that the remaining is open hole.

PB85

L BORING
CORE DRILLING
TEST DRILLING
ALSAY DRILLING, Inc.
WATER WELLS
A NAME TO REMEMBER
INDUSTRIAL —PUMPS— RESIDENTIAL
LAKE WORTH, FLORIDA 33460
O. BOX 1226

DRILLING LOG HIGHLAND BEACH

8" WELL #4
5/28/71

DEPTH	DESCRIPTION
0- 5	Top soil, white sand
5-10	Brownish sand
10-15	Brownish sand
15-20	Brownish sand
20-25	Brownish sand
25-30	Brownish sand
30-35	White layers rock
35-40	White layers rock
40-45	" " " "
45-50	" " " "
50-55	" " " "
55-60	" " " "
60-65	" " " "
65-70	" " " "
70-75	" " " "
75-80	" " " "
80-85	" " " "
85-90	" " " "
90-95	" " " "
95-100	" " " "
100-104	" " " "

NOTE: Casing installed to 54' depth and 20' well screen added.

An interview by T.A. Prickett with the drilling company indicates that 85 feet of casing and 20 feet of strainer is installed in this well. The above information was an estimate by the driller at the time the well was drilled and does not match the final construction. The size of the strainer is unknown.

PB85

account, Glover (1964) developed the following approximate equation for the shape of the freshwater-saltwater interface

$$z^2 - \frac{2qx}{(\rho_s - \rho_f)K} - \frac{q^2}{(\rho_s - \rho_f)^2 K^2} = 0 \qquad (11.7)$$

where q = flow in aquifer per unit length of shoreline
K = hydraulic conductivity of aquifer
x, z = coordinate distances from shoreline (Figure 11.6)

For freshwater aquifers in contact with seawater, $\rho_s - \rho_f = 0.025$. Substituting $z = 0$ in Eq. (11.7) yields

$$W = \frac{q}{2(\rho_s - \rho_f)K} \qquad (11.8)$$

for the width W of the bottom zone through which fresh water seeps into the ocean. The depth z_0 of the freshwater-saltwater interface beneath the shoreline is calculated as

$$z_0 = \frac{q}{(\rho_s - \rho_f)K} \qquad (11.9)$$

by substituting $x = 0$ in Eq. (11.7). The interface position calculated with Eq. (11.7) is closer to the ocean than that obtained with Eq. (11.6).

Exact solutions for the shape of the saltwater front were obtained by Henry (1959; see also Pinder and Cooper, 1970) using conformal mapping and assuming a sharp interface. Pinder and Cooper (1970) developed a numerical model for predicting movement of saltwater fronts in coastal aquifers. The alternating-direction iterative procedure used in this model enabled inclusion of dispersion, transient flow, and nonhomogeneous or irregularly shaped aquifers in the solutions.

Upconing

When fresh groundwater is underlain by saline water, pumping a well in the freshwater zone causes the freshwater-saltwater interface to rise below the well (Figure 11.7). This "upconing" is in response to the pressure reduction on the interface due to drawdown of the water table around the well. If the bottom of the well is close to the saline water or the well discharge is relatively high, the saltwater cone may reach into the well, causing the well discharge to be a mixture of fresh and saline groundwater.

Assuming steady, horizontal flow of fresh water to the well, no lateral movement of salt water, and a sharp interface, the height z of the cone below the well center can be calculated in the same manner as the Ghyben-Herzberg lens, yielding

$$z = \frac{\rho_f s_w}{\rho_s - \rho_f} \qquad (11.10)$$

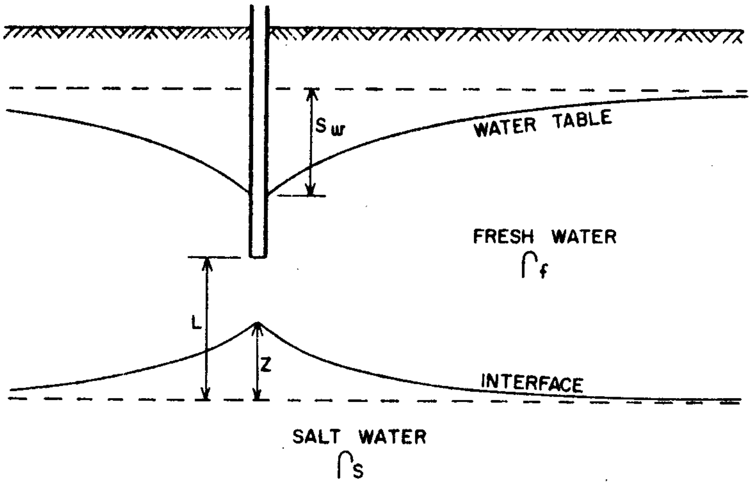


Figure 11.7 Geometry and symbols for upconing of salt water beneath a pumped well (dashed lines represent static positions of water table and interface).

where s_w = drawdown of water table at well. A more rigorous solution for upconing of saline water was developed by Bear and Dagan (1968), who presented the following equation for the rise of the cone below the center of the well (modified from the equation given by Schmorak and Mercado, 1969):

$$z_t = \frac{\rho_f Q}{2\pi(\rho_s - \rho_f)K_x L}\left(1 - \frac{2\rho_f nL}{2\rho_f nL + (\rho_s - \rho_f)K_z t}\right) \tag{11.11}$$

where z_t = rise of cone center at time t
Q = well discharge
L = depth of freshwater-saltwater interface below well bottom prior to pumping
K_x = K of aquifer in horizontal direction
K_z = K of aquifer in vertical direction
n = porosity of aquifer
ρ_s = density of salt water
ρ_f = density of fresh water
t = time since start of pumping

For $t = \infty$, Eq. (11.11) becomes

$$z_\infty = \frac{\rho_f Q}{2\pi(\rho_s - \rho_f)K_x L} \tag{11.12}$$

where z_∞ is the ultimate or equilibrium height of the saline-water cone below the well center. Values of z calculated with Eq. (11.11) agreed with field measurements up to some critical cone height, which generally was between $0.4L$ and $0.6L$ (Schmorak and Mercado, 1969). Similar results were obtained by Haubold (1975) using a Hele-Shaw model. When the cone height exceeded this critical value, z was no longer linear with Q and in some cases the cone reached the bottom of the well with a sudden jump, indicating conditions of instability. Saline water then entered the well, which in the studies by Schmorak and Mercado (1969) increased the salinity of the well discharge by 5 to 8 percent of the salt concentration of the saline water. Thus, where fresh groundwater is underlain by saline water, prediction of upconing is important for determining safe depths and pumping rates of wells (including "skimming" wells) that prevent entry of saline water into the well.

11.3 ROAD SALT

Another source of salt contamination of groundwater is the salt applied to snow- or ice-covered roads to provide "June driving conditions in January" (Field et al., 1974 and 1975). The bare-pavement policy of many highway departments in snowbelt states has resulted in greatly increased use of de-icing salts and less use of sand or other abrasives. The salts consist mostly of commercial rock salt and marine salt. Ferric ferrocyanide and sodium ferrocyanide are added to minimize caking of salt stocks. The sodium ferrocyanide is water-soluble and when exposed to sunlight it can generate cyanide in concentrations that are in excess of maximum limits for drinking water (Field et al., 1974, and references therein). Other additives include chromate and phosphate, which are used to reduce the corrosiveness of the salt. The chromate can produce excessive concentrations of hexavalent chromium in the melt water.

Highway salting rates generally range from 100 to 300 kg/km per application (Field et al., 1974, and references therein). In a winter season, roads may receive 10 000 kg of salt per lane per kilometer, which adds up to about 50 000 kg/km for typical highways. Chloride levels in road runoff during snow melt have been observed to range from 1 130 to 25 100 mg/l (Field et al., 1974, and references therein). Upon infiltration, this runoff and the leachate from exposed, year-around stockpiles of salt can seriously contaminate groundwater. Many such cases have been reported.

Field et al. (1974) alone cite and discuss over 20 references on the subject. In Massachusetts, for example, increases in the salt content of groundwater have been observed in more than 60 communities, forcing the abandonment of various wells. The city of Burlington, Massachusetts, suspended road salting when chloride contents in its wells began to increase to levels that eventually could exceed the maximum concentration of 250 mg/l for drinking water. In the town of Becket, the chloride content of water from a well increased to 1 360 mg/l due to salt storage upgradient from the well. For communities around Boston, road salting may eventually increase average concentrations of NaCl in groundwater from the natural 50 to 100 mg/l range to about 160 mg/l (Huling and Hollocker, 1972). Concentrations in excess of 59 mg/l are undesirable for heart patients and other persons restricted to a sodium intake of less than 1 g/day. Salt-contaminated

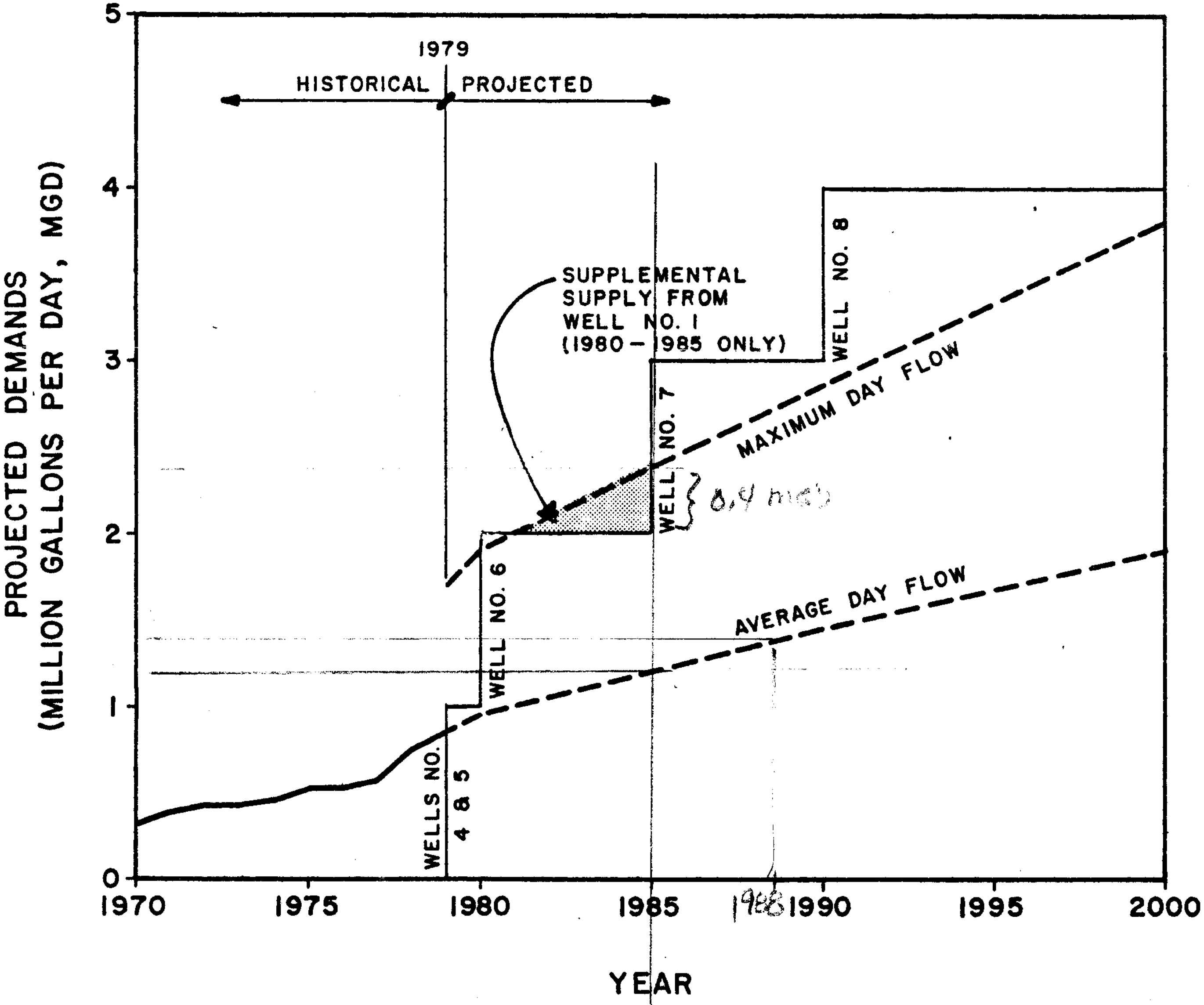


FIGURE 6-3 WATER DEMANDS AND WELL CONSTRUCTION SCHEDULE

CDM
environmental engineers, scientists, planners, & management consultants

ROSS SAARINEN BOLTON & WILDER
a Camp Dresser & McKee firm

P.O. Box 9626
Fort Lauderdale, Florida 33310
305 776-1731

February 15, 1979

HAND DELIVERED
Mr. Vern Kaiser
Water Resource Technician Supervisor
Resource Control Department
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

Highland Beach, Florida
Permit No. 50-00346-W

Dear Mr. Kaiser:

On behalf of the Town of Highland Beach, we would like to respond to the District's staff report covering the referenced permit application. The Town is satisfied with the amount and time period of the staff's recommended water allocation. However, certain statements and special conditions contained in the staff report seem to be excessively conservative and, in our opinion, are not in the best interest of the Town.

The first sentence on page 6 of the staff report reads, "The staff recommends that withdrawals be made from the western well field and that wells 1, 2, and 3 be used only on an emergency basis due to their close proximity to a saline water source." This statement has a tremendous economic impact on the Town of Highland Beach in that it terminates usage, except on an emergency basis, of approximately $250,000 worth of wells having a capacity of 1.22 MGD.

Both the Town and RSBW recognize the proximity of the east well field to the tidal canals. As in the past, the west well field will continue to be the main production field and the site for future wells. However, we propose that the east well field be used only during maintenance, peak, and emergency periods.

Attached to this letter is a figure showing projected water demands and the proposed well construction schedule for Highland Beach. This figure is taken from our ongoing design report on the Highland Beach Water Treatment Plant and Well Field Expansion. Existing western wells no. 4 and 5 have a design capacity of 250 gpm each but are able to produce 320 gpm each (0.92 MGD total) due to low friction loss in the 12-inch raw water transmission line. By the year 1980, an additional well with a 1.0 MGD capacity will be added in the western well field. Pumps on wells no. 4 and 5 will be replaced to give them a total design capacity of 1 MGD after the 1980 western well field expansion. An additional 1 MGD well in the western well field will be added in 1985 bringing the well field's total capacity to 3 MGD.

A review of the 1978 Highland Beach daily raw water pumpage records revealed that only 23 days were in excess of 0.92 MGD and only two days were in excess of 1.0 MGD. Assuming that demand in excess of 0.92 MGD was supplied by well no. 1 which has a capacity of 350 gpm (0.5 MGD), and that the total demand was 1 MGD, well no. 1 would operate for about four hours. This amount of operation is very minimal and is barely above the amount needed to maintain the pump in working order.

It will not be possible for demands during 1979 to be as high as is indicated on the attached figure. This is due to restrictions on the water treatment plant capacity. We anticipate that water usage during 1979 will increase only moderately in spite of continued growth due to further implementation of water conservation measures by the Town.

The eastern well field will be required to meet maximum and near maximum day demands above 2 MGD from 1981 to 1985. Supplemental supply required from the eastern well field is shown on the attached figure. As was the case in 1978, pumpage from the eastern well field would be minimal. The greatest dependence on the eastern well field would be during 1985 when a flow of approximately 0.4 MGD would be required on maximum day. The 0.4 MGD amount is based on a maximum day to average day ratio of 2.0. There is a high probability that this ratio and the associated eastern well field pumping will be less.

Both the U.S.G.S. monitoring wells in the vicinity of the eastern well field and the three production wells serve as monitoring wells. These monitoring wells insure that any movement of the saltwater front toward the eastern well field would be detected. For this reason and the fact that usage would be very small, infrequent, and required only through 1985, we request that the first sentence on page 6 of the staff report be amended to read, "The staff recommends that withdrawals be made from the western well field and that wells 1, 2, and 3 be used only during maintenance, peak, and emergency periods due to their close proximity to a saline water source."

We request that the time constraint of special condition number 24 be restated.to read, "The monitoring well shall be constructed and operable at the time of completion of a new well in the western well field." Although we feel that an additional well will be constructed in the western well field within one year, it is not certain at this time. Therefore, it is possible that the deep monitoring well will not be required in one year if delays are encountered in the well field expansion.

Two corrections should be noted. On page 1, the total design withdrawal capacity is 1350 gpm (1.95 MGD). The individual well design capacities are:

Well No.	Capacity
1	350 gpm
2	250 gpm
3	250 gpm
4	250 gpm
5	250 gpm

On page 3, the year for which the use was 273 MGY was 1978 and not 1977.

We appreciate your consideration of our requested wording changes in the District's staff report. Although we feel these changes are important and appropriate, we wish to emphasize that the Town has far more concern for the immediate approval of the staff's recommended annual allocation. Prompt approval of the staff's recommended annual allocation is crucial to the timely completion of our design report on the Highland Beach Water Treatment Plant and Well Field Expansion and the subsequent bond referendum to finance the needed improvements. It is not our intent to hinder in anyway the Governing Board's approval of the annual allocation.

We are available at your convenience to discuss our requested amendments to the staff report. Please contact us if you have any questions.

Sincerely,

ROSS, SAARINEN, BOLTON & WILDER

John L. Roberts

JLR/dl

Enclosure

File: RSBW 306-78-52

cc's: Ms. Elaine W. Roberts, w/enc. - Hand Delivered
Dr. Patrick J. Gleason, w/enc. - Hand Delivered

bc's: Arthur W. Saarinen, Jr., w/enc.
Thomas A. Prickett, w/enc.

Highland Beach   4" Observation Well

Neuman Analysis

Q = 322 GPM
r = 135 ft   b = 207 ft
β = .001

✓ t = 1   Sd = 4.1 ✓
S = 1   ts = 100 ✓

$$T = \frac{114.6\ Q\ s_d}{S}$$
$$= \frac{114.6(322)(4.1)}{1}$$
$$= 151{,}294 \text{ GPD/FT} \checkmark \quad (20{,}227 \text{ FT}^2/\text{DAY})$$

$$S = \frac{Tt}{2693 r^2 t_s}$$
$$= \frac{151{,}294\ (1)}{2693(135)^2(100)}$$
$$= 3.08 \times 10^{-5} \checkmark$$

$$\beta = \frac{r^2}{b^2}\left(\frac{K_z}{K_H}\right) = \frac{(135)^2}{(207)^2}\left(\frac{K_z}{K_H}\right)$$

$$\frac{K_z}{K_H} = \frac{(207)^2}{(135)^2}(.001) = .0024 \checkmark$$

$$K_H = \frac{T}{b} = \frac{151294}{207} = 731 \text{ GPD/FT}^2 \checkmark$$

$$K_z = .0024\ (731) = 1.8 \text{ GPD/FT}^2$$

Good Match (3)

~~Neuman II~~   ~~β = .01~~

~~t = 1 min   Sd = 6.5~~
~~s = 1 ft   ts = 3.5~~

$$\cancel{T = \frac{Q\ s_d}{4\pi s} = \frac{(322 \text{ GPM})(6.5)}{4\pi(1 \text{ ft})} = 166 \frac{\text{GPM}}{\text{ft}} = 239{,}962 \frac{\text{GPD}}{\text{FT}}}$$

$$\cancel{K_H = \frac{T}{b} = \frac{239{,}962 \text{ GPD/FT}}{207 \text{ FT}} = 1159 \text{ GPD/FT}^2 = 154 \text{ FT/day}}$$

Highland Beach APT | 4" Observation Well

Streltsova I

$r = 135\ ft$
$Q = 322\ gpm = 43.05\ ft^3/min$ ✓
✓ $\gamma' = .4$
✓ $l' = .4$
$\beta' = .05$
$b = 207\ ft$

✓ $s = .63\ ft$ $\quad \theta = 1$ ✓
✓ $t = .027\ min$ $\quad W = 1$ ✓

$$T = \frac{WQ}{4\pi s l'}$$

$$= \frac{(1)(43.05\ ft^3/min)}{(4)(\pi)(.63\ ft)(.4)} = \boxed{13.59\ ft^3/min\text{-}ft} ✓ \times 7.48\ g/ft^3 = \boxed{101.69\ gpm/ft} ✓$$

19586 $\frac{FT^2}{DAY}$

$\times$ 1440 m/d
$= \boxed{146,429\ gpd/ft}$ ✓

$$S = \frac{4Tt}{\theta r^2}$$

$$= \frac{(4)(13.59\ ft^3/min\text{-}ft)(.027\ m)}{(1)(135\ ft)^2} = \boxed{8.05 \times 10^{-5}} ✓$$

$K_h = T/b$
$= \frac{146,429\ gpd/ft}{207\ ft}$
$= \boxed{707.4\ gpd/ft^2}$ ✓
94.6 ft^2/day

$\beta = \beta' b$
$= (.05)(207\ ft)$
$= 10.35\ ft$

$\beta = \sqrt{K_v/K_h}\ r$
$\frac{10.35\ ft}{135\ ft} = \sqrt{K_v/K_h}$
$\boxed{K_v/K_h = .0059}$ ✓

$K_v = (K_v/K_h)(K_h)$
$= (.0059)(707.4\ gpd/ft^2)$
$\boxed{= 4.16\ gpd/ft^2}$ ✓ ✓
.56 FT/day

Good Match (3)

Streltsova II

$Z' = .44$
✓ $l' = .44$
✓ $l' = .35$
$\beta = .05$

✓ $t = 1\ min$ $\quad W = .9$ ✓
✓ $s = 1\ ft$ $\quad \theta = 14.8$ ✓

$$T = \frac{WQ}{4\pi s(l' - l')}$$

$$= \frac{(.9)(43.05\ ft^3/min)}{(4)(\pi)(1\ ft)(.44 - .35)} = \boxed{34.26\ ft^3/min\text{-}ft} ✓ \times 7.48\ g/ft^3 = \boxed{256.25\ gpm/ft}$$

49,357 ft^2/DAY

$\times$ 1440 m/d
$\boxed{= 369,001\ gpd/ft}$

$$S = \frac{4Tt}{\theta r^2}$$

$$= \frac{(4)(34.26\ ft^3/min\text{-}ft)(1\ min)}{(14.8)(135\ ft)^2} = \boxed{5.08 \times 10^{-4}} ✓$$

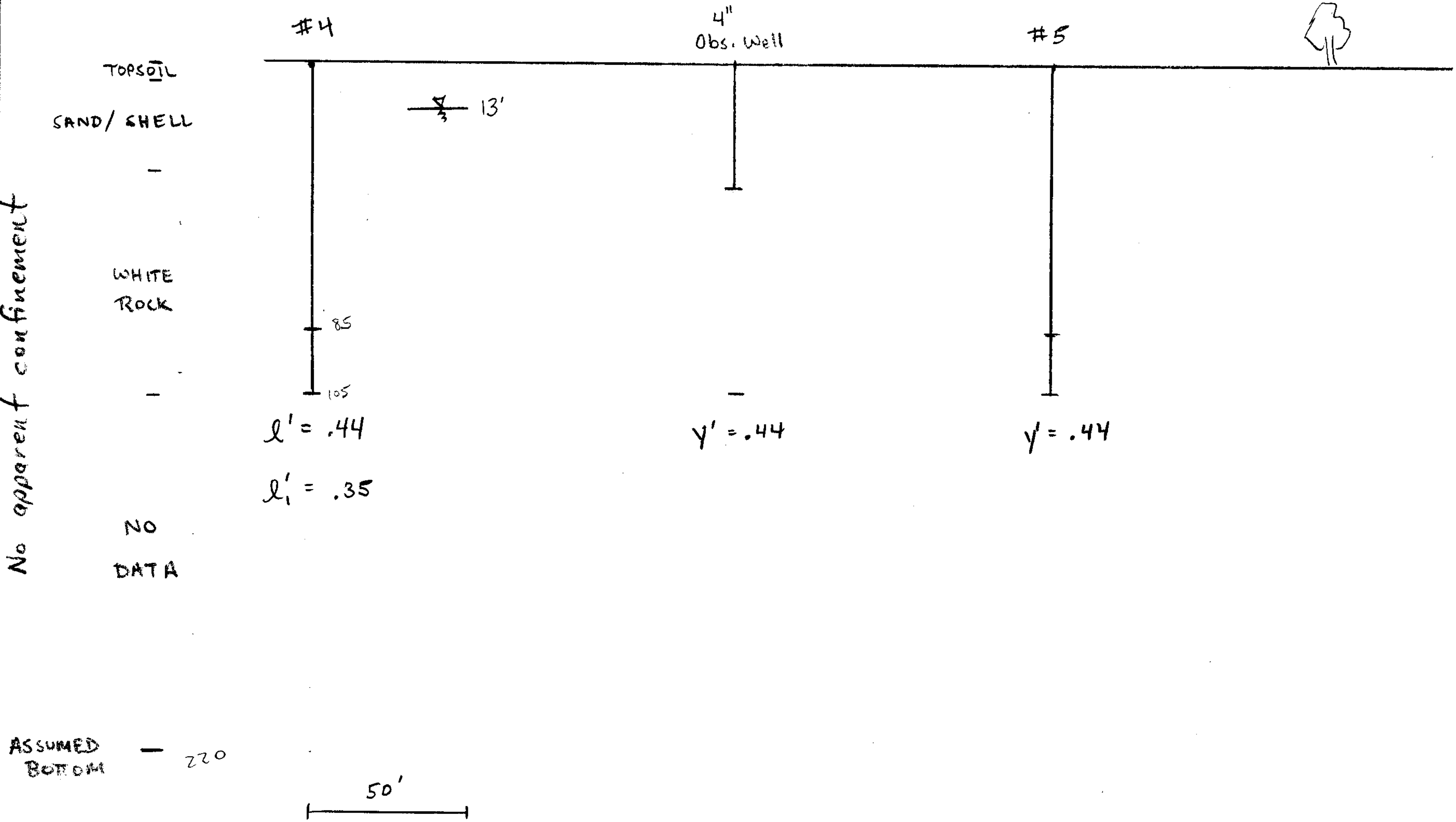
$K_h = T/b$
$= \frac{369,001\ gpd/ft}{207\ ft}$
$\boxed{= 1782.6\ gpd/ft^2}$ ✓

$K_v = (K_v/K_h)(K_h)$
$= (.0059)(1782.6\ gpd/ft^2)$
$\boxed{= 10.48\ gpd/ft^2}$ ✓

Good Match 3

Highland Beach APT PB85 Card 2

Q = 322 GPM   Duration = 25 hours



No apparent confinement

$$x = \tfrac{1}{2}(0.025)\left(\frac{y^2}{\gamma i}\right)$$

$$\cancel{y^2 -} \nabla^{0} \frac{2\varphi}{\gamma k} x - \left(\frac{\varphi}{\gamma k}\right)\left(\frac{\varphi}{\gamma k}\right) = 0$$

$$\frac{2\varphi}{\gamma k} x = -\left(\frac{\varphi}{\gamma k}\right)\left(\frac{\varphi}{\gamma k}\right)$$

$$2x = -\frac{\varphi}{\gamma k}$$

$$x = -\frac{1\varphi}{2\gamma k}$$

$$Y^2_1 - \frac{2\varphi}{\gamma k}(X) - \frac{\varphi}{\gamma k} \; \frac{\varphi}{\gamma k} = 0$$

$$\frac{\gamma k Y^2}{2\varphi} - X - \frac{\varphi}{\gamma k 2} = 0$$

$$X = \frac{\gamma k Y^2}{2\varphi} - \frac{\varphi}{\gamma k 2}$$

$$X = \frac{0.025 \quad Y^2 K}{2 \quad KIA} - \frac{KIA}{0.025\, K2}$$

$$X = \frac{0.025}{2} \frac{Y^2}{Id} - \frac{Id}{0.025(2)}$$

	#895	#1006	ΔX	ΔX/134' GRADIENT
Oct	2.98	1.93	1.05	7.83×10^{-3}
Nov	3.03	2.40	0.63	4.70×10^{-3}
Dec 77	3.04	2.26	0.78	5.82×10^{-3}
March 78	3.47	2.71	0.76	5.67×10^{-3}
May	2.36	1.80	0.56	4.18×10^{-3}
Aug	3.87	2.71	1.16	✓ 8.66×10^{-3}
Sept	3.04	2.49	0.55	✓ 4.10×10^{-3}
	3.11 AVE	2.33 ave	0.78 ave	5.83×10^{-3}

y	X $i = 4.10 \times 10^{-3}$ Low Gradient	$i = 8.66 \times 10^{-3}$ High Gradient
50	30'	-9'
75	84'	16'
100	160'	52'
125	258'	99'
150	378'	156'
175	519'	223'
	$X_0 = -14'$	$X_0 = -30'$

$$X = \tfrac{1}{2}(0.025)\left(\frac{y^2}{di}\right) - \frac{id}{0.025(2)}$$

X = Horizontal Distance from coast (ft)

y = Vertical Distance (ft) from top of Aquifer

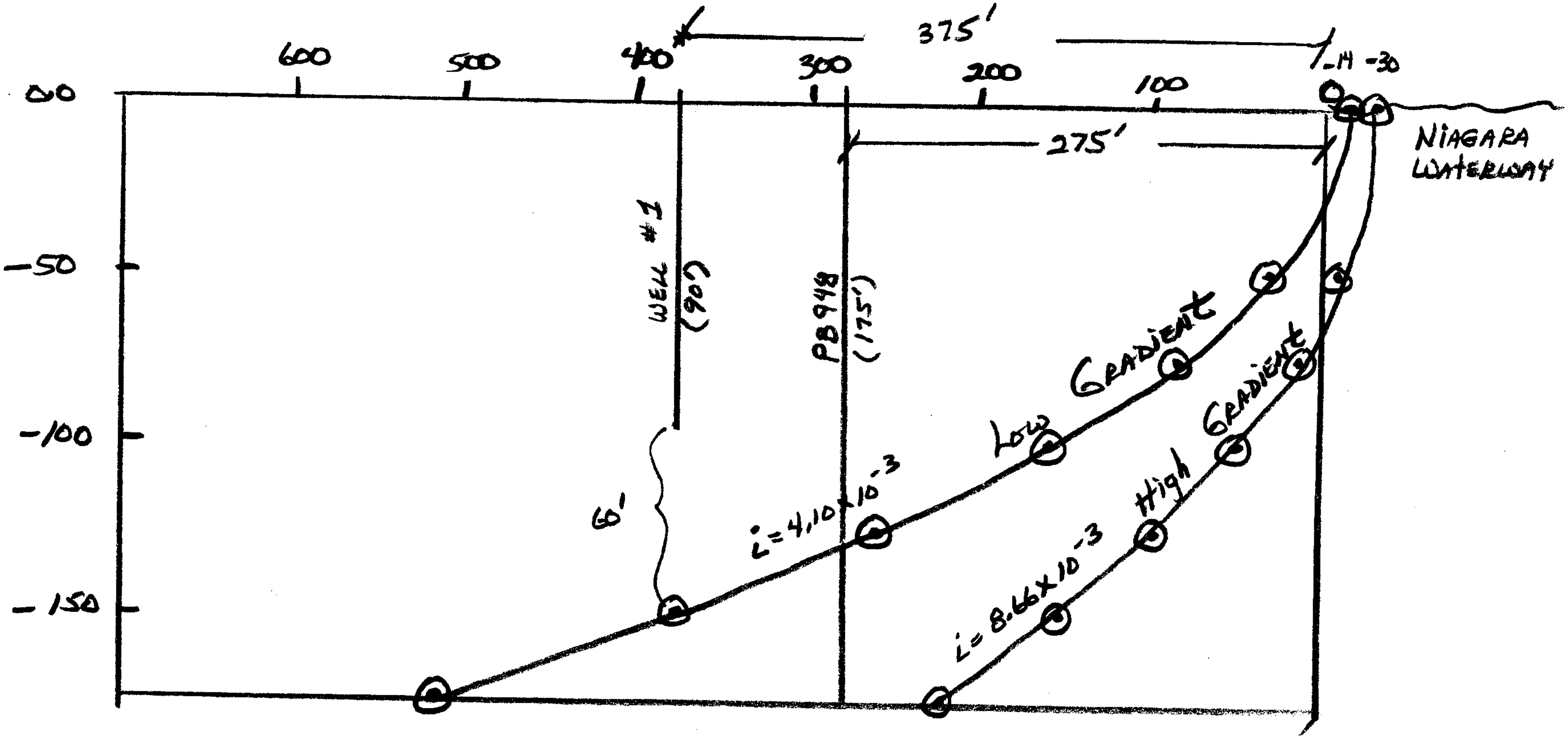
d = aquifer thickness (ft)

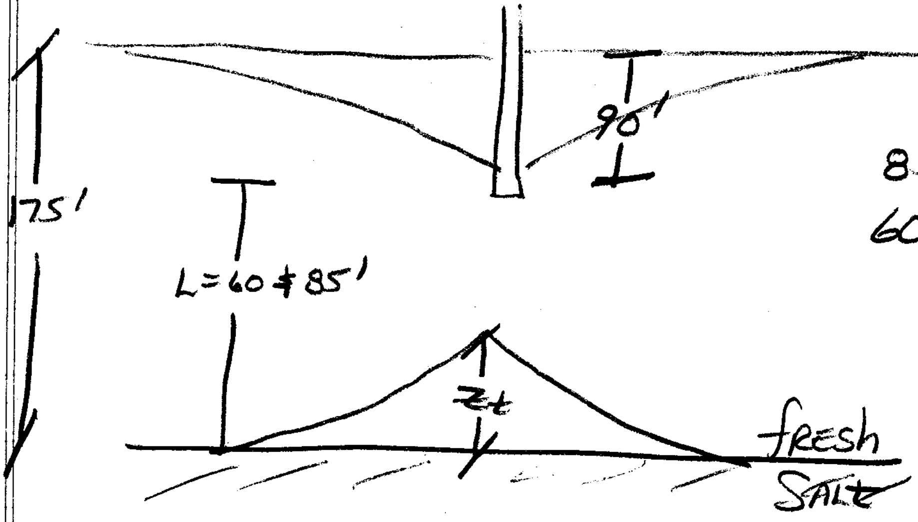
i = Gradient (ft/ft)

d = 175 ft.

$i = 4.10 \times 10^{-3}$

$$X_0 = -\tfrac{1}{2}\left(\frac{di}{0.025}\right)$$


375'
600
500
400
300
200
100
-14
-30
00
-50
-100
-150
275'
NIAGARA
WATERWAY
WELL #1
(90')
PB948
(175')
60'
i=4.10x10^-3
Low Gradient
High Gradient
i=8.66x10^-3



85' = 175 − 90
60' = 150 − 90

$$K_x = \frac{130{,}000}{175'}\ \frac{gal}{Day\text{-}ft} = 743\ \frac{gal}{Day\text{-}ft^2}$$

$$Q = 566{,}000\ gal/Day = 393\ gpm$$

$$\rho_f = 1.00$$

$$\rho_s = 1.025$$

$$\rho_s - \rho_f = 0.025$$

$$\text{for } K_z = \tfrac{1}{2} K_x = 372\ \frac{gal}{Day\text{-}ft^2}$$

$$\& \ K_z = K_x = 743\ \frac{gal}{Day\text{-}ft^2}$$

For L = 60'

$$Z_t = \frac{\rho_f Q}{2\pi(\rho_s - \rho_f)K_x L}\left(1 - \frac{2\rho_f n L}{2\rho_f n L + (\rho_s - \rho_f) K_z (t)}\right)$$

$$Z_t = \frac{(1.0)(566{,}000)}{2\pi(0.025)(743)(60)}\left(1 - \frac{2(1.0)(.2)(60)}{2(1.0)(.2)(60) + 0.025\left(\frac{372}{7.48}\right)(t)}\right)$$

$$Z_t = 80.8\left(1 - \frac{24}{24 + 1.24(t)}\right) \text{ for } K_z = 372$$

$$Z_t = 80.8\left(1 - \frac{24}{24 + 2.48(t)}\right) \text{ for } K_z = 743$$

$$ft = \frac{()\left(\frac{gal}{Day}\right)\left(\frac{Day\text{-}ft^2}{gal}\right)}{()\ (ft)}\left(1 - \frac{()()()(ft)}{()()()(ft) + ()\left(\frac{gal}{Day\text{-}ft^2}\right)\left(\frac{ft^3}{7.48\,gal}\right)(DAY)}\right)$$

t (Days)	Z_t for $K_3 = 372$	Z_t for $K_3 = 743$
1	3.9	7.6
10	27.5	41.0
100	67.7	73.7
1000	79.2	80.0
∞	80.8	80.8
8.18	24'	
15.55	36'	
4.09		24'
7.78		36'

Unstable at $Z_t = 0.4(60) = 24'$ to $0.6(60) = 36'$

For $L = 85'$

$$Z_t = \frac{1.0\ (566{,}000)}{2(\pi)(0.025)(743)(85)}\left(1 - \frac{2(1.0)(.2)(85)}{2(1.0)(.2)(85) + 0.025\,\frac{372}{7.48}(t)}\right)$$

$$Z_t = 57.05\left(1 - \frac{34}{34 + 1.24(t)}\right) \text{ for } K_3 = 372$$

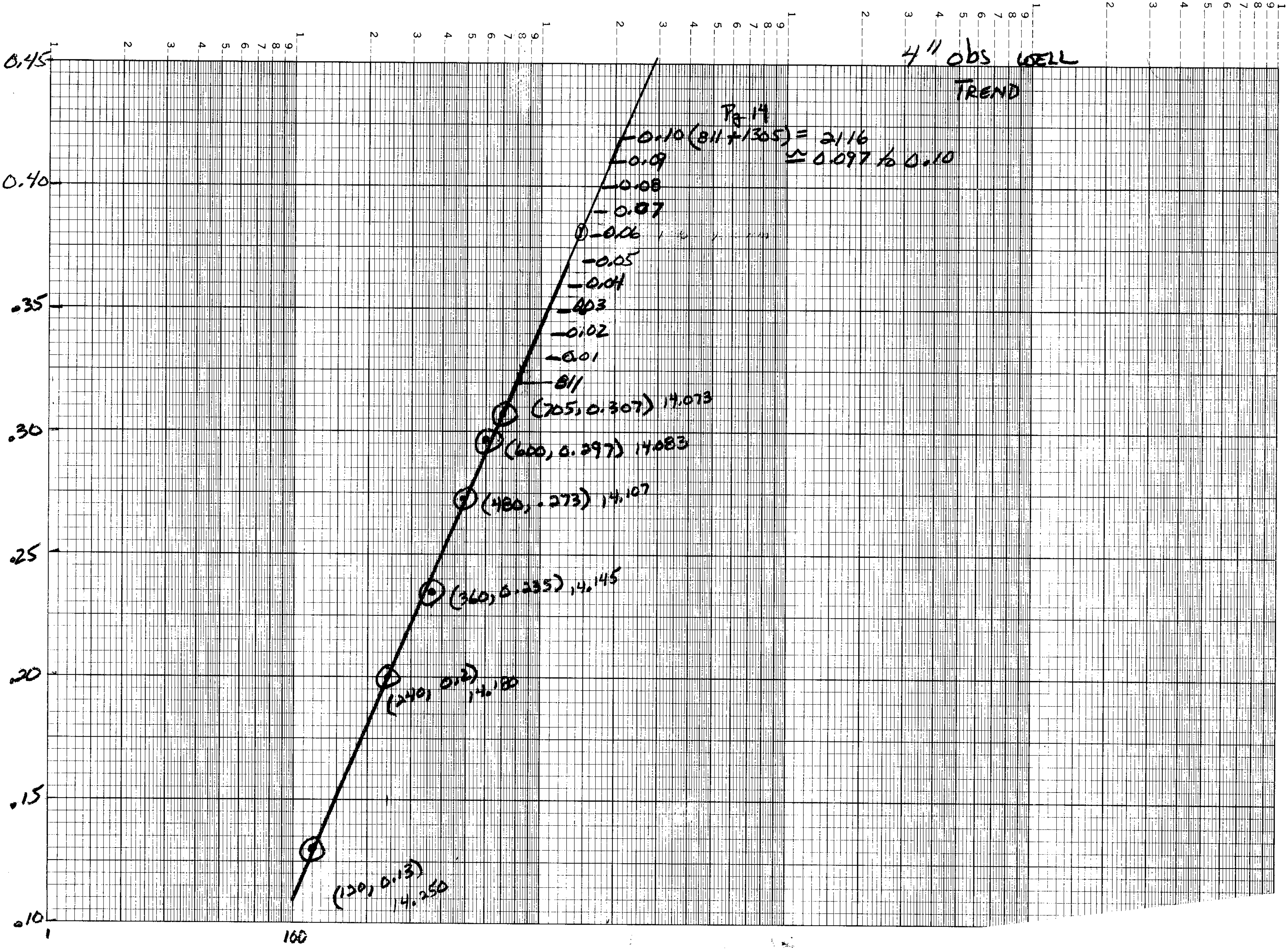
$$Z_t = 57.05\left(1 - \frac{34}{34 + 2.48(t)}\right) \text{ for } K_3 = 743$$

t (Days)	Z_t for $K_3 = 372$	Z_t for $K_3 = 743$
1	2.0	3.9
10	11.0	24.1
100	44.7	50.2
1000	55.5	56.3
∞	57.1	57.1
40.4	34'	
231	51'	
20.2		34'
116		51'

Unstable at $Z_t = 0.4(85) = 34'$ to $0.6(85) = 51'$

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



4" obs WELL TREND

Pg 14

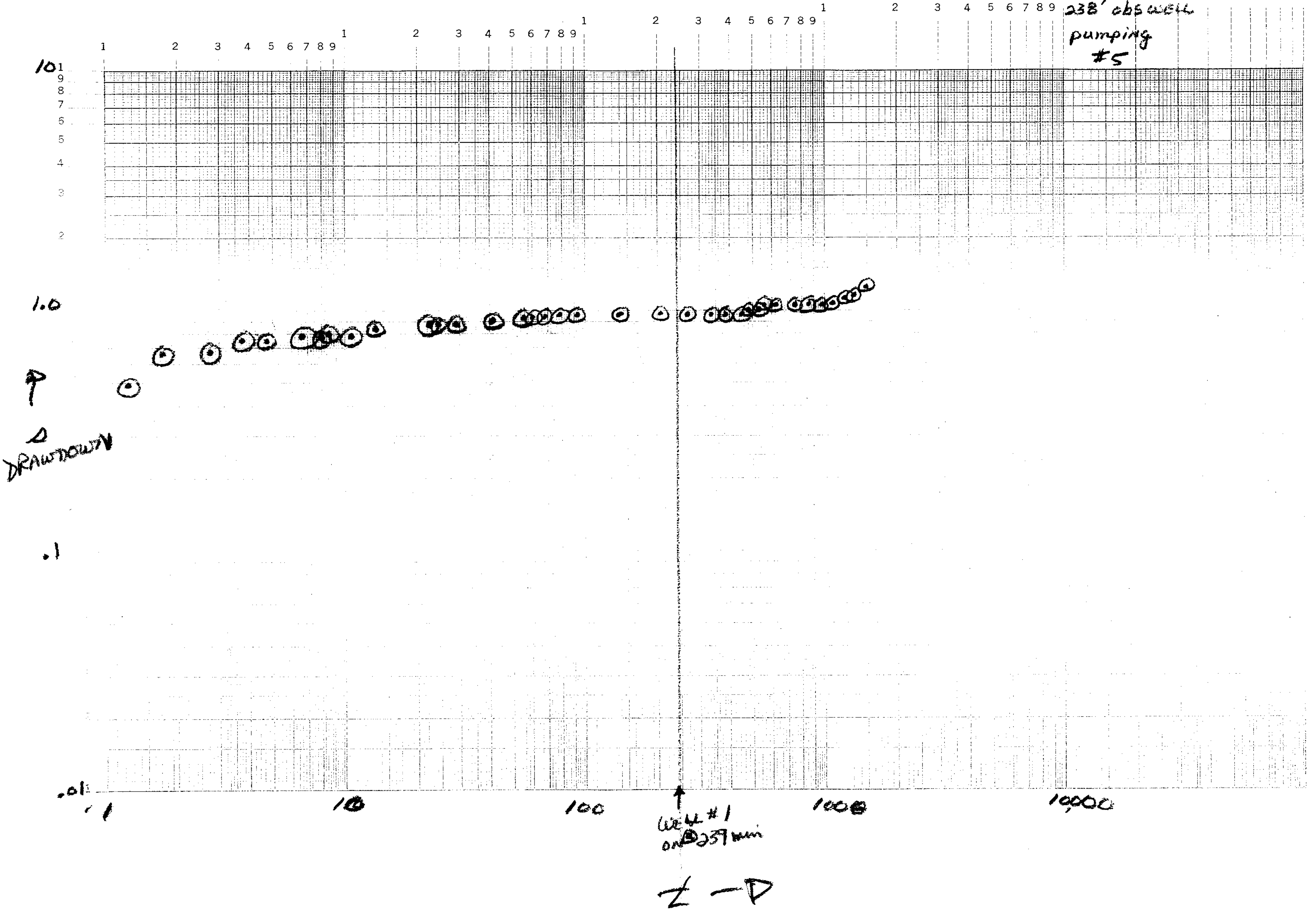
0.10 (811 + 1305) = 2116
≅ 0.097 to 0.10

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

Pg. 9

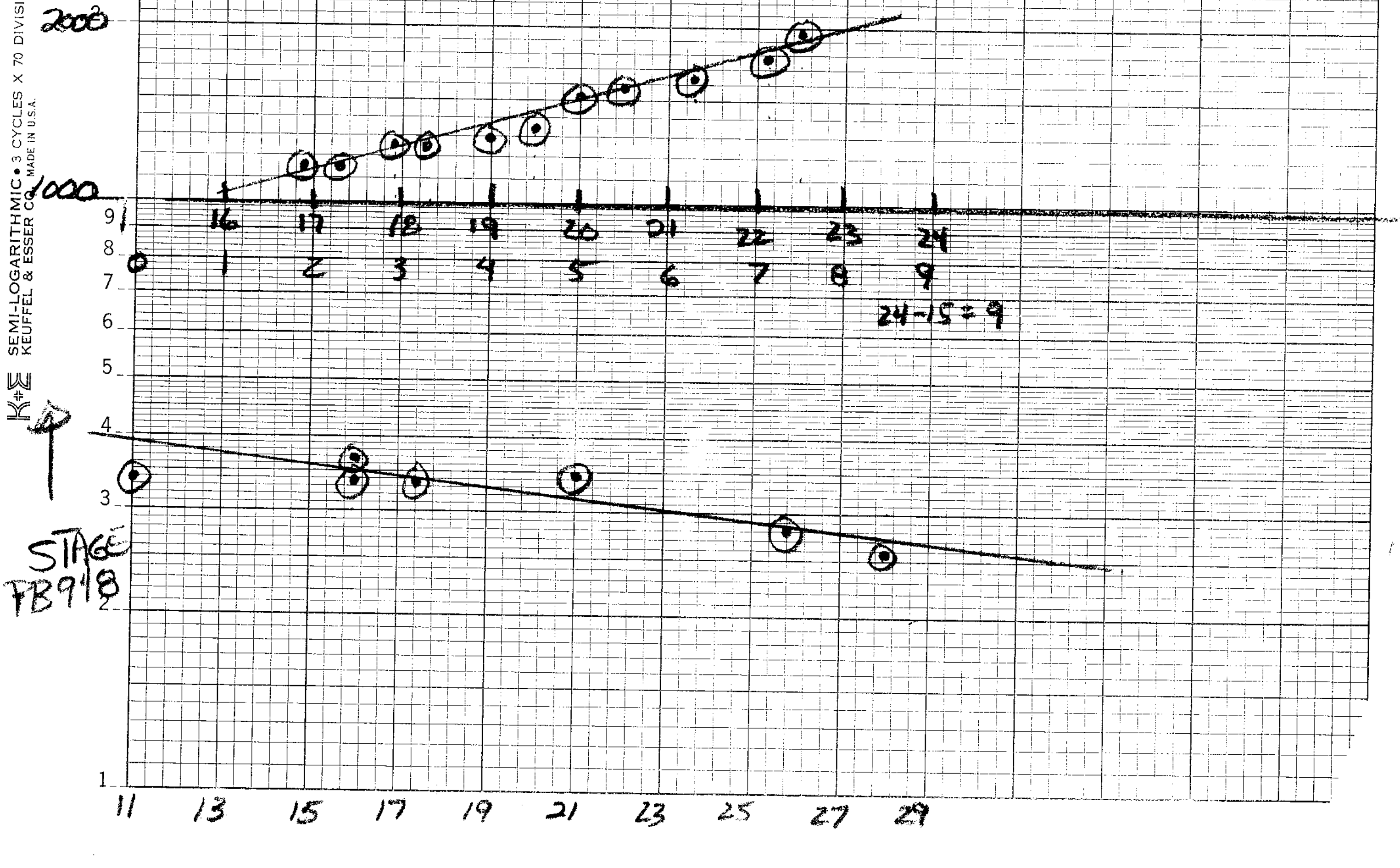
UNCORRECTED
238' obs well
pumping
#5



$Y = (954,799)(10)^{0.0394579(x)}$

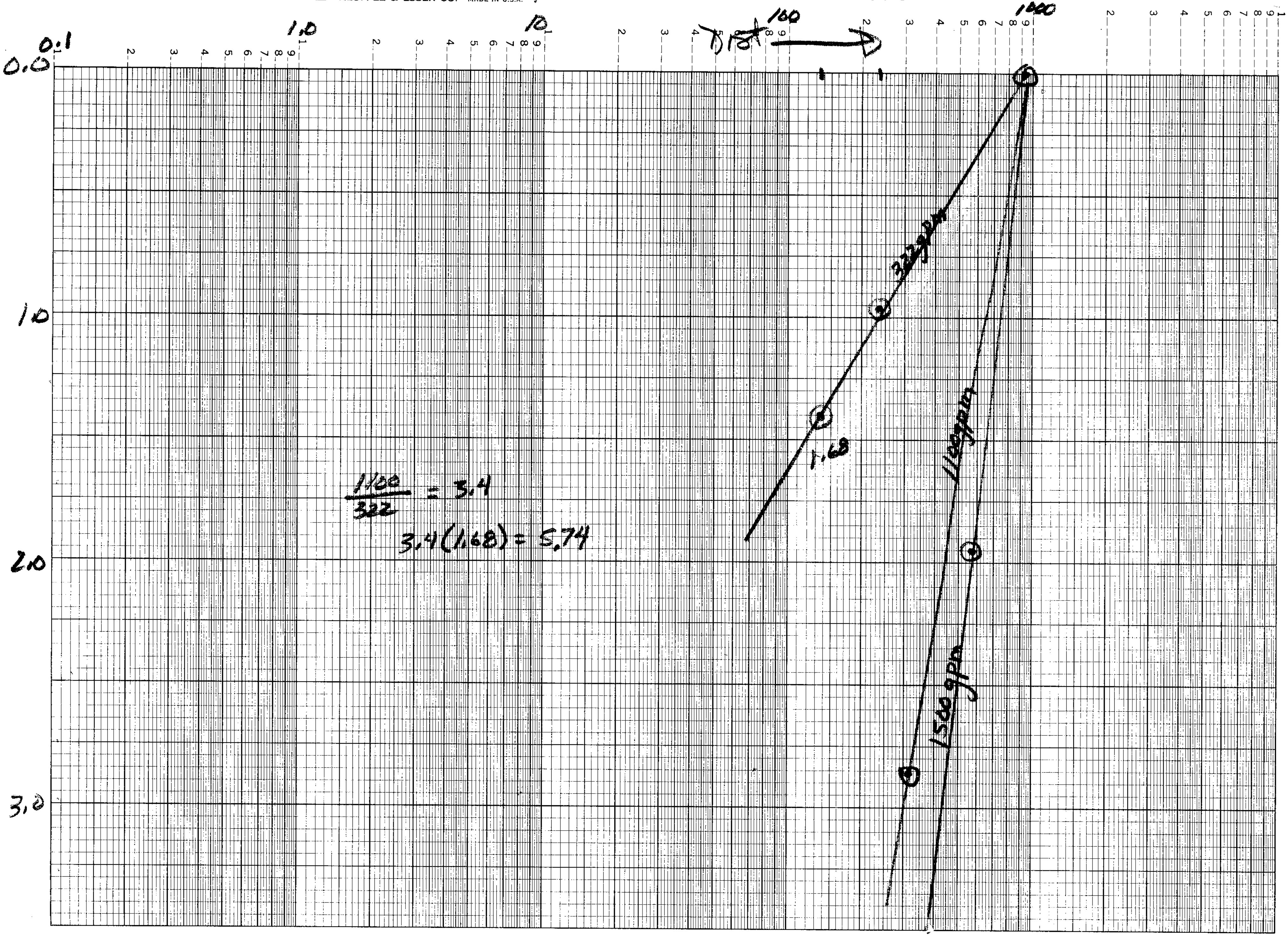
83

1.6 mgd = 48 mg/m = 19,400 mg/l
2.16 mgd = 64.8 mg/m = 90,131 mg/l.
498



K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



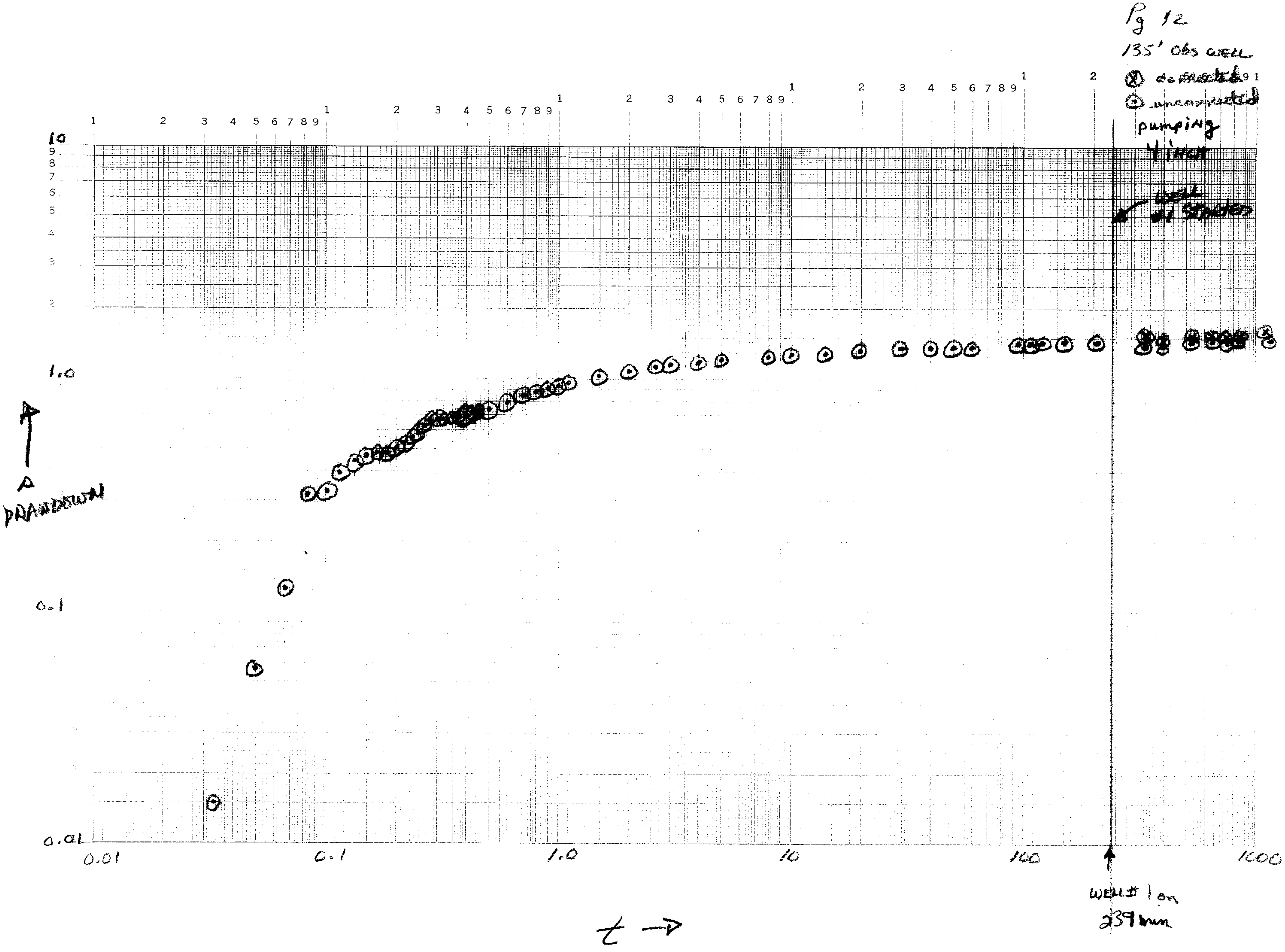
$\frac{1100}{322} = 3.4$

$3.4(1.68) = 5.74$

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

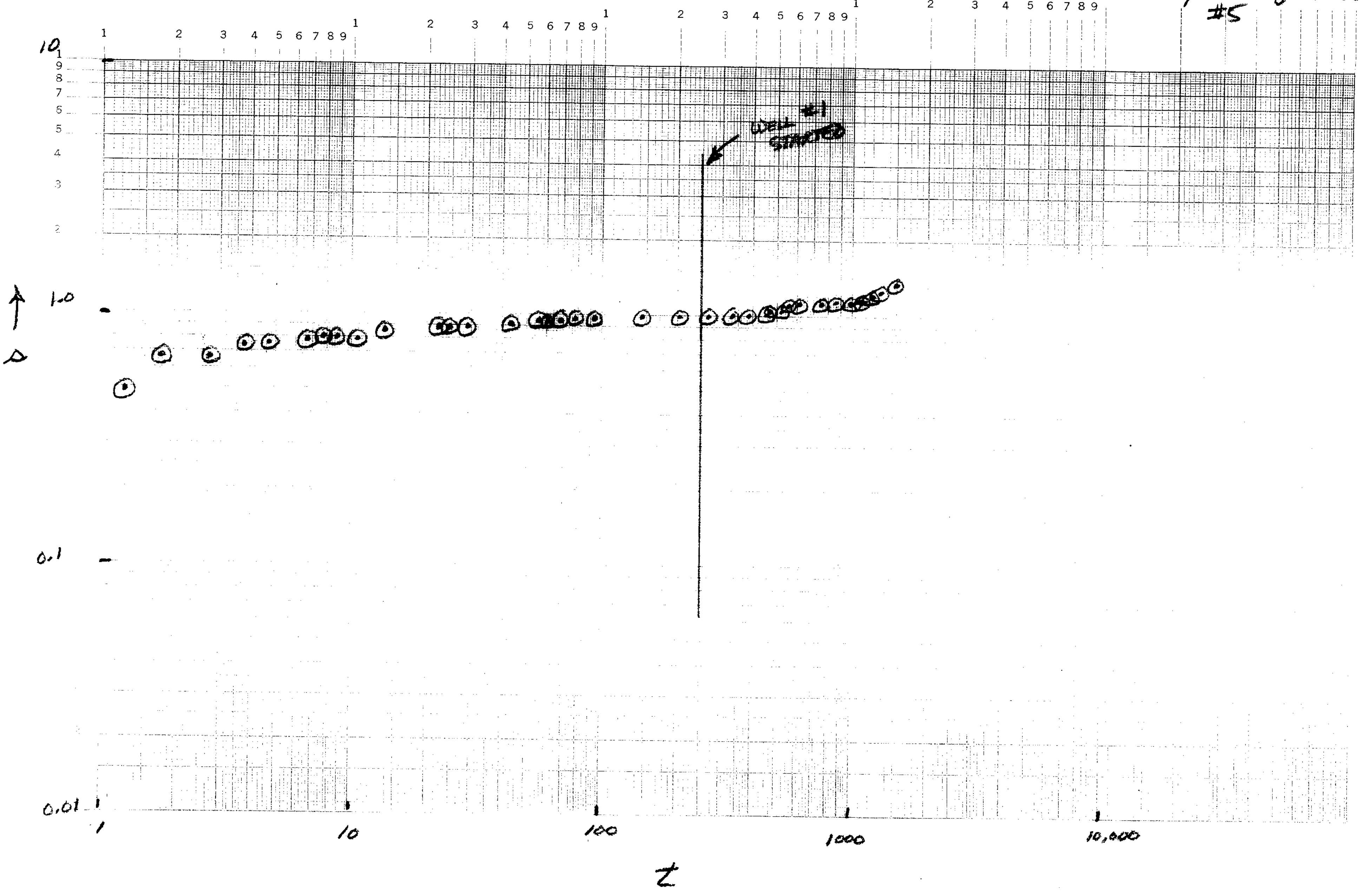
SFWMD



K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

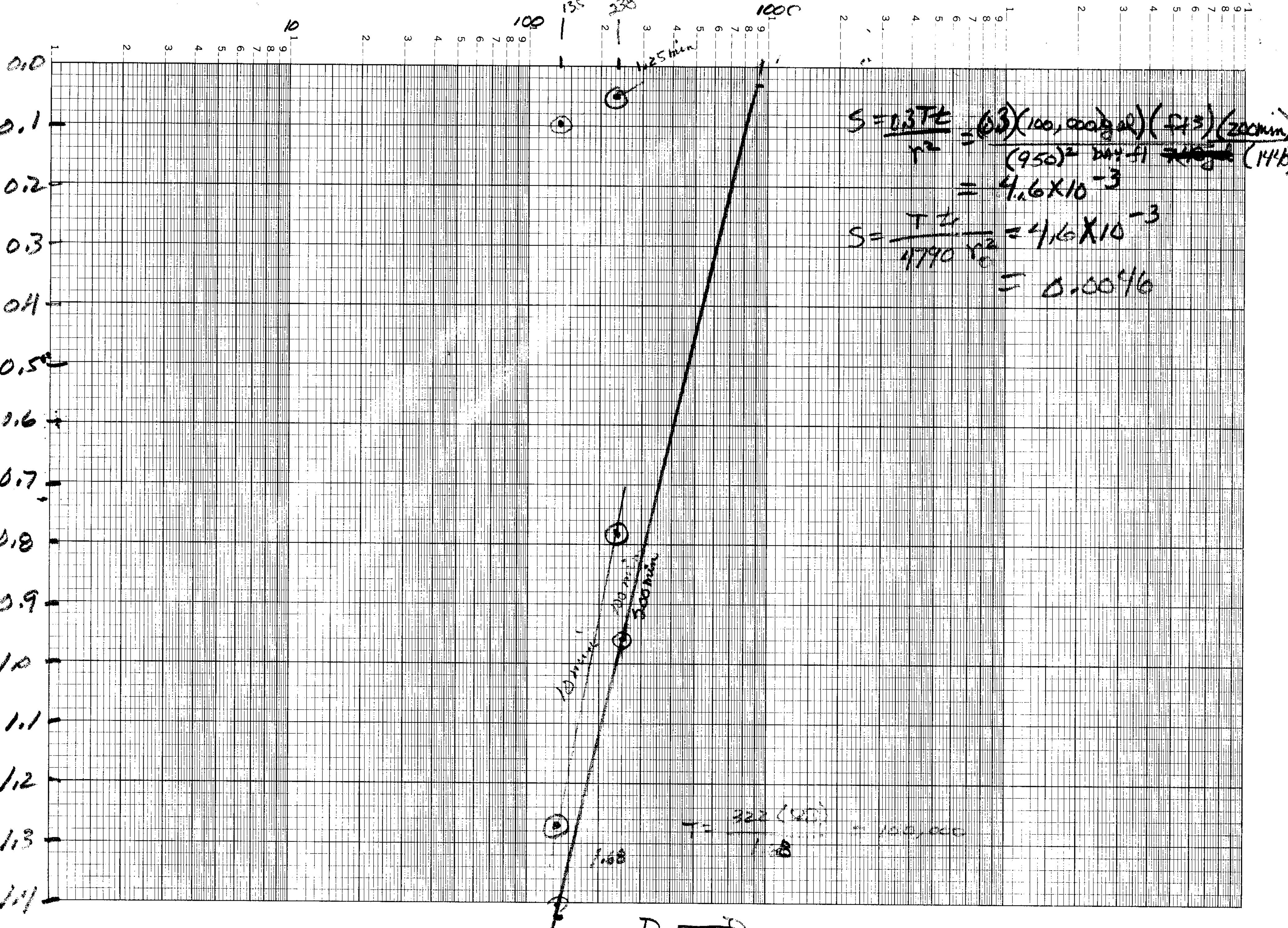
46 7522

Pg. 9
CORRECTED
238' obs WELL
pumping
#5



K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



$$S = \frac{0.3Tt}{r^2} = \frac{(0.3)(100{,}000\ \text{gal/day-ft})(\text{ft}^3/\text{~~7.48 gal~~})(200\ \text{min}}{(950)^2\ \text{day-ft}\ ~~\text{7.48 gal}~~\ (144}$$

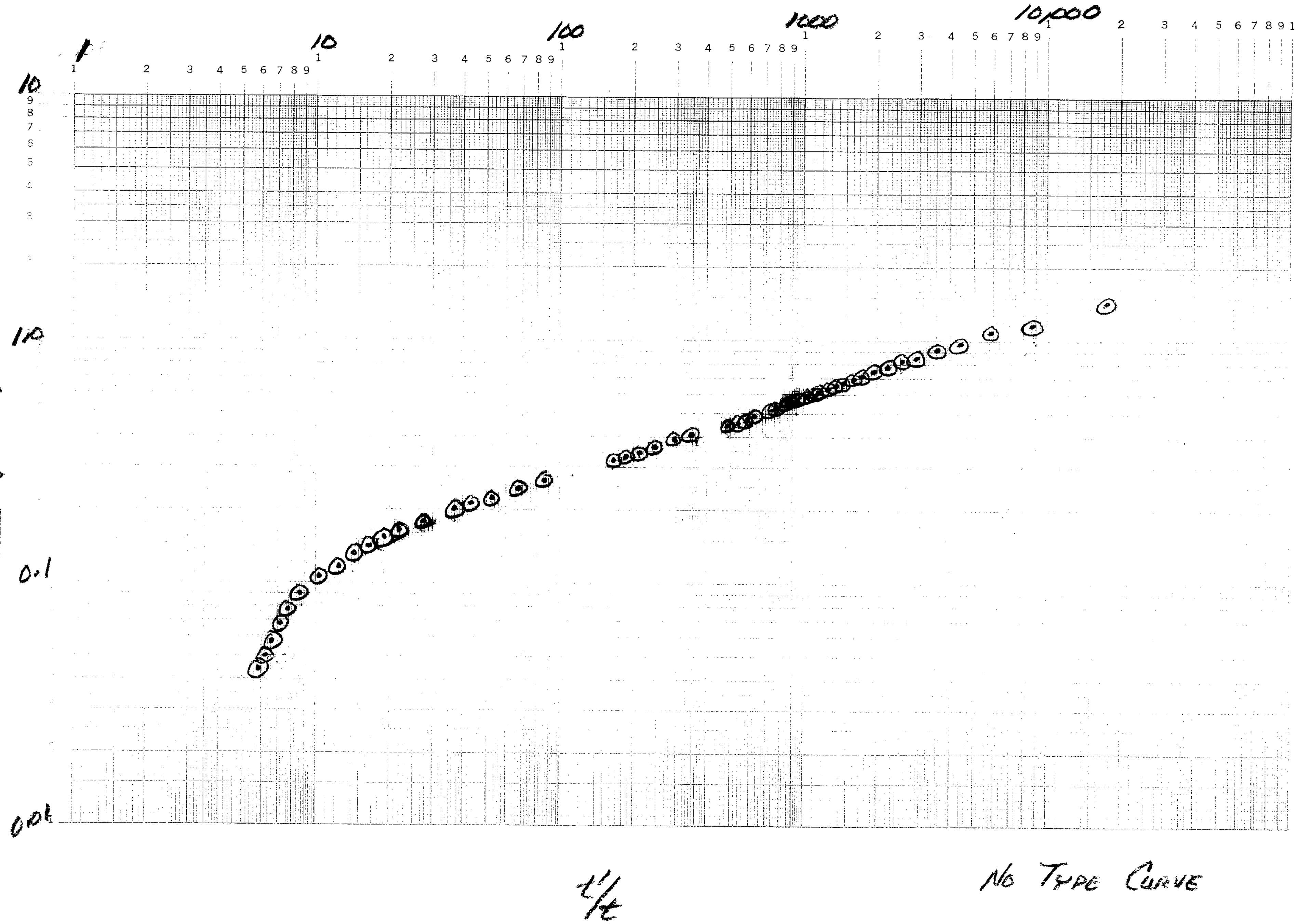
$$= 4.6 \times 10^{-3}$$

$$S = \frac{T\,t}{4790\,r_e^2} = 4.6 \times 10^{-3}$$

$$= 0.0046$$

$$T = \frac{322\,(520)}{1.68} = 100{,}000$$

46 7522

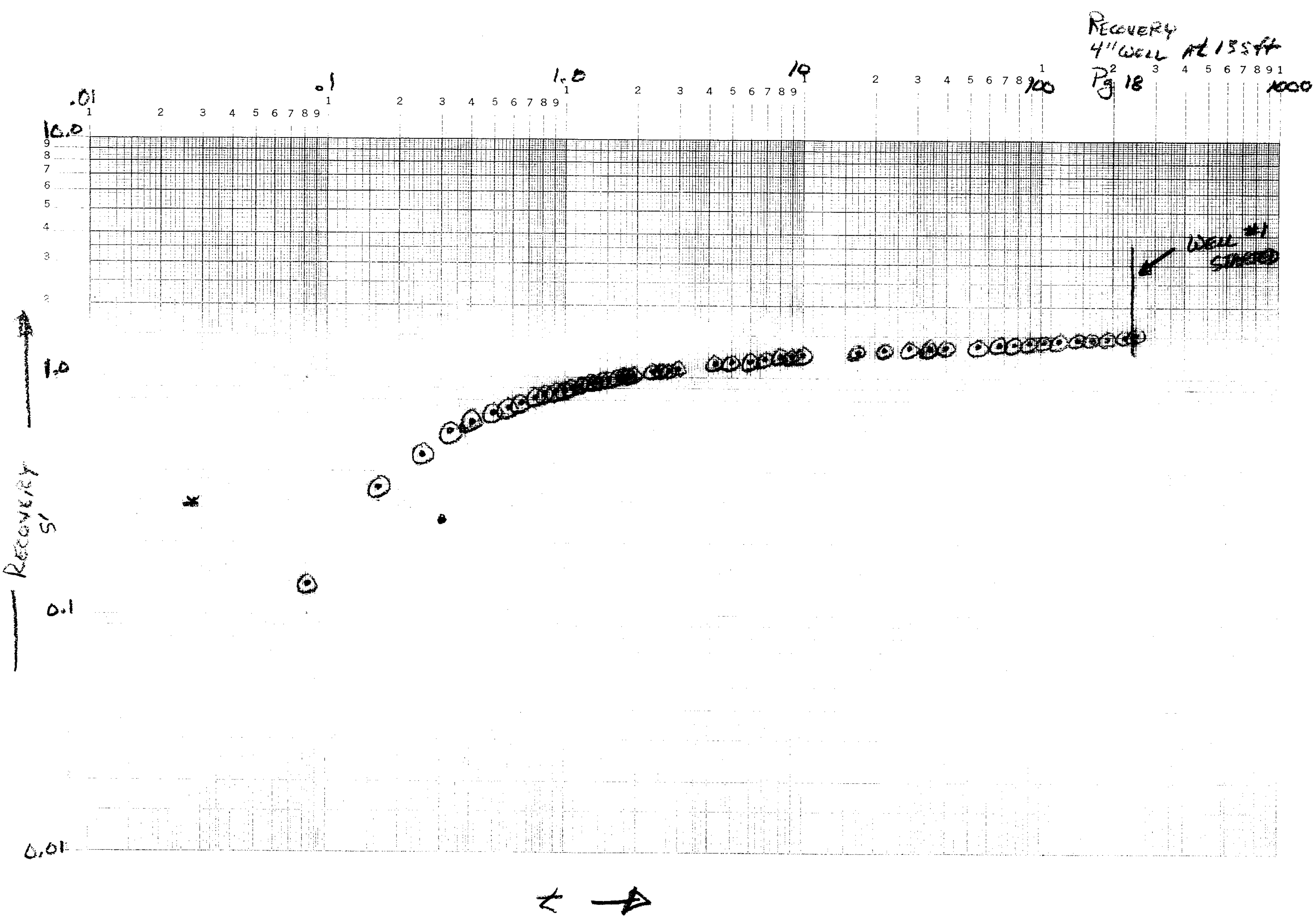


No Type Curve

K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522

L. Housma
SFWMD



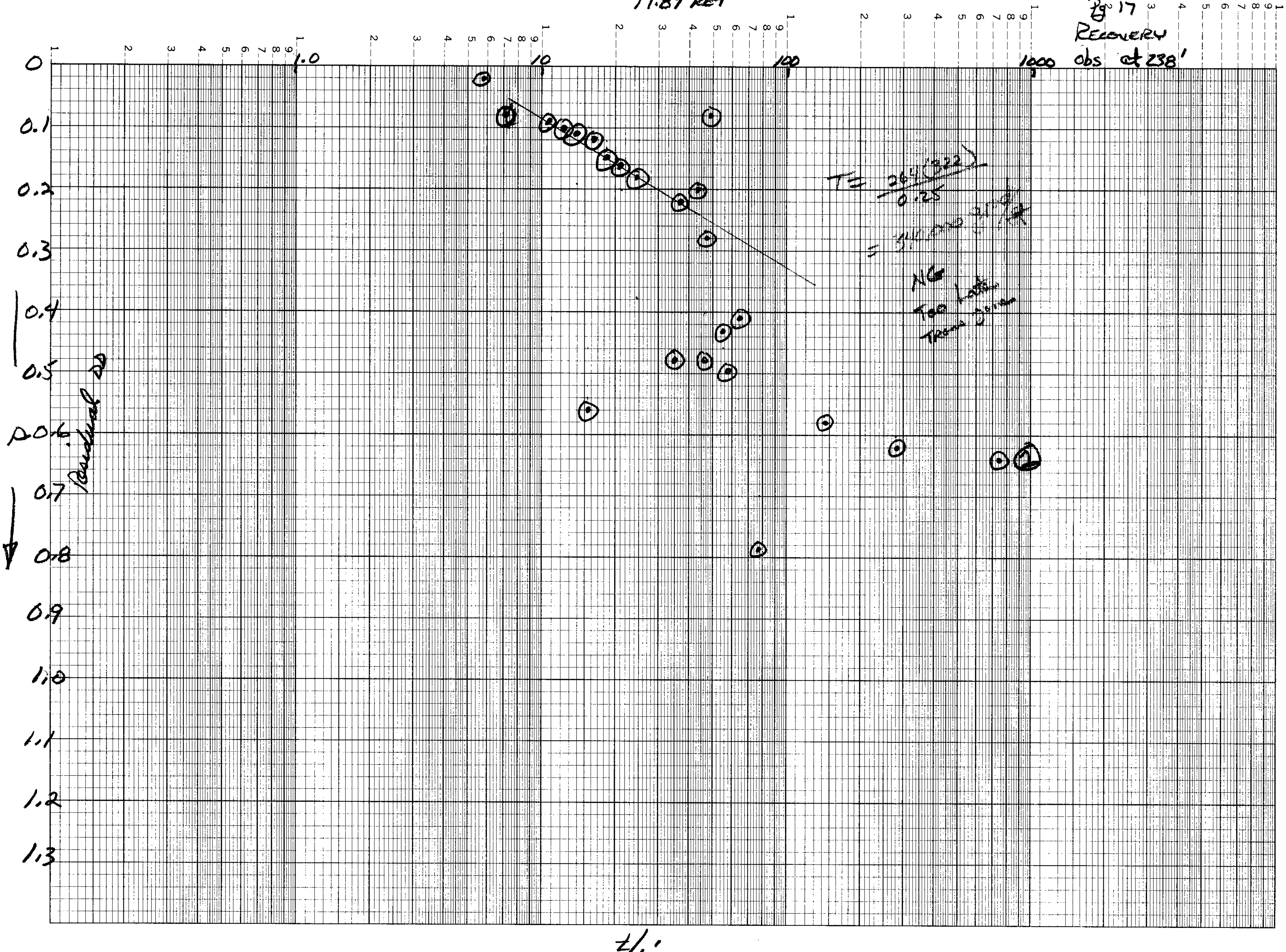
Recovery
4" Well at 135 ft
Pg 18

L. Howard
SFWMD

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210

14.84 ref



Pg 17
Recovery
obs at 238'

$T = \frac{264(322)}{0.25}$

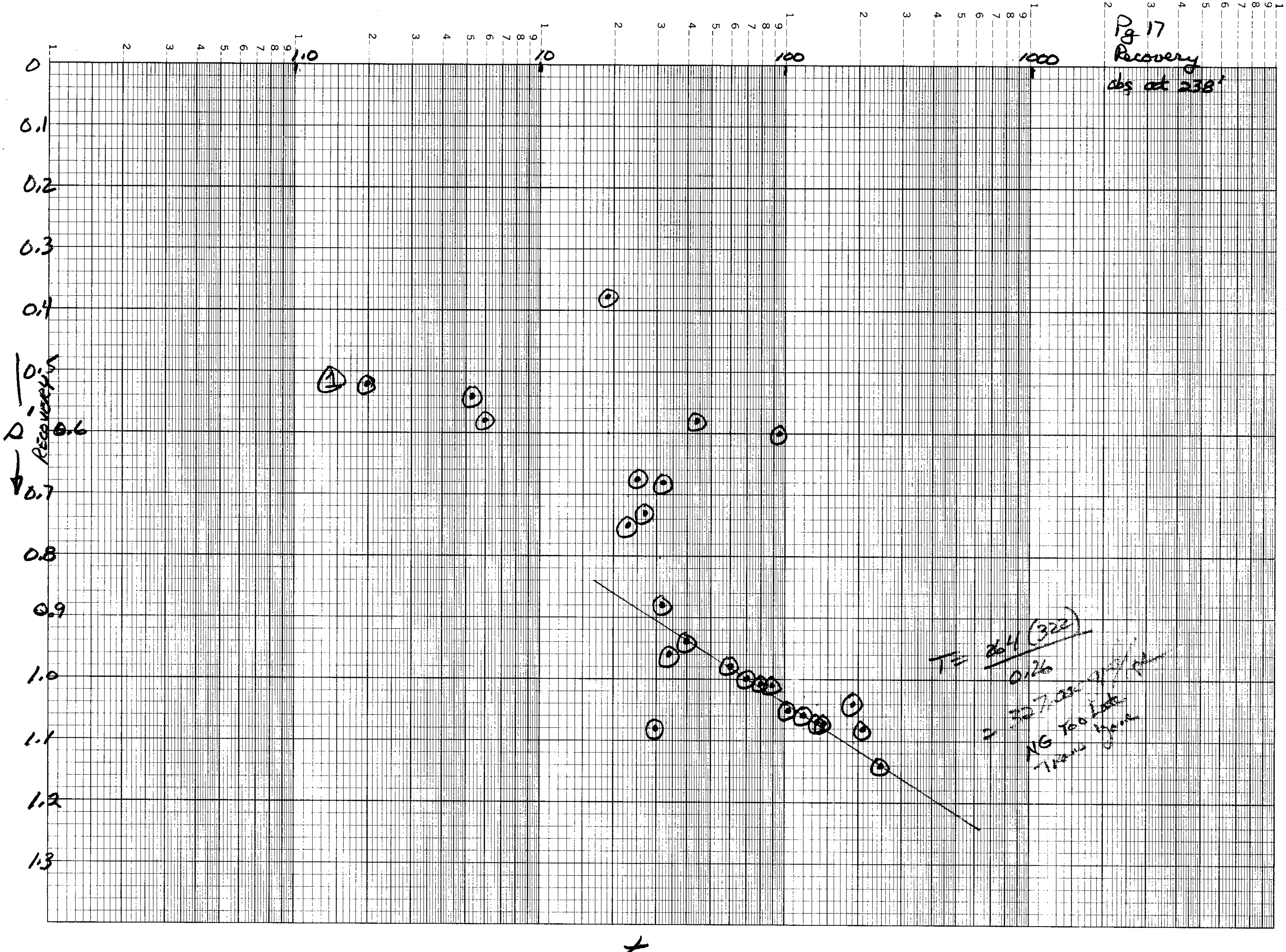
= 340,000 gpd/ft

NG
Too late
Trans Gone

L. Howard
SFWMD

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



Pg 17
Recovery
obs at 238'

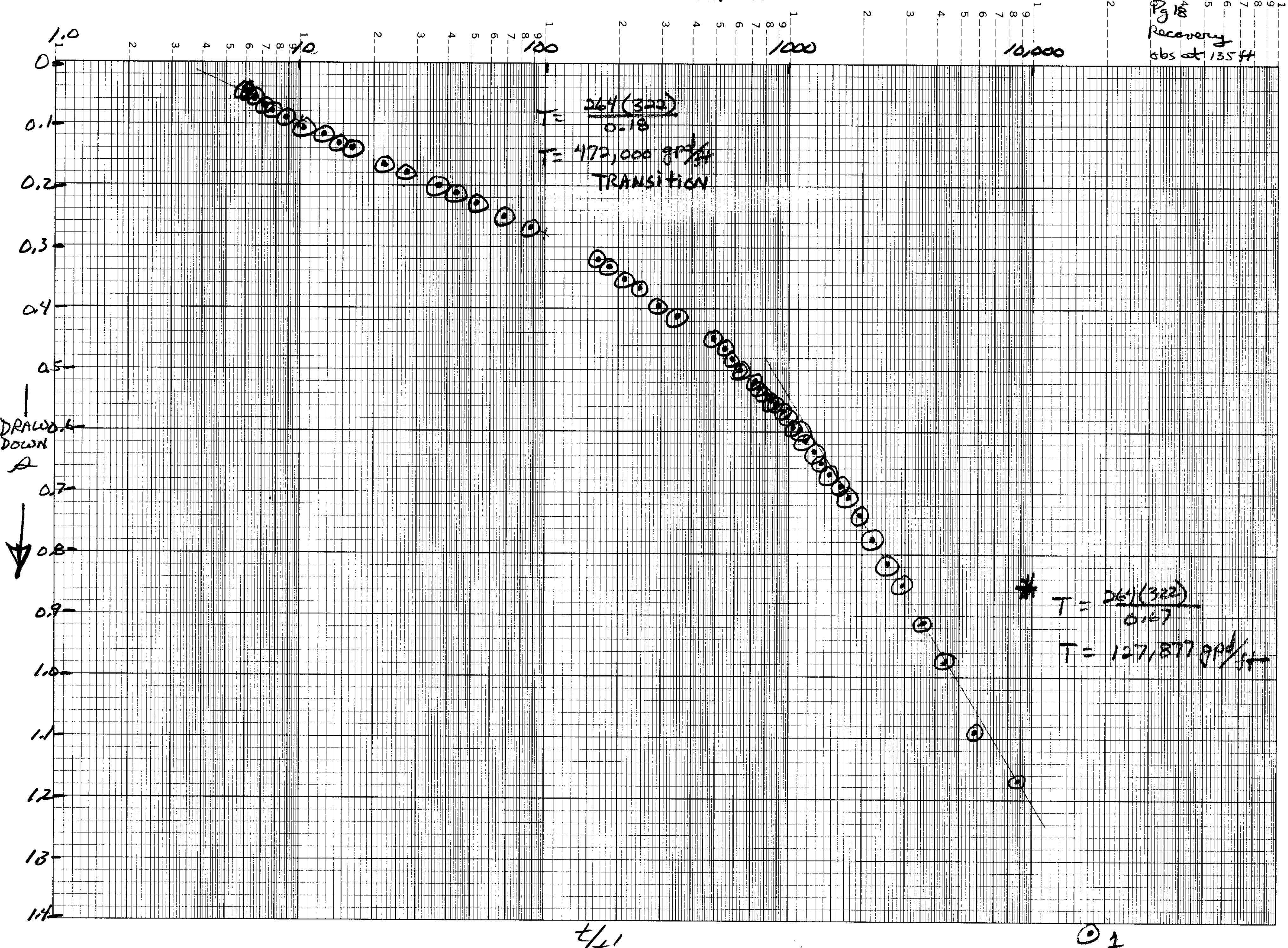
T = 264 (322) / 0.26
= 327,230 gpd/ft
NG Too Late
Trans. Eff

L. HOWARD
SFWMD

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

Ref = 14.822

46 6210



Pg 18
Recovery
obs at 135 ft

$T = \frac{264(322)}{0.18}$

T = 472,000 gpd/ft

TRANSITION

$T = \frac{264(322)}{0.67}$

T = 127,877 gpd/ft

L. HOWARD
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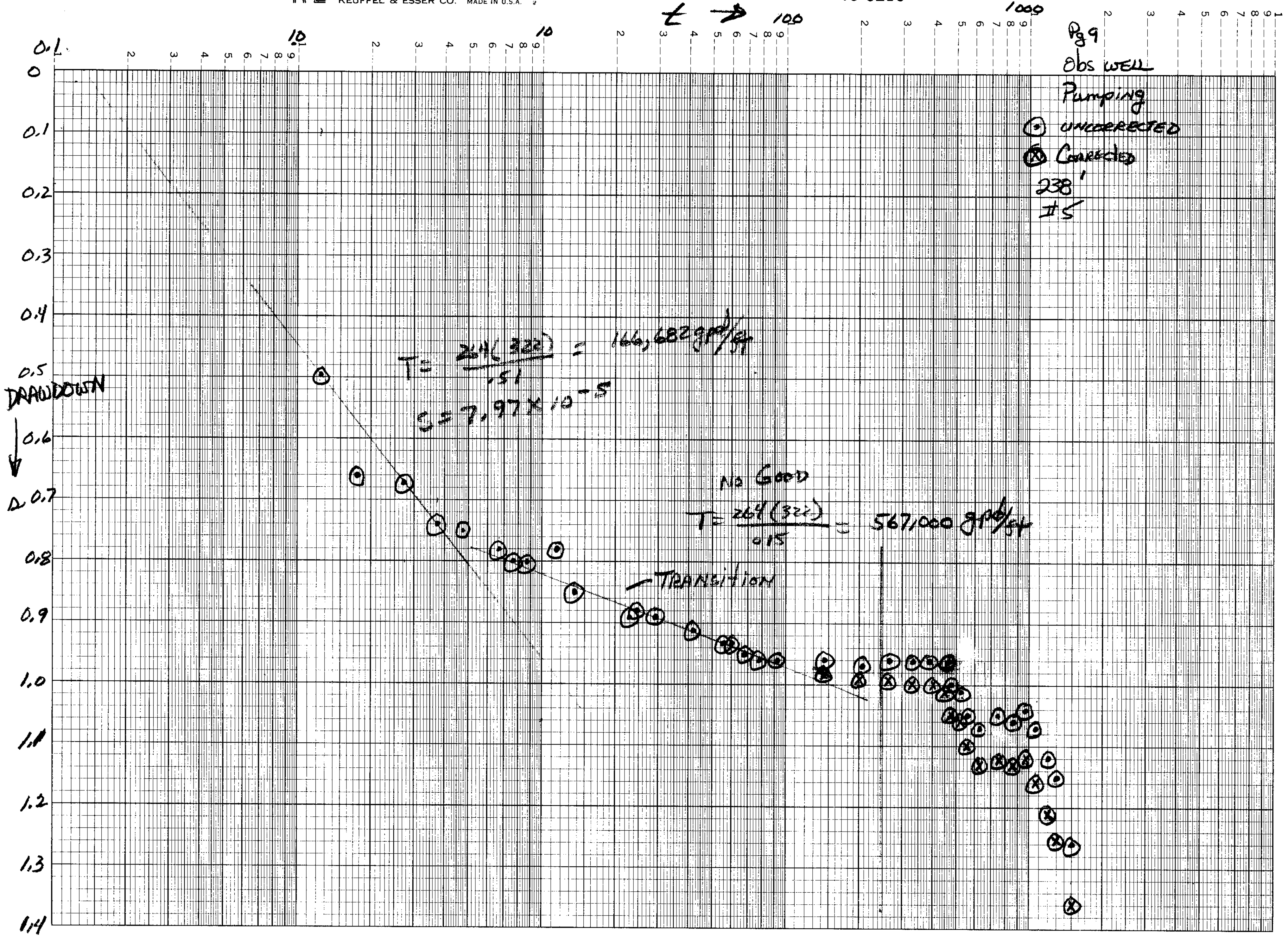
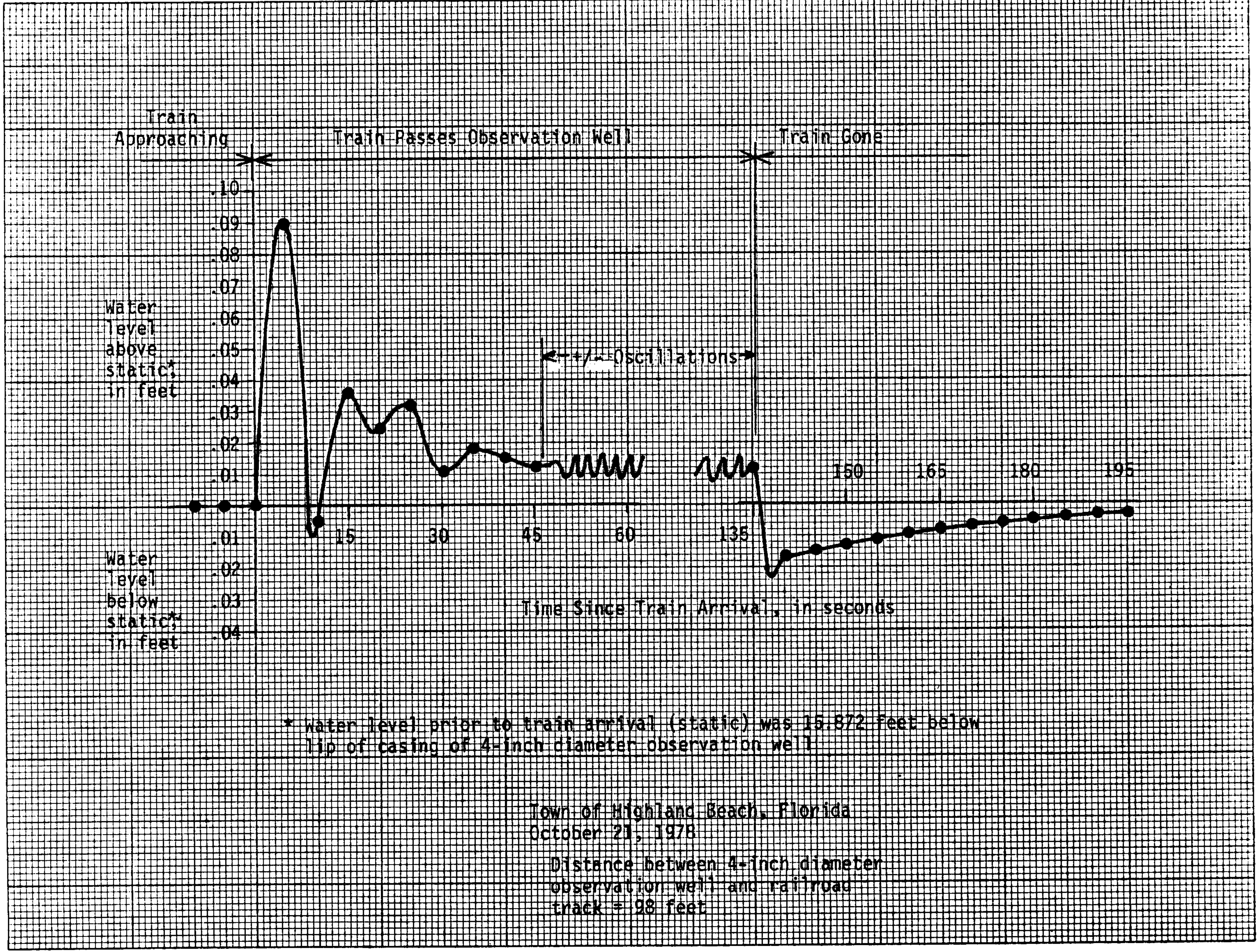
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210





* water level prior to train arrival (static) was 15.872 feet below lip of casing of 4-inch diameter observation well

Town of Highland Beach, Florida
October 21, 1978

Distance between 4-inch diameter observation well and railroad track = 98 feet

Figure 5. Typical water-level fluctuations due passing train traffic at 2:09 AM October 21, 1978

L. HOWARD
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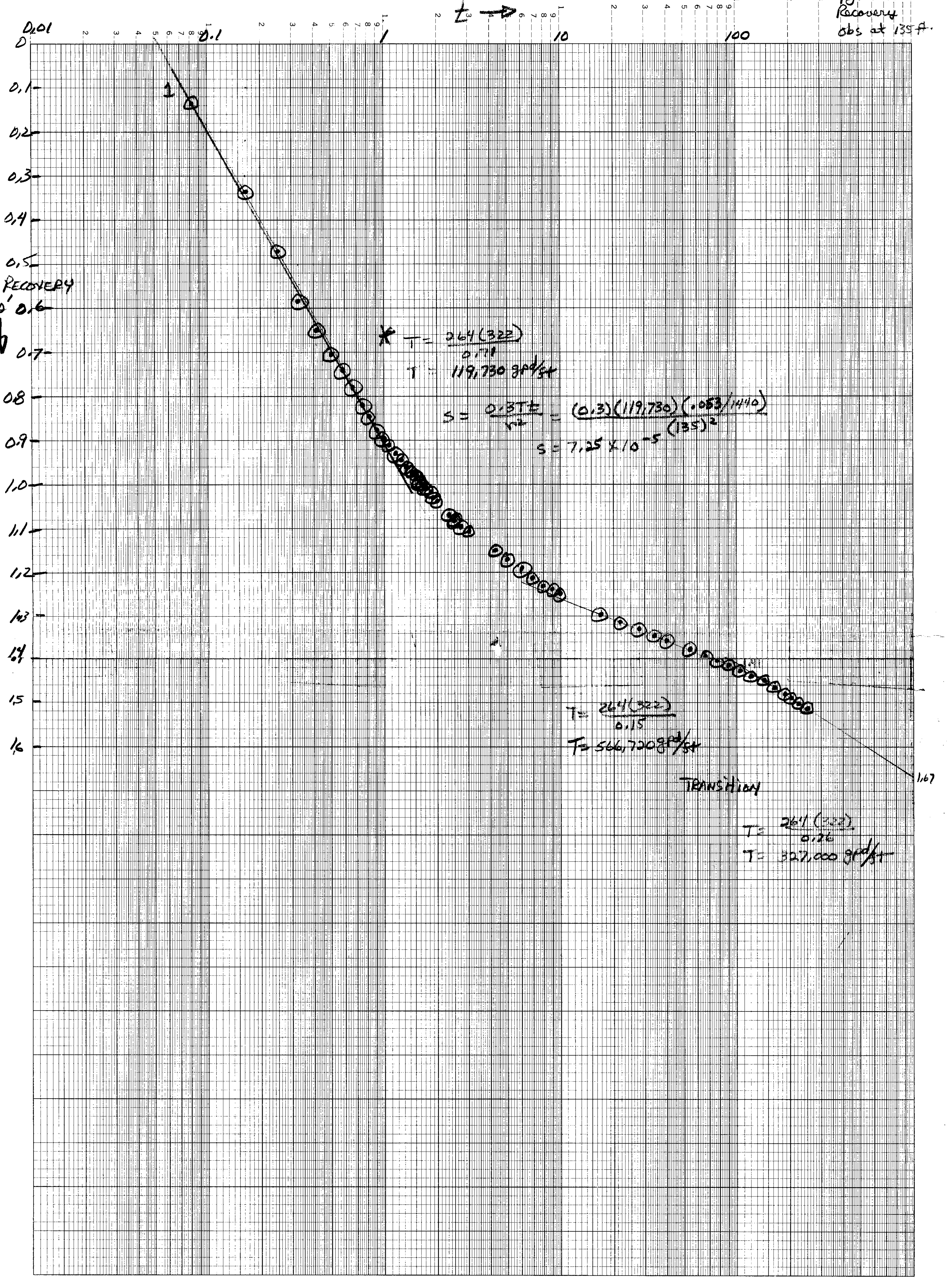
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210

Pg 18
Recovery
obs at 135 ft.



* T = $\frac{264(322)}{0.71}$

T = 119,730 gpd/ft

S = $\frac{0.3Tt}{r^2}$ = $\frac{(0.3)(119,730)(.053/1440)}{(135)^2}$

S = 7.25 X 10^{-5}

T = $\frac{264(322)}{0.15}$

T = 566,720 gpd/ft

TRANSITION

T = $\frac{264(322)}{0.26}$

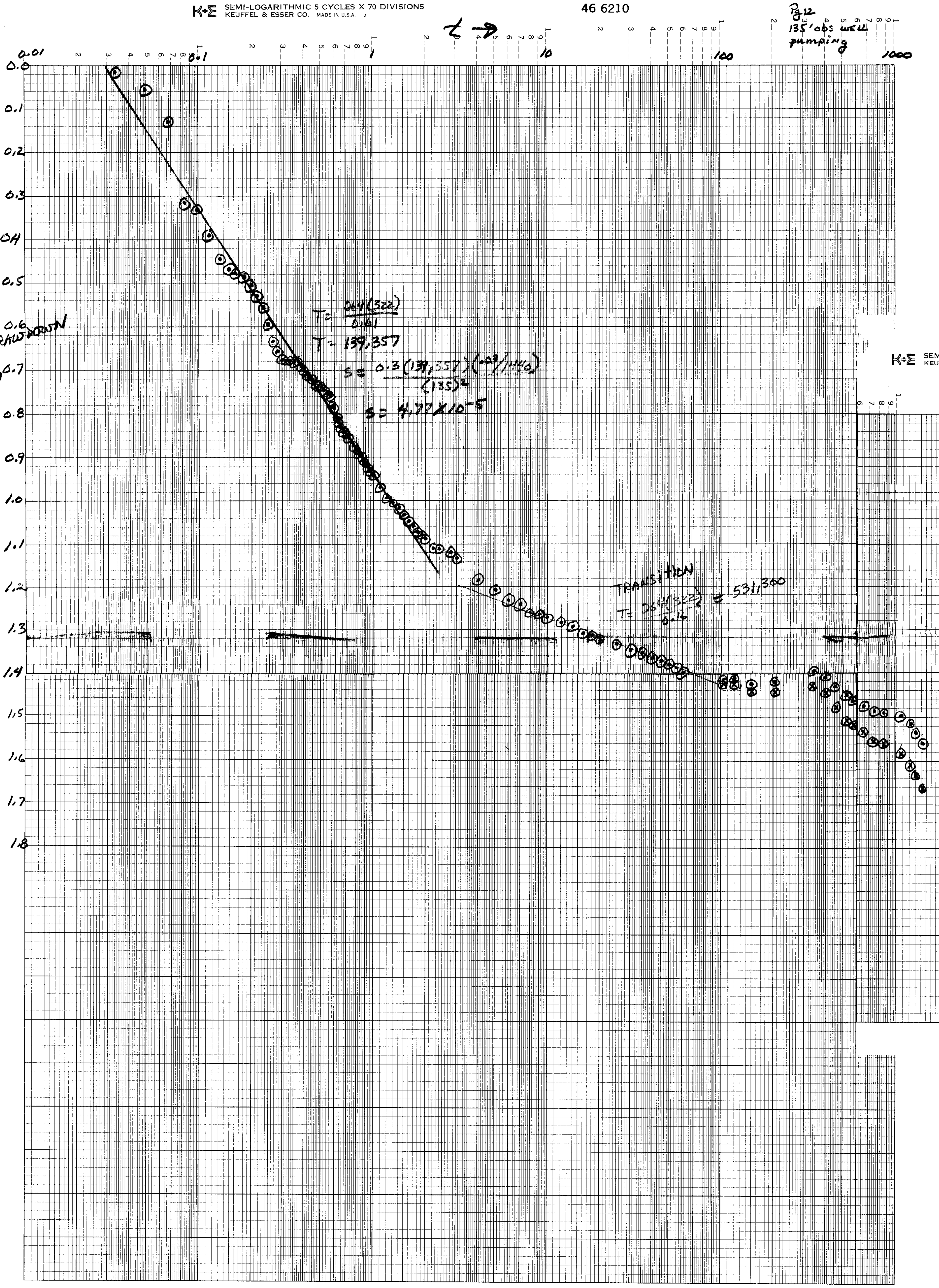
T = 327,000 gpd/ft

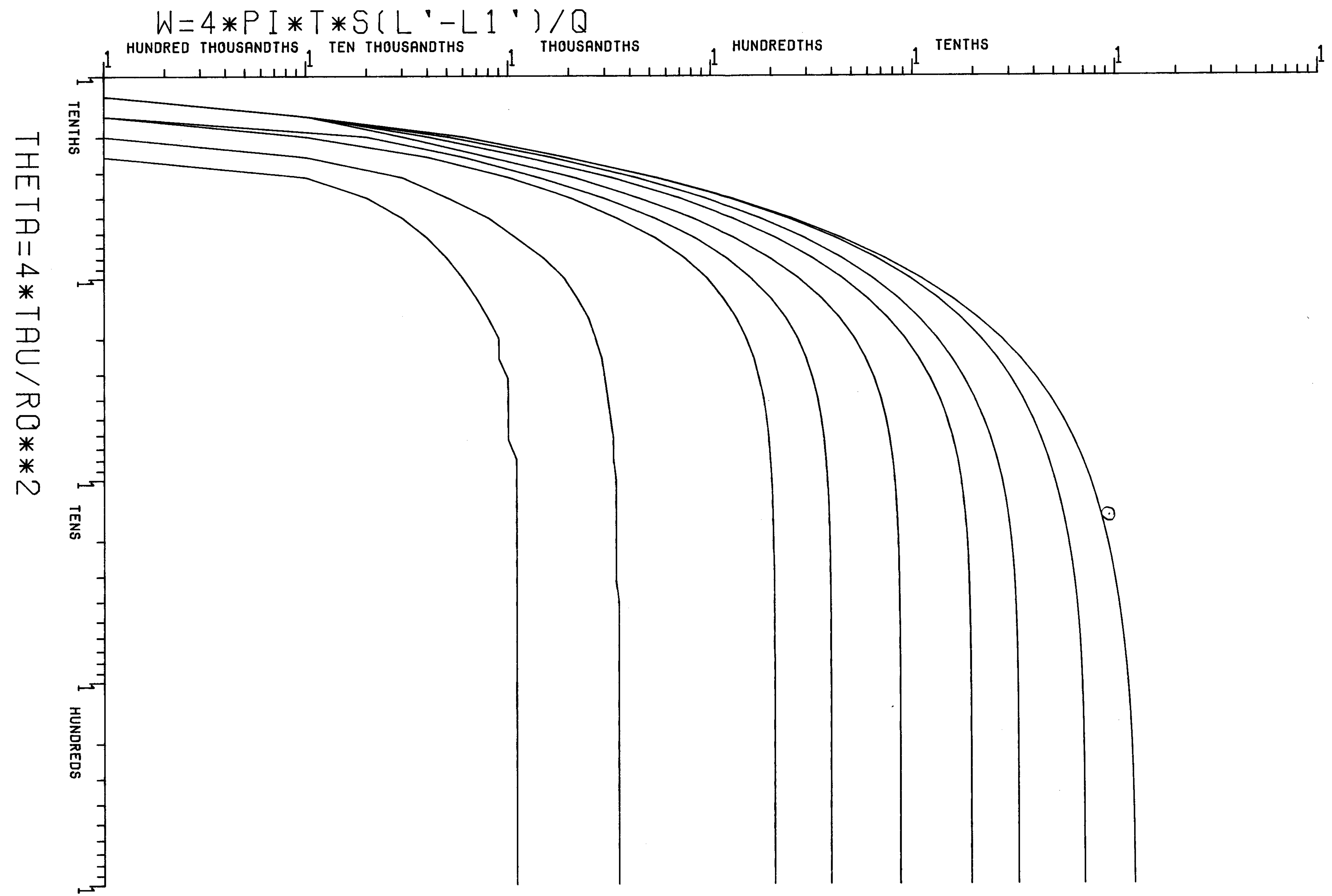
L. HOWARD
SFWMD

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210

Pg 12
135' obs well
pumping

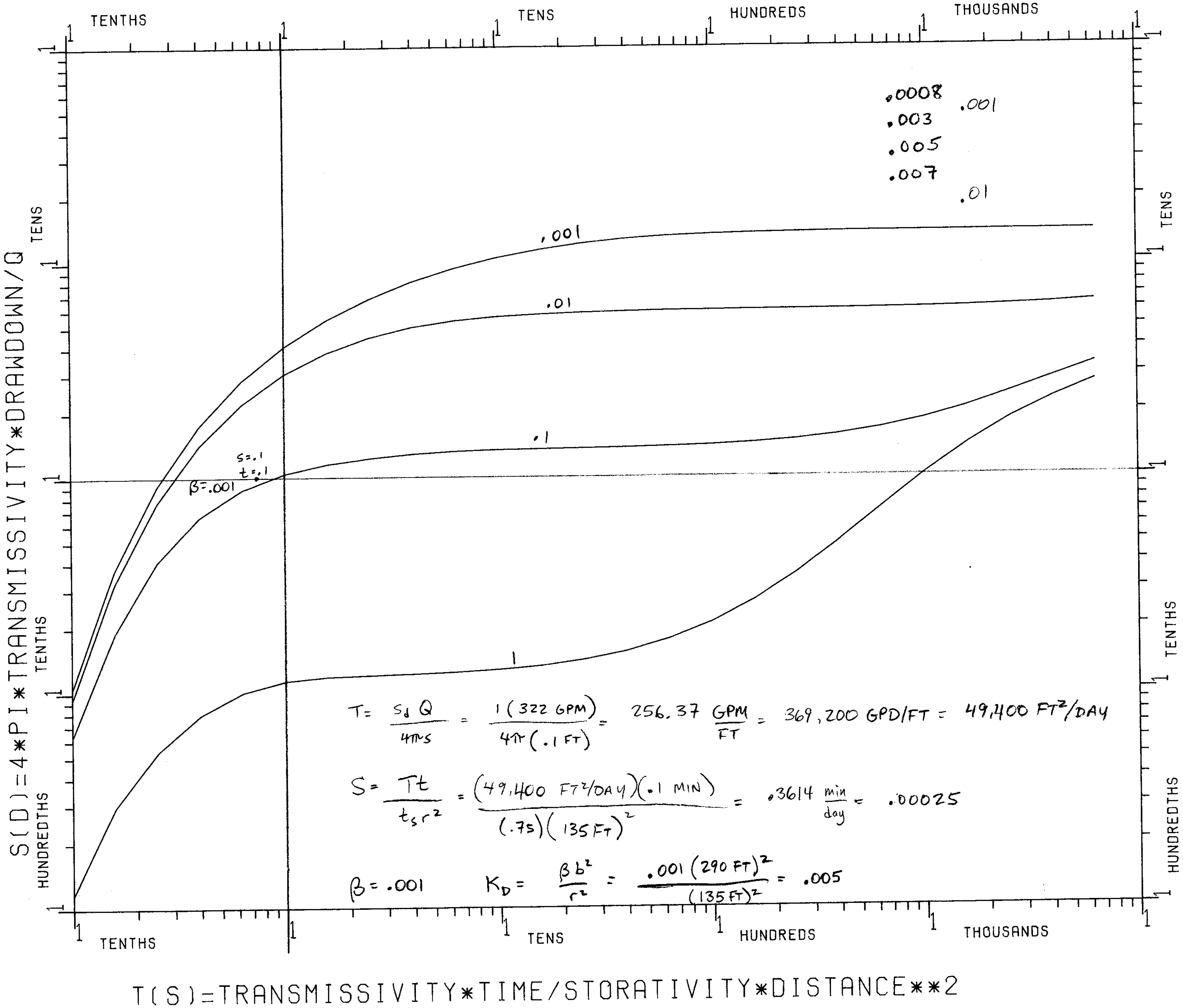



W=4*PI*T*S(L'-L1')/Q
HUNDRED THOUSANDTHS
TEN THOUSANDTHS
THOUSANDTHS
HUNDREDTHS
TENTHS
1
THETA=4*TAU/RQ**2
TENTHS
TENS
HUNDREDS

HIGHLAND BEACH 4" OBS WELL

NEUMAN PARTIAL PENETRATION SOLUTION
B: 290' PW TD/CD: 90'/70' OW TD/CD: 90'/30'
ZD1=.6897, ZD2=.8966, PD=.3103, DD=.2414
BETA = .001, .01, .1, 1

PROC NEUMAN RUN AT 14.55.11. 86/11/24.



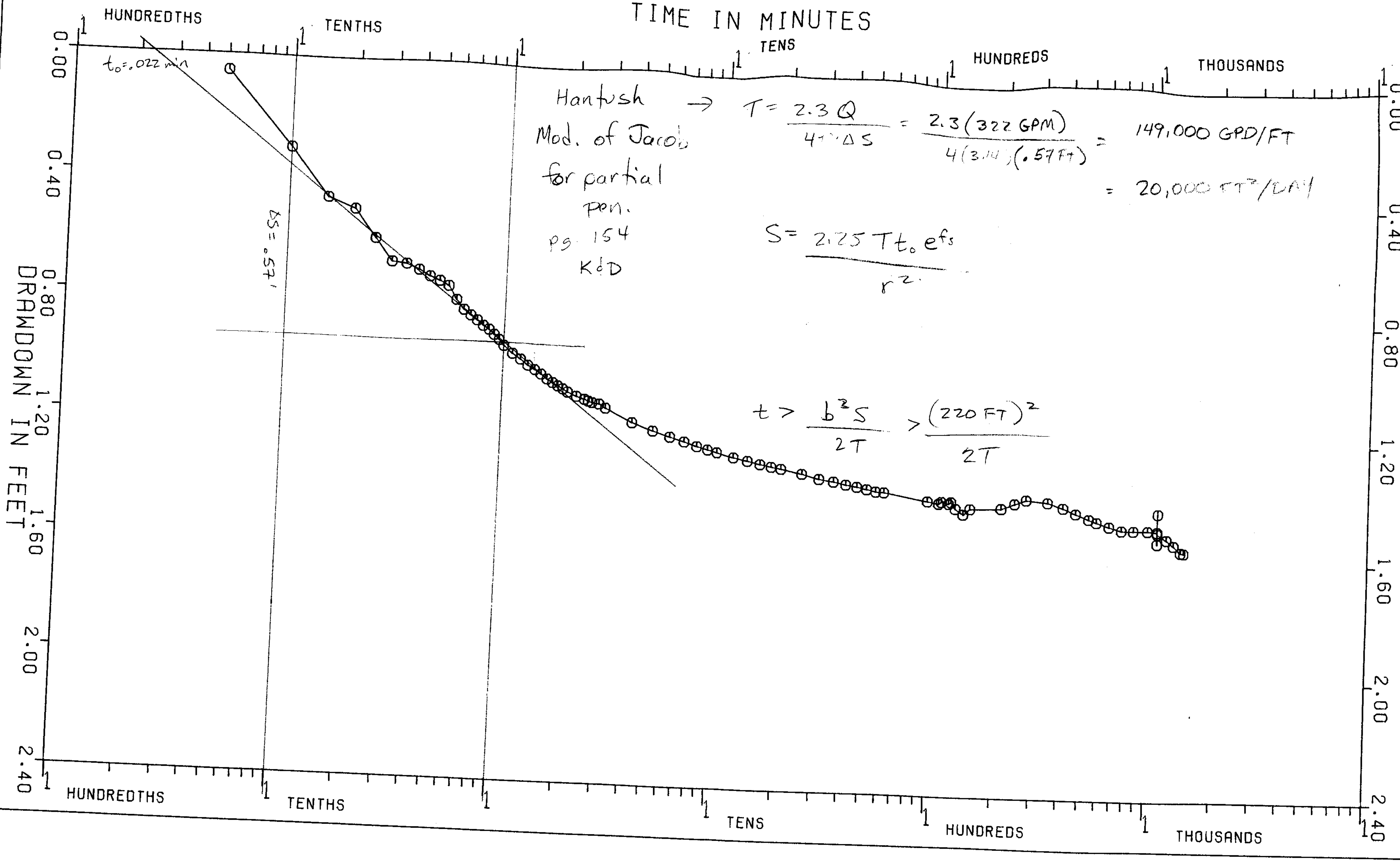
$$T = \frac{s_d Q}{4\pi s} = \frac{1\,(322\text{ GPM})}{4\pi(.1\text{ FT})} = 256.37\ \frac{\text{GPM}}{\text{FT}} = 369{,}200\text{ GPD/FT} = 49{,}400\text{ FT}^2/\text{DAY}$$

$$S = \frac{Tt}{t_s r^2} = \frac{(49{,}400\text{ FT}^2/\text{DAY})(.1\text{ MIN})}{(.75)(135\text{ FT})^2} = .3614\ \frac{\text{min}}{\text{day}} = .00025$$

$$\beta = .001 \qquad K_D = \frac{\beta b^2}{r^2} = \frac{.001\,(290\text{ FT})^2}{(135\text{ FT})^2} = .005$$

OBSERVATION WELL: 4" OBSERVATION WELL

R= 135 Q= 322 GPM b = 220'



$t_0 = .022$ min

$\Delta s = .57'$

Hantush Mod. of Jacob for partial pen.
pg. 154
K&D

$\rightarrow T = \frac{2.3Q}{4\pi \Delta S} = \frac{2.3(322 \text{ GPM})}{4(3.14)(.57 \text{ FT})} = 149{,}000$ GPD/FT

$= 20{,}000$ FT²/DAY

$S = \frac{2.25 T t_0 e^{fs}}{r^2}$

$t > \frac{b^2 S}{2T} > \frac{(220 \text{ FT})^2}{2T}$

WMD

TAPENO 6355
USER NO SHINE

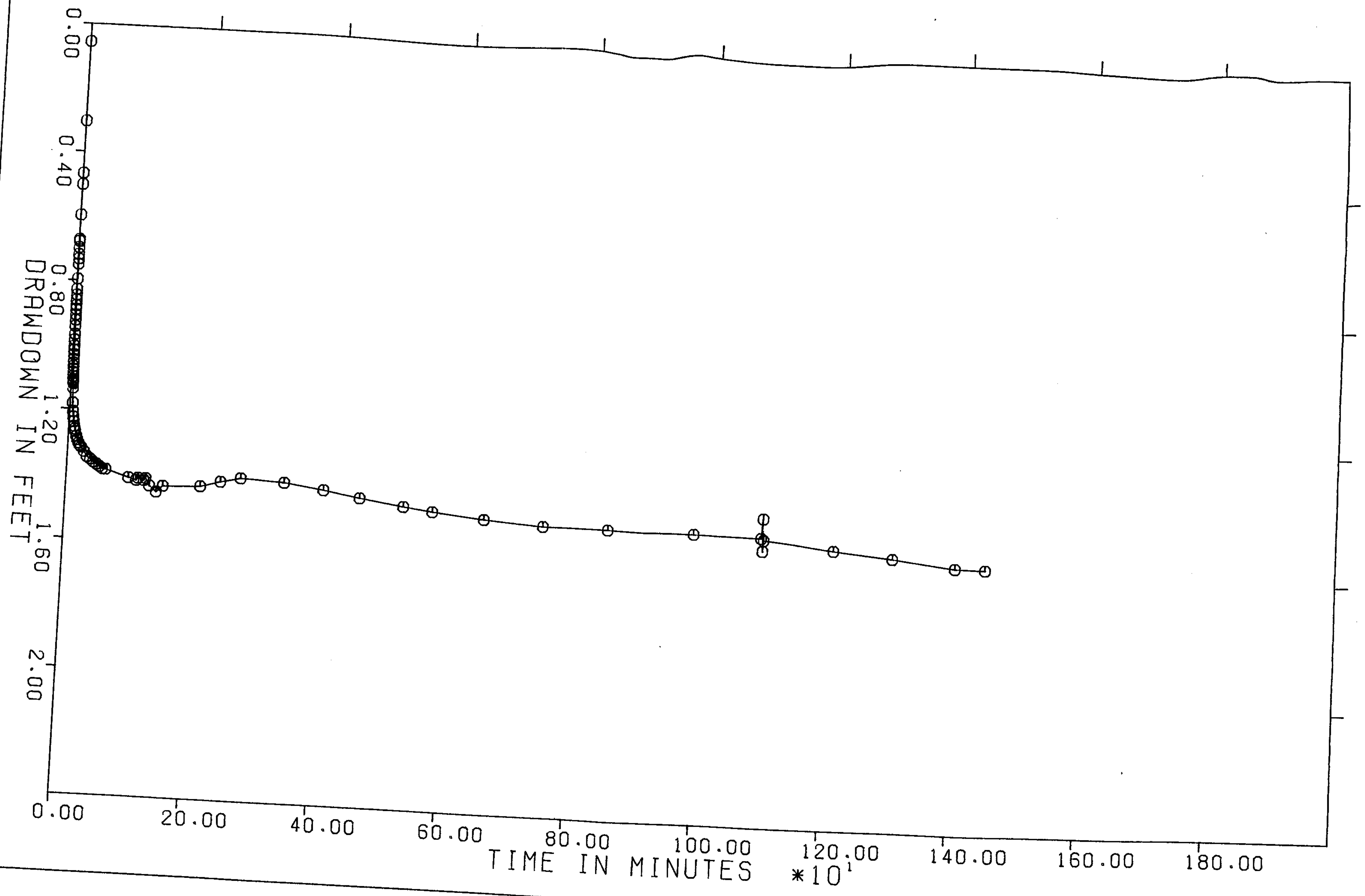
PLOT NO 0001
DATE 87/08/20

TIME 16:09

DRAWDOWN

OBSERVATION WELL: 4" OBSERVATION WELL

R= 135 Q= 322



WMD

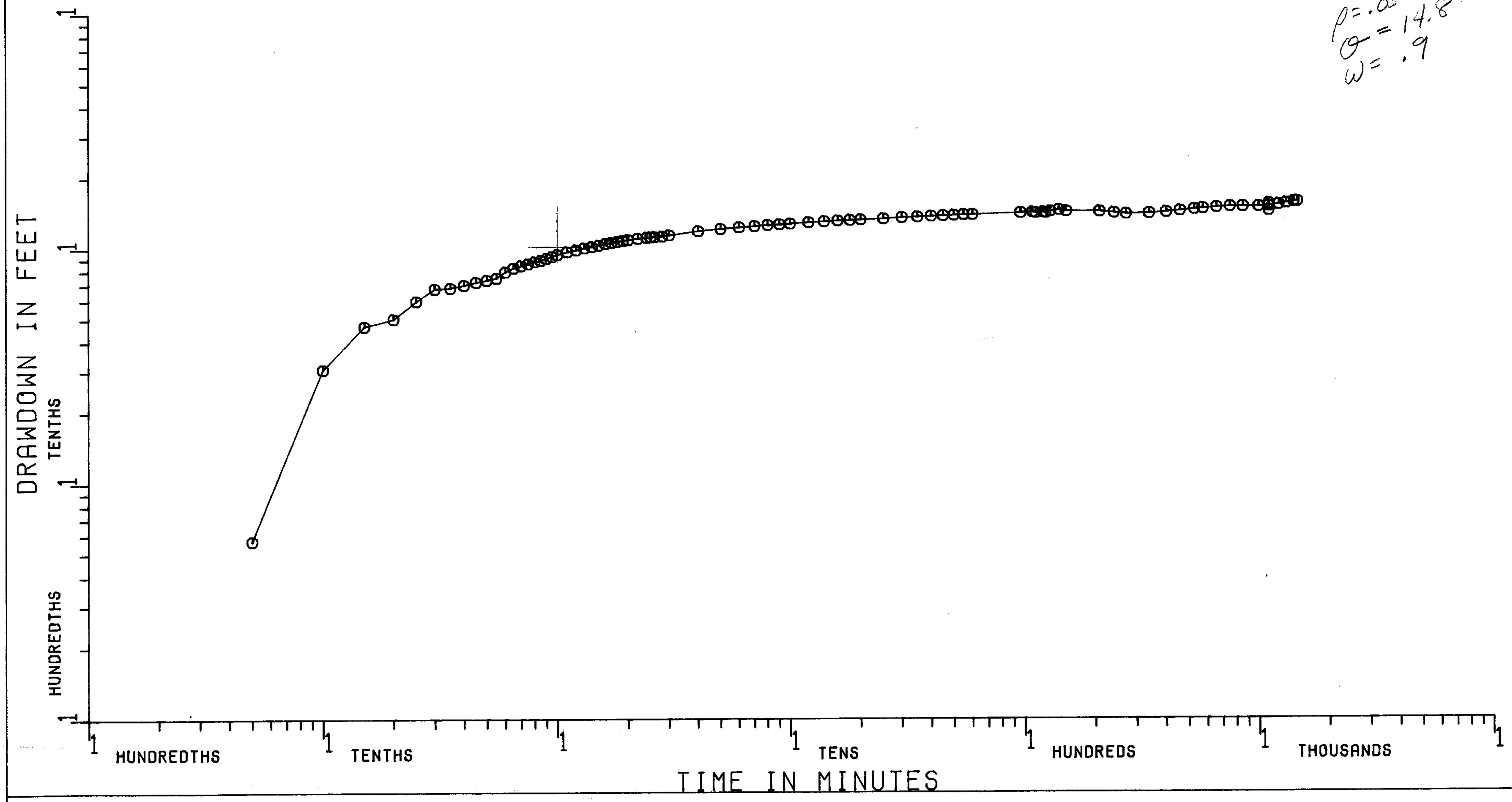
TAPENO 6265 PLOT NO 0319 TIME 12:54
USER NO NELMS DATE 86/05/05

OBSERVATION WELL: 4" OBSERVATION WELL

R= 135 Q= 322

(61,989 FT³/DAY)

$S=1$
$t=1$
$\rho=.05$
$\sigma=14.8$
$\omega=.9$



HIGHLAND BEACH

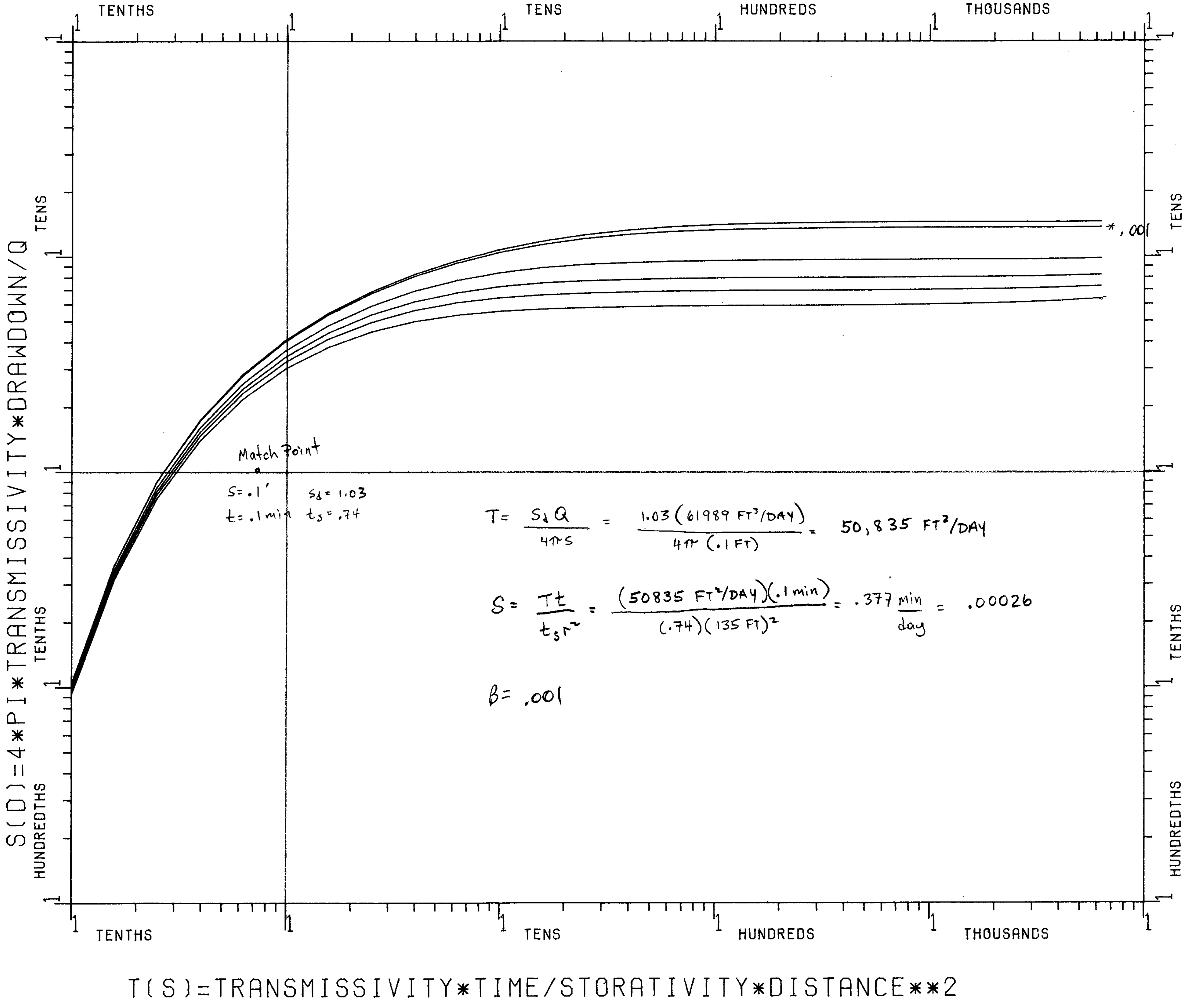
WMD

TAPENO 6230 PLOT NO 0015
USER NO PALM3D DATE 87/06/10 TIME 16:51

PROC NEUMAN RUN AT 16.01.33. 87/06/10.

HIGHLAND BEACH 4" OBS WELL

NEUMAN PARTIAL PENETRATION SOLUTION
B: 290' PW TD/CD: 90'/70' OW TD/CD: 90'/30'
ZD1=.6897, ZD2=.8966, PD=.3103, DD=.2414
BETA = .0008, .001, .003, .005, .007, .01



$s = .1'$ $s_d = 1.03$

$t = .1 \text{ min}$ $t_s = .74$

$$T = \frac{s_d Q}{4\pi s} = \frac{1.03(61989 \text{ FT}^3/\text{DAY})}{4\pi(.1 \text{ FT})} = 50,835 \text{ FT}^2/\text{DAY}$$

$$S = \frac{Tt}{t_s r^2} = \frac{(50835 \text{ FT}^2/\text{DAY})(.1 \text{ min})}{(.74)(135 \text{ FT})^2} = .377 \frac{\text{min}}{\text{day}} = .00026$$

$\beta = .001$

HIGHLAND BEACH 4" OBS WELL

NEUMAN PARTIAL PENETRATION SOLUTION
B= 290' PW TD/CD: 90'/70' OW TD/CD: 90'/30'
ZD1=.6897, ZD2=.8966, PD=.3103, DD=.2414
BETA = .02, .002