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TRANSMITTAL OF THE ADDENDUM PREDESIGN INVESTIGATION AND SIT SELECTION REPORT FOR THE ON-SITE DISPOSAL FACILITY

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ADDENDUM

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ADDENDUM
PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON-SITE DISPOSAL FACILITY

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

OCTOBER 1996
VOLUME IV

U. S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

000001

Department of Energy

Ohio Field Office
Fernald Area Office
P. O. Box 538705
Cincinnati, Ohio 45253-8705
(513) 648-3155

DOE-0124-97

Mr. James A. Saric, Remedial Project Director
U.S. Environmental Protection Agency
Region V - SRF-5J
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

Mr. Tom Schneider, Project Manager
Ohio Environmental Protection Agency
401 East 5th Street
Dayton, Ohio 45402-2911

Dear Mr. Saric and Mr. Schneider:

TRANSMITTAL OF THE ADDENDUM PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON-SITE DISPOSAL FACILITY

Enclosed for your review and approval is the Addendum Predesign Investigation and Site Selection Report for the On-Site Disposal Facility. This addendum is in response to the additional activities, identified in Section 6, "Predesign Investigation and Site Selection Report for the On-Site Disposal Facility," July 1995. These activities focused on the substantive hydrogeological requirements not addressed by the Predesign Investigation. All of the activities were completed as identified in Section 6, except the Flow Meter Readings. Based on the manufacturer's specifications, the KV Flowmeter™ was anticipated to be able to measure flow rates as low as 0.1 ml/minute. However, subsequent efforts to calibrate the KV Flowmeter proved impractical for low flow rates. This is consistent with U.S. EPA's Specific Comment #1, February 22, 1996, noting that, "...in a low-flow environment such as tills at the site, the accuracy of such meters is questionable."

If you have any questions or comments, please call Rod Warner at (513) 648-3156.

Sincerely,

Susan M Pelle

for Johnny W. Reising
Fernald Remedial Action
Project Manager

FEMP:Warner

Enclosure: As Stated

Recycled and Recyclable

cc w/enc:

S. Fauver, EM-425/GTN
G. Jablonowski, USEPA-V, 5HRE-8J
R. Beaumier, TPSS/DERR, OEPA-Columbus
F. Bell, ATSDR
D. S. Ward, GeoTrans
R. Vandegrift, ODOH
S. McLellan, PRC
T. Hagen, FDF/65-2
J. Harmon, FDF/90
AR Coordinator/78
EDC, FDF/52-7

cc w/o enc:

C. Little, FDF/2

475

ADDENDUM PREDESIGN INVESTIGATION AND SITE SELECTION REPORT FOR THE ON-SITE DISPOSAL FACILITY

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FERNALD AREA OFFICE

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1.0 INTRODUCTION

1.1 Purpose

Volume IV, Addendum to the Predesign Investigation and Site Selection Report, presents the information collected during the Addendum Activities to the Project Specific Plan for Phase I and II of the Operable Unit 2 Predesign Field Investigation, and should be included as part of the Predesign Investigation and Site Selection Report, July 1995 (PDIR). In Volume I, Section 6 (Path Forward), additional activities were identified to provide further clarification of the hydrogeology within the On-Site Disposal Facility (OSDF) footprint. This Addendum was developed to present the results of the additional activities that focused on further evaluation of the nature and extent of identified potential contamination found in Wells 11547 and 11548, determination of the location of existing underground drainage tiles within the OSDF footprint, and confirmation of the protectiveness of the gray till by seasonal sampling and testing of the wells installed during the Predesign Investigation.

The following is a summary of the Addendum activities and how they address the substantive requirements discussed in Section 6 of Volume I:

Slug Tests:	Evaluate horizontal conductivity and determine if engineered flow barriers are required.
Flow Meter Readings:	Determine the flow direction of the perched groundwater.
Tile Probes:	Determine the location and depth of the drain tiles and address potential flow issues in the OSDFdesign and construction planning.
Groundwater and Soil Sampling:	Characterize the nature and extent of contamination found in Wells 11547 and 11548.
Lysimeter Sampling:	Sampling of lysimeters until they reach equilibrium.

1.2 Report Organization

The results of the Addendum to the Predesign Investigation are presented in Section 2.0 and 3.0 of this report.

- Section 2.0 describes the field investigation activities and analytical program, and presents the data and results.
- Section 3.0 provides an interpretation of the data and conclusions, and relates the conclusions back to the Predesign Investigation.

2.0 FIELD COMPONENTS

2.1 Introduction

This section summarizes the field investigation program and results for the Addendum activities.

2.2 Slug Tests

Rising and falling head tests (slug tests) were completed on the following 23 wells, which are located within the OSDF footprint (See Figure 2.1):

11067	1064	11491	11492
11493	11494	11496	11497
11498	11499	11500	11501
11502	11503	11504	11505
11546	11547	11548	11681
11685	11687	11693	

Slug tests were completed from May 1995 to June 1995. Tests could not be completed in Well 11495 because of insufficient water present in the well casing at the time of testing. Slug tests were conducted in accordance with the procedures outlined in the Fernald Environmental Management Project (FEMP) Glacial Till/Vadose Zone Hydraulic Investigation Work Plan (1993). Water levels were recorded using HERMIT™ data loggers and pressure transducers.

2.2.1 Slug Test Analysis

Well boring logs and water levels at the time of testing were reviewed to determine where the potentially highest permeable zone existed within the screened interval (includes sand pack). The screened intervals were determined during the time of well installation as the

interval with the greatest potential to yield water; i.e, highest sand/gravel content with the greatest observable moisture content. If a high permeability zone was suspected to exist in the screened interval and water levels were above that interval, then testing was assumed to be under confined conditions. This was subsequently verified by barometric responses that indicated that the wells installed in the till respond as if they are confined. Data were analyzed by the Ramey et al.(1975) method as well as the Bouwer and Rice (1976) method to gain confidence in the results. While the Ramey et al. method uses the full data set, the Bouwer and Rice method requires only early time data. Water levels were always above the top of the screened interval during the rising and falling head tests; therefore, well casing radius did not require any corrections. A more detailed discussion of the slug test analysis procedures are contained in Appendix A.

2.2.2 Slug Test Summary Results

Lithologic information from boring logs and the static water level measurements taken before the slug tests were used to determine whether the hydraulic conditions were confined or unconfined in the proximity of each test well. Rising and falling head tests were analyzed by the Ramey et al. (1975) and/or the Bouwer and Rice (1976) method as described in Appendix A. Results of slug test analyses are presented in Table 2.1, Slug Test Results. Values of hydraulic conductivity from these two methods were in agreement with each other (see Appendix A for backup and a detailed discussion).

A representative value of hydraulic conductivity for each well is also provided (see Table 2.1). When multiple slug tests were conducted in a well, a geometric mean is considered a representative value of the hydraulic conductivity.

Wells were divided into two groups for the purpose of data analysis. The first group

Table 2.1 Slug Test Results

Well	Tested Interval (Ft.)	Bouwer and Rice Hydraulic Conductivity cm/s Rising	Bouwer and Rice Hydraulic Conductivity cm/s Falling	Cooper et. al. Hydraulic Conductivity cm/s Rising	Cooper et. al. Hydraulic Conductivity cm/s Falling	Most Representative Hydraulic Conductivity (cm/s)
Wells Screened Across The Brown/Gray Interface						
11067	3	8.48E−05	NA	1.65E−05	Na	1.65E−05
11494	8.25	1.83E−04	2.18E−04	1.81E−04	2.60E−04	2.08E−04
11496	7.25	1.39E−03	1.36E−03	2.76E−03	2.08E−03	1.89E−03
11504	4.25	5.06E−05	4.25E−05	7.00E−05	4.40E−05	5.15E−05
11546	4.25	2.62E−08	1.11E−08	ISD	ISD	1.72E−08
11547	4.25	1.17E−08	2.06E−08	6.09E−09	7.35E−09	1.02E−08
11548	4.25	3.29E−07	NA	6.79E−07	NA	4.72E−07
11681	5.25	8.50E−05	5.07E−05	1.12E−04	1.48E−04	9.21E−05
11685	4.5	1.78E−05	NA	2.05E−05	NA	1.91E−05
11687	4.5	4.35E−06	4.96E−06	6.61E−06	6.81E−06	5.58E−06
11693	4	1.28E−06	1.22E−06	4.31E−06	3.41E−06	2.19E−06
Wells Screened in the Gray Till						
1064	16	3.92E−07	4.58E−07	5.21E−07	1.19E−07	3.25E−07
11491	4.25	9.85E−06	7.48E−06	2.00E−05	2.02E−05	1.31E−05
11492	6.25	3.45E−06	4.19E−05	2.33E−06	2.29E−06	2.96E−06
11493	6.25	1.00E−07	5.84E−08	ISD	1.13E−07	8.71E−08
11497	4.25	6.11E−08	8.13E−09	1.67E−08	ISD	3.19E−08
11498	4.25	9.36E−08	4.14E−08	ISD	ISD	6.23E−08
11499	4.25	1.49E−08	1.73E−08	6.22E−09	6.93E−09	1.03E−08
11500	4.95	5.17E−07	5.26E−07	7.69E−07	3.09E−07	5.04E−07
11501	4.25	9.49E−07	1.12E−06	7.19E−07	4.38E−07	7.61E−07
11502	1.25	9.19E−06	5.96E−06	2.86E−05	3.41E−05	1.62E−05
11502	4.25	3.23E−08	1.77E−08	3.20E−08	ISD	2.63E−08
11505	4.25	5.56E−06	3.43E−06	8.65E−06	2.93E−06	4.69E−06

Geometric Mean

Brown/Gray Till Interface	6.3E−06
Gray Till (all wells)	4.0E−07
Gray Till (w/o 11491 and 11502)	2.0E−07

NA – No Data Available
ISD – Insufficient Data For Analysis

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includes wells screened (including sand pack) only in the gray till. The second group contains wells screened across the gray and brown till interface.

The hydraulic conductivities for Wells 11491 and 11502, which are screened in sand/gravel lenses within the gray till, were 1.31 x 10^{-5} cm/sec and 1.62 x 10^{-5} cm/sec, respectively. Hydraulic conductivities for the remaining wells screened only in the gray till ranged from 1.03 x 10^{-8} cm/sec for Well 11499 to 4.69 x 10^{-6} cm/sec for Well 11505. The geometric mean hydraulic conductivity for these Wells was 1.95 x 10^{-7} cm/sec. The calculated hydraulic conductivity of 4.69 x 10^{-6} cm/sec at Well 11505 is the upper limit for gray till.

The range of hydraulic conductivity for wells screened across the brown/gray till interface range from 1.02 x 10^{-8} cm/sec at Well 11547 to 1.89 x 10^{-3} cm/sec at Well 11496. The high hydraulic conductivities measured for Wells 11494, 11496, and 11681 is consistent with what would be expected for coarse grained soils (i.e., granular) observed in this area. The geometric mean hydraulic conductivity for wells screened across the brown/gray till interface was 6.3 x 10^{-6} cm/sec, approximately one order of magnitude higher than the hydraulic conductivity of the underlying gray till.

2.3 Flow Meter Measurements

KV flowmeters were used to determine the direction of groundwater flow in perched groundwater monitoring wells in the proximity of the OSDF footprint (Figure 2.1). Based on the manufacturer's specifications, it was initially anticipated that the KV flowmeter could possibly be used to accurately measure the flow rates of groundwater in the till. This subsequently proved not to be practical due to not being able to configure the soil material to simulate those existing conditions in the till. That is, soils could not be placed and compacted in the calibration chamber of the flowmeter to adequately simulate the density, permeability, and effective porosity of the naturally-occurring conditions. The calibration

and verification process is defined by manufacturer's manuals and guidance, and is discussed in detail in Appendix B. The KV flowmeter is a thermal pulse meter and is capable of measuring groundwater flow direction and rates in low permeability soils. The instrument is capable of measuring flow rates down to 0.01 ft/day; however, this sensitivity is contingent upon the accuracy of the calibration curves. This is discussed further in Section 2.3.2.

2.3.1 Field Methods

Flowmeter measurements were taken from 21 wells (Table 2.2, Flowmeter Measurements) at intervals that were determined from boring logs to potentially have the highest hydraulic conductivity in the screened interval. Prior to placement of the probes into the wells, an initial water level measurement was taken. Subsequent water level measurements were taken to determine when the well would reach hydraulic equilibrium, which is when the water levels stop falling or rising. After it was determined that the wells reached hydraulic equilibrium, initial flowmeter readings were recorded to establish a baseline. Subsequent channel readings were recorded periodically to determine when the wells reached thermal equilibrium. This was determined when the channel readings were stable. Thereafter a thermal pulse was induced and final channel readings were taken. Multiple measurements were taken in selected wells to determine the consistency and accuracy of the measurements. At the completion of the tests, the probes were rotated 180 degrees and the groundwater in the well was allowed to reach thermal equilibrium prior to the initiation of the second and final phase of the test. The second phase was conducted in the same manner as the first phase. Channel readings were recorded on groundwater flow worksheets, and the flow vectors were used to determine the flow direction of the perched groundwater for each well (see Appendix B).

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TABLE 2.2 FLOWMETER MEASUREMENTS

WELL NUMBER	METER NUMBER	NUMBER OF MEASUREMENTS	DEPTH FROM TOP OF WELL (FT)	FLOW DIR.	FLOW RATE (FT/DAY)	FLOW RATE (FT/YR)
11491	2 2	2 1	28.5 27.5	NNE NE	.4, .3, .33	146, 109 120
11492	1 1	3 2	205 20	SSW S	.21, .23, .26 .16, .19	76,84,95 58,69
11493	2 2	2 1	23.5 22.5	NNW NNW	.28,.28 .3	102,102 109
11494	1 1	2 1	15.5 14.5	N NW	.09,.1 .087	33,37 32
11496	1	2	16	S	.17,.14	62,51
11497	2	3	33.5	S	.2,.2,.15	73,73,55
11498	1	2	30.25	N	.12,.12	44,44
11499	2	2	18.25	NW	.22,.28	80,102
11500	2	1	24	E	.17	62
11501	2 2	2 1	36 35	E E	.56,.44 .36	204,161 131
11502	1 1	1 1	21.5 21	WNW NW	.17 .1	62 36
11503	1	1	29.1	E	.24	88
11504	2	1	15	N	.15	55
11505	1	1	28	N	.1	36
11546	1	1	14	NNW	.27	99
11547	1 2	2 2	14 14	NONE NW	.21,.09 .07,.07	77,33 26,26
11548	2	1	15	E	.35	128
11681	1	2	13	NW	.4,.12	146,44
11685	2	3	17.5	E	.17,.16,.25	62,58,91
11687	2	1	13.5	NE	.25	91
11693	1	1	15	SSW	.39	149

2.3.2 Flowmeter Results

The results for the flow directions can be considered reasonably accurate since they could be duplicated with regularity. The flow rate results, however, are questionable due to the following factors:

1. The calibration curves were developed with an accuracy of $\pm .1$ ft/day to $\pm .4$ ft/day, which gives a potential of a 50% to over 100% error in the value. This level of error makes the measured horizontal flow rates suspect.

2. The instrument calibration was conducted in material with an effective porosity of .25, which is higher than the expected range of .04 to .16 for the till. Material with the higher effective porosity was used for ease of compaction and placement of material in the chamber and allowed for obtaining uniform conditions in the flow chamber (Appendix B). The manufacturer of the KV flowmeter suggests calibrating the meter in the same material that the wells are screened in. However, this could not be practicably accomplished with the flow chambers used for calibration; consequently, making the calibration questionable for use in the till to determine flow rates.

3. The calibration curves were suitable for flow rates of 1.2 ft/day to 10 ft/day, while the expected flow rates in the till varied from 2.9×10^{-5} ft/day to 5.3 ft/day.

The horizontal flow directions are spatially variable (Table 2.2) from well to well indicating that horizontal flow components are highly localized, and a regional horizontal flow direction for the perched groundwater should not be inferred. Consequently, the vertical flow component for the perched groundwater in the footprint of the OSDF should be the only flow

component used in determining protection of human health and the environment. This is consistent with the fate and transport modeling performed in the Operable Unit 5 Feasability Study. Therefore, horizontal engineered barriers would not be effective.

2.4 Nature and Extent of Contamination From Wells 11547 and 11548

During the Predesign Investigation, concentrations of 198.61 μg/L and 59.9 μg/L total uranium were found in Wells 11547 and 11548, respectively. Additional water samples were collected from these two locations, as well as from 8 locations around Well 11547 and 16 locations around Well 11548 using a Geoprobe™ samplerm (see Figure 2.1). The Geoprobe™ is vehicle-mounted and uses the static weight of the carrier vehicle and hydraulic push (dispersed with percussion hammer action) to drive sample tools. Also, surface soil samples were collected at the eight Geoprobe™ locations around Well 11547 and at the 8 Geoprobe™ locations around Well 11548 to determine whether surface soil contamination contributed to the perched groundwater contamination.

2.4.1 Perched Groundwater And Surface Soil Results

The unfiltered perched groundwater total uranium Geoprobe™ results from around Well 11548 ranged from 1.1 μg/L to 32 μg/L, and the filtered total uranium results ranged from 0.3 μg/L to 15 μg/L (Table 2.3, Geoprobe Water and Soil Results). The results for the perched groundwater unfiltered total uranium Geoprobe™ results around Well 11547 ranged from 6.0 μg/L to 21 μg/L, and the filtered total uranium results ranged from 1.2 μg/L to 5.1 μg/L. The groundwater results from Well 11547 were 54.47 μg/L unfiltered, and 47.9 μg/L filtered; and the results from Well 11548 were 17.9 μg/L unfiltered and 14.9 μg/L filtered.

The surface soil results ranged from 6 mg/kg to 49 mg/kg around Well 11547, and 8 mg/kg to 24 mg/Kg around Well 11548 (Table 2.3).

Table 2.3 Geoprobe Water And Soil Results

LOCATION	MATRIX	DEPTH	TOTAL U RESULT
12044	SOIL	0-6"	23 PPM
	WATER	12-15.5' (FILT)	3.3 UG/L
	WATER	12-15.5'	11 UG/L
12045	SOIL	0-6"	24 PPM
	WATER	11.5-14'	32 UG/L
	WATER	11.5-14' (FILT)	4.9 UG/L
12046	SOIL	0-6"	10 PPM
	WATER	10.5-14' (FILT)	6.3 UG/L
12047	SOIL	0-6"	9 PPM
12048	SOIL	0-6"	15 PPM
12049	SOIL	0-6"	13 PPM
	WATER	10.5-14' (FILT)	0.3 UG/L
	WATER	10.5-14'DUPE	2.1 UG/L
	WATER	10.5-14'	1.1 UG/L
12050	SOIL	0-6"	8 PPM
	WATER	7.5-11' (FILT)	3.8 UG/L
	WATER	7.5-11'	31 UG/L
	WATER	12.5-16' (FILT)	4.3 UG/L
	WATER	12.5-16'	5.5 UG/L
12051	SOIL	0-6"	13 PPM
12052	SOIL	0-6"	26 PPM
	WATER	9-12.5' (FILT)	5.1 UG/L
	WATER	9-12.5'	6.0 UG/L

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LOCATION	MATRIX	DEPTH	TOTAL U RESULT
12053	SOIL	0-6"	49 PPM
12054	SOIL	0-6"	48 PPM
	WATER	9.5-13' (FILT)	1.3 UG/L
	WATER	9.5-13'	16 UG/L
12055	SOIL	0-6"	36 PPM
	WATER	8.5-12' (FILT)	2.1 UG/L
	WATER	8.5-12'	16 UG/L
12056	SOIL	0-6"	6 PPM
	WATER	8.5-12' (FILT)	1.8 UG/L
	WATER	8.5-12'	12 UG/L
12057	SOIL	0-6"	20 PPM
	WATER	9.5-13' (FILT)	1.2 UG/L
	WATER	9.5-13'	21 UG/L
12058	SOIL	0-6"	21 PPM
	WATER	8-11.5' (FILT)	2.4 UG/L
	WATER	8-11.5'	9.0 UG/L
12059	SOIL	0-6"	26 PPM
	WATER	8-11.5' (FILT)	2.2 UG/L
	WATER	8-11.5'	13 UG/L
	WATER	8-11.5' (DUPE)	5.2 UG/L
12093	WATER	9.5-13' (FILT)	15 UG/L
	WATER	9.5-13'	20 UG/L
12094	WATER	9.5-12.5' (FILT)	2.7 UG/L
	WATER	9.5-12.5'	2.9 UG/L
12095	WATER	6.5-10' (FILT)	1.6 UG/L
	WATER	6.5-10'	2.6 UG/L
12096	WATER	6-9.5' (FILT)	4.7 UG/L

LOCATION	MATRIX	DEPTH	TOTAL U RESULT
12097	WATER	11.5-15' (FILT)	2.1 UG/L
	WATER	11.5-15'	3.1 UG/L
12098	WATER	13-16.5'(FILT)	7.0 UG/L
	WATER	13-16.5'	17.0 UG/L
12099	WATER	11-14.5' (FILT)	4.8 UG/L
12100	WATER	12.5-16'(FILT)	1.7 UG/L
	WATER	12.5-16'	2.3 UG/L
MW 11547 RINSATE	DI WTR	N/A	<.007 UG/L
MW 11547 F BLANK	DI WTR	N/A	<.06 UG/L
MW 11548 RINSATE	DI WTR	N/A	<0.1 UG/L
MW 11548 F BLANK	DI WTR	N/A	<0.1 UG/L

N/A - Not Applicable

2.5 Drain Tile Network Identification

During the Predesign Investigation multiple drain tile systems were observed within the OSDF footprint. Hand-held steel probes were used to identify the tiles starting from the tile surface exposure (i.e. ditch exit points) and moving outward. The probes were pushed from 2 to 3 feet below the surface until contact was made with the tile. The locations were marked and surveyed, and the resulting identified drain tile network is shown on Figure 2.1. Field observations and the surveyed results indicate that the tile was installed to allow for the maximum amount of infiltration while using the least amount of drain tile. This is demonstrated by the irregular pattern of the network, which generally follows historical surface drainage patterns. Within the footprint the drainage flow direction is mainly from the northeast and east to the southwest and west (see Figure 2.1).

2.6 Perched Groundwater Verification Sampling

During Phase II of the Predesign Investigation 18 wells were installed and sampled for total uranium only. To verify the perched groundwater total uranium concentrations from these wells, another round of samples was collected and analyzed for total uranium during the Addendum activity. In addition to the total uranium analysis for this round, technetium-99 was analyzed for also. After this round, a subsequent round of sampling from these wells was conducted and only technetium-99 analysis was performed. Therefore, two complete rounds of sampling were conducted for total uranium and technetium-99 for the Phase II wells.

In addition to the Phase II wells, four wells were installed during Phase III of the Predesign Investigation. These four additional wells were not sampled before the completion of the

PDIR, but were sampled twice during the Addendum activity for total uranium and technetium-99. This additional sampling brings the total number of wells to 22. The following is the list of wells sampled during the Addendum activity for total uranium and technetium-99:

11491 11492 11493 11494 11547 11548 11681 11687
11495 11496 11497 11498 11685 11693 11502 11503
11499 11546 11500 11501 11504 11505

The concentrations for total uranium ranged from 1.6 μg/L to 54 μg/L (Table 2.4, Groundwater Confirmation Results), which is within the range of values for the Predesign Investigation. The concentrations for technetium-99 were below detection limits for all of the samples.

2.7 Lysimeter Sampling

Analysis of the results for the lysimeters installed prior to the Predesign Investigation indicated that the lysimeters reached equilibrium approximately 12 months after installation. Therefore, the lysimeters installed during the Predesign Investigation were sampled to determine if they had reached equilibrium. Table 2.5, Lysimeter Total Uranium Concentrations, shows the results from this sampling activity. As shown in Table 2.5, the total uranium concentrations generally decreased or stayed approximately the same for all of the lysimeters except lysimeter 11559, which increased significantly over time. Lysimeter 11559 is located approximately 2500 feet west of the waste pits. The blank spaces labeled NA (not available) are due to the lysimeter not yielding an adequate sample volume for analysis. Also, according to American Society for Testing and Materials (ASTM) D4696-92 "results of analyses from suction lysimeter samples are good for qualitative analysis, but they cannot be used for quantitative analysis."

Table 2.4 Groundwater Confirmation Results

Well #	Total U Round I (μg/L)			Total U Round II (μg/L)			Tech. Round	99 I (μCi/L)	Tech. Round	99 II (μCi/L)
	Unfil.	Filt.	Date	Unfil.	Filt.	Date	Filt.	Date	Filt.	Date
11491	3.2	2.6	1-23-96				<0.24	1-23-96	<0.045	2-20-96
11492	1.9	1.9	1-23-96				<0.34	1-23-96	<-0.06	2-20-96
11493	5.1	12.0	1-23.96	11	10	3-6-96	<0.42	1-23-96	<-0.3	2-21-96
11494	2.3	2.3	1-23-6				<0.46	1-23-96	<0.12	2-21-96
11495	4.0	3.7	1-23-96	3	2.6	3-6-96	<0.3	1-23-96	<0.15	2-21-96
11496	2.2	2.2	1-23-96				<0.26	1-23-96	<0.0031	2-21-96
11497	3.7	2.4	1-26-96				<-0.18	1-26-96	<-0.04	2-22-96
11498	1.7	1.6	1-23-96				<0.18	1-23-96	<0.27	2-22-96
11499	3.2	3.2	1-23-96				<0.42	1-23-96	<-0.088	2-22-96
11500	0.69	0.63	1-24-96				<0.024	1-24-96	<-0.13	2-22-96
11501	0.43	0.4	1-24-96				<0.088	1-24-96	<-0.092	2-22-96
11502	6.9	4.8	1-24-96				<0.33	1-24-96	<0.07	2-22-96
11503	0.44	0.19	1-24-96				<0.21	1-24-96	<0.014	2-22-96
11504	3.1	3.1	1-25-96				<0.027	1-25-96	<0.13	2-20-96
11505	1.1	0.87	1-25-96				<0.15	1-25-96	<-0.23	2-20-96
11546	11	11	1-24-96	14	13	3-6-96	<0.096	1-24-96	<0.052	2-27-96

Well #	Total U Round I (μg/L)			Total U Round II (μg/L)			Tech. Round	99 I (μCi/L)	Tech. Round	99 II (μCi/L)
11547	54	48	1-25-96	22	21	3-6-96	<-0.19	1-25-96	<-0.000015	2-21-96
11548	45	47	1-25-96	19	19	3-6-96	<0.04	1-25-96	<-0.092	2-21-96
11681	2.6	3.0	1-25-96				<-0.017	1-25-96		
11685	8.7	8.6	1-25-96				<0.19	1-25-96		
11687	4.3	4.3	1-25-96	2.7		2-23-96	<0.14	1-25-96	<-0.14	2-23-96
11693	9.5	11	1-25-96	16.9		2-21-96	<-0.092	1-25-96	<0.019	2-21-96

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TABLE 2.5
LYSIMETER TOTAL URANIUM CONCENTRATIONS
(μg/L)

Wells	11482	11483	11484	11486	11488	11557	11558	11559
Dates								
Jan 95	4.2	4.4	7.0	4.4	4.8	NA	NA	NA
Mar95	NA	0.5	NA	0.3	1.7	NA	1.8	12
Jun 95	NA	NA	NA	0.4	NA	NA	32	NA
Jul 95	NA	NA	NA	0.2	NA	NA	32	NA
PDI	22	0.5	2.9	4.4	1.8	10.8	35	23.6
Jan 96	20	0.3	2.1	2.7	1.7	9.5	31	42
Feb 96	21	0.6	2.0	3.0	1.9	9.8	29	70
Mar 96	21	0.5	2.1	2.9	2.2	11	29	96

NA - Not Available, recoverable water volumes were inadequate for analysis.

3.0 CONCLUSIONS

3.1 Overview

The Predesign Investigation demonstrated that the selected location for the OSDF has the most suitable hydrogeology. The selected location has the highest overall average gray till thickness, and satisfies the substantive hydrogeological/geotechnical requirements of the Ohio Solid Waste Disposal Regulations (OAC 3745-27-06). Section 5.0 of the PDIR discusses these requirements and how they were met. However, certain requirements needed additional action (Section 6.1, PDIR). The following is a summary of the additional actions:

Slug Tests:	Evaluate horizontal conductivity and determine if engineered flow barriers are required.
Flow Meter Readings:	Determine the flow direction of the perched groundwater.
Tile Probes:	Determine the location and depth of the drain tiles and address potential flow issues in the disposal facility design and construction planning.
Groundwater and Soil Sampling:	Characterize the nature and extent of contamination found in Wells 11547 and 11548.
Lysimeter Sampling:	Sample lysimeters until they reach equilibrium.

This section presents the conclusions associated with the above activities, how they meet the Predesing Investigation objectives, and satisfy the substantive hydrogeological/geotechnical requirements.

3.2 Slug Tests

The rising and falling head slug tests conducted during the Addendum activities had a wide range of horizontal conductivity results (five orders of magnitude). This wide range demonstrates the heterogeneity of the till and the anisotropic hydrogeological conditions in the till. In essence, the horizontal conductivities determined by the slug tests represent only localized conditions. The heterogeneity and localization of the perched groundwater flow conditions demonstrates that there is not a large-scale horizontal flow component in the till and that the vertical component is the most significant. This conclusion is further supported by the flowmeter readings (Section 3.3).

The conclusion that a significant horizontal flow component does not exist in the till is different from the conservative interpretation presented in Section 2.6.3 of the PDIR, July 1995, which indicates a potential southwesterly horizontal perched groundwater flow direction. This conservative interpretation was due to limited data for evaluation. The perched groundwater contours on Figure 2.20 of the PDIR were generated using water level measurements from wells screened across the brown/gray till interface. Since the brown/gray till interface is at the same approximate depth below the ground surface (approximately 11 feet), contouring water level measurements from wells screened across this interval gave an apparent potentiometric surface that approximated the ground surface contours trending to the southwest. This happens to any series of wells installed at a specific depth below the ground surface. For instance, if wells are screened 20 feet below the surface, the wells will have approximately the same hydraulic head which can be connected and will show apparent potentiometric contours approximating the ground surface contours. The interpretation of an extensive horizontal component in the till using these potentiometric surfaces can be grossly misleading since there is a strong vertical hydraulic flow component. This vertical component was demonstrated by the large hydraulic head differences in the nested wells. These head differences in the nested wells support the conclusion that the most

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significant flow component is vertical and that the horizontal flow component is localized for each well and not spatially continuous.

3.3 Flow Meter Readings

KV™ flowmeter readings were taken in wells installed during Phase II and III of the Predesign Investigation. Due to equipment calibration limitations, the only measurements usable are those for the flow directions. These flow directions (Figure 2.1) demonstrate that the flow directions are spatially variable. This further supports the conclusion that anisotropic hydrogeological conditions exist in the till and that horizontal flow is localized making the vertical flow component the predominant flow component.

3.4 Tile Probes

The location and depth of the clay agricultural drainage tile network was determined using hand-held probes. The location was mapped and flow directions indicated on Figure 2.1. The entire drain tile network within the OSDF footprint will be removed integral with the installation of the leachate collection and liner system (see OSDF Design Drawings SKG04391.DGN and 90X-6000-G-00073 for requirements). Any pipe that enters or exits the OSDF footprint will be excavated to its end points and backfilled with compacted soil that is below final remediation levels (FRLs). The removal of the drain tile and the backfilling will eliminate any flow that may have existed and eliminating any future flow problems associated with the drain tile system.

3.5 Groundwater and Surface Soil Sampling to Determine the Nature and Extent of the Contamination Found in Perched Groundwater From Wells 11547 and 11548

Surface soil samples were collected at each Geoprobe™ location prior to drilling and analyzed for total uranium. In accordance with the approved Project Specific Plan, Geoprobe™ borings were located approximately 50 feet from Wells 11547 and 11548 (Figure 2-1). After these surface soil samples were collected the Geoprobes™ were advanced to their planned depths and groundwater samples collected. Some of the groundwater samples with elevated total uranium concentrations may be correlatable to surface soil sample concentrations from the same Geoprobe™ locations. This association may be due to potential cross contamination from surface water transferred downhole with the Geoprobe™. In all cases, the surface soil contamination was observed to be below the FRLs. The perched groundwater total uranium concentrations will be included as part of the perched groundwater baseline or "haze" that will be considered in the OSDF leak detection trend analysis (Groundwater Detection Monitoring Program For The On-Site Disposal Facility, June 1996).

3.6 Perched Groundwater Verification Sampling

The perched groundwater from the wells installed during Phase II and III of the Predesign Investigation was resampled for total uranium and the results ranged from 1.6 μg/L to 54 μg/L. This range in within the range of 1.4 μg/L to 200 μg/L for the OSDF footprint area (Section 2, PDIR, July 1995), and confirms the results from both sampling events. The concentrations found in the perched groundwater do not constitute a problem for the design, construction, and operation of the OSDF since these concentrations will be included as part of the baseline or "haze" to be considered in the OSDF leak detection trend analysis.

3.7 Lysimeter Sampling

The lysimeters installed during the Predesign Investigation were sampled over a period of 12

months. This time period was chosen due to the fact that previously installed lysimeters at the FEMP took approximately 12 months to equilibrate. Results prior to this 12 month period may be considered as false positives. All of the lysimeters installed during the Predesign Investigation appeared to have reached equilibrium during the 12 month period except lysimeter 11559, which is a background lysimeter not in the proximity of the OSDF. The results from the lysimeters in the proximity of the OSDF ranged from 0.2 μg/L to 22 μg/L total uranium. These results are within the range of the perched groundwater results for the OSDF and do not indicate a problem. Also, according to ASTM D4696, "results of analyses from suction lysimeter samples are good for qualitative comparisons, but they cannot be used for quantitative analysis". Therefore, lysimeter results should be used with caution due to the propensity for false positives during the equilibration period.

3.8 Summary Conclusions

The Addendum activities support the following conclusions.

1. The horizontal flow component is localized and discontinuous.
2. The fate and transport models used in the Operable Unit 2 and Operable Unit 5 Feasibility Studies assumed vertical flow. The results of the Predesign Investigation and this addendum study support the conclusion that vertical groundwater flow predominates in the till in the OSDF footprint.
3. Existing perched groundwater total uranium contamination in the area of the OSDF is not a threat to human health and the environment and engineered flow barriers are not required for the OSDF.
4. Lysimeters at the FEMP need at least 12 months to equilibrate.
5. The drain tile network is adequately identified for removal during OSDF construction.

APPENDIX A

HYDRAULIC TESTING

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A.0 HYDRAULIC TESTING

This appendix describes the testing and analysis procedures used to interpret barometric response and slug tests that were conducted to obtain measurements of hydraulic parameters of the glacial till. These parameters are important in understanding the fate and transport of contaminants should leaks occurs in the liner of the On-Site Disposal Facility (OSDF).

A.1 BAROMETRIC RESPONSE

Static water level responds to changes in barometric pressure. No response in water level is observed, however, if an aquifer is unconfined. The barometric efficiency, E_b, is the ratio of change in well head to the change in barometric pressure when the well is open to atmosphere:

$$E_b = \frac{\Delta H}{\Delta P_a}$$

where ΔH is the change in water level in feet and ΔP_a is change in barometric pressure expressed in feet of water column. The barometric efficiency is related to the matrix compressibility, c_{ma}, and the storage coefficient of the aquifer, S, as follows (van der Kamp and Gale, 1983; McKee, Bumb, and Horner, 1990):

$$c_{ma} = \phi c_w \frac{1-E_b}{E_b}$$

$$S = \frac{1}{\gamma} b (c_{ma} + \phi c_w) \quad = \frac{1}{\gamma} b \, \phi c_w \frac{1}{E_b}$$

where b is the aquifer thickness or tested interval in feet, c_w is the compressibility of water (3.33 x 10^{-6} psi^{-1}), γ is the unit weight of water (0.433 psi/ft), and ϕ is the porosity. The geotechnical investigation for gray till under the OSDF indicate that the porosity is approximately 27.5 percent.

A.1.1 FIELD DATA

As an example, water levels in monitoring wells 11500, 11501, and 11546 were recorded on a 15 minute interval from June 6, 1995 to July 18, 1995. Water levels were recorded using HERMIT™ data loggers and pressure transducers (manufactured by In-Situ Inc.). Figure A-1 shows the water level changes as a function of time in wells 11500, 11501, and 11546.

Barometric pressure and precipitation were continuously measured using Climatronics instruments as part of the site-wide meteorologic data collection program. This information is summarized in Table A-1. Barometric pressures were averaged over 15 minute intervals while precipitation data were added to provide total precipitation for 15 minute intervals. When automatic Climatronics rain/snow gauge was suspected of malfunction, precipitation data from a National Weather Service approved manual gauge installed on-site were used. No on-site meteorologic data were available from June 30, 1995 to July 2, 1995 due to instrument/computer malfunction. To fill-in the barometric pressure data gap for this time period, hourly barometric pressure data from the Northern Kentucky-Cincinnati Airport were obtained and corrected for elevation difference of two weather stations. Accuracy of conversion was checked by comparing converted values with available on-site measurements between June 25, 1995 and July 8, 1995. Figure A-2 show barometric pressure and the recorded precipitation at the FEMP.

A.1.2 BAROMETRIC EFFICIENCY ANALYSIS

All three monitoring wells show a declining water level trend (Figure A-1). While wells 11500 and 11501 show response to changes in barometric pressure (Figure A-2), well 11546 does not seem to respond to changes in barometric pressure or precipitation events. Well 11546 is the shallowest well among the three wells and is screened across the brown/gray till interface. The lack of barometric influence is indicative of unconfined aquifer conditions at the Well 11546. The declining trend may be due to seasonal water level changes and water levels returning to static condition after water level rise from installation of the transducer in this well. The slow water level recovery to static conditions is consistent with approximately 10^{-8} cm/sec hydraulic conductivity values obtained from analysis of slug tests conducted at this well (see Section A.2).

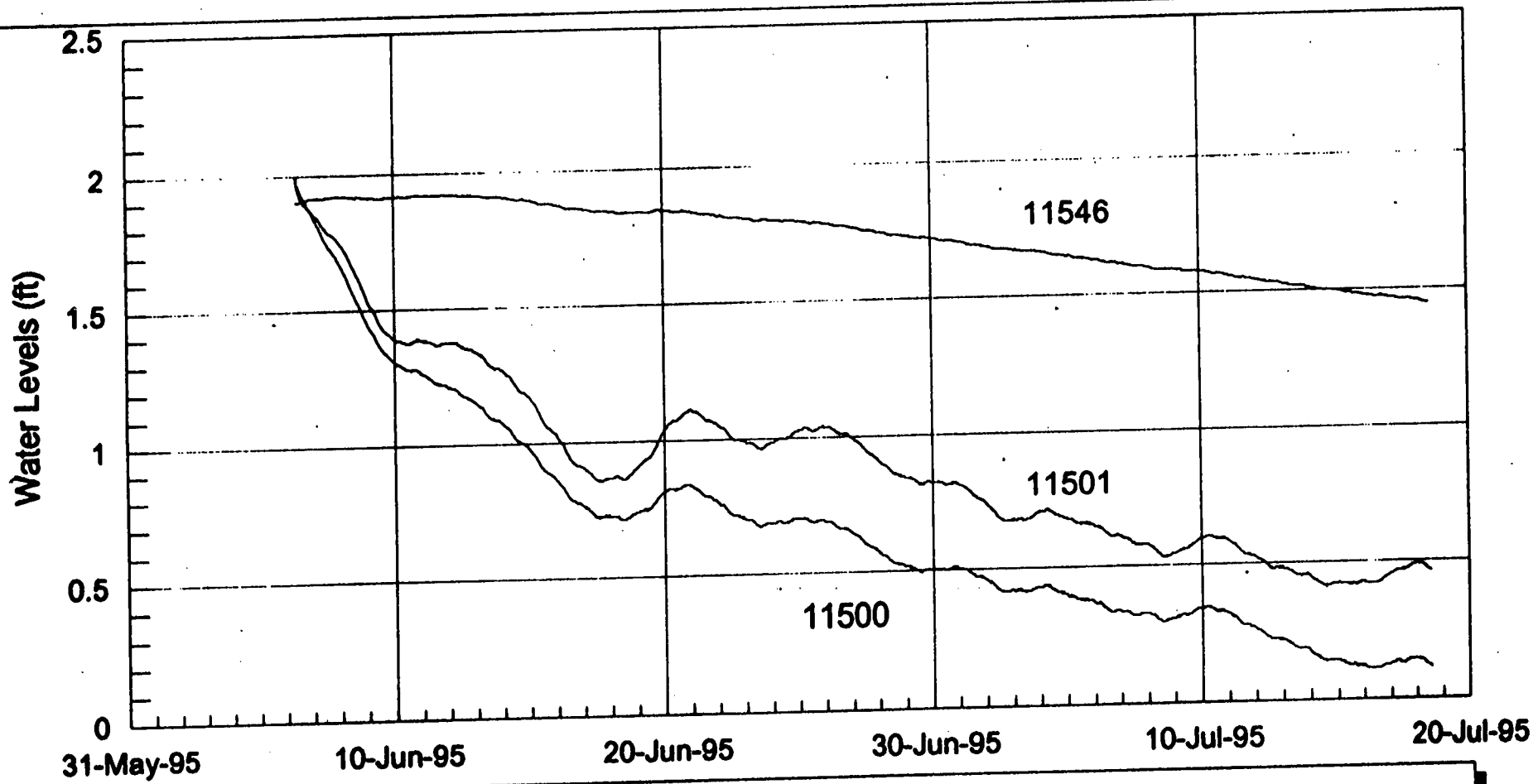

Figure A-1 Uncorrected Water Levels in Wells 11500, 11501, and 11546

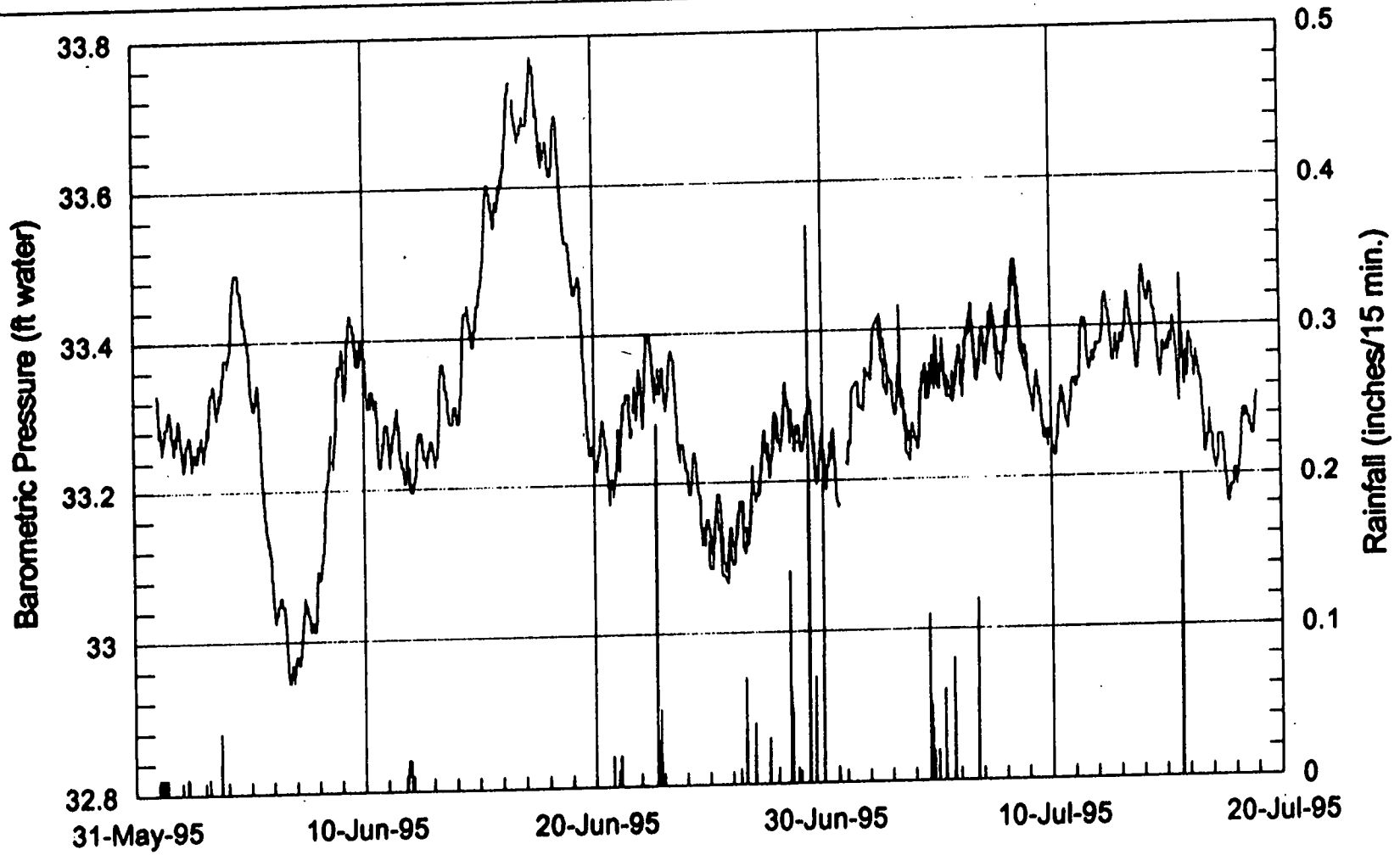

Figure A-2 Barometric Pressure and Precipitation Data

Table A-1 : Summary of Meteorological Data for the Fernald Environmental Management Project

Period Begin	Period End	Elapsed Time (days)	Barometric Pressure (ft)					Rainfall (inches)
			Minimum		Maximum		Change (ft)	
			(ft)	Time	(ft)	Time		
12-Jun-95	18-Jun-95	5.271	33.195	02:15	33.773	08:45	0.578	0.28
17-Jun-95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.02
20-Jun-95	23-Jun-95	2.688	33.183	16:30	33.376	09:00	0.193	0.66
23-Jun-95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.58
25-Jun-95	29-Jun-95	3.656	33.081	18:15	33.332	10:00	0.251	0.52
29-Jun-95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.01
30-Jun-95	02-Jul-95	1.750	33.206	16:00	33.422	10:00	0.215	0.71
02-Jul-95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.25
04-Jul-95	08-Jul-95	4.219	33.240	03:45	33.490	09:00	0.249	0.63
08-Jul-95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
10-Jul-95	13-Jul-95	3.812	33.229	04:00	33.478	23:30	0.249	0.59
13-Jul-95	17-Jul-95	3.760	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Barometric pressure is increasing

Barometric pressure is decreasing

Water level decline until June 10, 1995 for wells 11500 and 11501 is dominated by a response to installation of transducers and masks response to changes in barometric pressures. Therefore, data prior to June 10, 1995 were not analyzed.

Barometric response of wells 11500 and 11501 were corrected for the general decline in water level. General water level decline rate was calculated by selecting a time period with approximately equal barometric pressure at the start and end of the period. The two time periods selected for calculating average declining rate were from June 20 to July 18, 1995 and from July 2 to July 16, 1995. The least-squares fit was used to calculate average declining rates. The average declining rate for well 11500 was 0.0251 ft/day from June 20 to July 18, 1995 and was 0.0230 ft/day for the time period July 2 to July 16, 1995. The average declining rate for well 11501 was 0.0261 ft/day from June 20 to July 18, 1995 and was 0.0217 ft/day for the time period July 2 to July 16, 1995. Figures A-3 and A-4 show water level changes after correcting for the average water level decline observed from June 20 to July 18, 1995 and from July 2 to July 16, 1995, respectively.

Tables A-2 and A-3 provides a summary of barometric efficiency analysis and calculation of storage coefficients for wells 11500 and 11501, respectively. Average barometric efficiencies for wells 11500 and 11501 are 36 percent and 49.5 percent, respectively. There is a minor variation between barometric efficiencies calculated from data during increasing barometric pressure (decreasing water level) cycles and during declining barometric pressure cycles. However, impact on the calculated matrix compressibility and the storage coefficient is insignificant.

Barometric response data indicate that the matrix compressibility is about 10^{-6} psi^{-1} for the gray till. The calculated storage coefficient ranges from 3×10^{-6} to 7×10^{-6}. This is within the typical range for clayey and/or silty soils.

A.2 SLUG TESTS

Rising and falling head tests (slug tests) were attempted on 22 wells installed during the Pre-Design Investigation activities and wells 1064 and 11067 installed during remedial investigation activities at the FEMP. Slug tests were completed from May to June 1995. Tests could not be completed in Well No. 11495 because of insufficient water present in the well casing at the time of testing. Slug tests were conducted in accordance with the procedures outlined in the Fernald Environmental

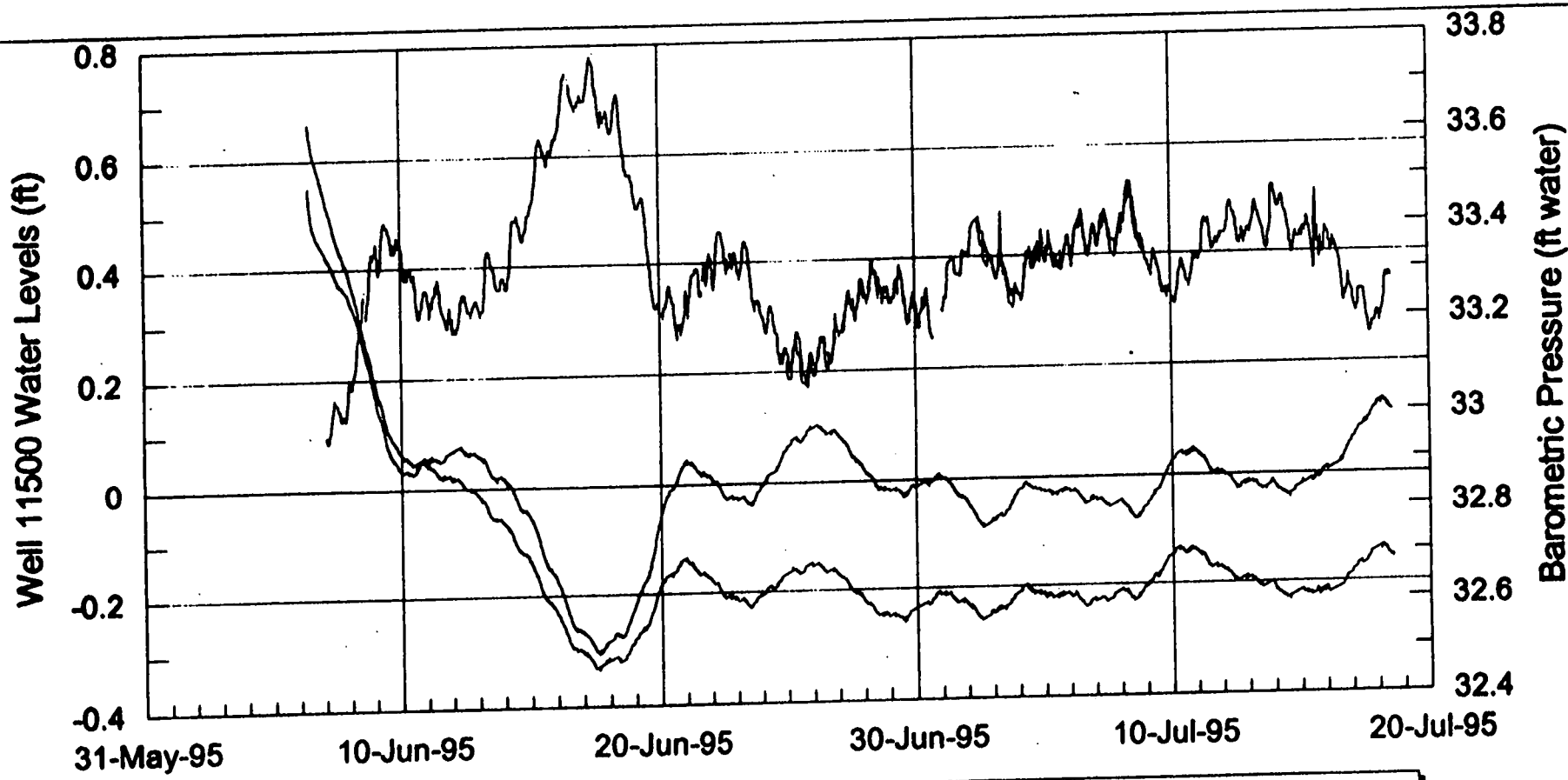

Figure A-3 : Water Levels Corrected Using Seasonal Declining Trend from June 20 to July 18, 1995

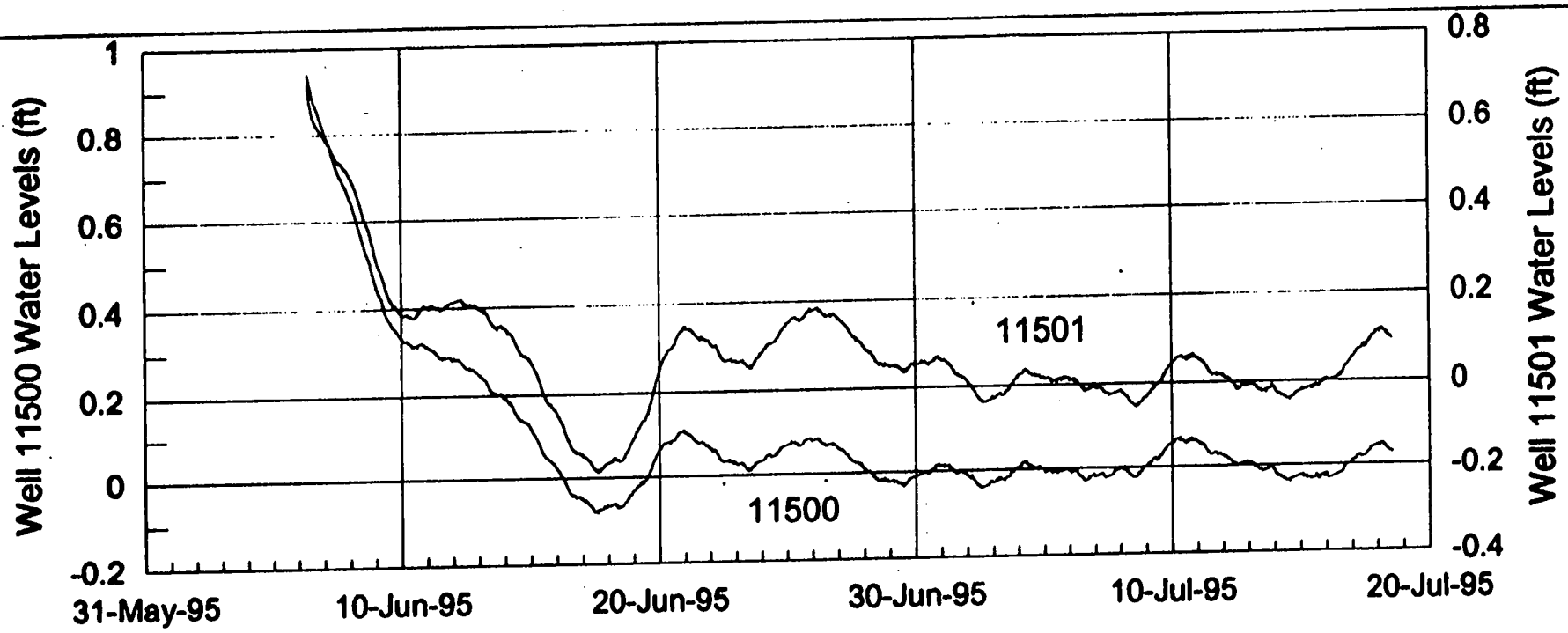

Figure A-4 Water Levels Corrected Using Seasonal Declining Trend from July 2 to July 16, 1995

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Table A-2: Summary of Barometric Efficiency Analysis for Well 11500

Analysis Interval From	Analysis Interval To	Change in Barometric Pressure (ft water)	Minimum Peak Time Hr:Min	Minimum Peak Time Lag Hr:Min	Maximum Peak Time Hr:Min	Maximum Peak Time Lag Hr:Min	Minimum Water Level (ft)	Maximum Water Level (ft)	Water Level Change (ft)	Barometric Efficiency (percent)	Matrix Compressibility (1/psi)	Storage Coefficient
Water Levels Corrected Using Declining Trend From 6/20/95 to 7/18/95												
12-Jun-95	17-Jun-95	0.578	12:58	04:13	05:13	02:58	-0.135	0.221	0.356	61.6	5.7E-07	4.0E-06
[illegible]	[illegible]	0.590	[illegible]	[illegible]	[illegible]	06:58	-0.035	0.064	0.099	33.8	1.8E-06	7.3E-06
17-Jun-95	20-Jun-95	[illegible]	[illegible]	[illegible]	23:28	06:58	-0.030	0.064	0.094	48.7	9.6E-07	5.1E-06
20-Jun-95	23-Jun-95	0.193	11:43	02:43	23:28	06:58	-0.030	0.051	0.081	27.4	2.4E-06	9.0E-06
23-Jun-95	26-Jun-95	0.295	[illegible]	02:43	22:43	04:28	-0.061	0.051	0.112	44.8	1.1E-06	5.5E-06
25/26-Jun-95	29-Jun-95	0.251	12:13	02:13	22:43	04:28	-0.061	-0.008	0.053	24.8	2.8E-06	1.0E-05
30-Jun-95	02-Jul-95	0.215	12:13	02:13	21:28	05:28	-0.061	0.003	0.064	35.3	1.7E-06	7.0E-06
02-Jul-95	[illegible]	0.181	[illegible]	[illegible]	[illegible]	03:28	-0.031	0.066	0.098	37.4	1.5E-06	6.6E-06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	03:23	-0.035	0.066	0.101	40.5	1.3E-06	6.1E-06
10-Jul-95	14-Jul-95	0.249	13:43	14:13	07:43	03:43	-0.035	0.063	0.098	30.9	2.0E-06	8.0E-06
14-Jul-95	18-Jul-95	0.318	[illegible]	[illegible]	[illegible]	[illegible]				36.0	1.7E-06	7.2E-06
Average*	Overall			05:07		05:28				39.7	1.6E-06	6.7E-06
	Increasing Barometric Pressure Cycle									33.0	1.9E-06	7.6E-06
	Declining Barometric Pressure Cycle											
Water Levels Corrected Using Declining Trend From 7/2/95 to 7/16/95												
12-Jun-95	17-Jun-95	0.578					-0.083	0.285	0.368	63.5	5.3E-07	3.9E-06
[illegible]	[illegible]	0.590					-0.083	0.109	0.192	32.6	1.9E-06	7.6E-06
17-Jun-95	20-Jun-95	[illegible]					0.010	0.109	0.099	51.5	8.6E-07	4.8E-06
20-Jun-95	23-Jun-95	0.193					0.010	0.086	0.076	25.6	2.7E-06	9.7E-06
23-Jun-95	26-Jun-95	0.295					-0.034	0.086	0.120	47.9	1.0E-06	5.2E-06
25/26-Jun-95	29-Jun-95	0.251					-0.040	0.017	0.057	26.4	2.6E-06	9.4E-06
30-Jun-95	02-Jul-95	0.215					-0.040	0.020	0.060	33.2	1.8E-06	7.5E-06
02-Jul-95	[illegible]	0.181					-0.023	0.070	0.094	35.9	1.6E-06	6.8E-06
[illegible]	[illegible]	0.261					-0.040	0.070	0.110	44.2	1.2E-06	5.6E-06
10-Jul-95	14-Jul-95	0.249					-0.040	0.051	0.090	28.5	2.3E-06	8.7E-06
14-Jul-95	18-Jul-95	0.318								36.2	1.8E-06	7.3E-06
Average*	Overall									42.5	1.4E-06	6.2E-06
	Increasing Barometric Pressure Cycle									31.1	2.1E-06	8.1E-06
	Declining Barometric Pressure Cycle											

Barometric pressure is increasing

Barometric pressure is decreasing

* Averages do not include barometric effects from 6/12/95 to 6/17/95 as water levels were still influenced by the introduction of the pressure transducer in the well.

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Table A-3: Summary of Barometric Efficiency Analysis for Well 11501

Analysis Interval From	Analysis Interval To	Change in Barometric Pressure (ft water)	Minimum Peak Time Hr:Min	Minimum Peak Time Lag Hr:Min	Maximum Peak Time Hr:Min	Maximum Peak Time Lag Hr:Min	Minimum Water Level (ft)	Maximum Water Level (ft)	Water Level Change (ft)	Barometric Efficiency (percent)	Matrix Compressibility (1/psi)	Storage Coefficient
Water Levels Corrected Using Declining Trend From 6/20/95 to 7/16/95												
12-Jun-95	17-Jun-95	0.578	12:58	04:13	07:43	05:28	-0.307	0.077	0.384	66.3	4.6E-07	2.5E-06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.307	0.044	0.351	50.5	6.2E-07	2.8E-06
20-Jun-95	23-Jun-95	0.193	13:13	04:13	00:43	08:13	-0.043	0.044	0.087	45.2	1.1E-06	3.7E-06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.043	0.104	0.146	49.6	9.3E-07	3.4E-06
25/26-Jun-95	29-Jun-95	0.251	11:58	01:58	04:58	10:43	-0.034	0.104	0.137	54.7	7.6E-07	3.1E-06
30-Jun-95	02-Jul-95	0.215	14:13	04:13	21:28	05:28	-0.092	0.010	0.102	47.2	1.0E-06	3.6E-06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.092	0.009	0.083	46.5	1.1E-06	3.7E-06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.082	0.048	0.130	50.0	9.2E-07	3.4E-06
10-Jul-95	14-Jul-95	0.249	13:58	14:28	20:43	16:43	-0.046	0.048	0.094	37.6	1.5E-06	4.5E-06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.046	0.132	0.177	55.9	7.2E-07	3.0E-06
Average*	Overall			06:03		08:46				49.5	9.7E-07	3.5E-06
	Increasing Barometric Pressure Cycle									46.2	1.1E-06	3.7E-06
	Declining Barometric Pressure Cycle									52.1	8.6E-07	3.4E-06
Water Levels Corrected Using Declining Trend From 7/2/95 to 7/16/95												
12-Jun-95	17-Jun-95	0.578					0.852	1.372	0.520	89.9	1.0E-07	1.9E-06
[illegible]	[illegible]	[illegible]					0.852	1.112	0.260	44.1	1.2E-06	3.8E-06
20-Jun-95	23-Jun-95	0.193					0.959	1.112	0.153	79.4	2.4E-07	2.1E-06
[illegible]	[illegible]	[illegible]					0.959	1.042	0.083	28.1	2.3E-06	6.0E-06
25/26-Jun-95	29-Jun-95	0.251					0.813	1.042	0.229	91.3	8.7E-08	1.8E-06
30-Jun-95	02-Jul-95	0.215					0.674	0.826	0.152	70.5	3.8E-07	2.4E-06
[illegible]	[illegible]	[illegible]					0.674	0.712	0.038	20.9	3.5E-06	8.0E-06
[illegible]	[illegible]	[illegible]					0.528	0.604	0.076	29.1	2.2E-06	6.8E-06
10-Jul-95	14-Jul-95	0.249					0.407	0.604	0.197	79.0	2.4E-07	2.1E-06
[illegible]	[illegible]	[illegible]					0.407	0.490	0.083	26.1	2.6E-06	6.4E-06
Average*	Overall									52.1	1.4E-06	4.3E-06
	Increasing Barometric Pressure Cycle									80.0	2.4E-07	2.1E-06
	Declining Barometric Pressure Cycle									29.7	2.4E-06	6.0E-06

Barometric pressure is increasing Barometric pressure is decreasing

* Averages do not include barometric effects from 6/12/95 to 6/17/95 as water levels were still influenced by the introduction of the pressure transducer in the well.

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Management Project (FEMP) Glacial Till/Vadose Zone Hydraulic Investigation Work Plan (1993). Water levels were recorded using HERMIT™ data loggers and pressure transducers (manufactured by In-Situ Inc.). A discussion of methodologies used for analysis is included in Section A.2.1. Section A.2.2 presents the results of the analysis.

A.2.1 SLUG TEST ANALYSIS PROCEDURE

Well boring logs and water levels at the time of testing were reviewed to determine if a high permeability zone was encountered within the screened interval. If a high permeability zone was suspected and water levels were above that zone, then testing may have been under confining conditions. Furthermore, barometric response indicates that wells installed in the gray till respond as if they are confined. Data were analyzed by the Ramey et al. method as well as the Bouwer and Rice method to gain confidence in the results. While the Ramey et al. method uses the full data set, the Bouwer and Rice method requires only early time data. Water levels were always above the top of screen/sand pack during the rising and falling head tests in all wells. Therefore, well casing radius did not require any corrections.

A.2.1.1 Slug Test Analysis Using Ramey et al. Method

Ramey et al. (1975) method, which is an extension of the Cooper et al. (1967) method, assumes that aquifer is confined. The following assumptions were used in the analysis of data using this method:

- The saturated thickness is defined as the distance between the lower and upper aquitard or lower hydraulic conductivity layers.
- The effective screen length is defined as the portion of the sand pack which lies between the lower and upper aquitard.
- Clay is considered an aquitard when it lies above or below a more permeable material (e.g., sand or silt).

Test starting time was selected from the raw data to coincide with the time when the slug was completely in or out of the water. Initial head (H_o), and static water levels were determined by plotting the data on a semi-log scale. Initial oscillations in the data were not considered for selecting H_o. Slug test data were then analyzed using STEP-MATCH™ software, which uses the Ramey et al. method for the analysis (Bumb and Ramesh 1992).

The Ramey et al. (1975) method also calculates skin factor based on the input value of the storage coefficient. Skin factor is a measure of permeability in the immediate vicinity of the wellbore as compared to permeability of the aquifer. High positive skin factors indicate significant wellbore damage from the drilling activity, while negative skin factors indicate increased permeability near the wellbore.

A.2.1.2 Slug Test Analysis Using Bouwer and Rice Method

The following definitions were used in the analysis of data from tests of unconfined conditions (see Figure H-5):

- The effective aquifer thickness (H) is defined as the distance between the bottom of the aquifer and the static water level.
- The effective saturated thickness in the well (L_w) is defined as the distance between the bottom of the sand pack or the bottom of the aquifer (whichever is higher) and the static water level.
- The effective screen length (L_e) is defined as the distance between the bottom of the aquifer or the bottom of the sand pack (whichever is higher) and the top of the sand pack or the static water level (whichever is lower).

After determining static water level and starting time for the test, water level data were plotted on semi-log paper, with elapsed time on the linear scale and height of the water column on the log scale. The effects of the water level rising in the sand pack in the well is depicted by the "double straight line" observed when plotting the data with the Bouwer and Rice method. The first straight line has a greater slope and represents flow of water through the highly permeable sand pack. The second curve is less steep and more accurately represents the flow of water through the less permeable aquifer. In all cases, the slope of the second straight line was used in calculating the hydraulic conductivity of the aquifer.

A.2.2 SLUG TEST RESULTS

Information pertaining to slug tests from well construction and boring logs is summarized in Table A-4. Lithologic information from boring logs and static water level measurements taken before the slug tests was used to determine whether the confined or unconfined conditions best represents the aquifer in the neighborhood of each test well. Table A-4 also presents the effective aquifer thickness.

Table A-4: SUMMARY OF WELL CONFIGURATION FOR THE SLUG TESTS, PRE-DESIGN INVESTIGATION

Well	Top of Well (ft ags)	Depth to Water (ft TOW)	Screen Top (ft bgs)	Screen Bottom (ft bgs)	Top of Filter Pack (ft bgs)	Bottom of Filter Pack (ft bgs)	Aquifer Top (ft bgs)	Aquifer Bottom (ft bgs)	Saturated Thickness (ft)	Well Water Column (ft)	Screen Length (ft)	Casing Diameter (inch)	Wellbore Diameter (inch)	Confined/ Unconfined
Wells Screened In The Gray Till Only														
1064	2	12.81	18.0	28.0	15.0	31.0	0.0	31.0 est.	20.19	20.19	16.00	4	10.75	U
11491	2	16.90	27.0	29.0	25.0	29.3	19.0	47.0 est.	28.00	10.25	4.25	2	6.25	C
11492	2	15.22	17.0	21.0	15.0	21.3	10.5	22.0 est.	8.78	8.03	6.25	2	6.25	U
11493	2	17.06	20.0	24.0	18.0	24.3	14.2	43.0 est.	27.94	9.19	6.25	2	6.25	U
11497	2	24.80	30.0	32.0	28.0	32.3	26.5	37.0 est.	10.50	5.75	4.25	2	6.25	C
11498	2	25.79	29.0	31.0	27.0	31.3	23.0	33.0 est.	9.21	7.46	4.25	2	6.25	U
11499	2	7.43	17.0	19.0	15.0	19.3	13.0	19.7	6.70	6.25	4.25	2	6.25	C
11500	2	6.58	21.0	25.0	19.0	25.3	20.3	25.0	4.70	4.95	4.95	2	6.25	C
11501	2	14.56	35.0	37.0	33.0	37.3	35(?)	37.0 est.	24.44	24.69	4.25	2	6.25	U
11502	2	6.41	20.0	22.0	18.0	22.3	21.0	22.5	1.50	1.25	1.25	2	6.25	C
11503	2	23.66	26.0	28.0	24.0	28.3	0.0	35.0 est.	13.34	6.59	4.25	2	6.25	U
11505	2	17.50	25.0	27.0	23.0	27.3	10.2	27.3 est.	11.75	11.75	4.25	2	6.25	U
Wells Screened Across The Brown/Gray Till														
11087	2	5.97	17.0	19.4	15.0	20.0	17.0	20.0 est.	3.00	3.00	3.00	4	10.00	C
11494	2	2.91	10.0	16.0	8.0	16.3	6.0	17.0 est.	11.00	10.25	8.25	3	6.25	C
11496	2	4.03	11.0	17.0	9.0	17.3	10.0	16.5	6.50	7.25	7.25	2	6.25	C
11504	2	8.09	16.0	18.0	14.0	18.3	0.0	18.3 est.	12.21	12.16	4.25	2	6.25	U
11546	2	6.55	11.0	13.0	9.0	13.3	0.0	13.3 est.	8.75	8.70	4.25	2	6.25	U
11547	2	5.79	11.0	13.0	9.0	13.3	0.0	13.3 est.	9.51	9.46	4.25	2	6.25	U
11548	2	7.26	12.0	14.0	10.0	14.3	0.0	14.3 est.	9.04	8.99	4.25	2	6.25	U
11681	2	4.03	10.0	12.0	8.0	13.3	0.0	13.3 est.	11.27	11.22	5.25	2	8.50	U
11685	2	6.71	14.5	16.5	12.5	17.0	0.0	21.5 est.	16.79	12.29	4.50	2	8.50	U
11687	2	3.30	10.5	12.5	8.5	13.0	0.0	13.0 est.	11.70	11.70	4.50	2	8.50	U
11693	2	4.59	12.0	14.0	10.5	14.5	5.0	14.5 est.	9.50	9.50	4.00	2	8.50	C

ags - above ground surface
bgs - below ground surface
TOW - from top of well

Rising and falling head tests were analyzed by the Ramey et al. (1975) and/or the Bouwer and Rice (1976) method as described in Section A.2.1. Sufficient data were not available to perform Ramey et al analysis for falling head tests conducted at wells 11493, 11498, and 11546 and for rising head tests conducted at wells 11497, 11498, 11503, and 11546. No data were available for the rising head tests at wells 11067, 11548, and 11685. Furthermore, data from slug tests at well 11548 were unavailable. However, due to the low hydraulic conductivity at this well, recovery of water levels to static condition after the transducer was placed in the well provided an opportunity to calculate hydraulic conductivity. Results of slug test analysis are presented in Table A-5, and calculations/graphs are attached. Values of hydraulic conductivity from these two methods were in agreement with each other.

A representative value of hydraulic conductivity for each well is also provided. When multiple slug tests are conducted in a well, a geometric average is considered a representative value of the hydraulic conductivity. The representative values are, therefore, geometric average of all valid results. The falling head test plot for the well 11067 shows an unexpected and uncharacteristic decline in water level recovery rate to static water level at about 30 minutes into test. It makes analysis by the Bouwer and Rice Method difficult. Therefore, results of the Bouwer and Rice method were not considered valid for the well 11067.

Due to low recovery from the falling head test at well 11497 before the rising head test was conducted, the rising head test was not considered valid and was ignored while calculating a representative value for this well. The rising head test data from the well 11502 shows unusual characteristics that water level remains steady for 10 minutes, then drops slightly, and then start rising. Therefore, results of the rising head test at well 11502 were not used in calculating representative value of hydraulic conductivity.

Wells were divided into two groups. The first group includes wells screened (and sand packed) only in the gray till. The second group contains wells with their sand pack installed across the gray and brown till interface.

Table A-5: SUMMARY OF SLUG TEST RESULTS, PRE-DESIGN INVESTIGATION

Well	Tested Interval (ft)	Bouwer & Rice Method				Ramey et al. (Cooper et al.) Method				Representative Hydraulic Conductivity (cm/sec)
		Hydraulic Conductivity (ft/min)		Hydraulic Conductivity (cm/sec)		Transmissivity (cm^2/sec)		Hydraulic Conductivity (cm/sec)		
		Falling	Rising	Falling	Rising	Falling	Rising	Falling	Rising	
Wells Screened In The Gray Till Only										
1064	16.00	7.72E-07	9.02E-07	3.92E-07	4.58E-07	2.54E-04	5.79E-05	5.21E-07	1.19E-07	3.25E-07
11491	4.25	1.94E-05	1.47E-05	9.85E-06	7.48E-06	2.59E-03	2.62E-03	2.00E-05	2.02E-05	1.31E-05
11492	6.25	6.79E-06	8.25E-06	3.45E-06	4.19E-06	4.44E-04	4.37E-04	2.33E-06	2.29E-06	2.96E-06
11493	6.25	1.97E-07	1.15E-07	1.00E-07	5.84E-08	NSD	2.16E-05	NSD	1.13E-07	8.71E-08
11497	4.25	1.20E-07	1.60E-08	6.11E-08	8.13E-09	2.16E-06	NSD	1.67E-08	NSD	3.19E-08
11498	4.25	1.84E-07	8.16E-08	9.36E-08	4.14E-08	NSD	NSD	NSD	NSD	6.23E-08
11499	4.25	2.94E-08	3.40E-08	1.49E-08	1.73E-08	8.06E-07	8.98E-07	6.22E-09	6.93E-09	1.03E-08
11500	4.95	1.02E-06	1.04E-06	5.17E-07	5.26E-07	1.16E-04	4.66E-05	7.69E-07	3.09E-07	5.04E-07
11501	4.25	1.87E-06	2.21E-06	9.49E-07	1.12E-06	9.32E-05	5.67E-05	7.19E-07	4.38E-07	7.61E-07
11502	1.25	1.81E-05	1.17E-05	9.19E-06	5.96E-06	1.09E-03	1.30E-03	2.86E-05	3.41E-05	1.62E-05
11503	4.25	6.37E-08	3.48E-08	3.23E-08	1.77E-08	4.14E-06	NSD	3.20E-08	NSD	2.63E-08
11505	4.25	1.09E-05	6.75E-06	5.56E-06	3.43E-06	1.12E-03	3.79E-04	8.65E-06	2.93E-06	4.69E-06
Wells Screened Across The Brown/Gray Till Interface										
11067	3.00	1.67E-04	NA	8.48E-05	NA	1.51E-03	NA	1.65E-05	NA	1.65E-05
11494	6.25	3.61E-04	4.29E-04	1.83E-04	2.18E-04	4.54E-02	6.54E-02	1.81E-04	2.60E-04	2.08E-04
11496	7.25	3.24E-03	2.68E-03	1.64E-03	1.36E-03	6.10E-01	4.60E-01	2.76E-03	2.08E-03	1.89E-03
11504	4.25	1.56E-04	1.17E-04	7.90E-05	5.96E-05	9.07E-03	5.70E-03	7.00E-05	4.40E-05	6.17E-05
11546	4.25	6.39E-08	2.59E-08	3.25E-08	1.31E-08	NSD	NSD	NSD	NSD	2.07E-08
11547	4.25	3.02E-08	4.75E-08	1.54E-08	2.41E-08	7.89E-07	9.52E-07	6.09E-09	7.35E-09	1.13E-08
11548	4.25	7.78E-07	NA	3.95E-07	NA	8.80E-05	NA	6.79E-07	NA	5.16E-07
11661	5.25	2.36E-04	1.26E-04	1.20E-04	6.40E-05	1.80E-02	2.37E-02	1.12E-04	1.46E-04	1.06E-04
11665	4.50	3.50E-05	NA	1.78E-05	NA	2.61E-03	NA	2.05E-05	NA	1.91E-05
11667	4.50	1.07E-05	1.10E-05	5.45E-06	5.60E-06	9.06E-04	9.34E-04	6.61E-06	6.61E-06	6.09E-06
11693	4.00	3.16E-06	2.98E-06	1.61E-06	1.51E-06	5.25E-04	4.17E-04	4.31E-06	3.42E-06	2.44E-06

NA - Data not available
NSD - Not sufficient data for analysis

Geometric Mean Hydraulic Conductivity:

Gray Till (all wells)	4.01E-07
Gray Till (except wells 11491 and 11502)	1.95E-07
Brown/Gray till interface	6.82E-06

11/22/95 08:30 AM

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The hydraulic conductivities for wells 11491 and 11502, screened in sand/gravel lenses within the gray till, were 1.31 x 10^{-5} cm/sec and 1.62 x 10^{-5} cm/sec, respectively. Hydraulic conductivities for the remaining wells screened only in the gray till ranged from 1.03 x 10^{-8} cm/sec for well 11499 to 4.69 x 10^{-6} for well 11505. The average hydraulic conductivity for these wells was 1.95 x 10^{-7} cm/sec, and for all wells screened in the gray till was 4.01 x 10^{-7} cm/sec. Falling and rising head tests at the well 11505 show a break in recovery curves at approximately 70 percent recovery and 5 to 9 minutes into tests. This may be reflective of a small isolated vertical cavity near the wellbore, as indicated in the wellbore log. The calculated hydraulic conductivity of 4.69 x 10^{-6} cm/sec at this well, therefore, is the upper limit for gray till at this location.

Note that the inverse modeling predicted average vertical hydraulic of gray till to be approximately 4 x 10^{-7} cm/sec (Section 3.1, PDI REPORT, 1995). Similar values of vertical and horizontal hydraulic conductivities implies lack of layering, stratification, or preferential orientation of particles in the gray till; therefore, indicates heterogeneity of the till.

The range of hydraulic conductivity for wells screened across the brown/gray till interface range from 1.02 x 10^{-8} cm/sec at well 11547 to 1.89 x 10^{-3} cm/sec at well 11496. The high hydraulic conductivities measured for wells 11494, 11496, and 11681 is consistent with coarse grained soils observed in this area during field investigation and predicted by the inverse modeling (Section 3.1, PDI REPORT, 1995). The five orders of magnitude variation in the hydraulic conductivity is consistent with the heterogeneity of the til and anisotropy of the hydrogeology in the till. The average hydraulic conductivity for wells screened across the brown/gray till interface was 6.3 x 10^{-6} cm/sec, approximately one order of magnitude higher than the underlying gray till.

All slug tests, except falling head test at the well 11693, resulted in negative skin factors indicating that the hydraulic conductivity is higher in the immediate vicinity of the wellbore than in the surrounding till. A positive skin factor for the falling head test at well 11693 indicates a potential for wellbore damage or that well was underdeveloped. However, the value of the positive skin factor was small and a small negative skin factor (-0.2) calculated from the rising head test indicate that wellbore damage or underdevelopment was negligible.

A.3 REFERENCES

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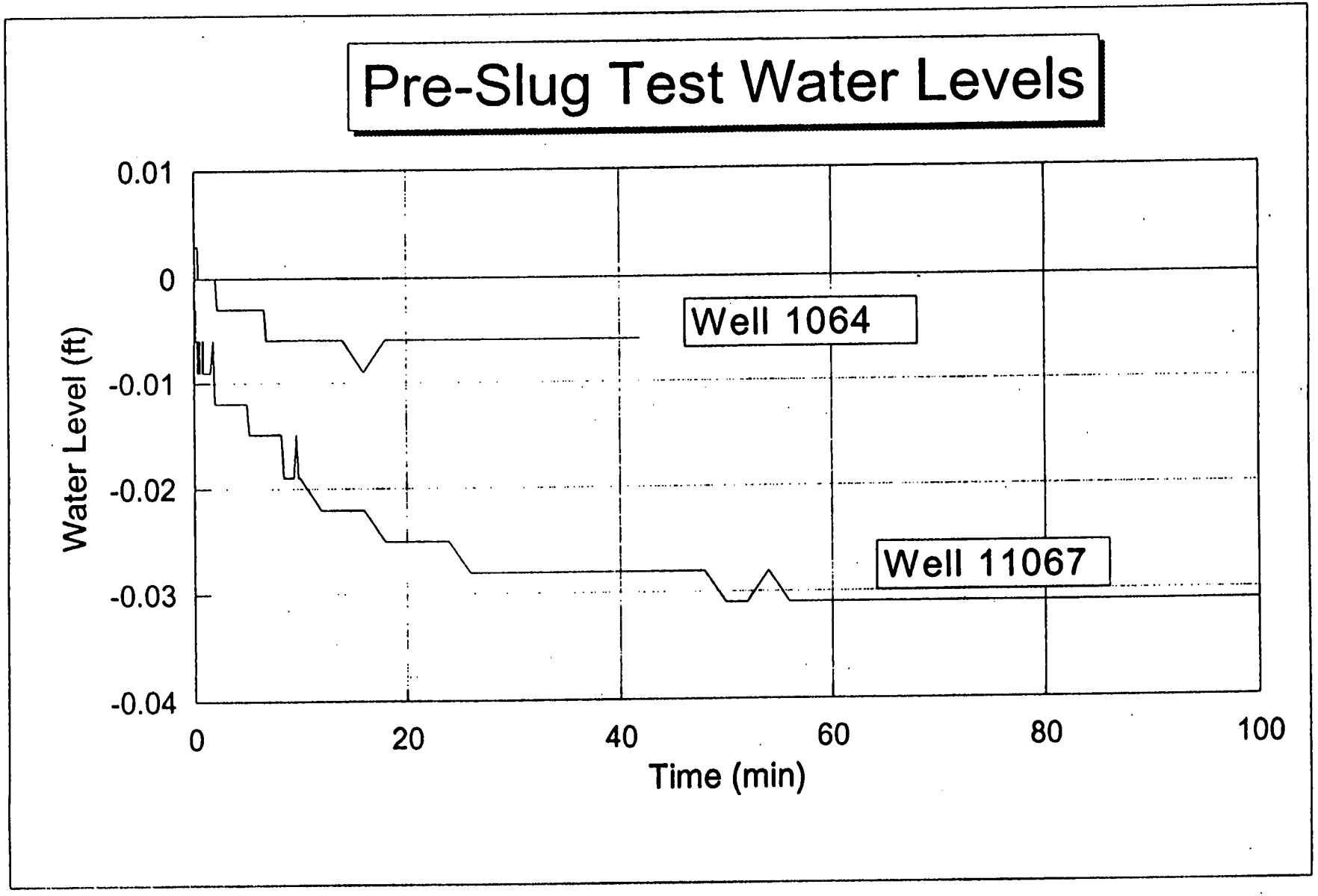
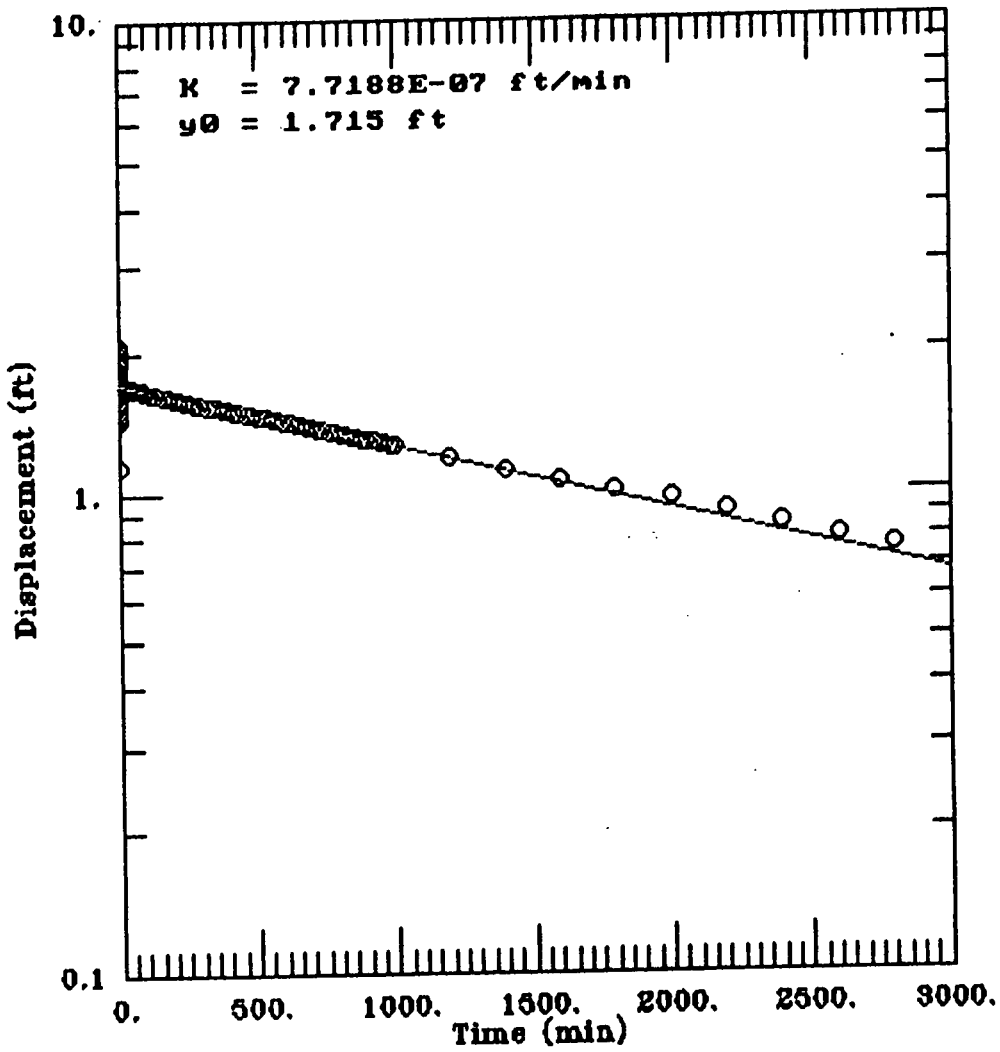
van der Kamp, G., and J.E. Gale, 1983, "Theory of Earth Tide and BArometric Effects in Porous Formations with Compressible Grains," Water Resources Research, Volume 19, No. 2, pp. 538-44.

A.4 Slug Test Graphical Data

1


Pre-Slug Test Water Levels
Water Level (ft)
0.01
0
-0.01
-0.02
-0.03
-0.04
0
20
40
60
80
100
Time (min)
Well 1064
Well 11067

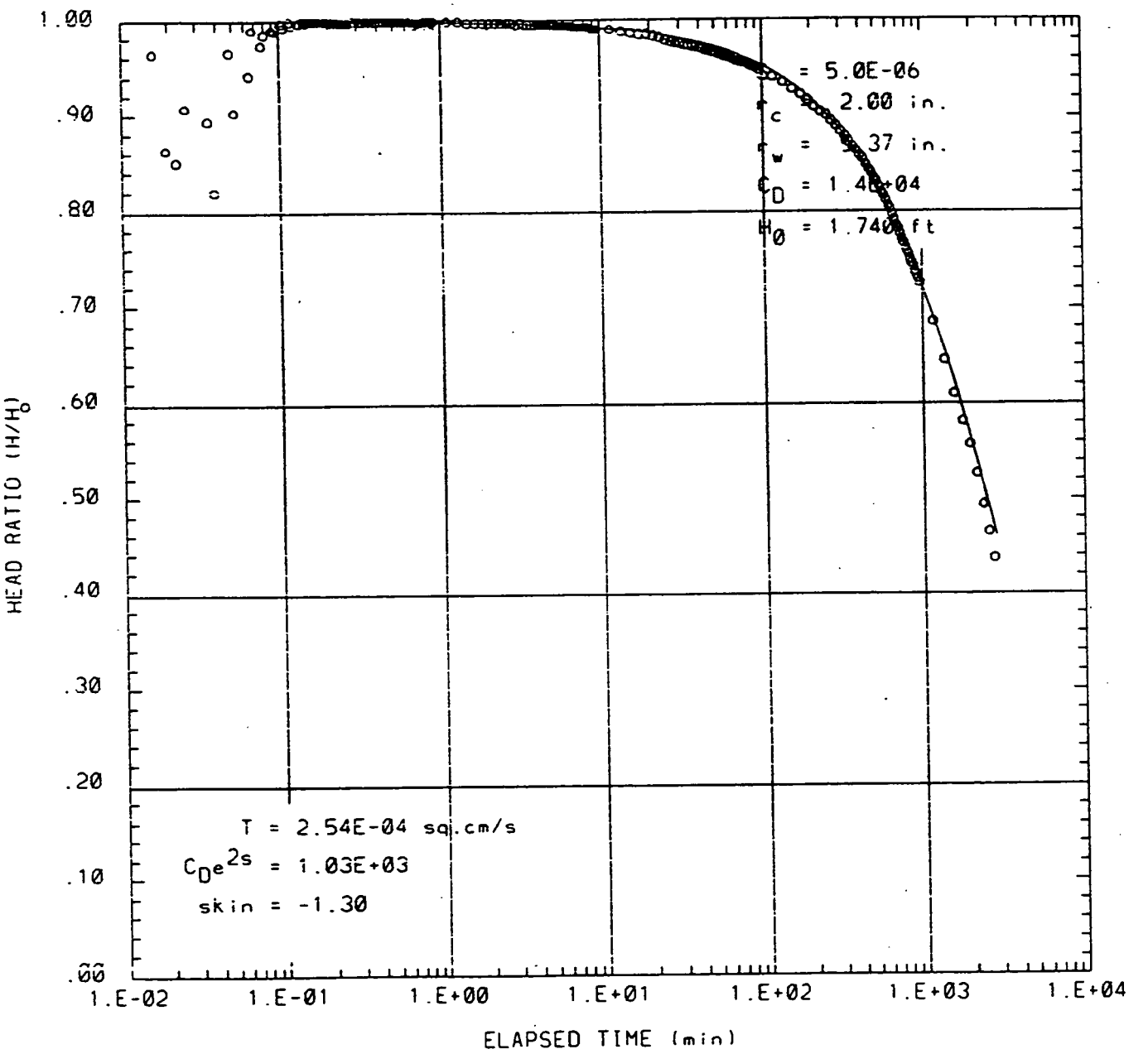
Well 1064 Falling Head Test



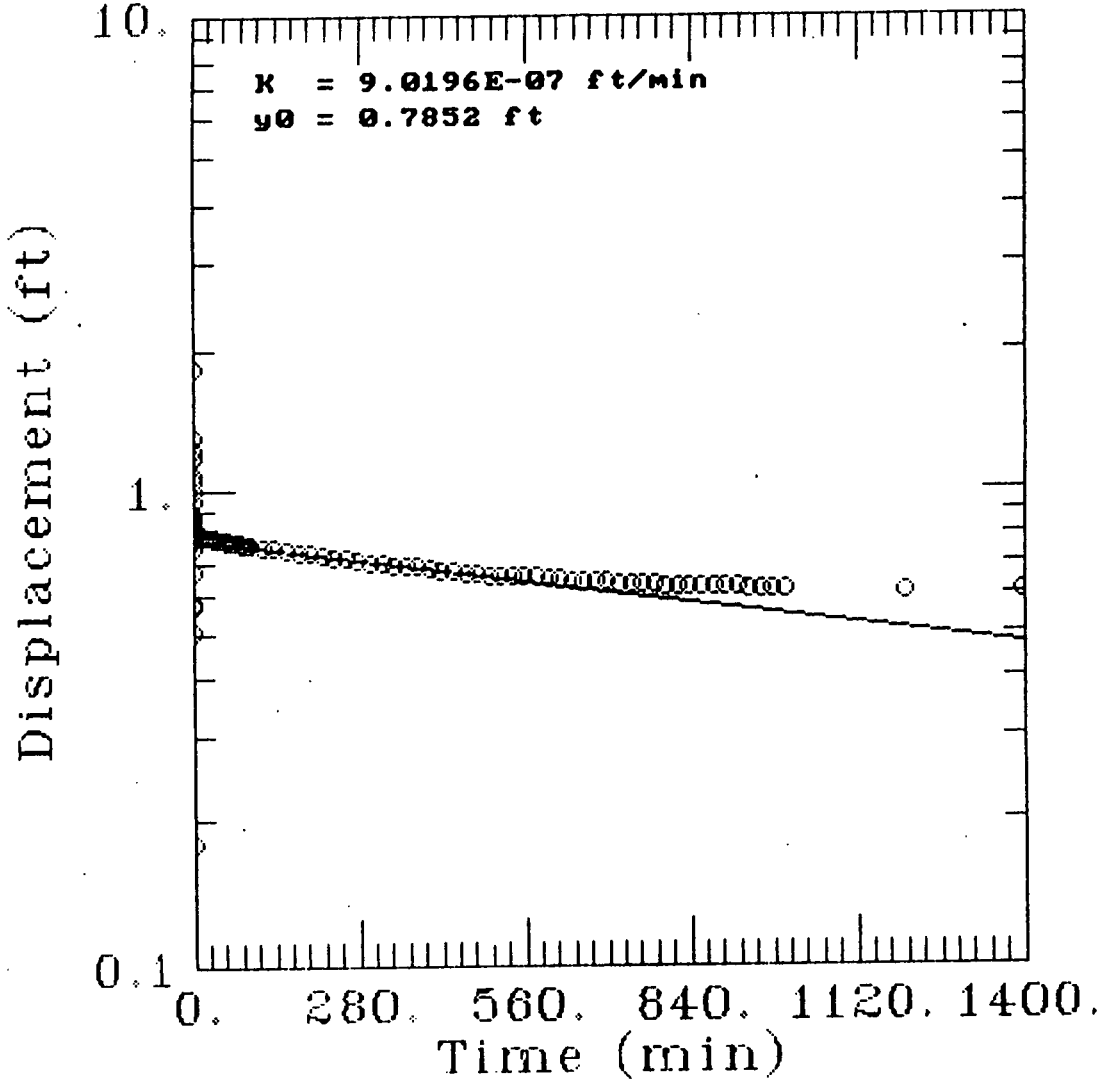
000053

Well 1064 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 1064 Rising Head Test



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Well 1064 Rising Head Test

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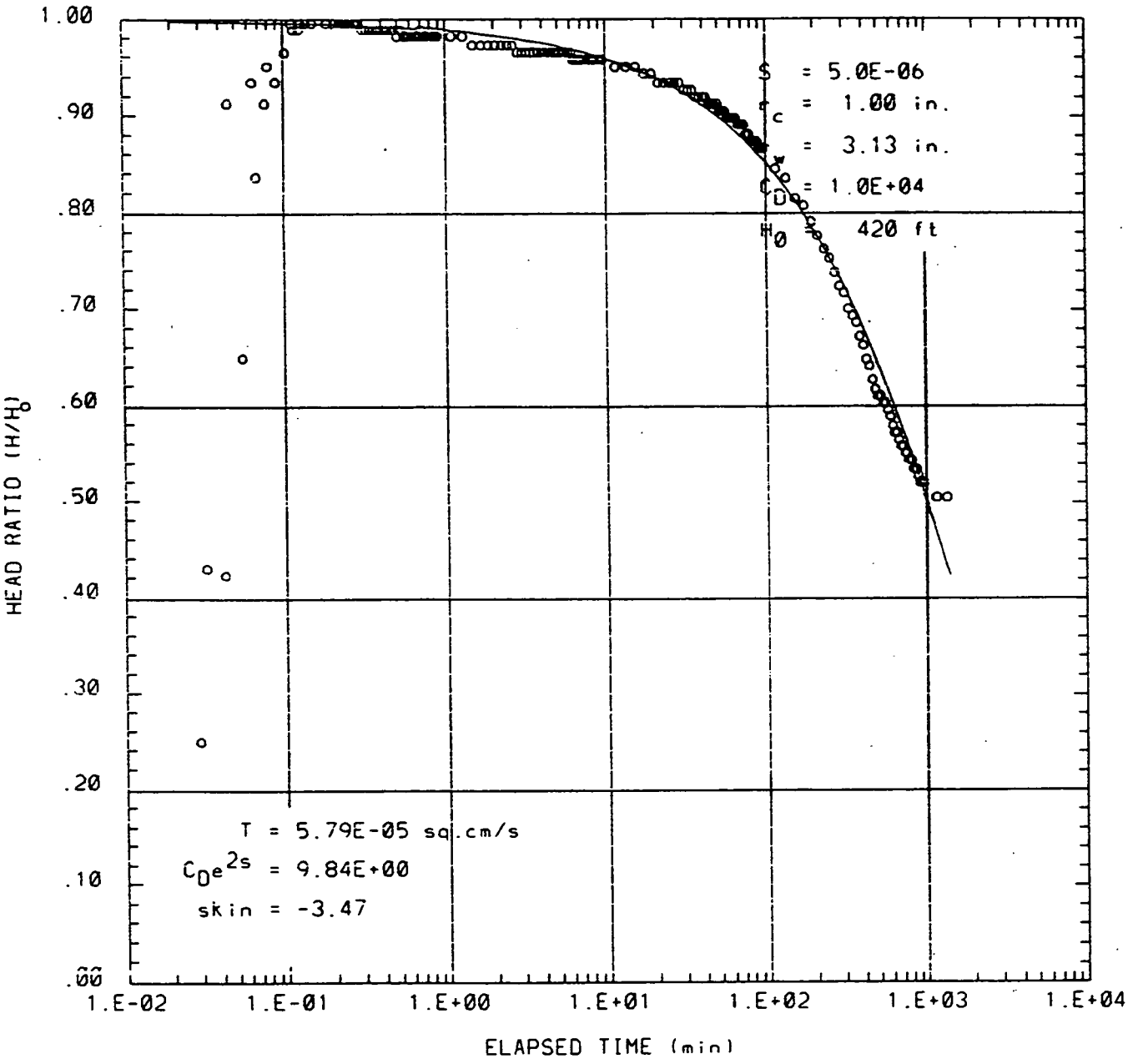
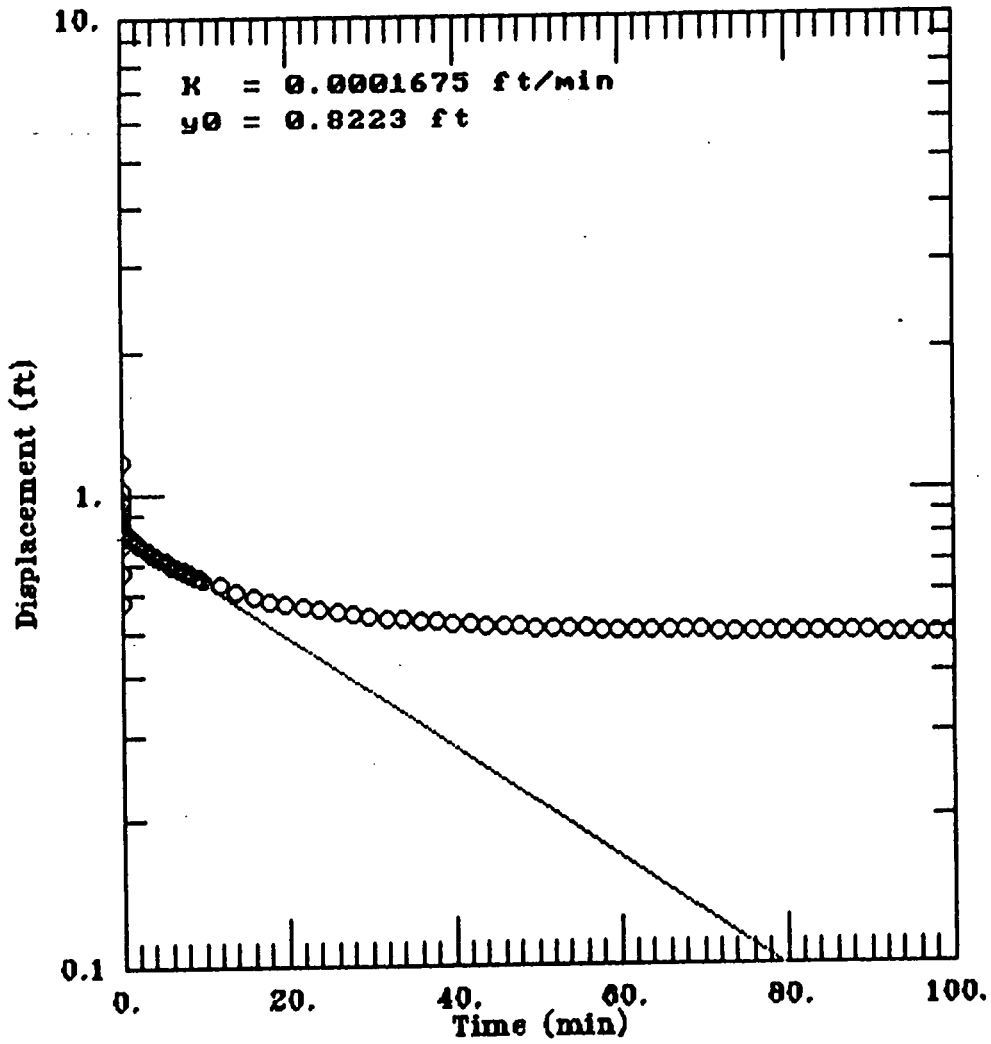


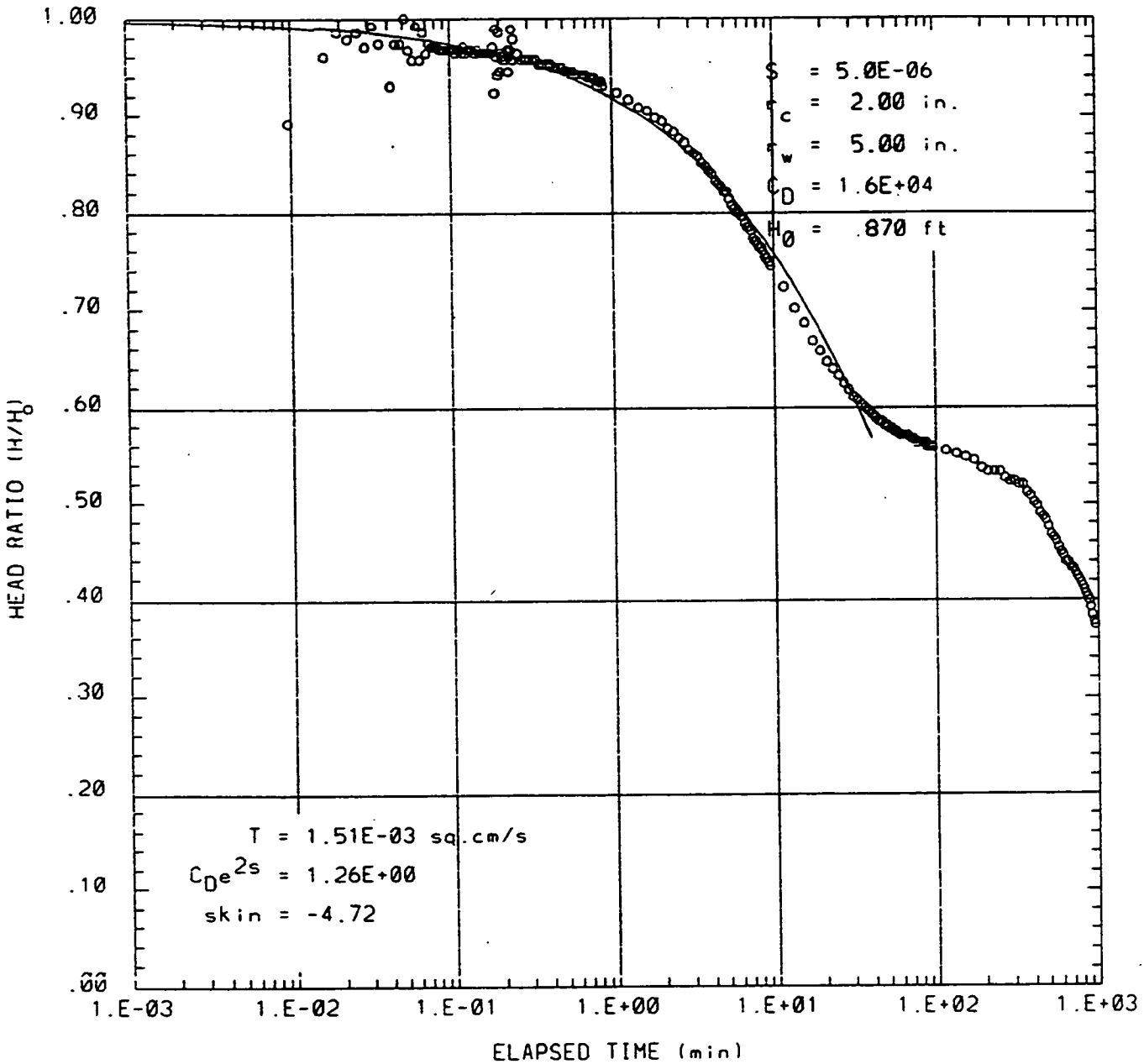
Well 11067 Falling Head Test



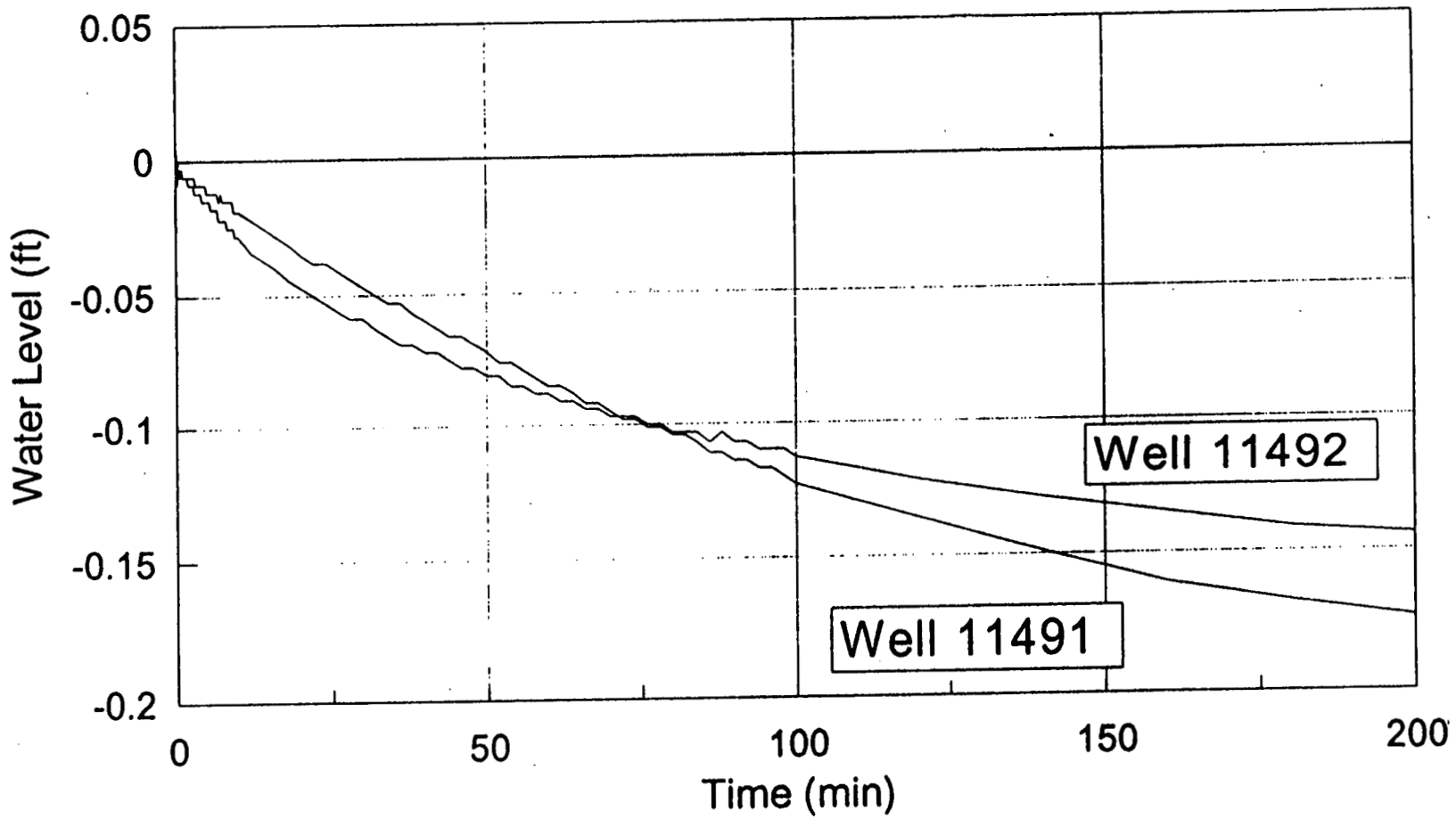
250000

Well 11067 Falling Head Test

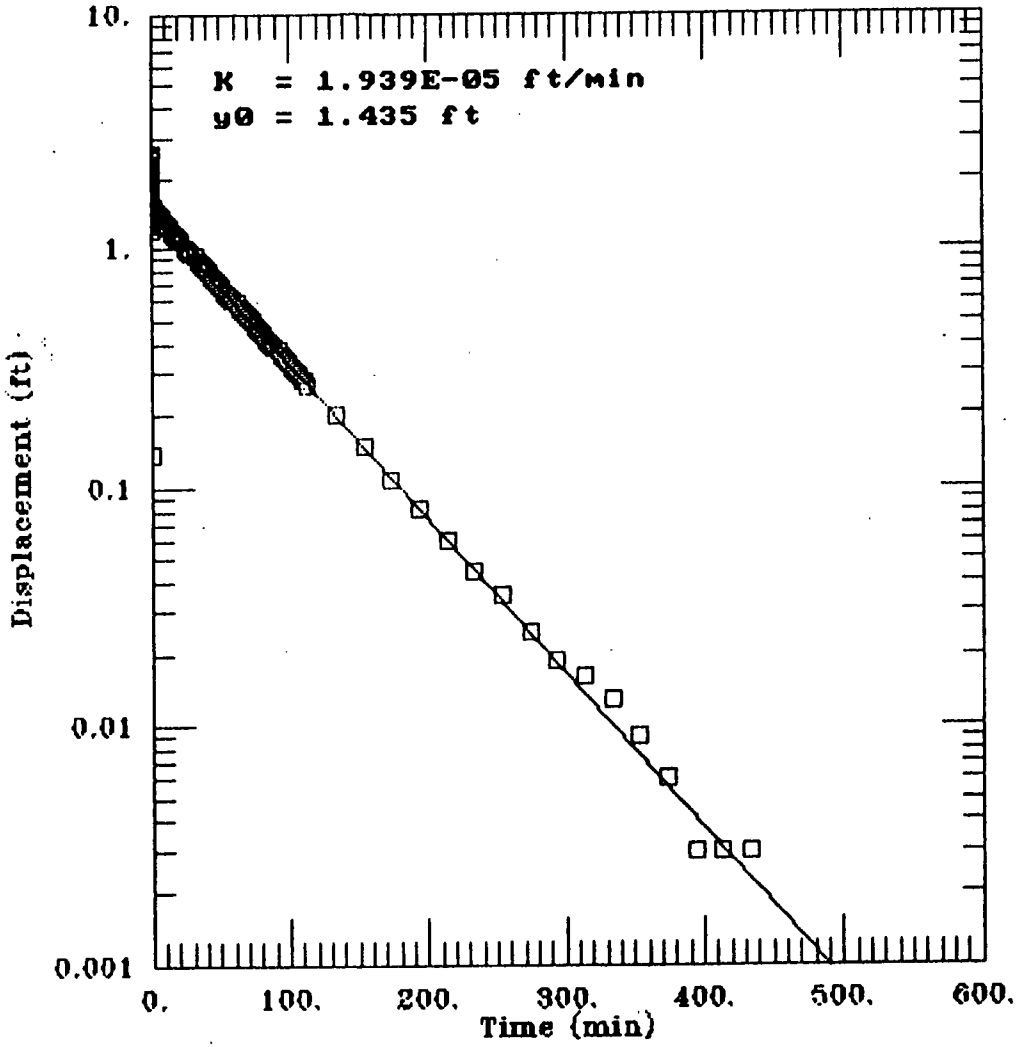
STEP (Slug) Test Automated Type-Curve Match (V1.2)



Pre-Slug Test Water Levels

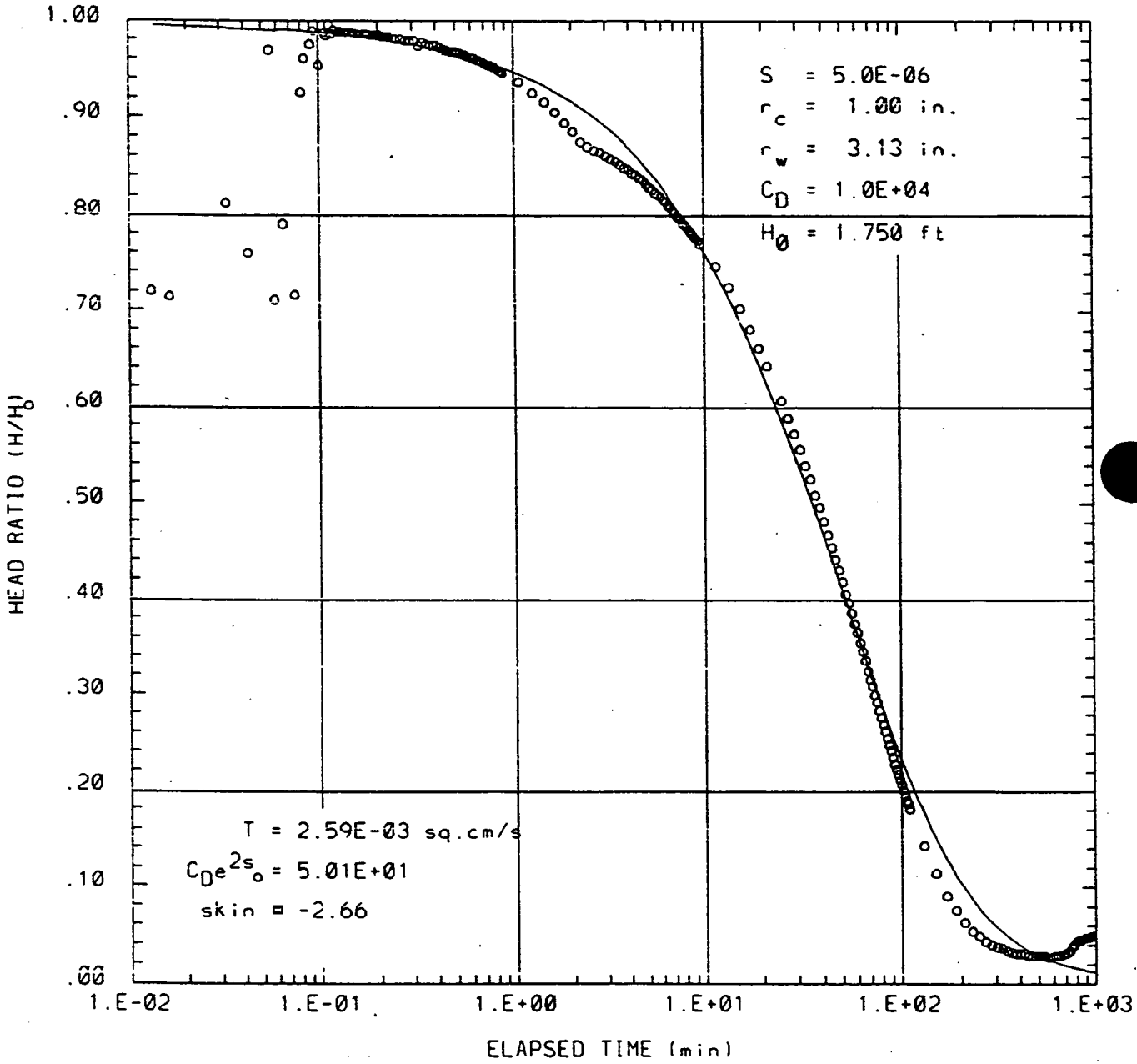


Well 11491 Falling Head Test

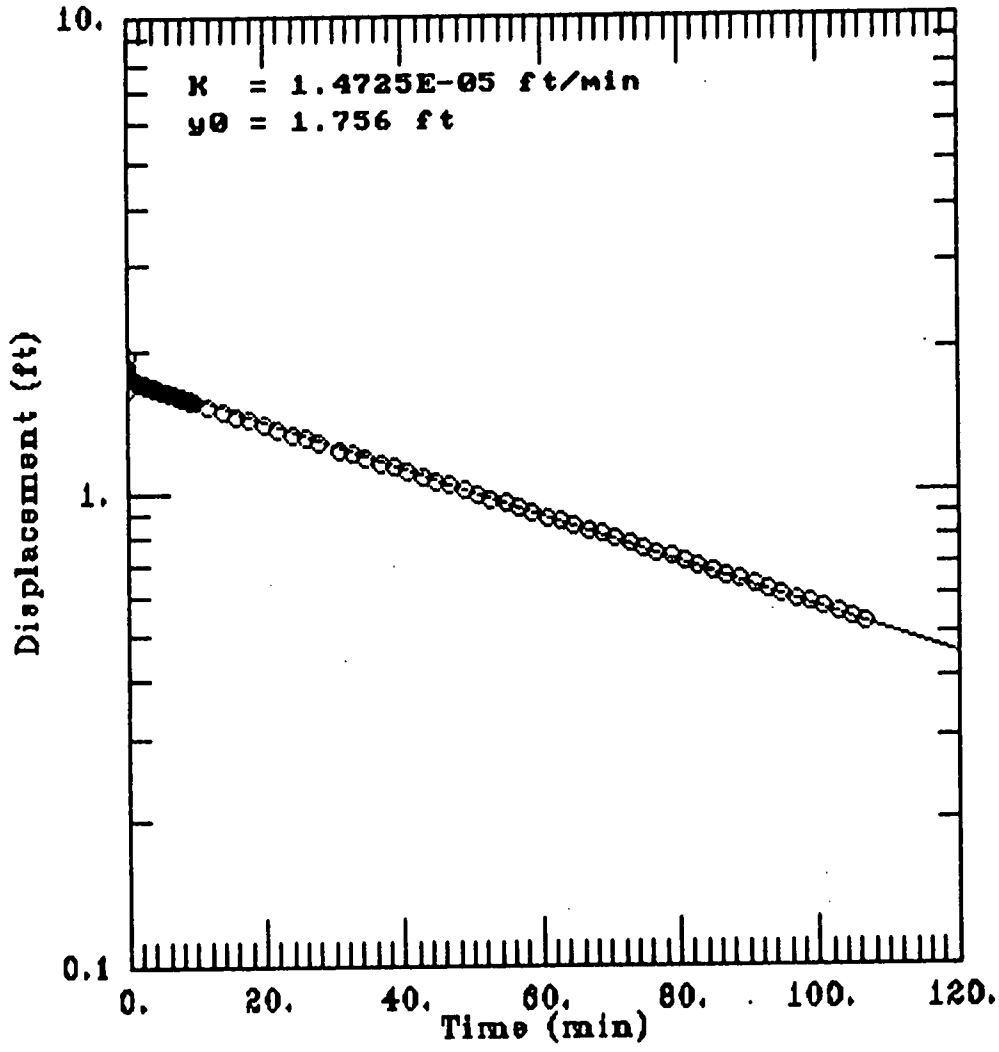


Well 11491 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)

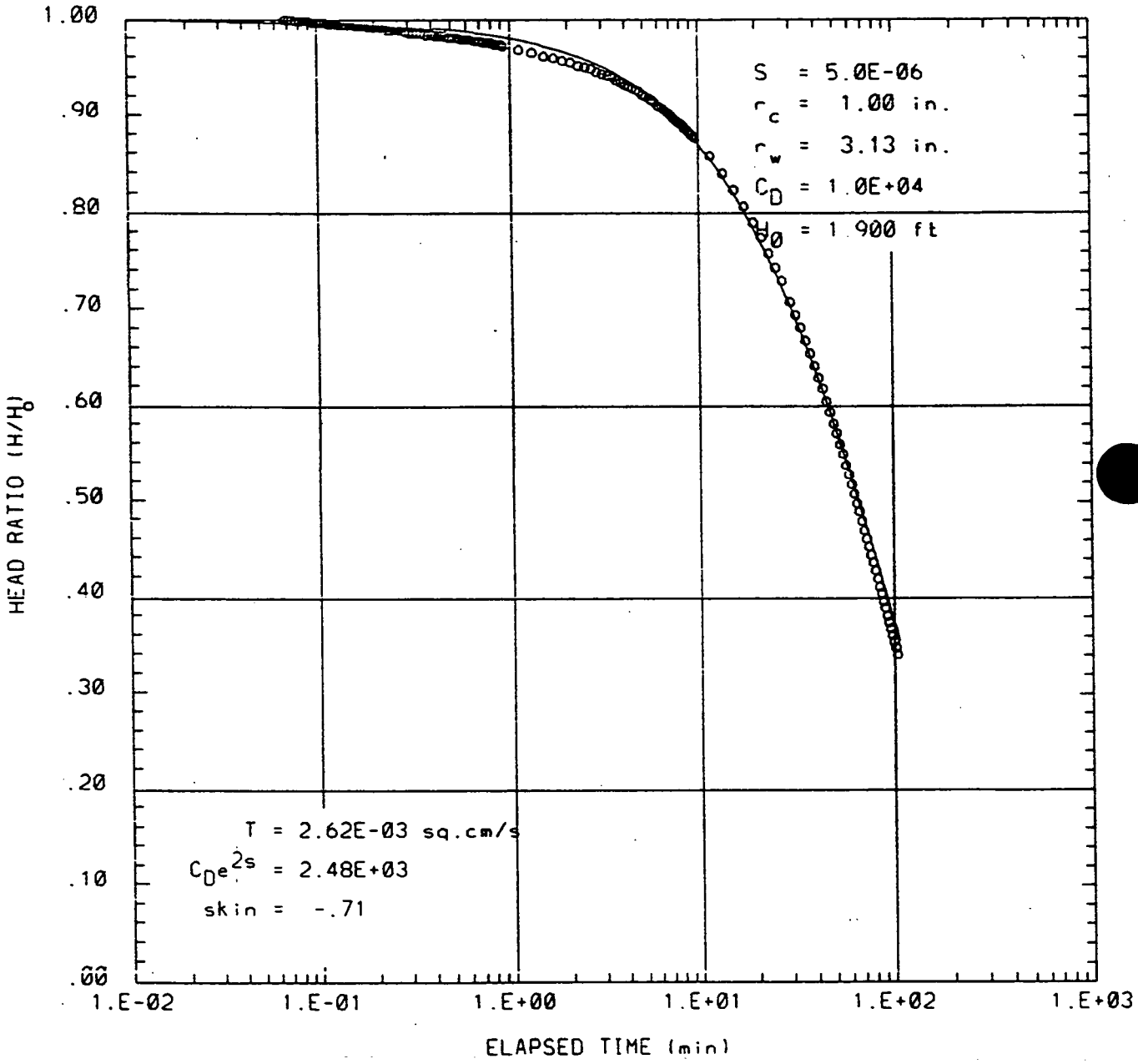


Well 11491 Rising Head Test



Well 11491 Rising Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



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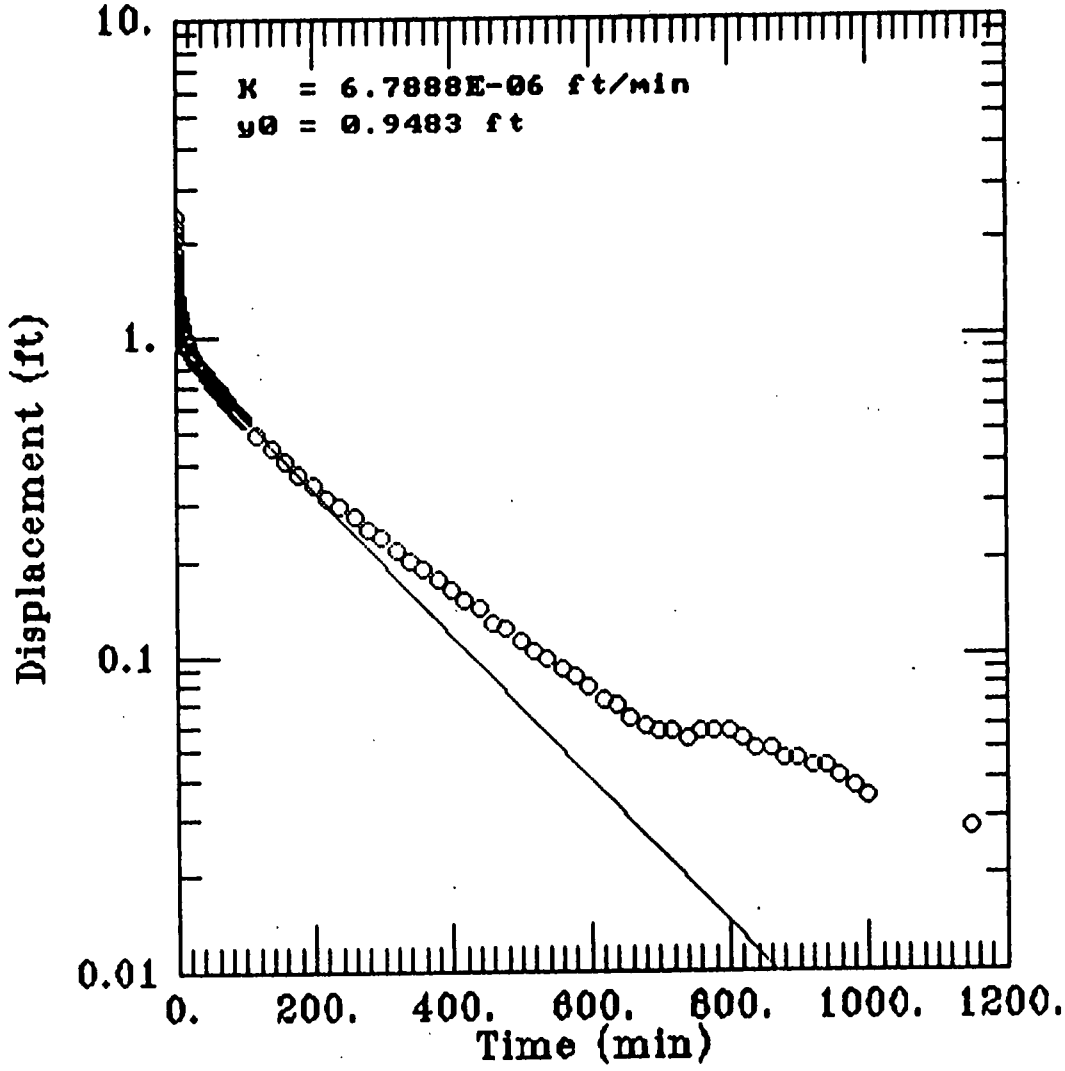
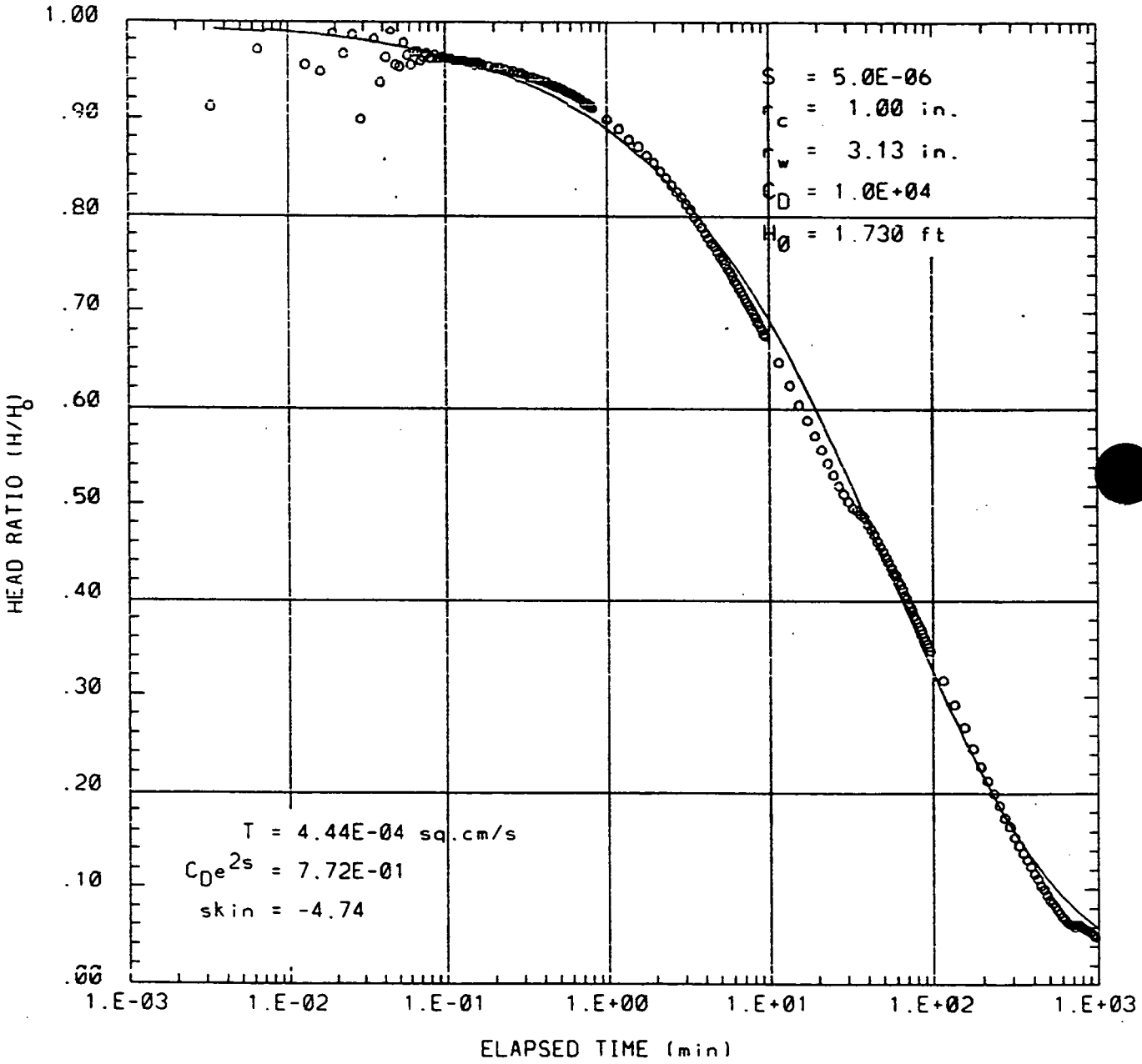
Well 11492 Falling Head Test

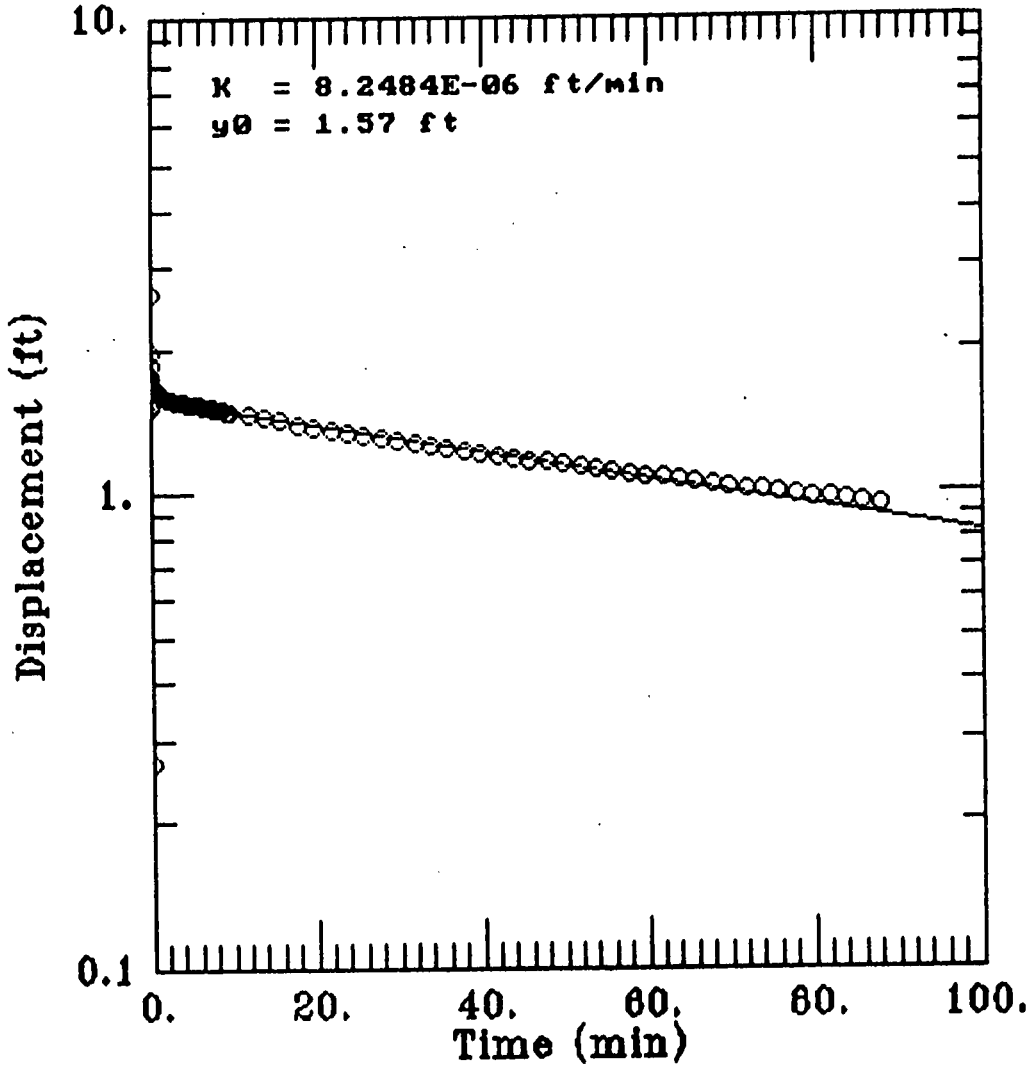


Well 11492 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)

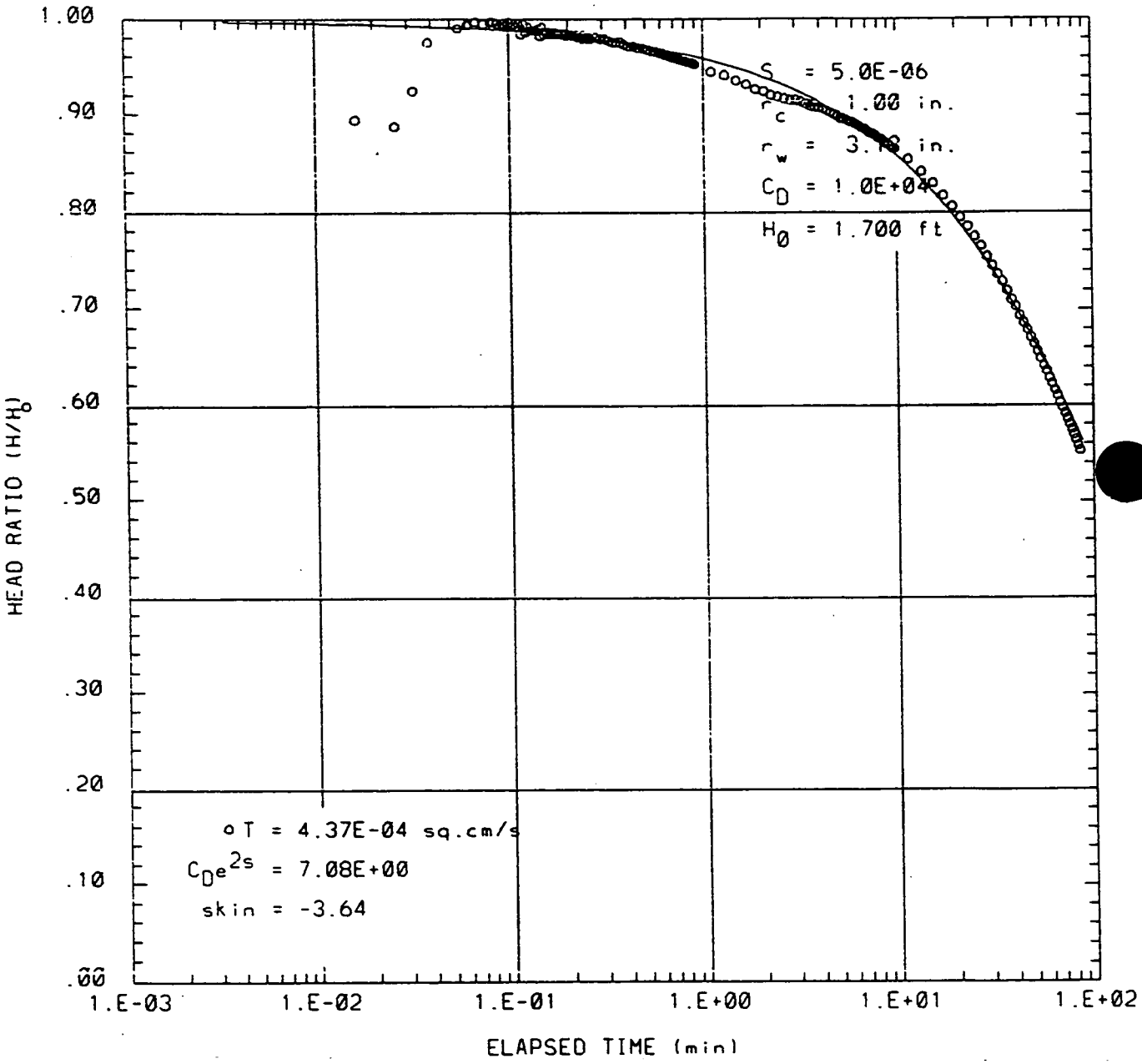


Well 11492 Rising Head Test



Well 11492 Rising Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



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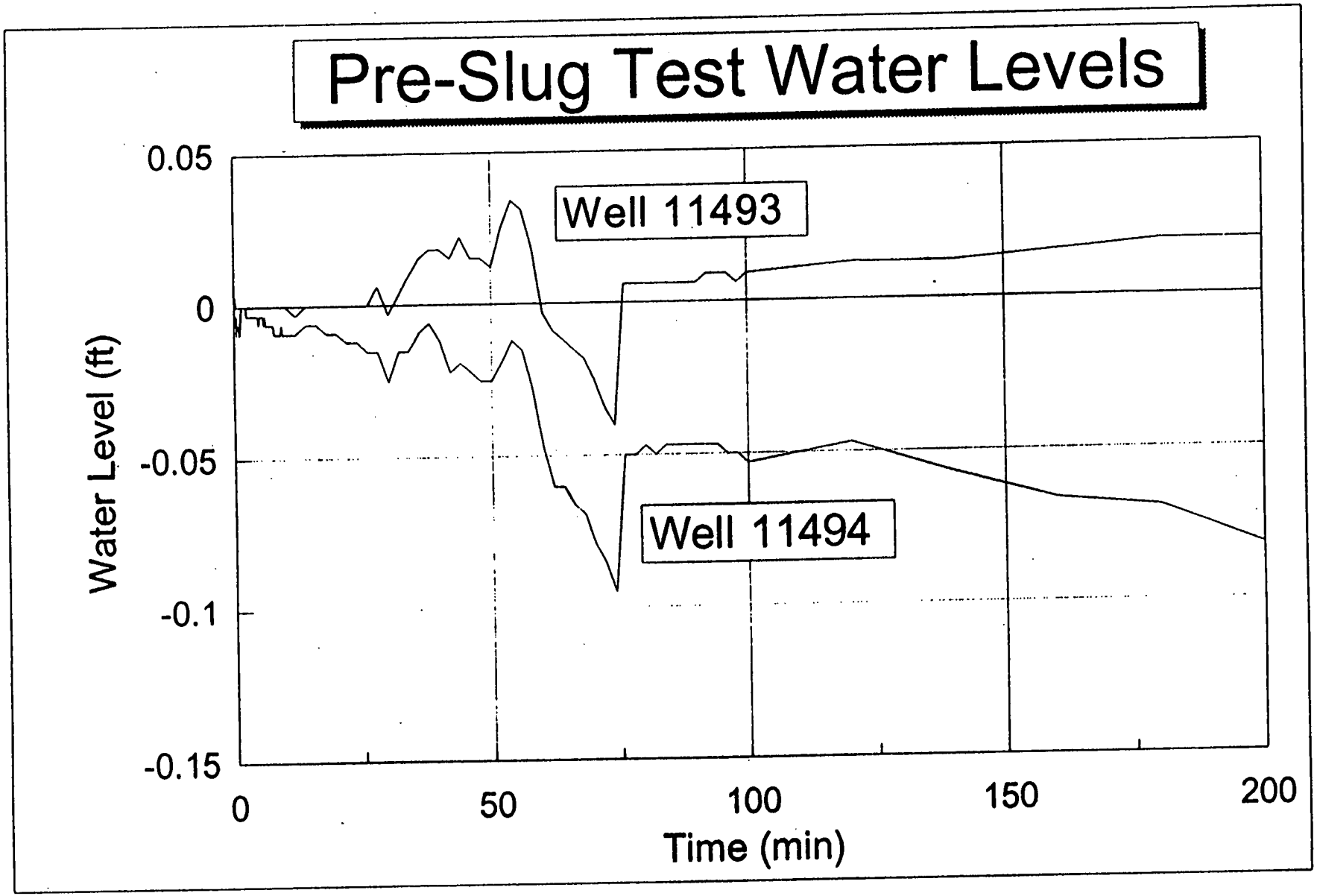
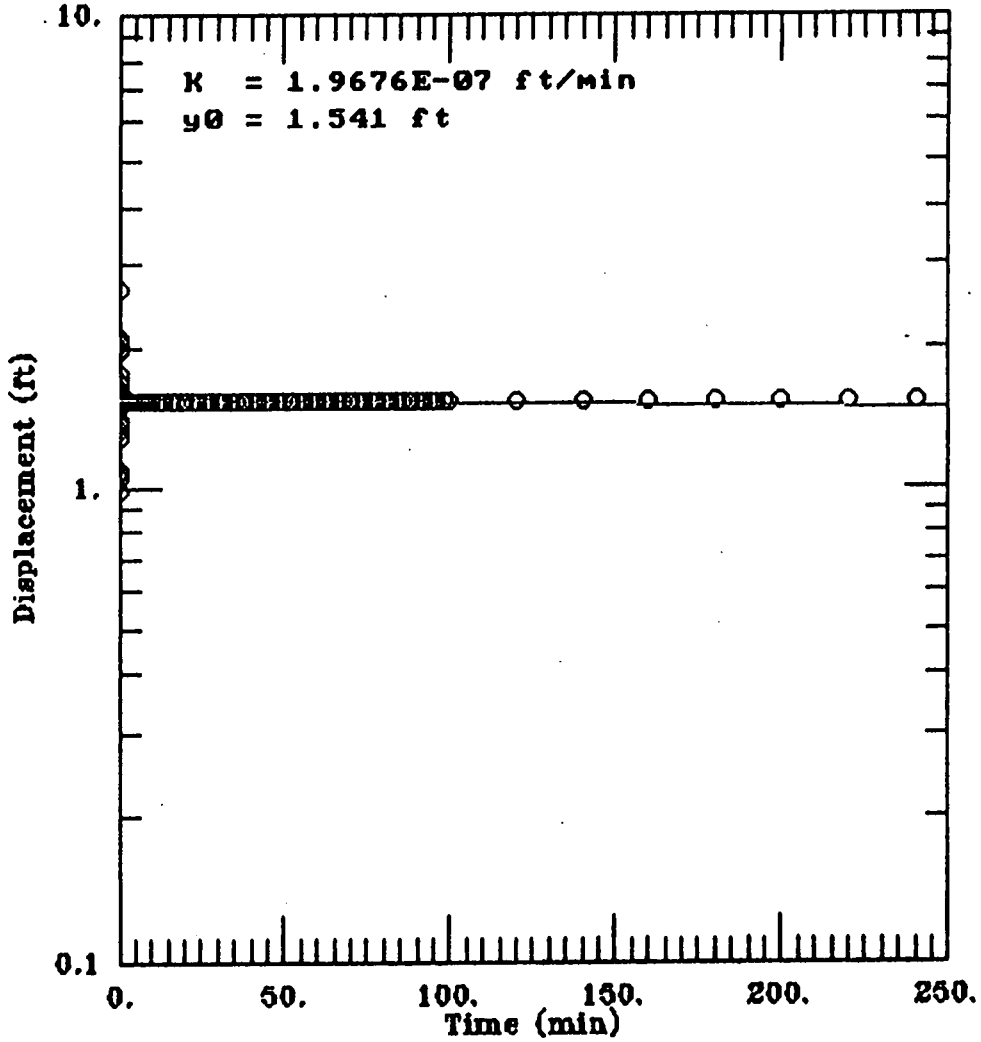

Pre-Slug Test Water Levels
Well 11493
Well 11494
Water Level (ft)
0.05
0
-0.05
-0.1
-0.15
0
50
100
150
200
Time (min)

Well 11493 Falling Head Test



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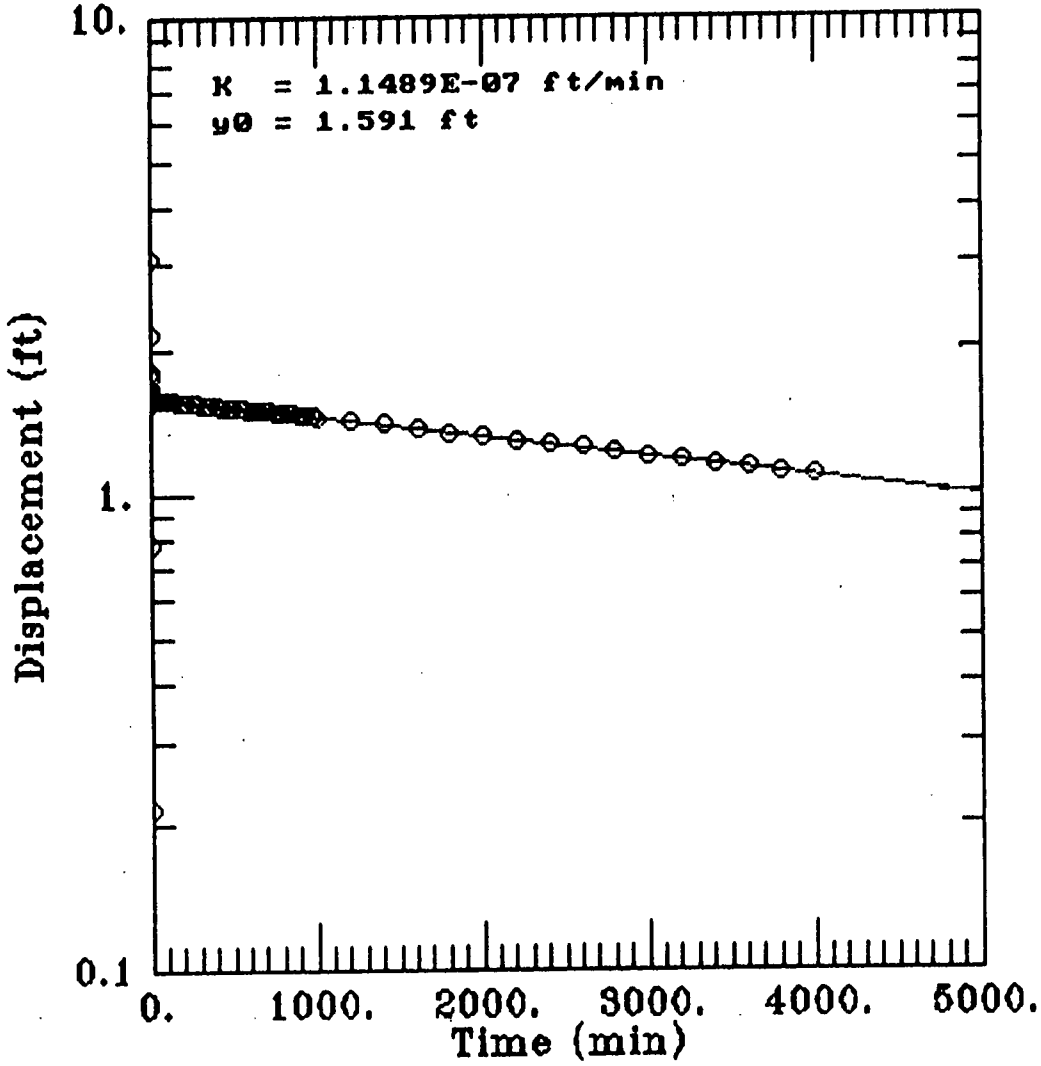

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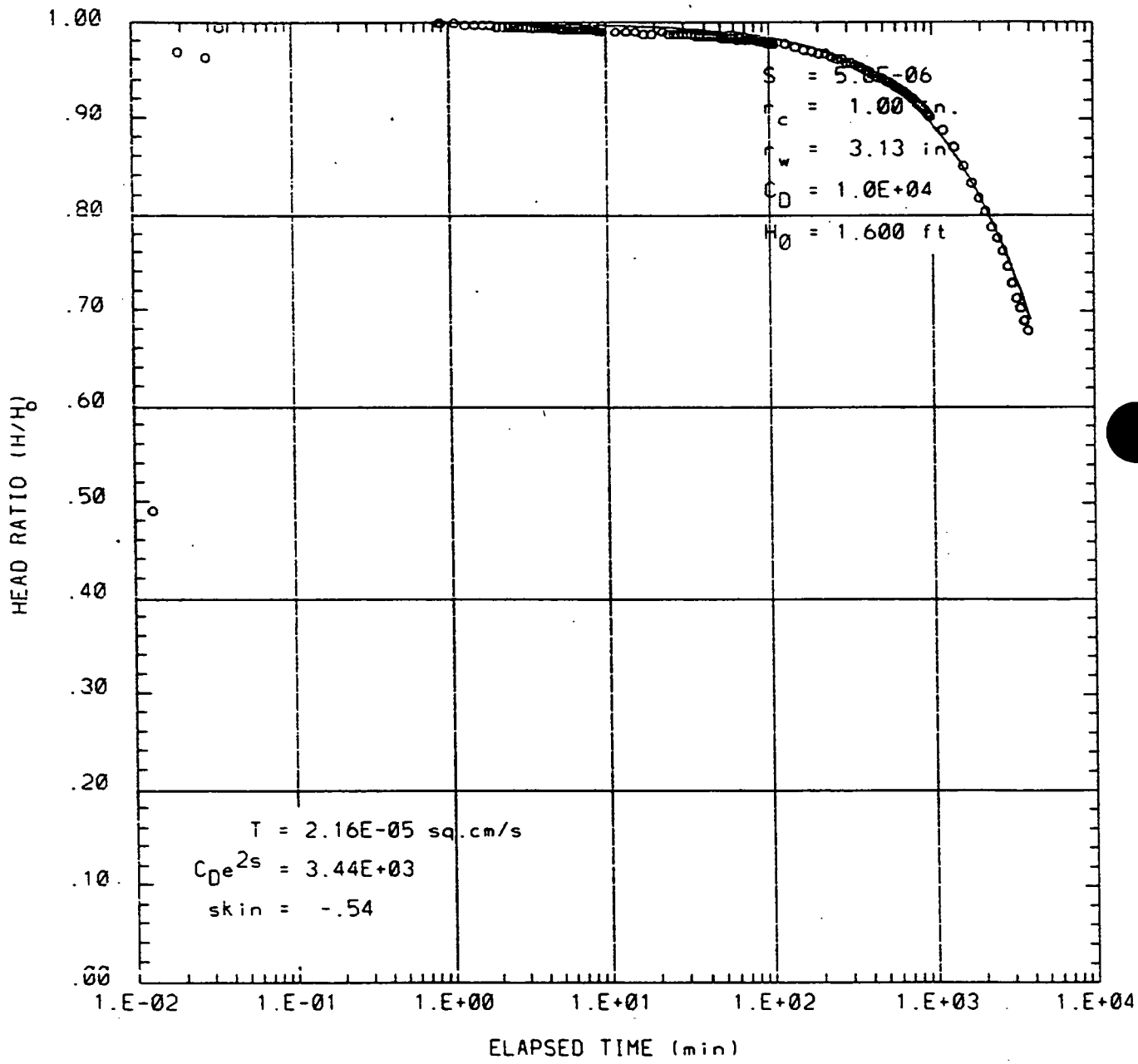
Well 11493 Rising Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



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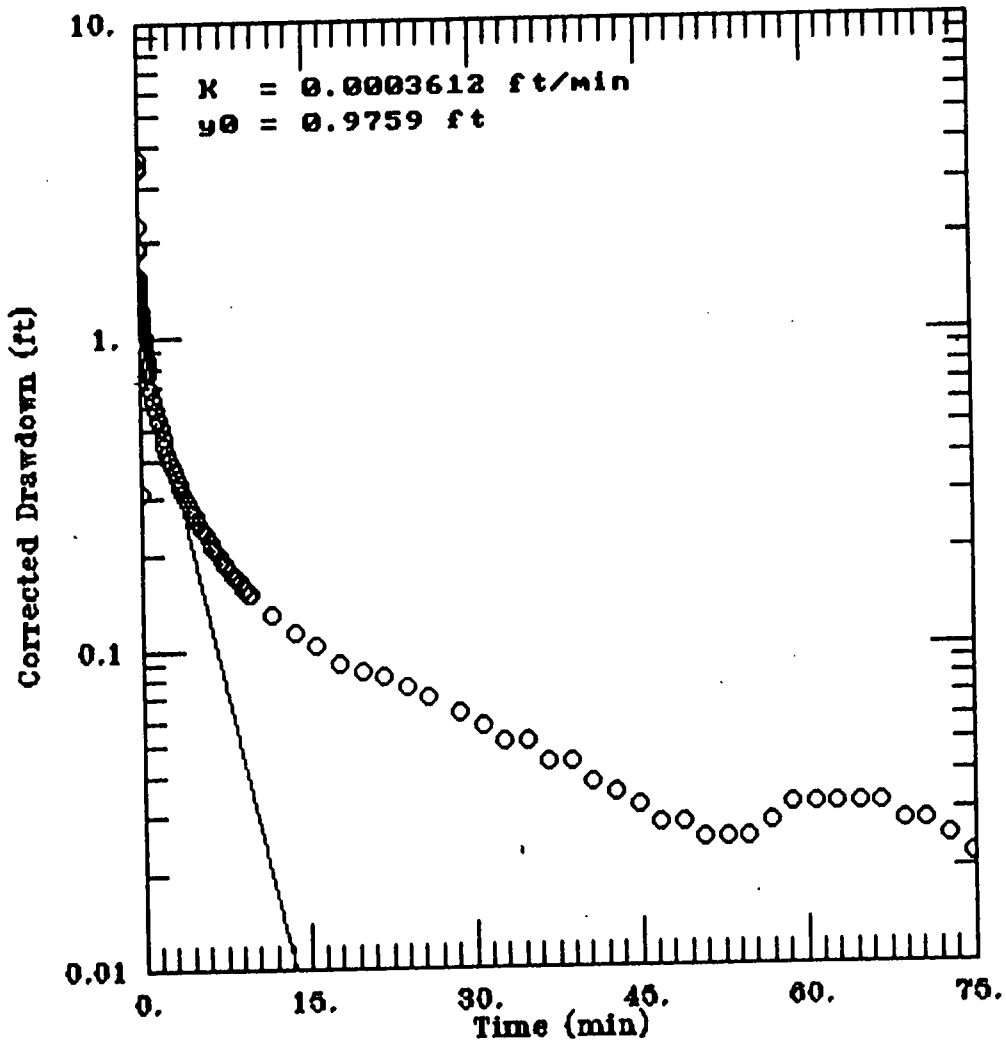
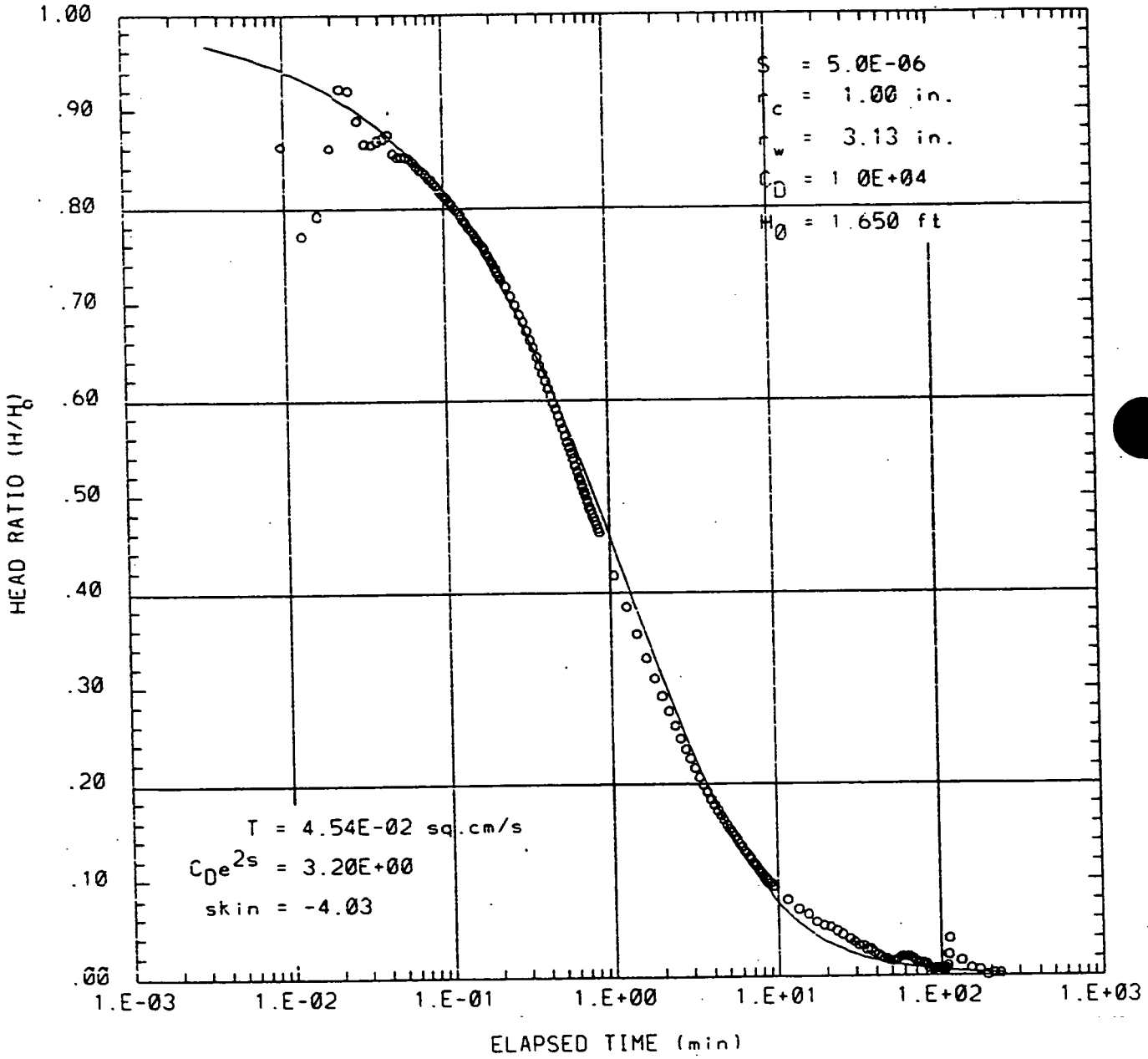


Well 11494 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



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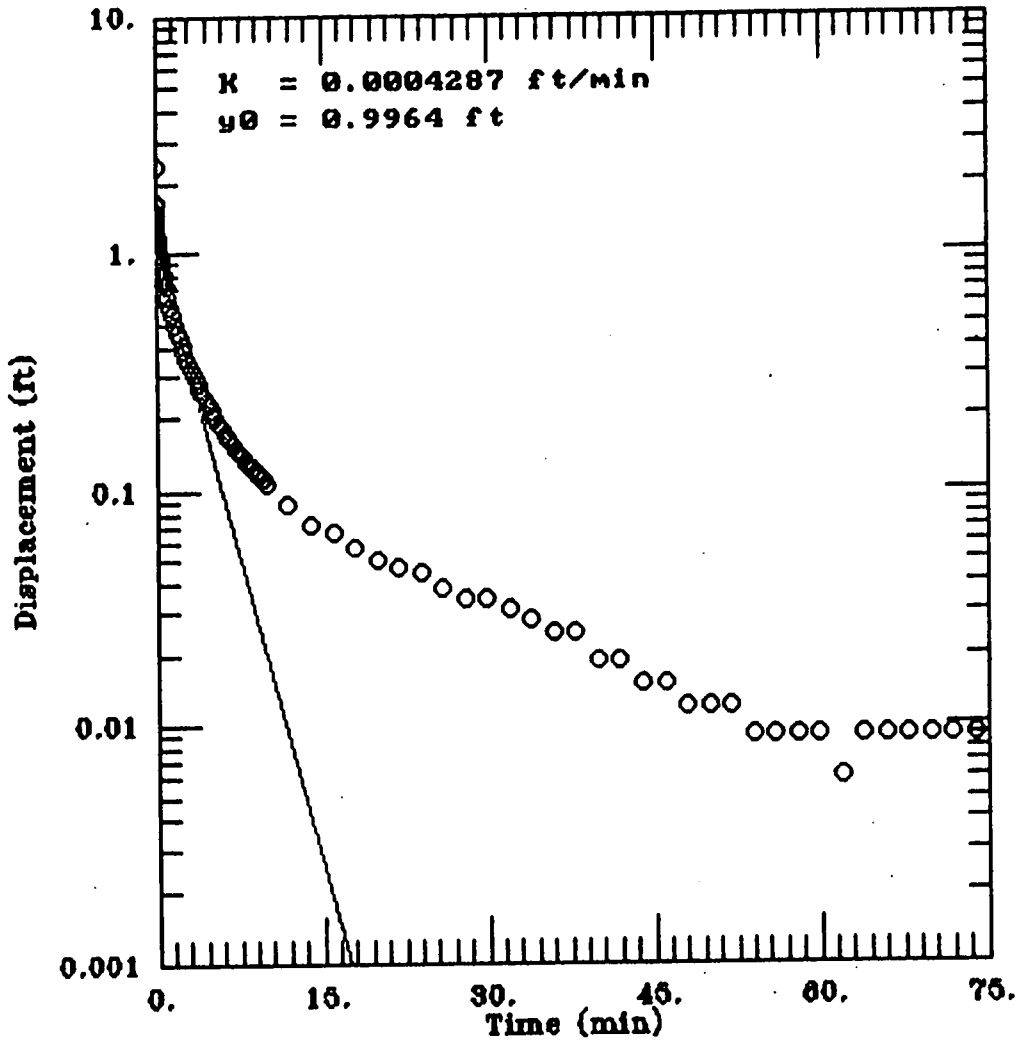
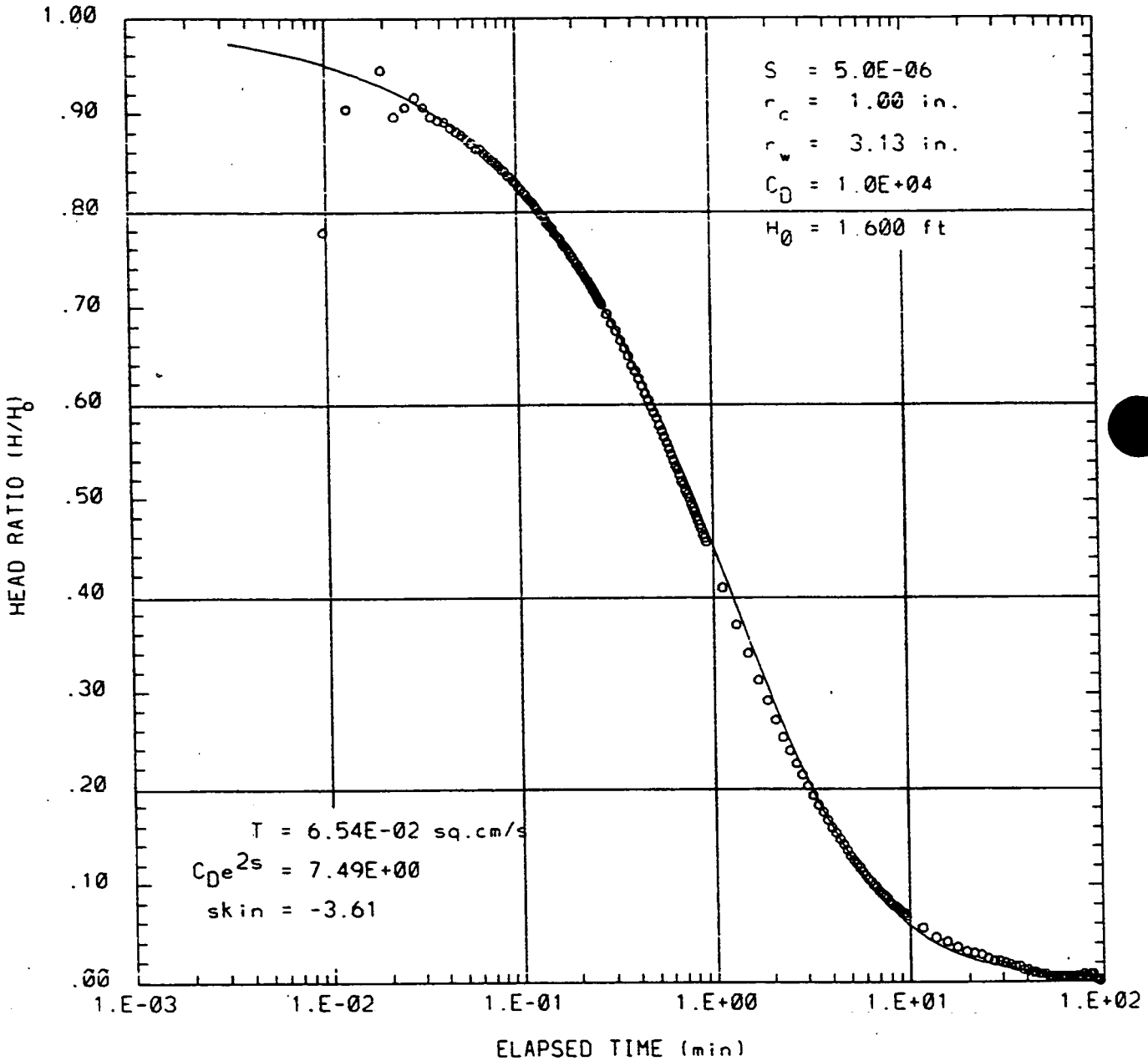
Well 11494 Rising Head Test



Well 11494 Rising Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



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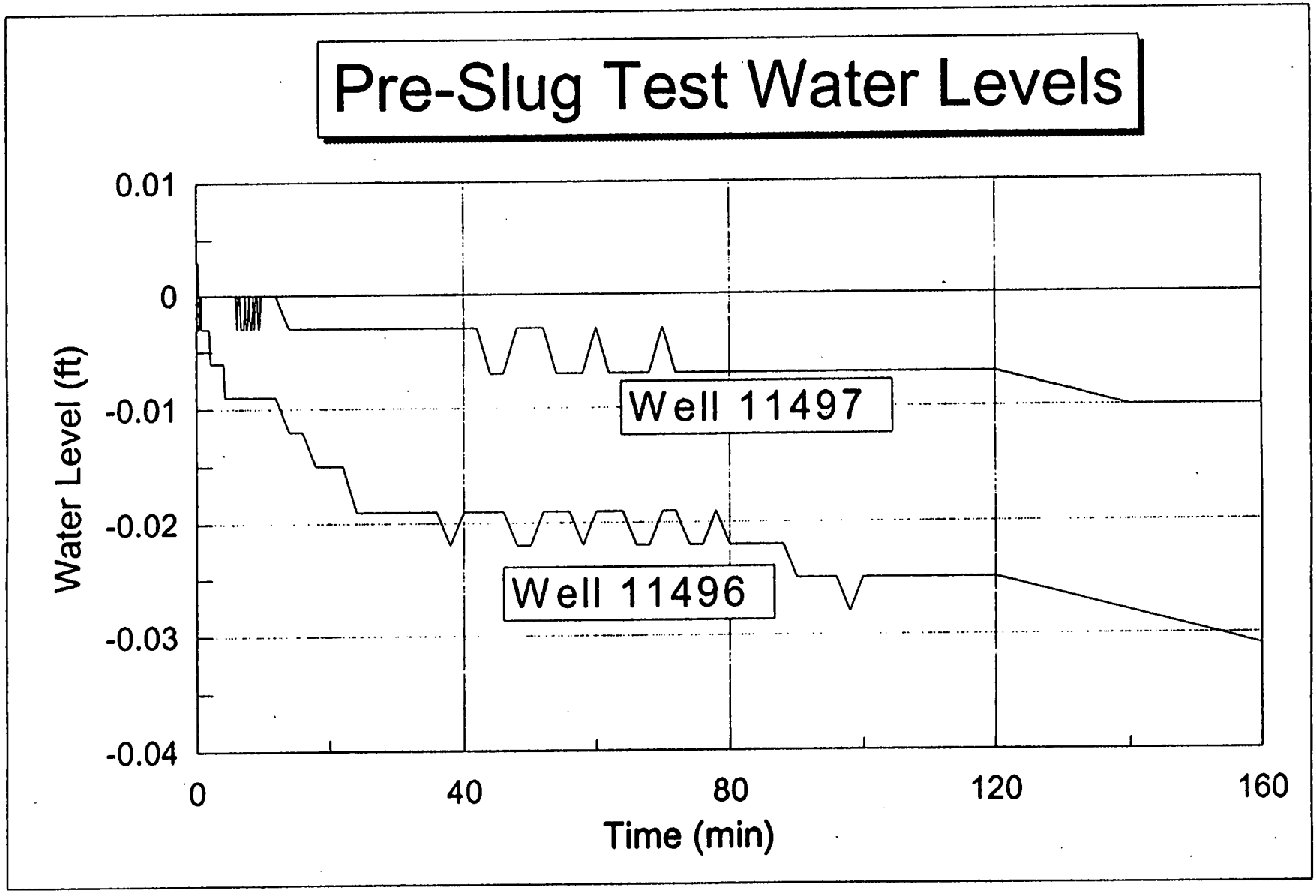
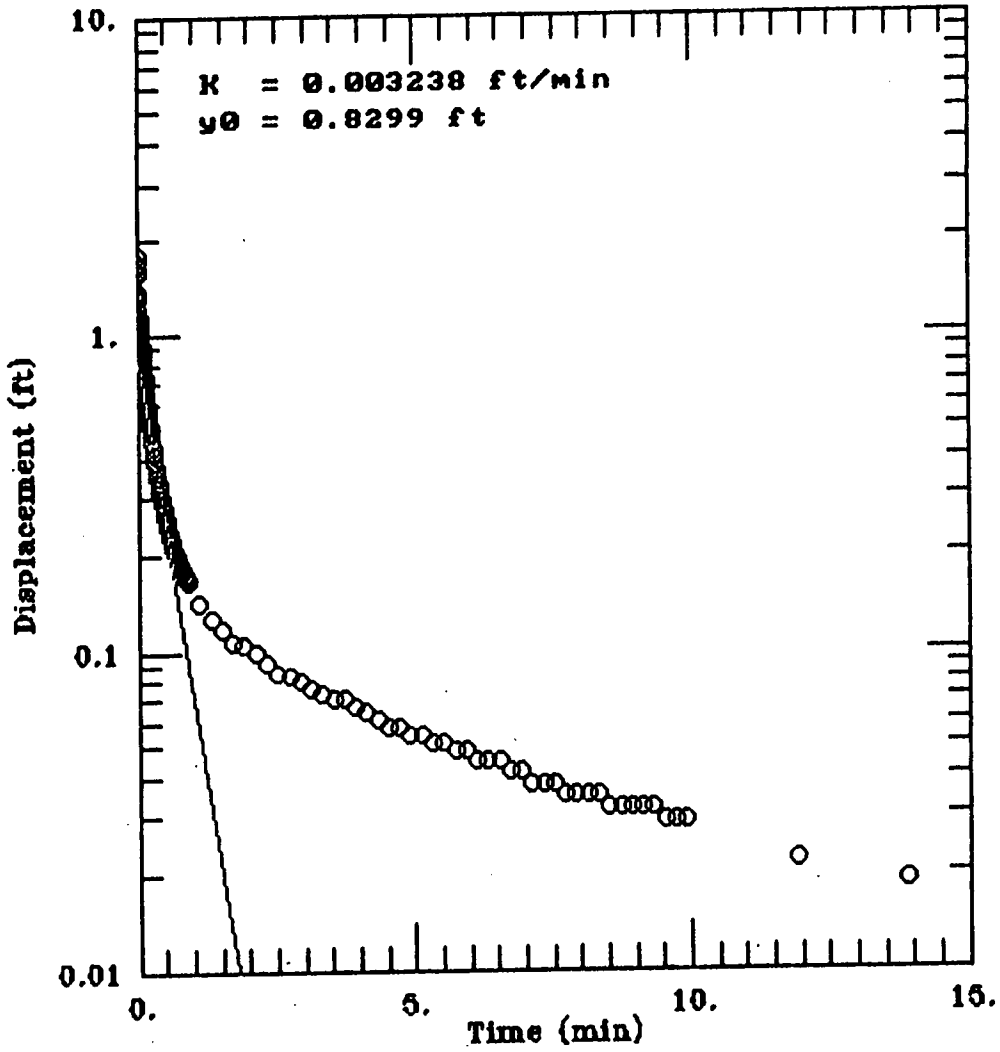

Pre-Slug Test Water Levels
0.01
0
-0.01
-0.02
-0.03
-0.04
Water Level (ft)
0
40
80
120
160
Time (min)
Well 11497
Well 11496

000026

Well 11496 Falling Head Test



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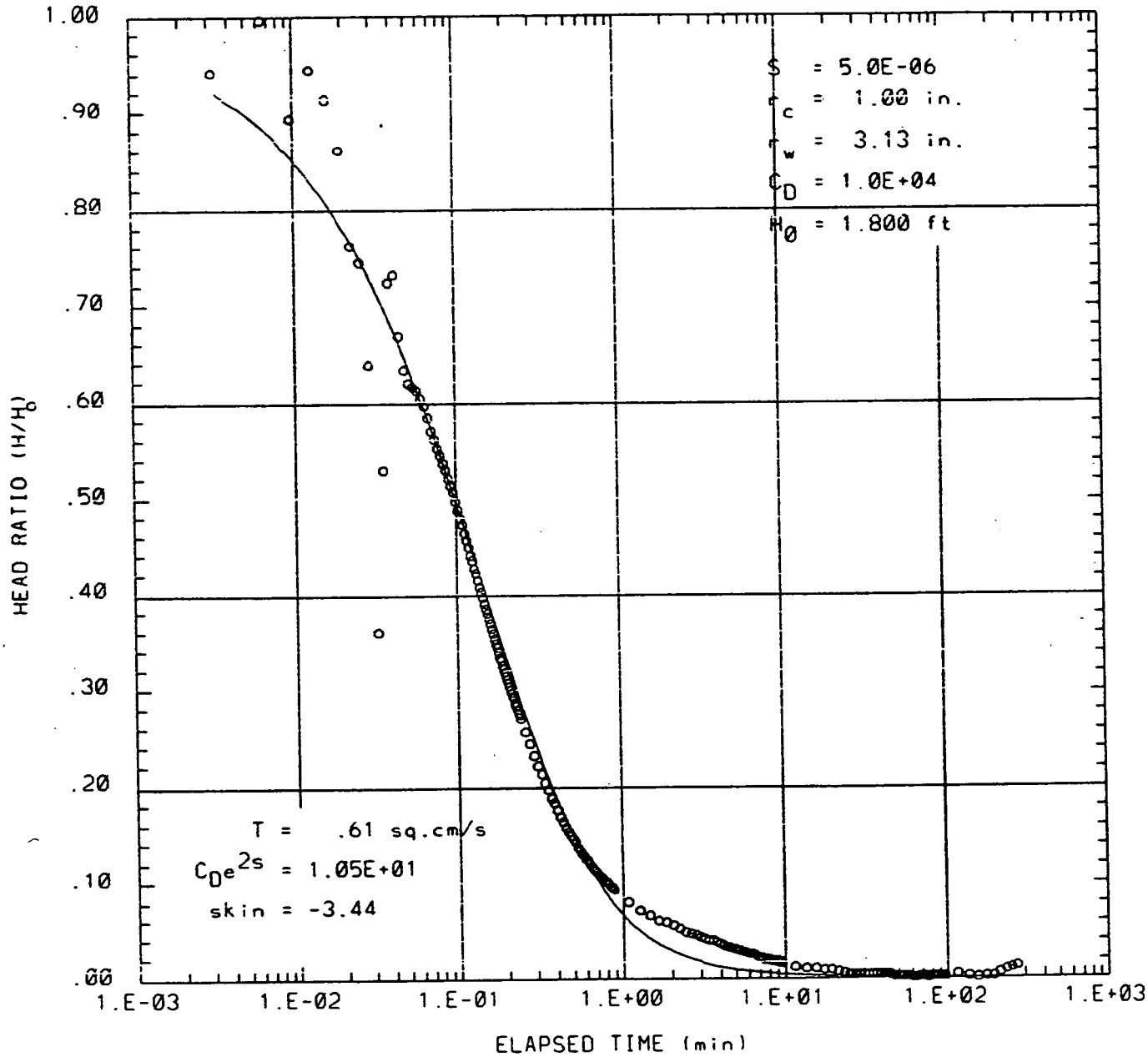
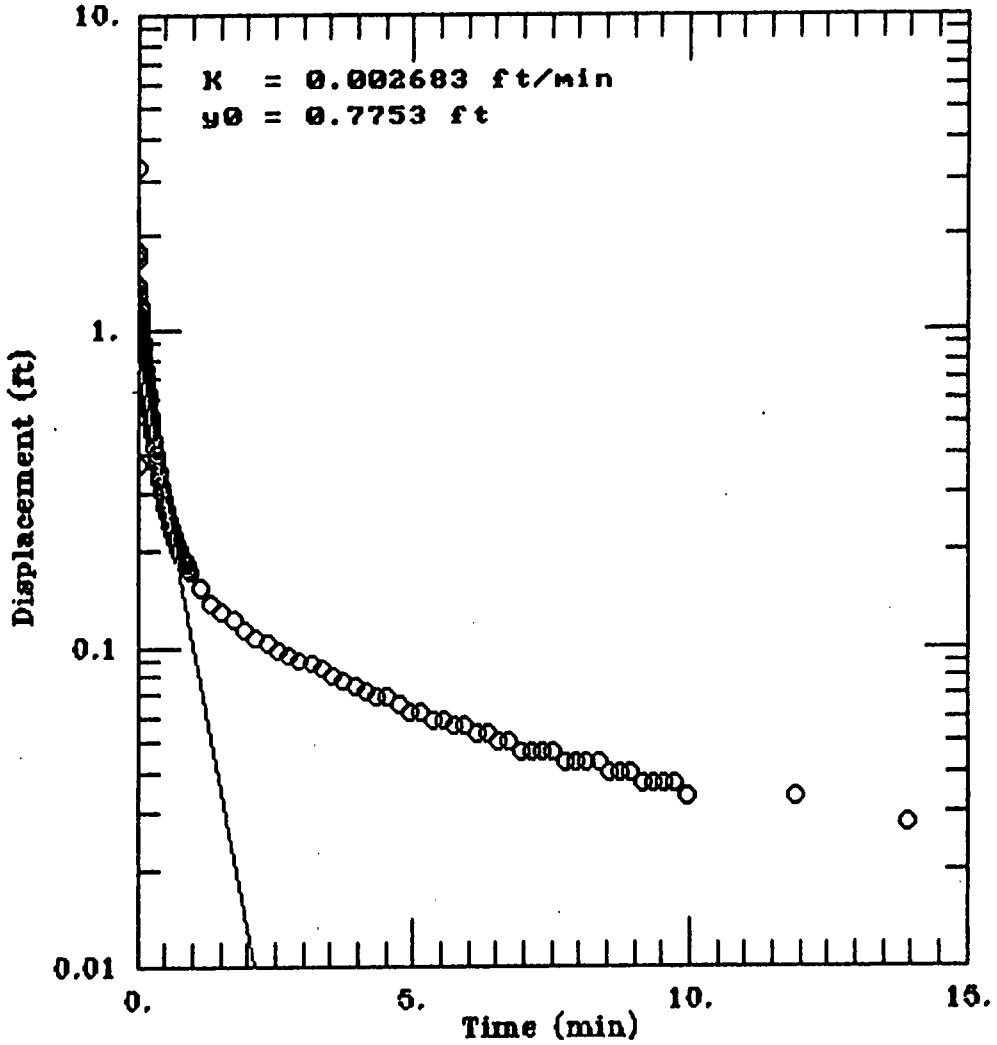
Well 11496 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11496 Rising Head Test



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Well 11496 Rising Head Test

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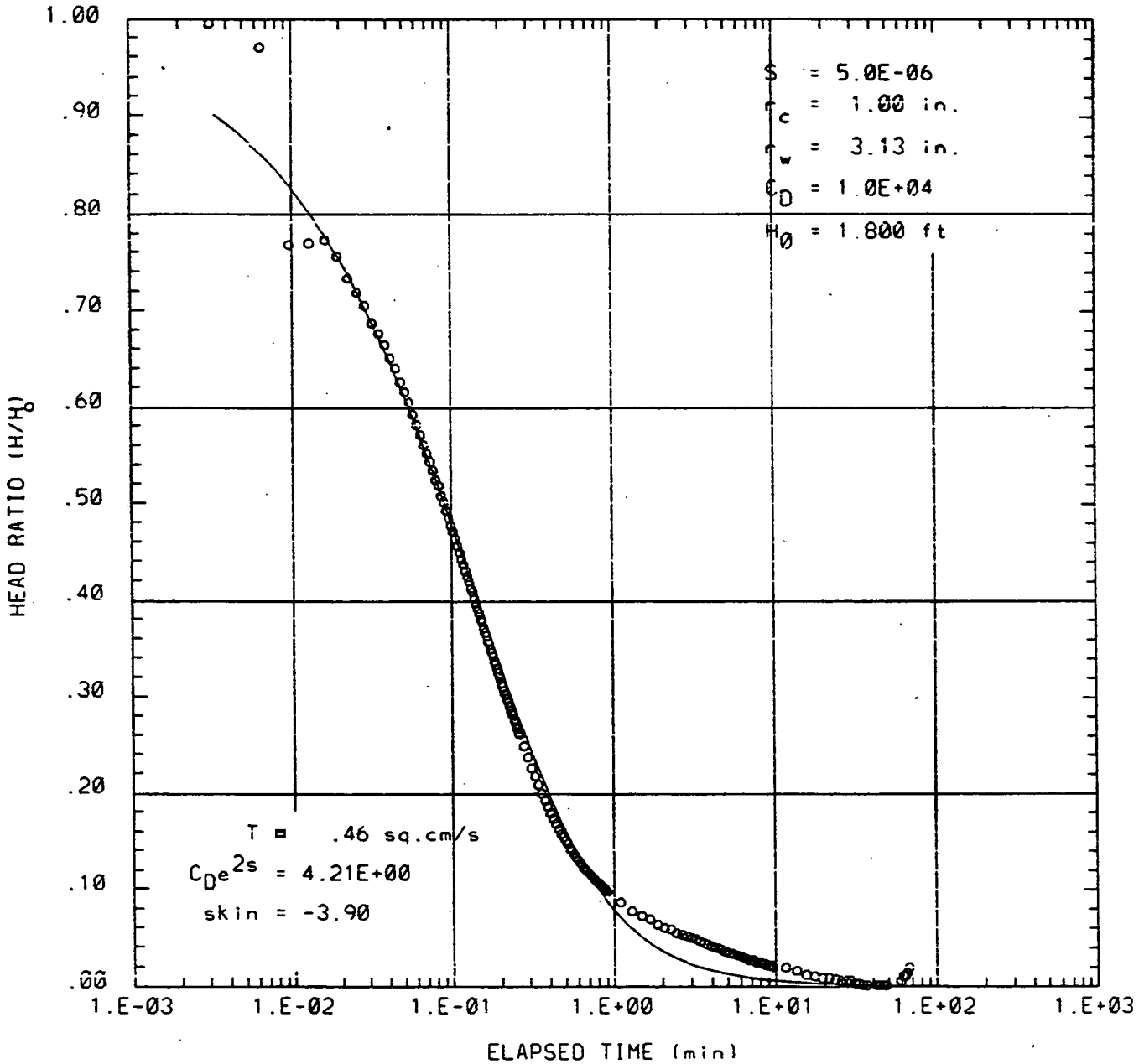
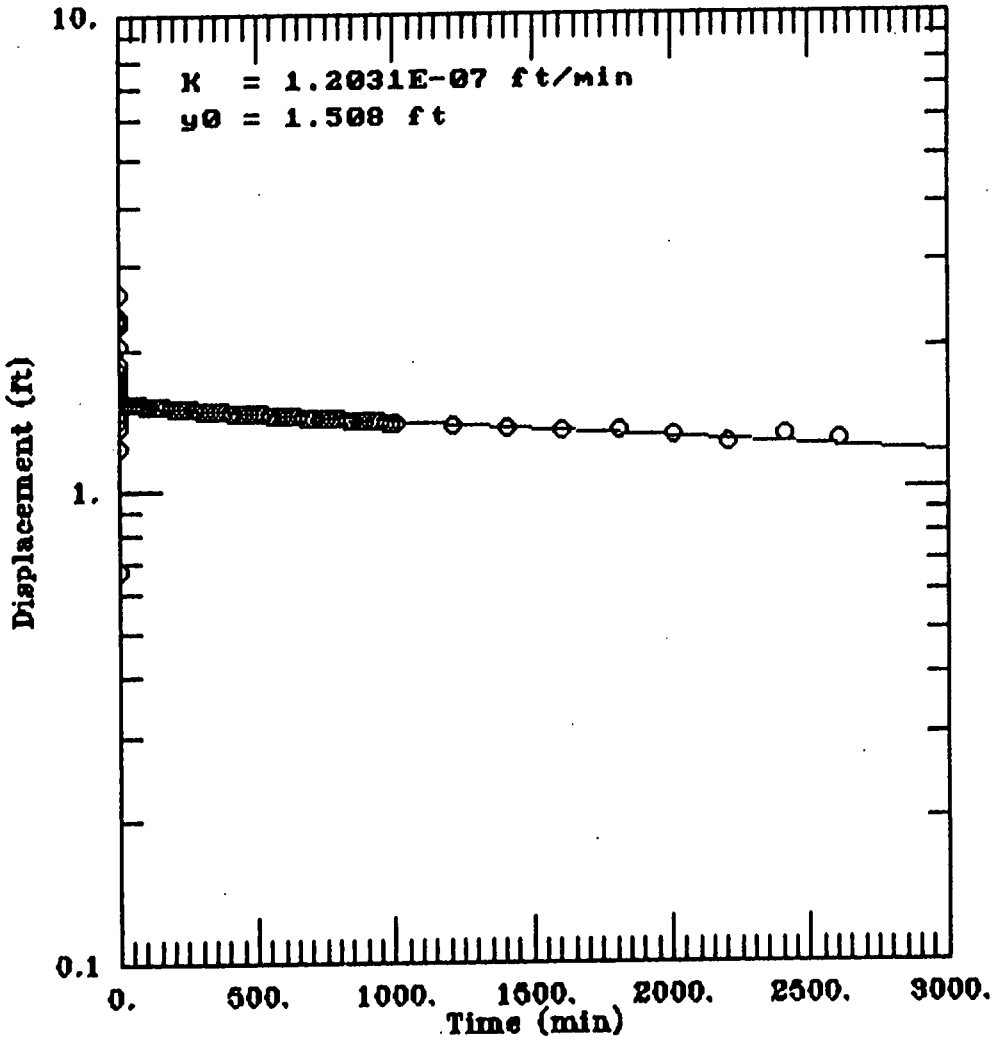


Well 11497 Falling Head Test



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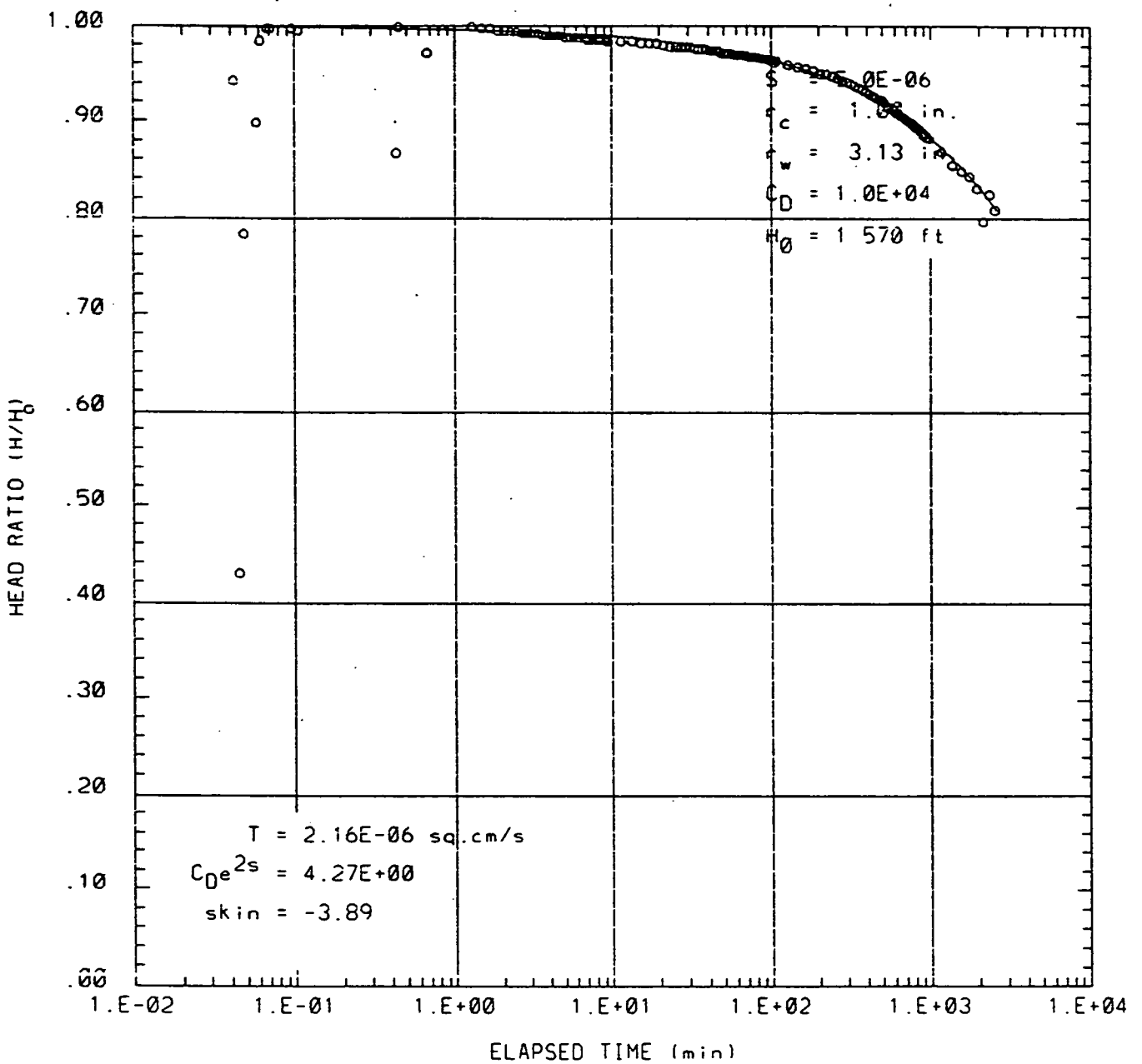
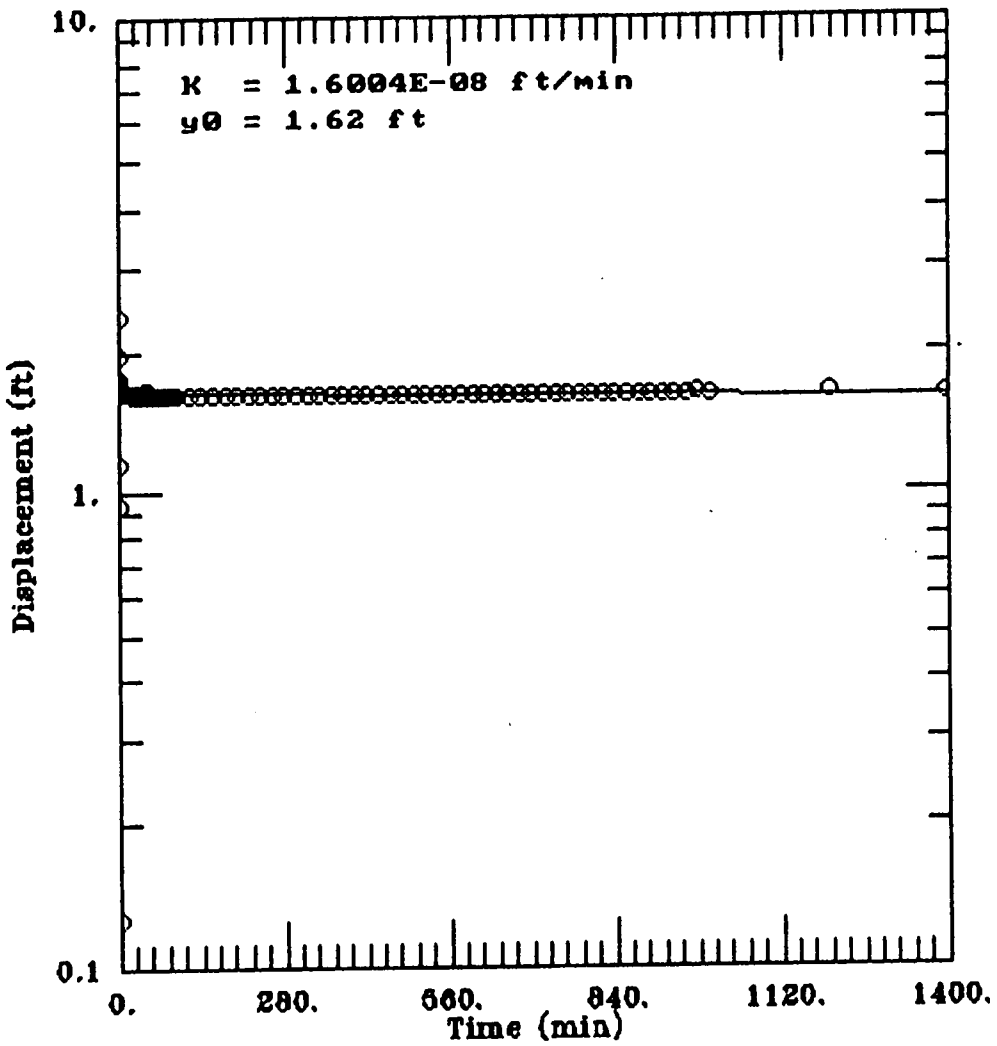
Well 11497 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11497 Rising Head Test



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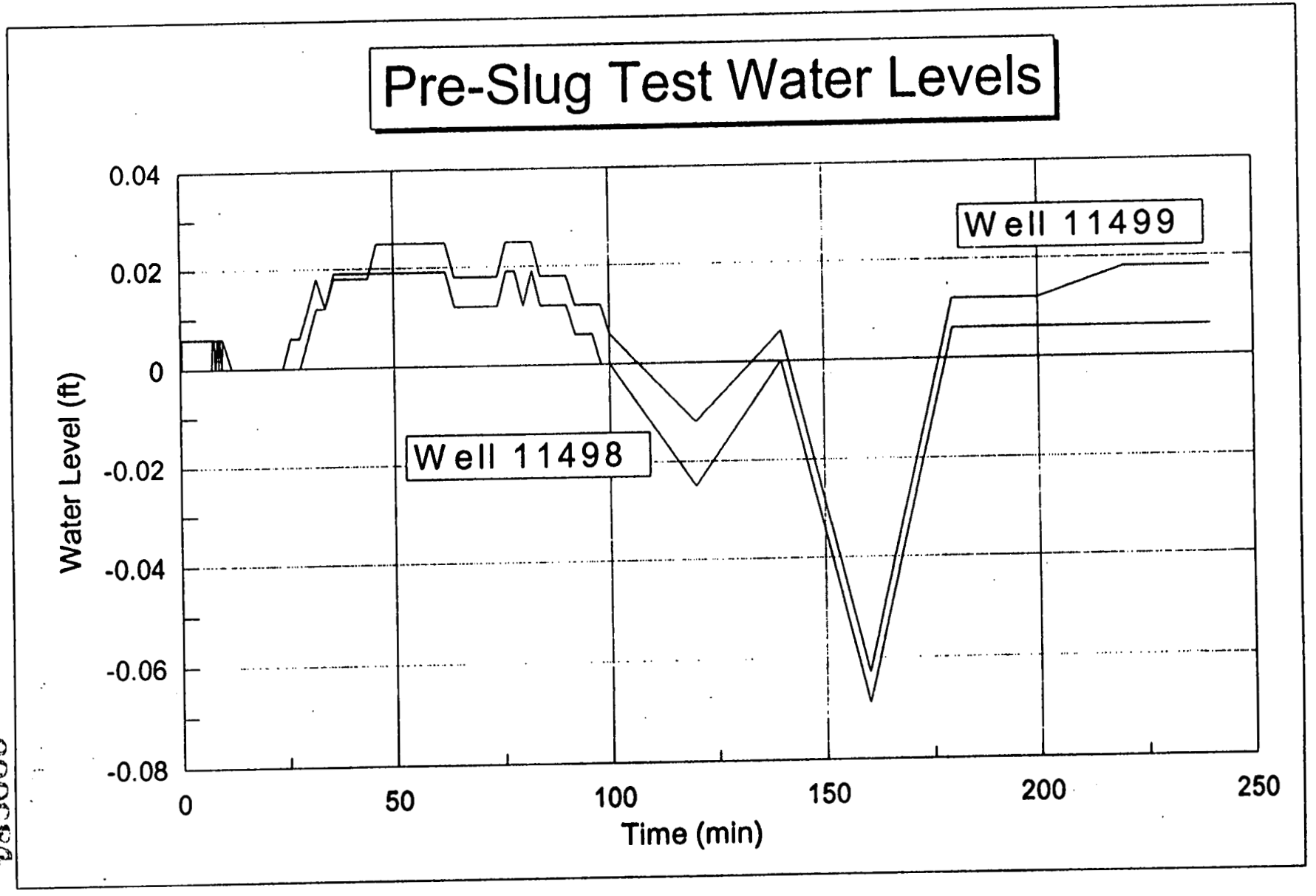
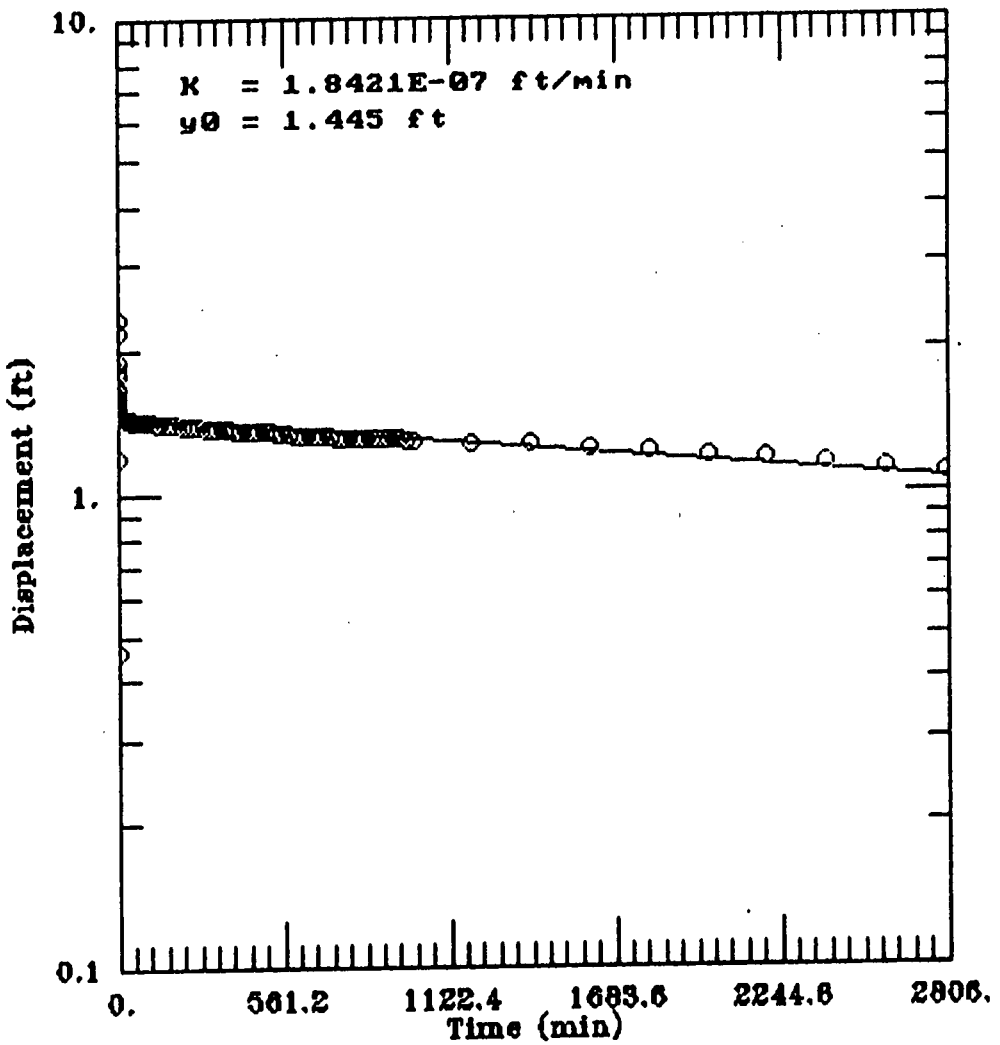

Pre-Slug Test Water Levels
Well 11499
Well 11498
Water Level (ft)
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
0
50
100
150
200
250
Time (min)

Well 11498 Falling Head Test



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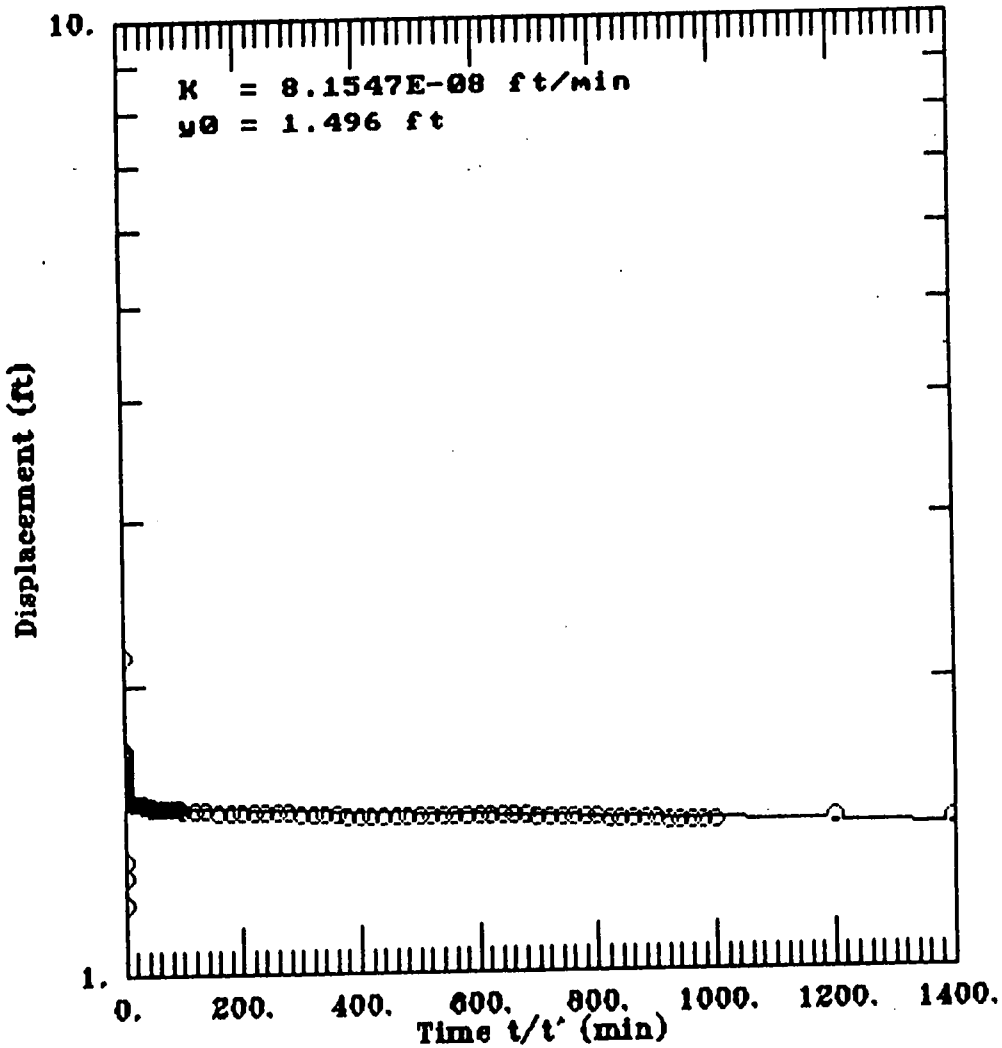
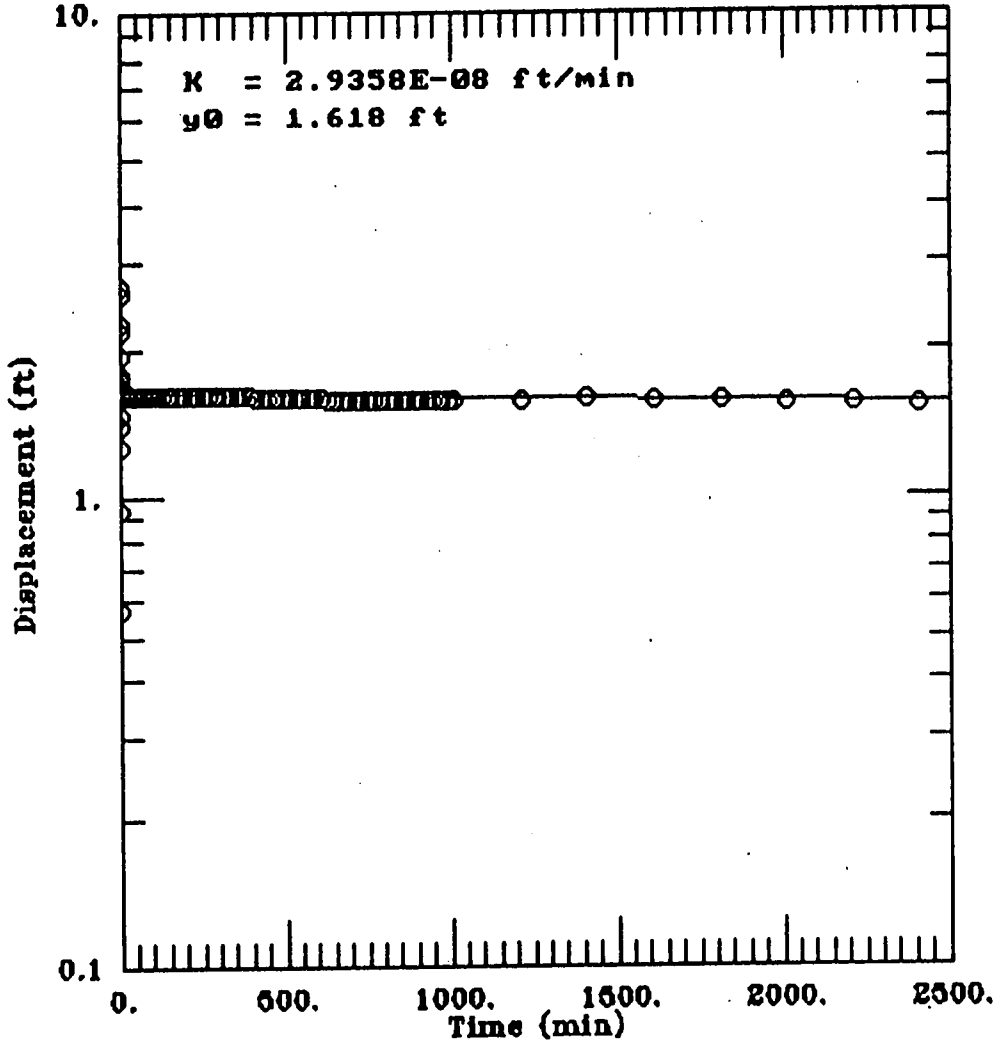
Well 11498 Rising Head Test



Well 11499 Falling Head Test



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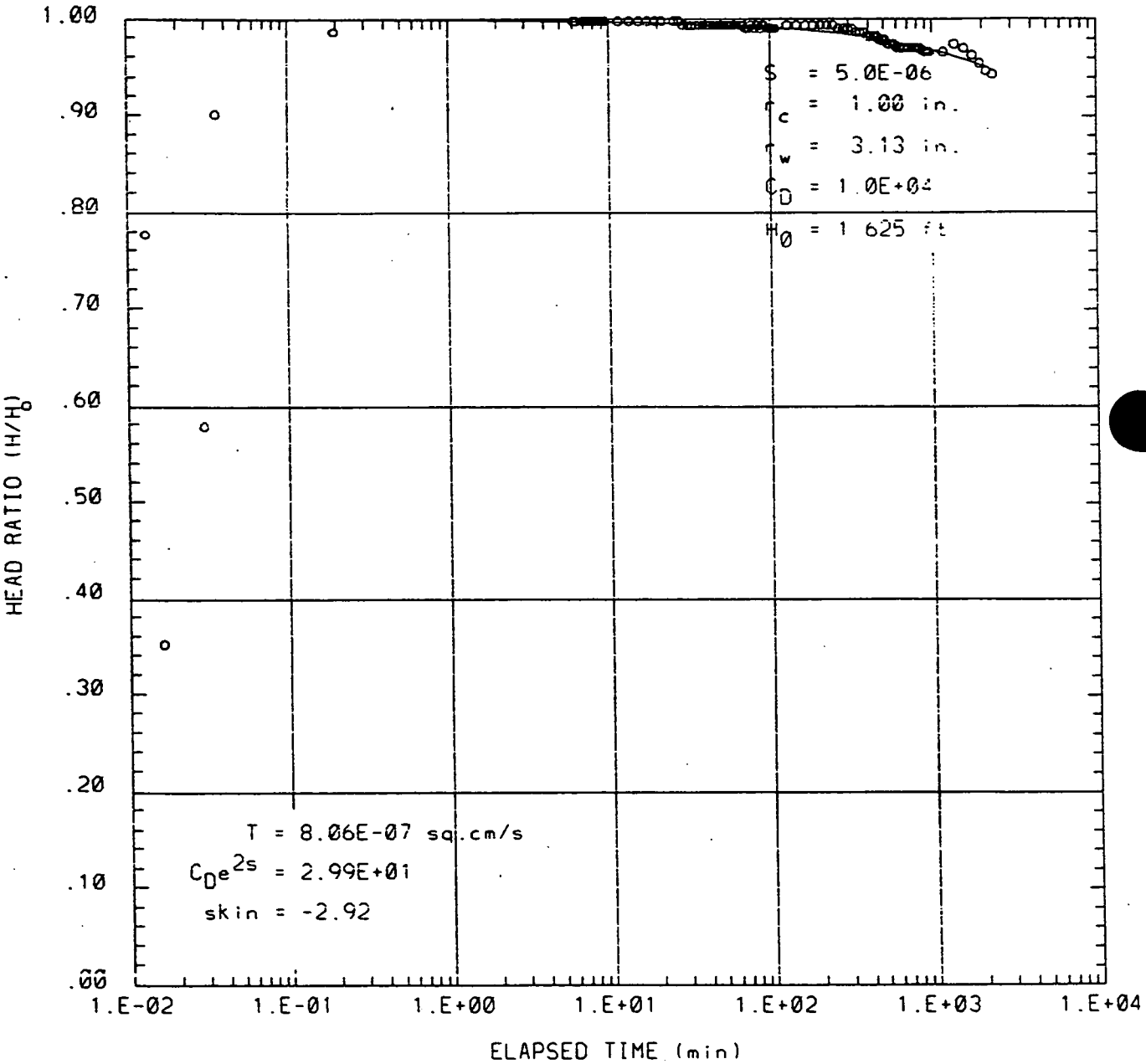
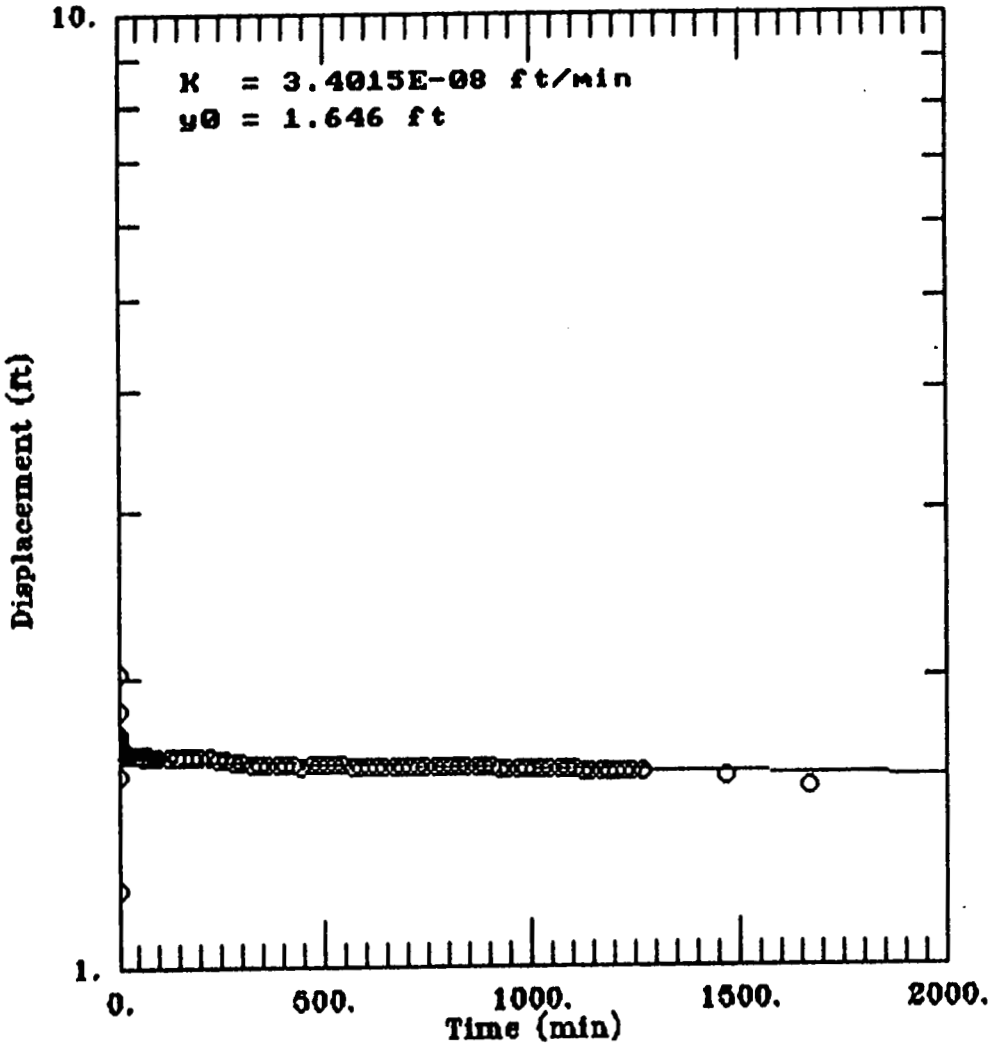
Well 11499 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)

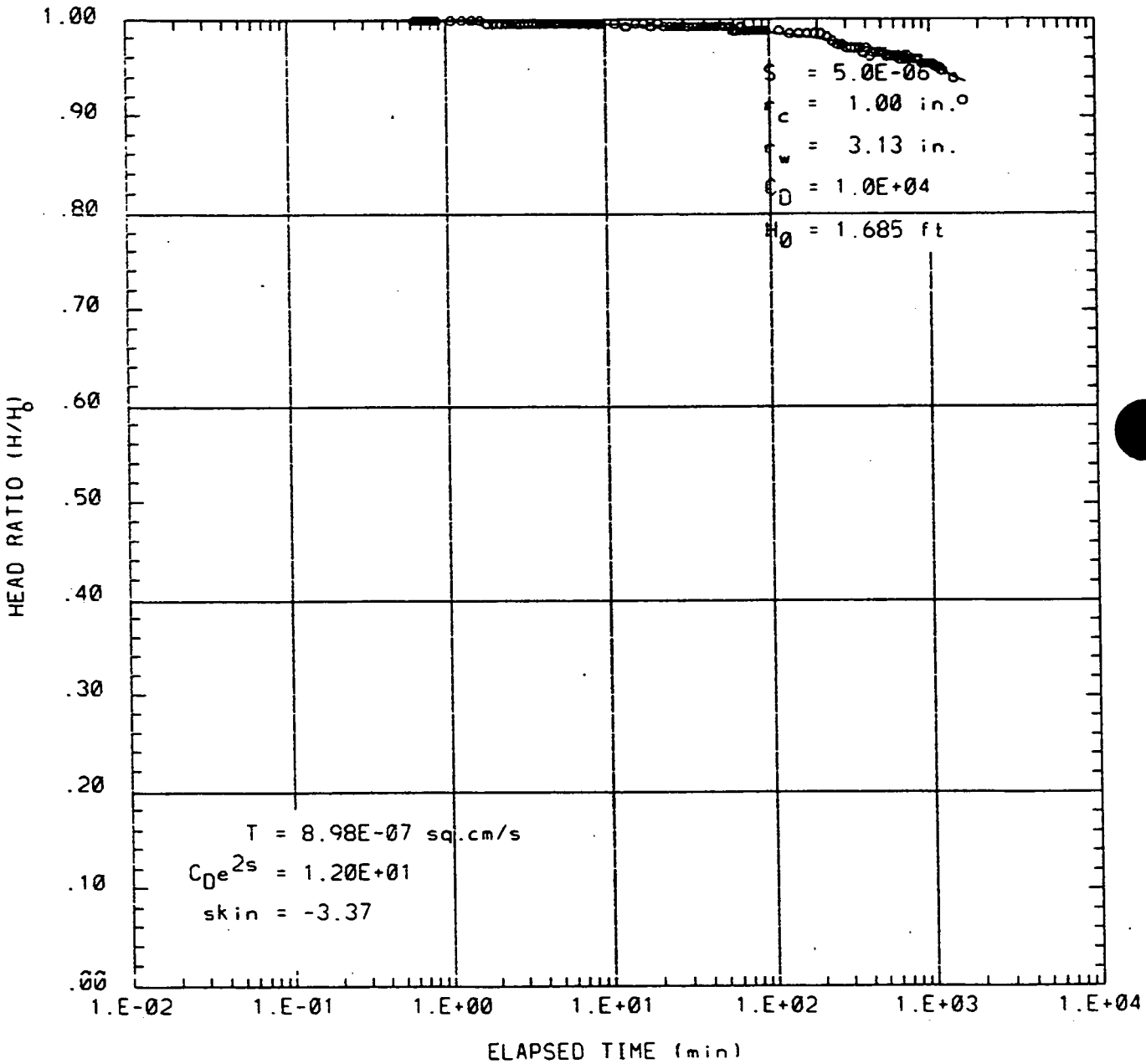


Well 11499 Rising Head Test



Well 11499 Rising Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



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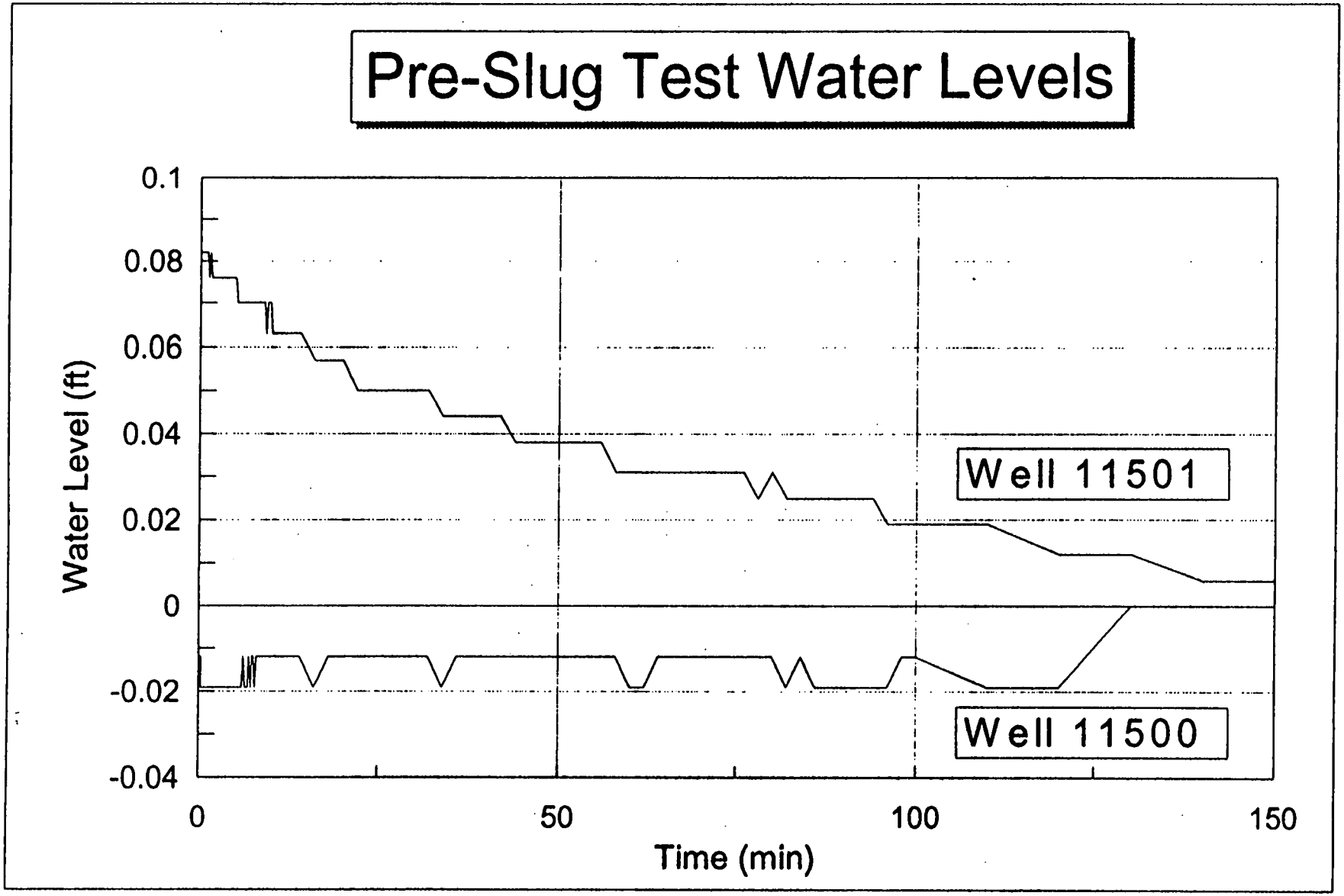
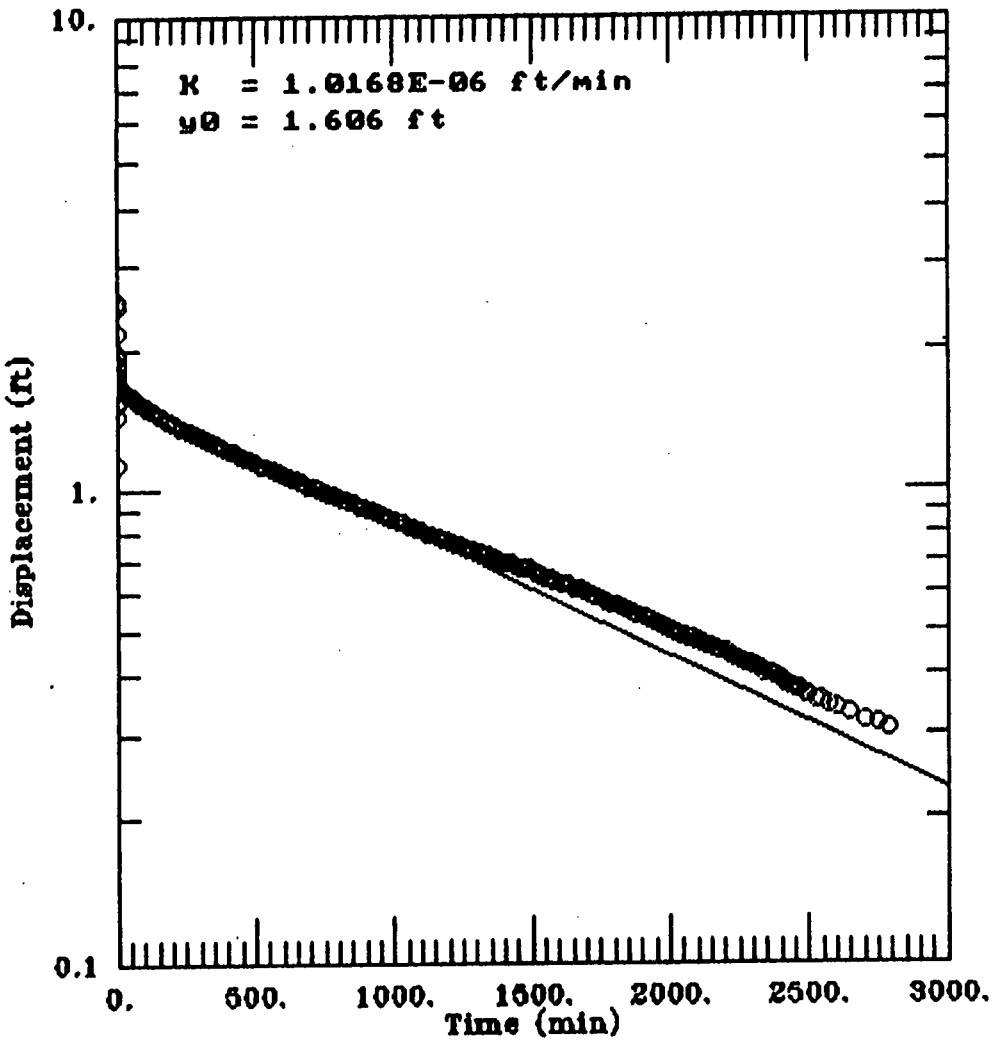

Pre-Slug Test Water Levels
Water Level (ft)
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
0
50
100
150
Time (min)
Well 11501
Well 11500

000091

Well 11500 Falling Head Test



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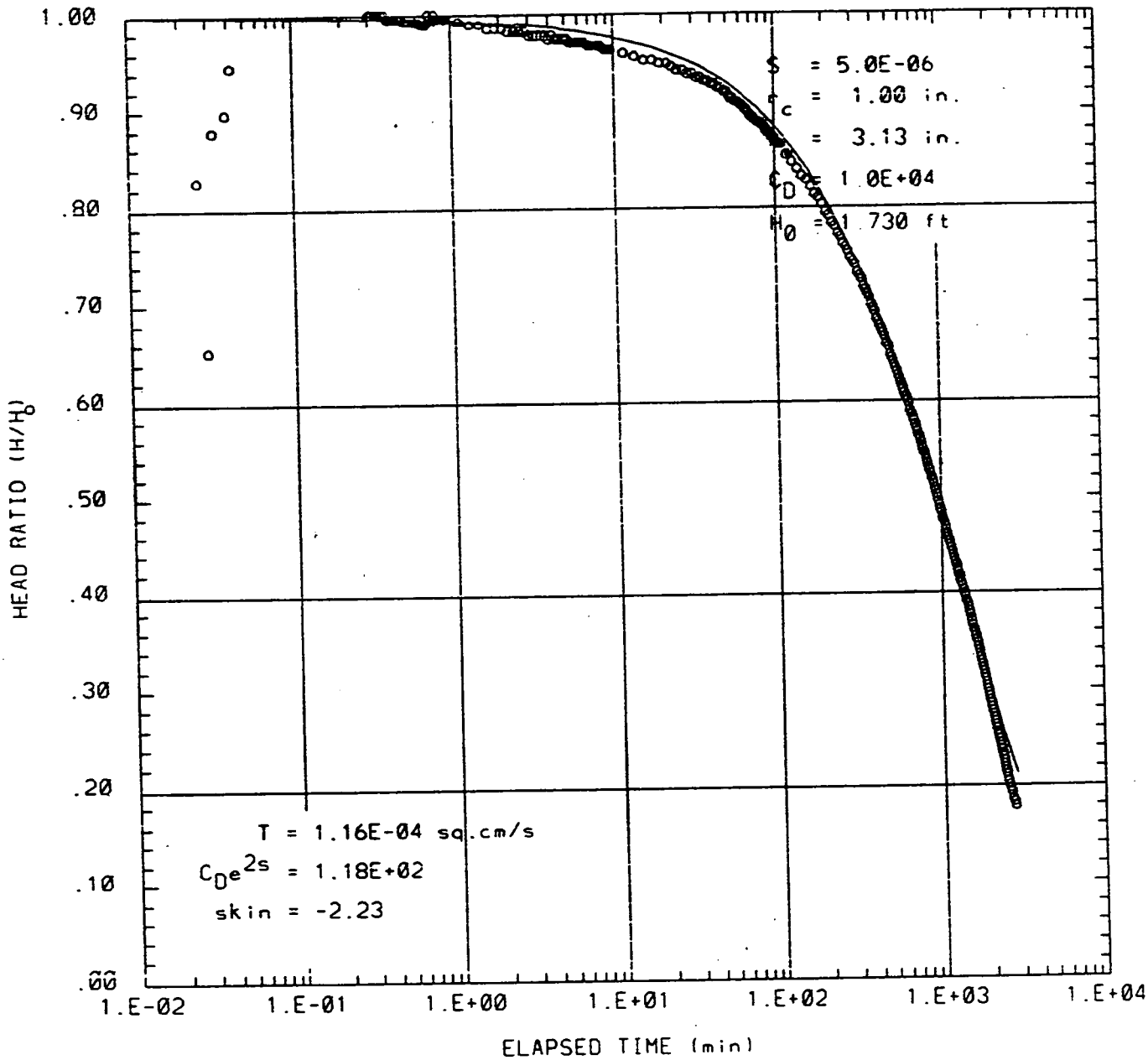
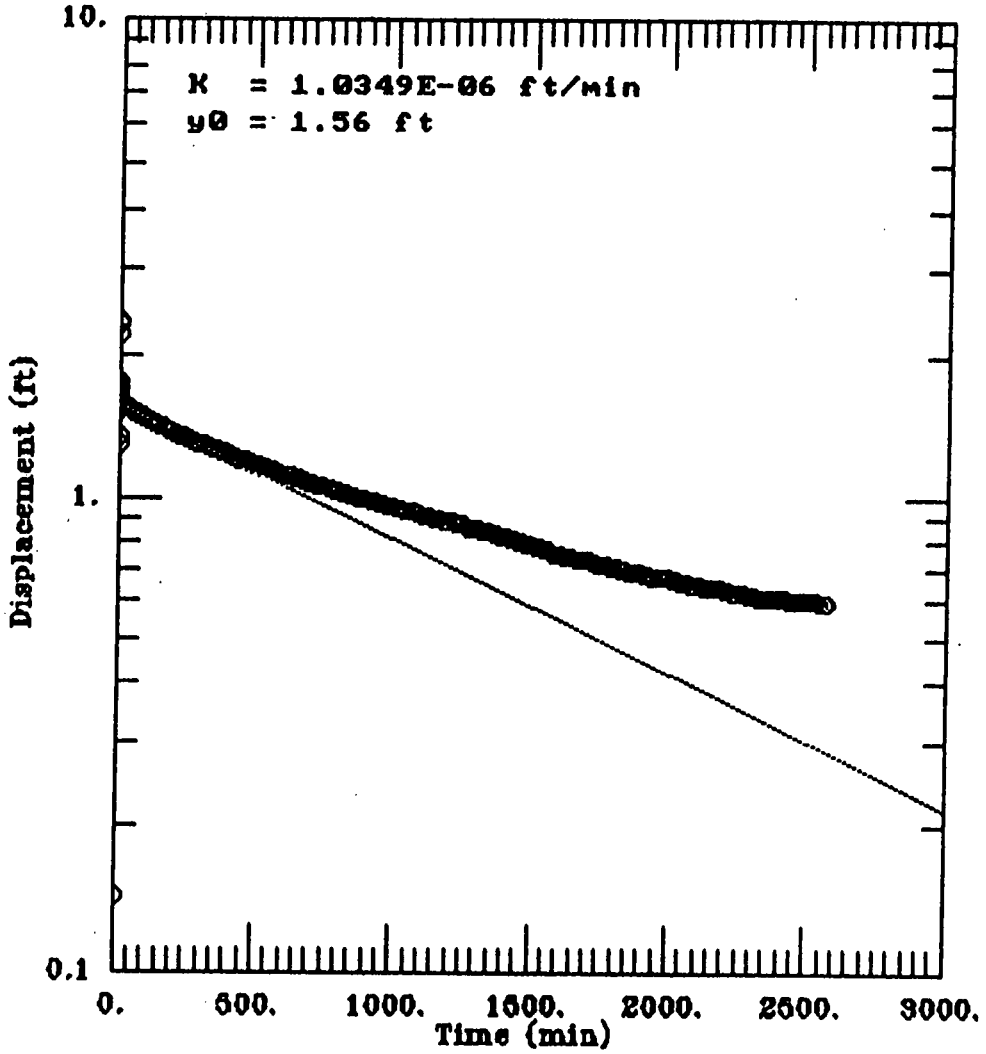
Well 11500 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11500 Rising Head Test



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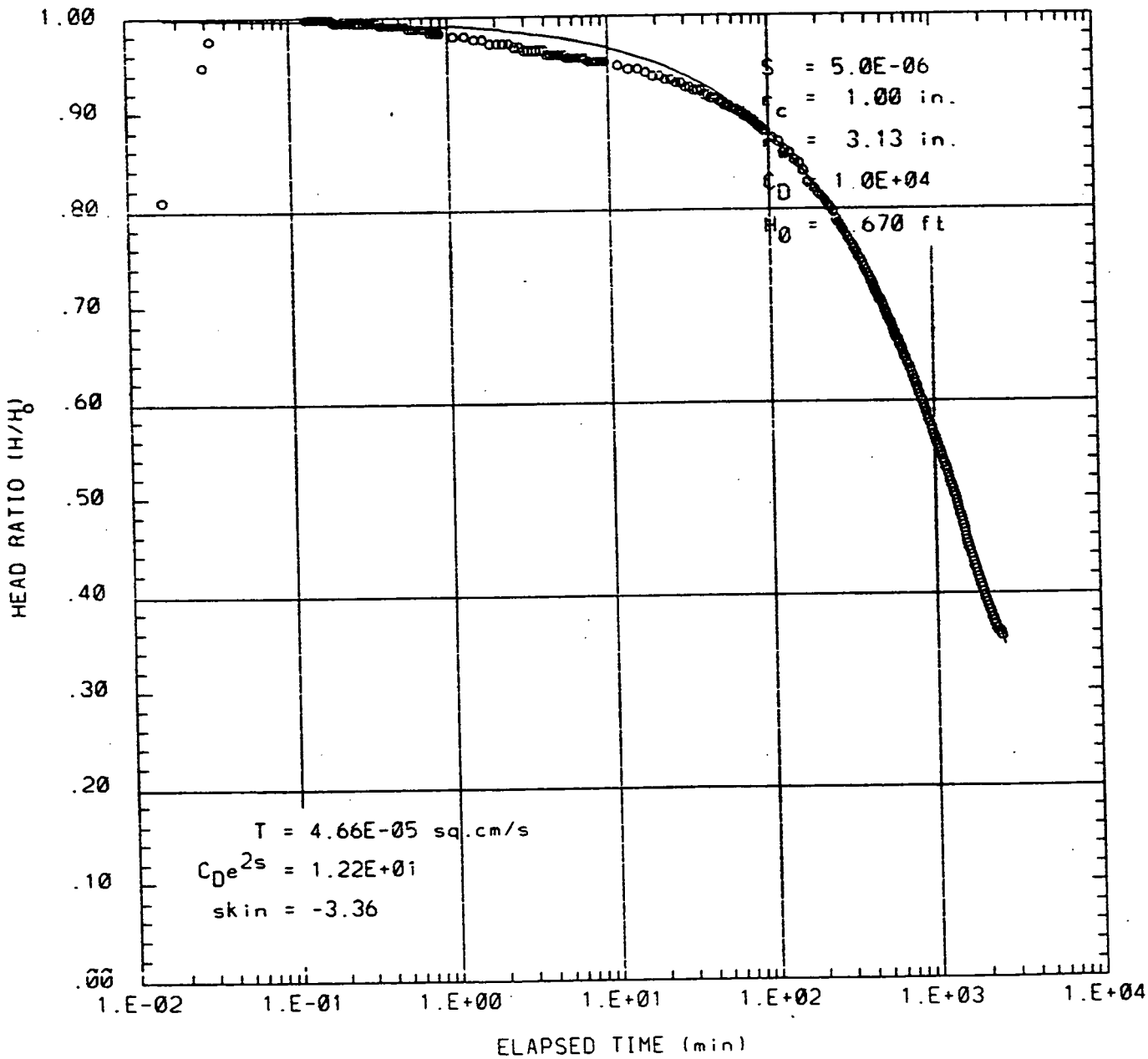
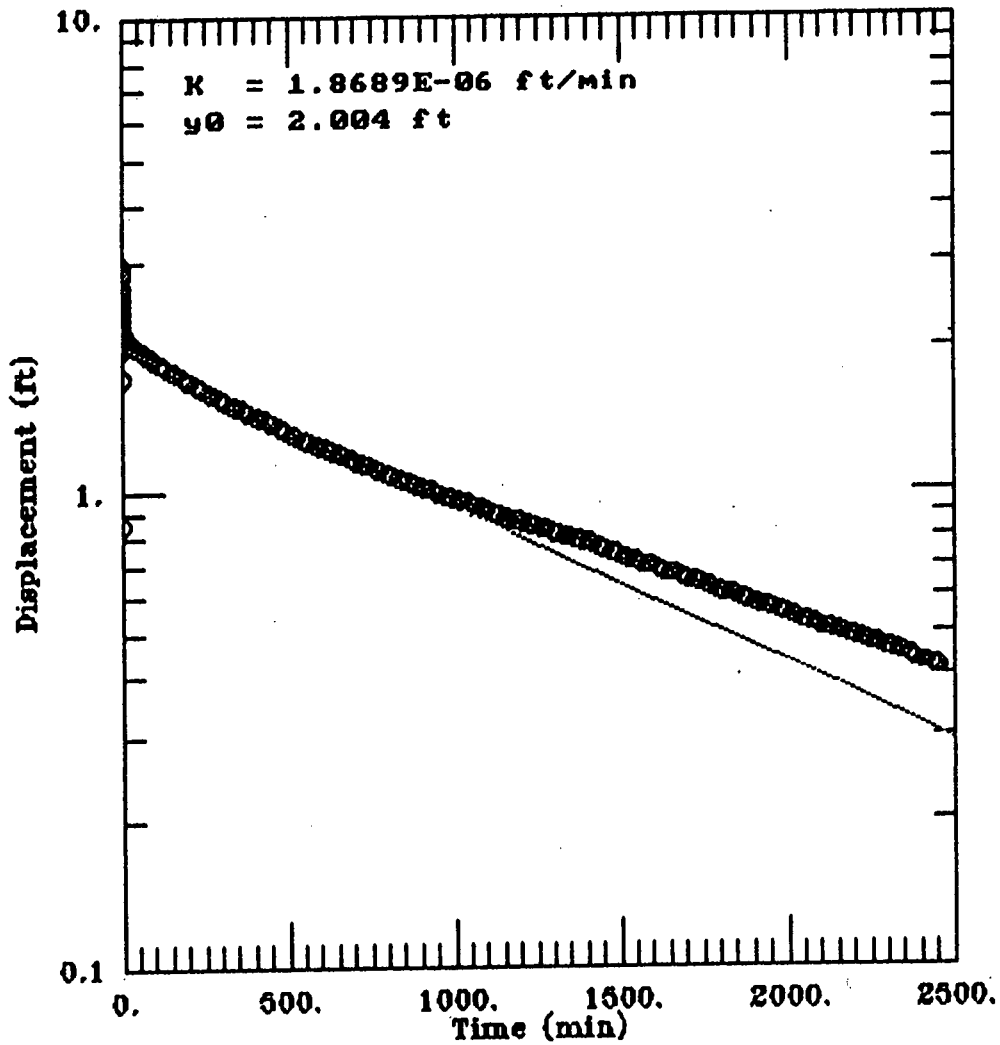
Well 11500 Rising Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11501 Falling Head Test



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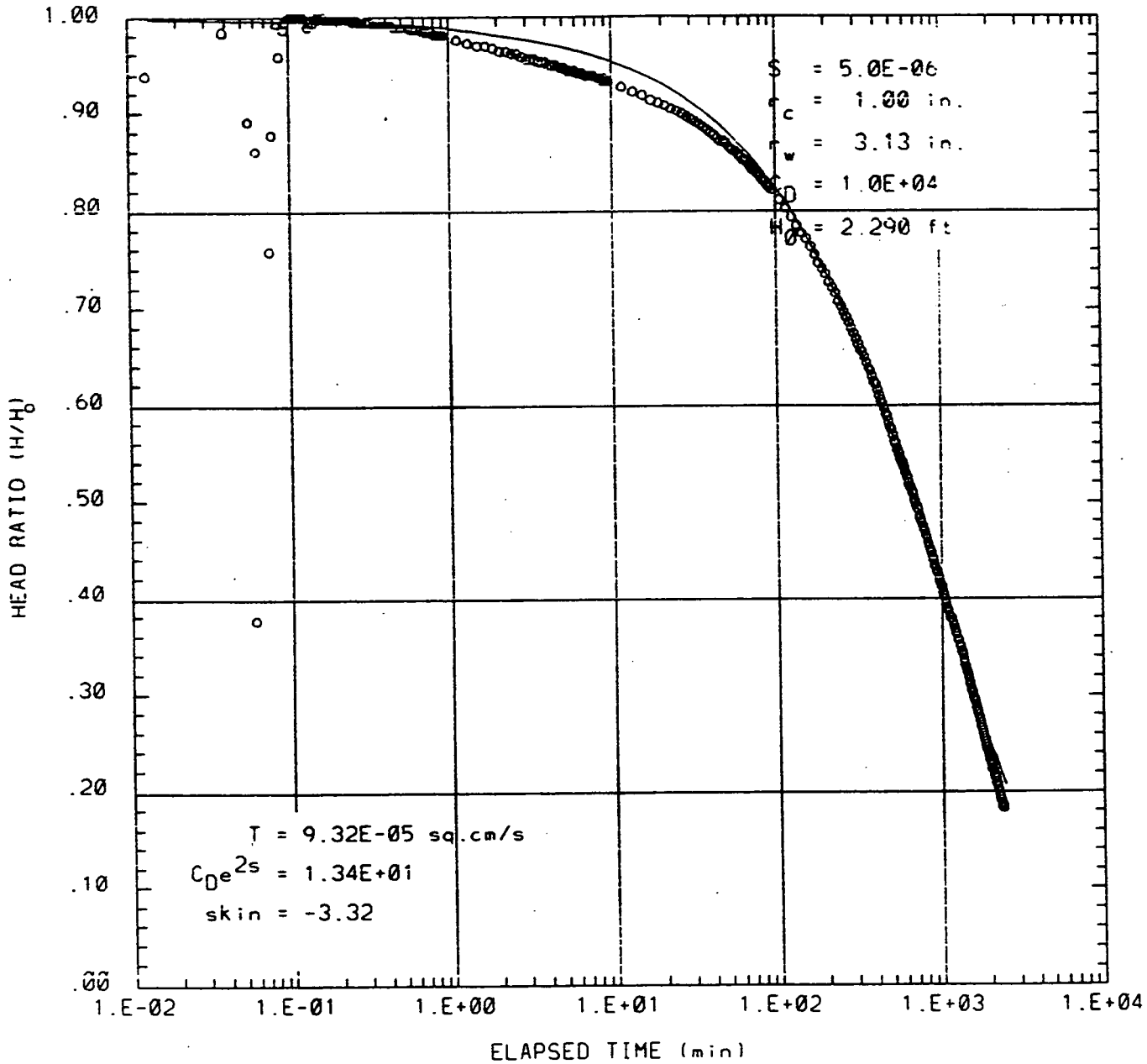
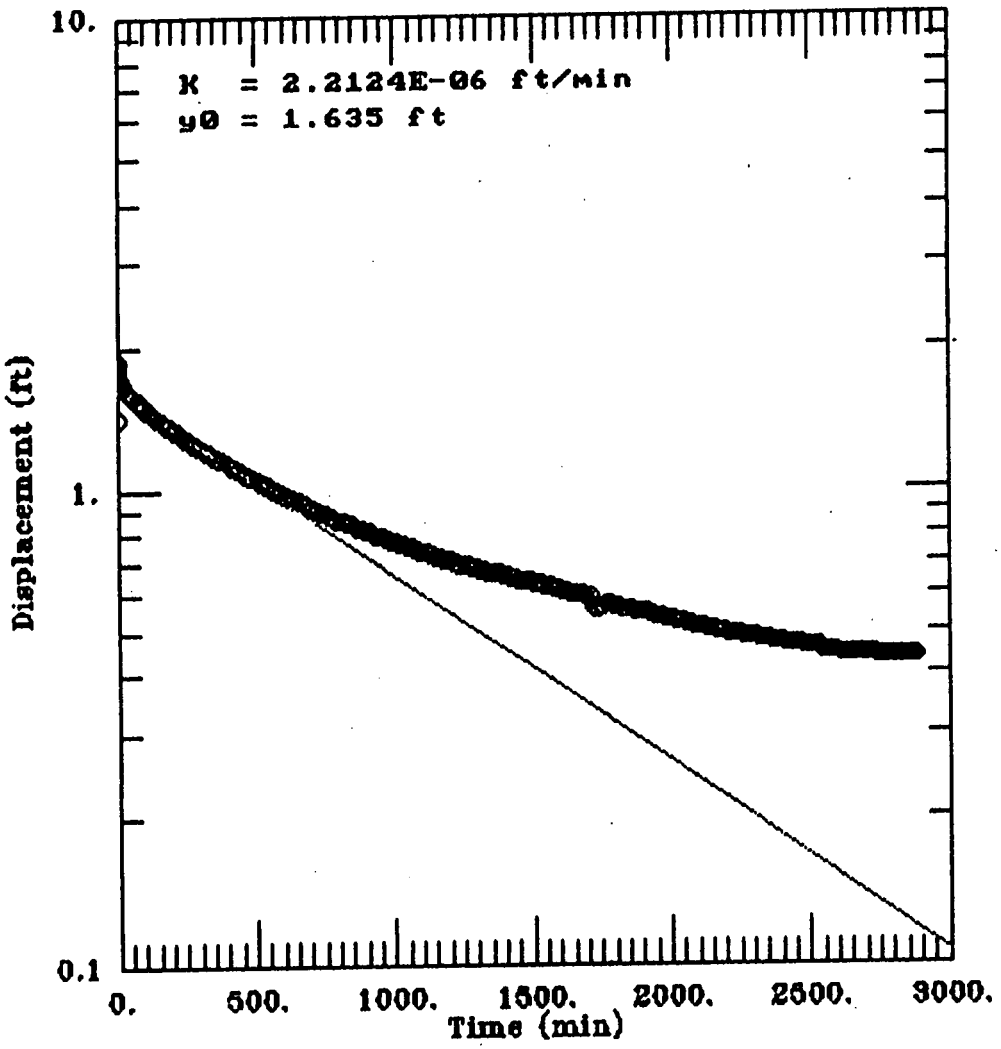
Well 11501 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11501 Rising Head Test



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Well 11501 Rising Head Test

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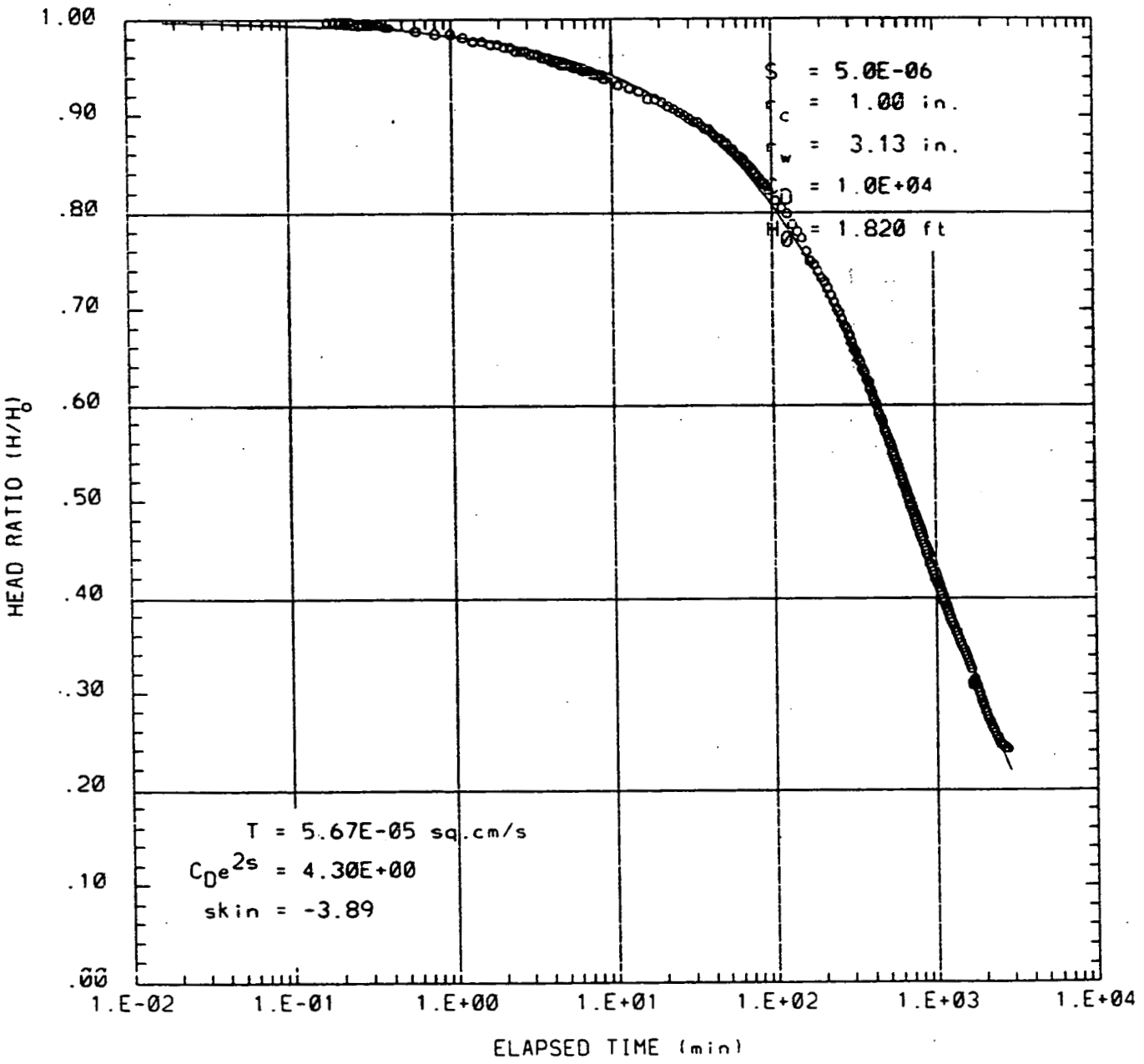
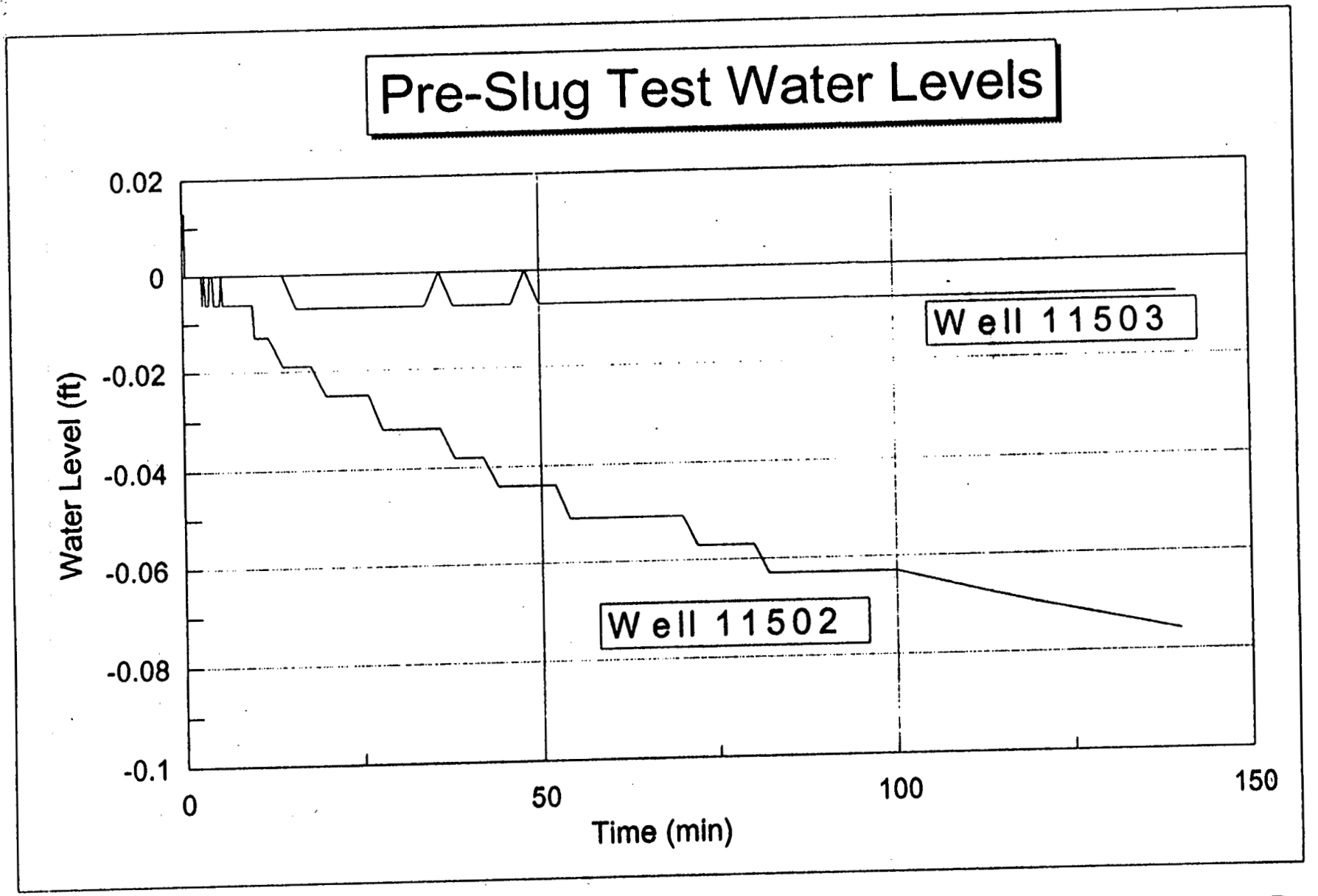
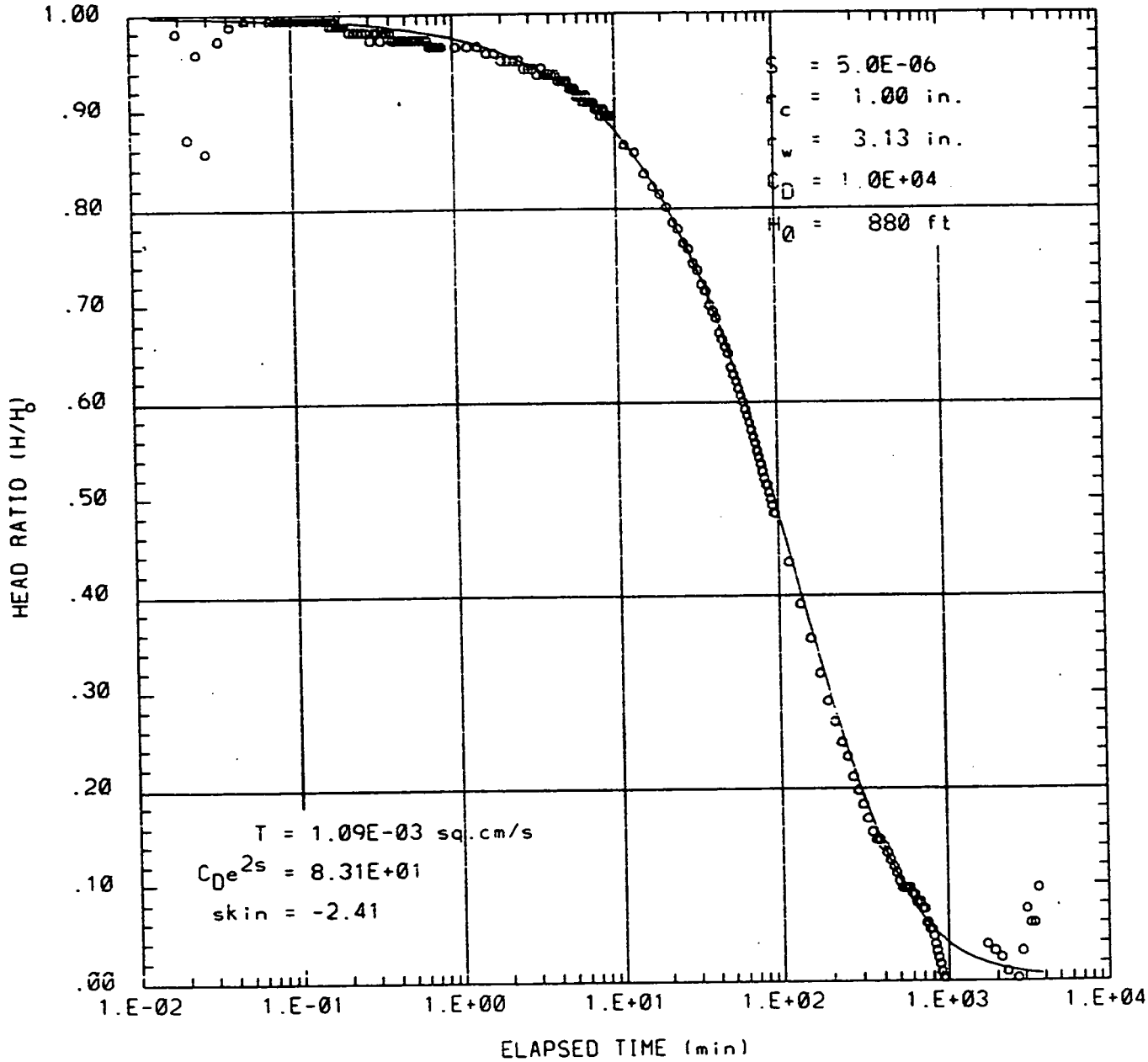


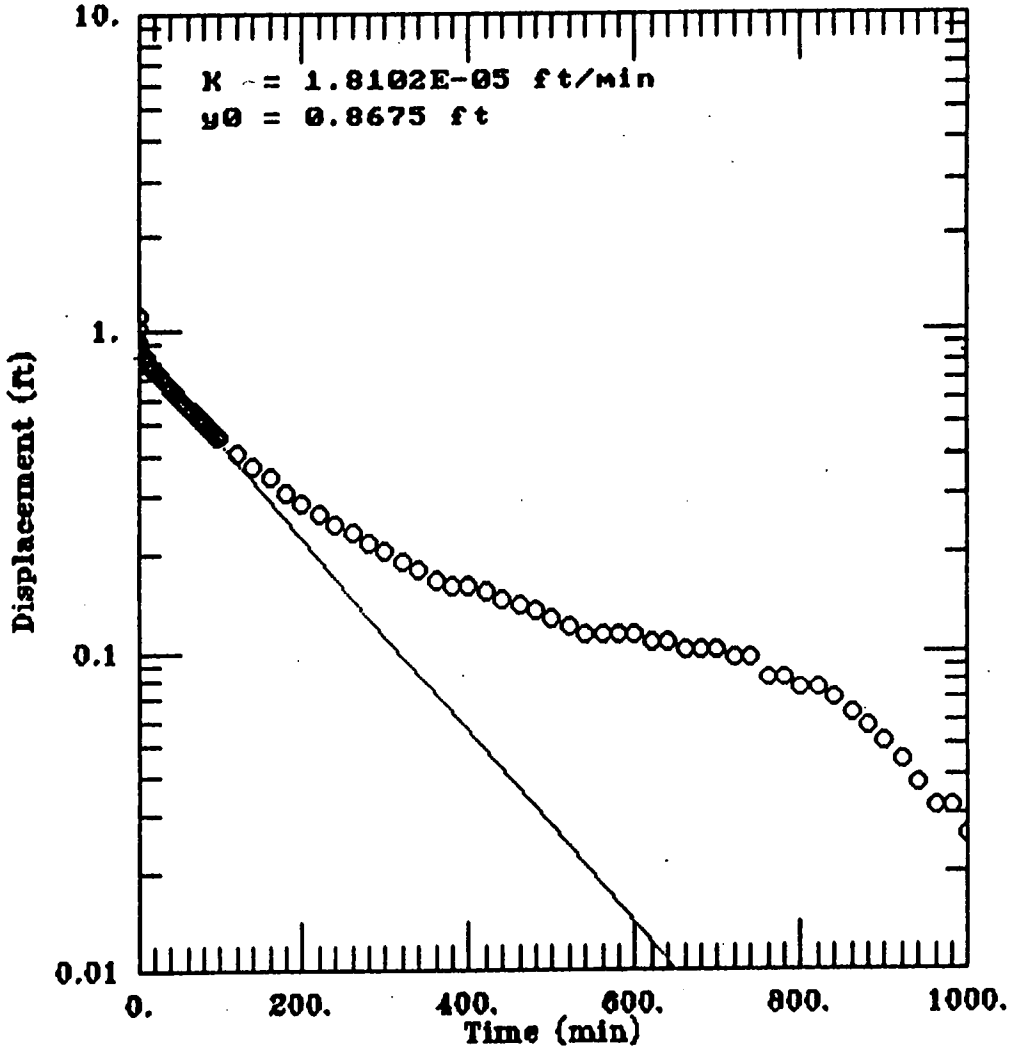

Pre-Slug Test Water Levels
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
Water Level (ft)
0
50
100
150
Time (min)
Well 11503
Well 11502

Well 11502 Falling Head Test

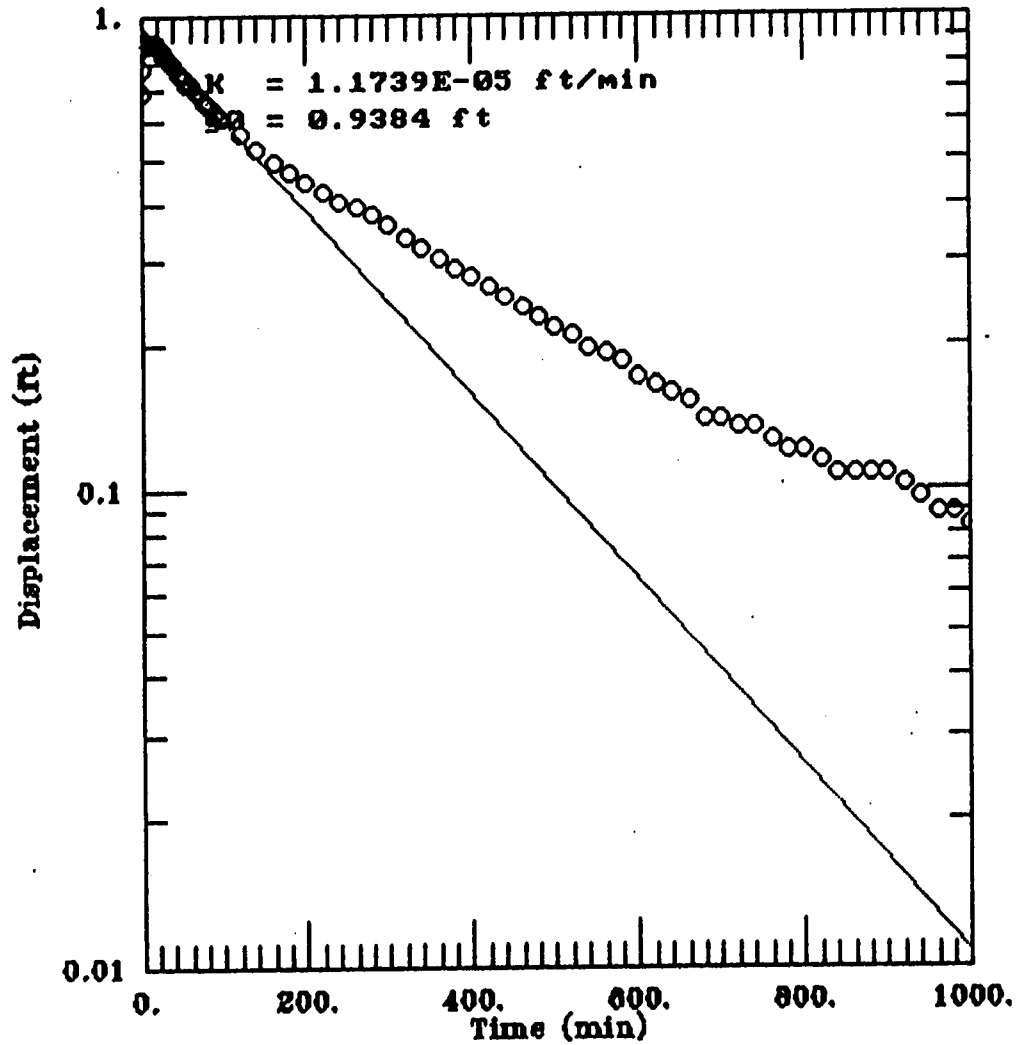
STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11502 Falling Head Test

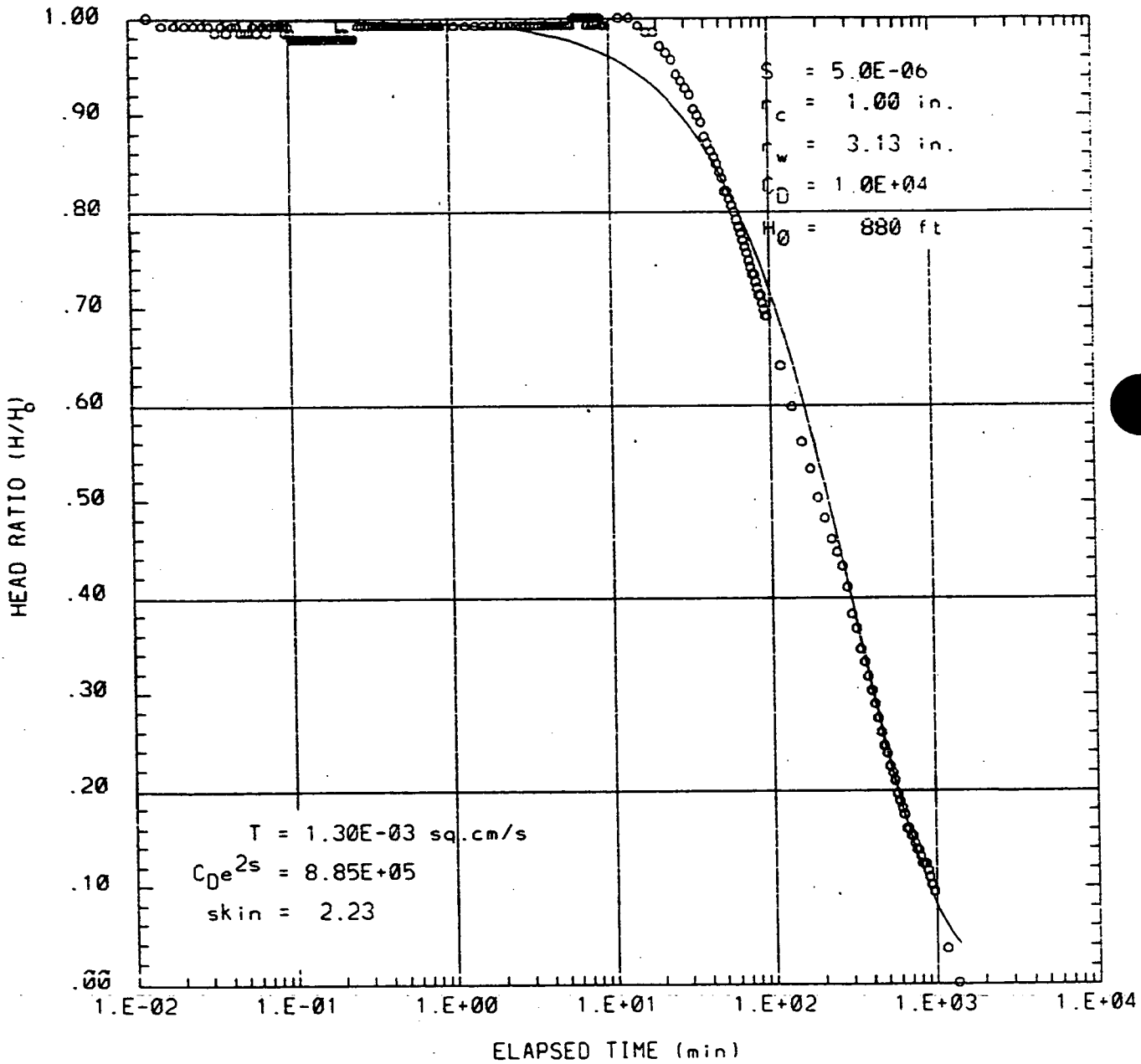


Well 11502 Rising Head Test



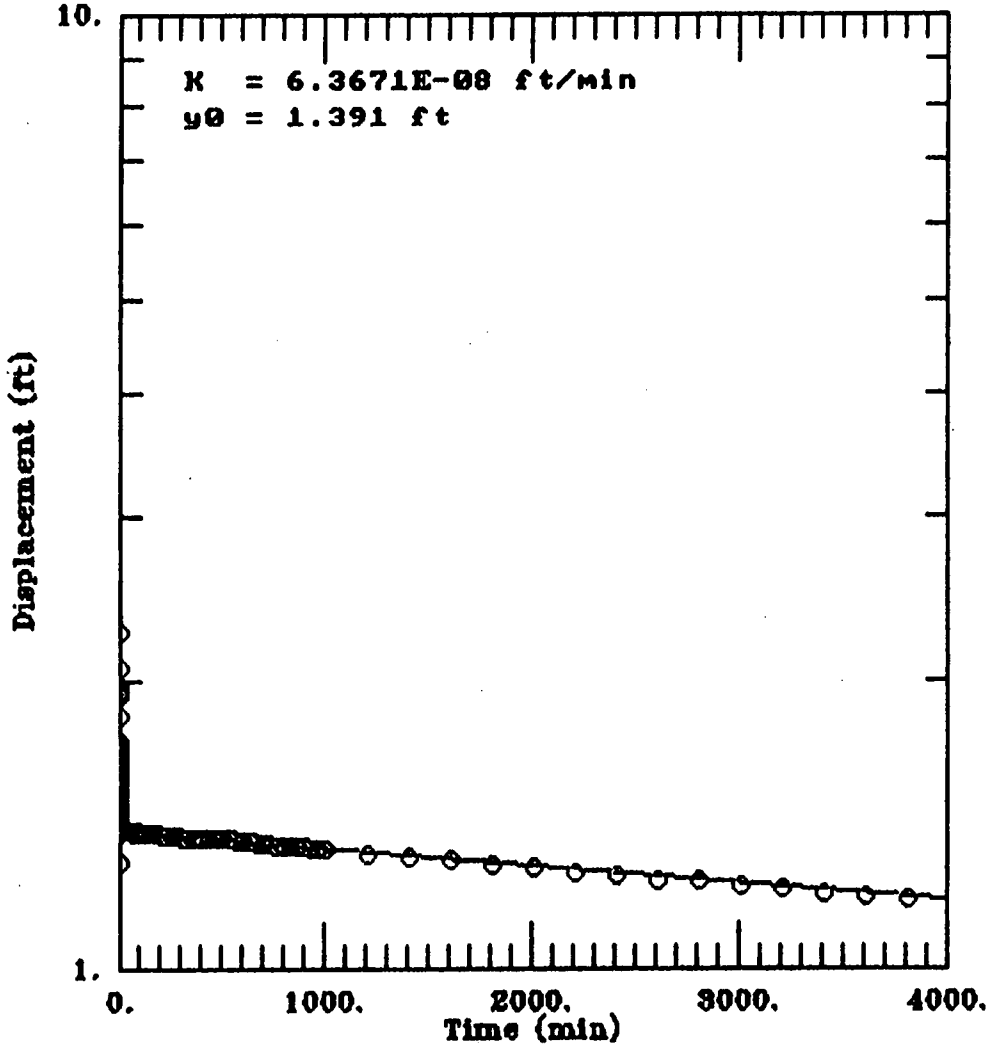
Well 11502 Rising Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



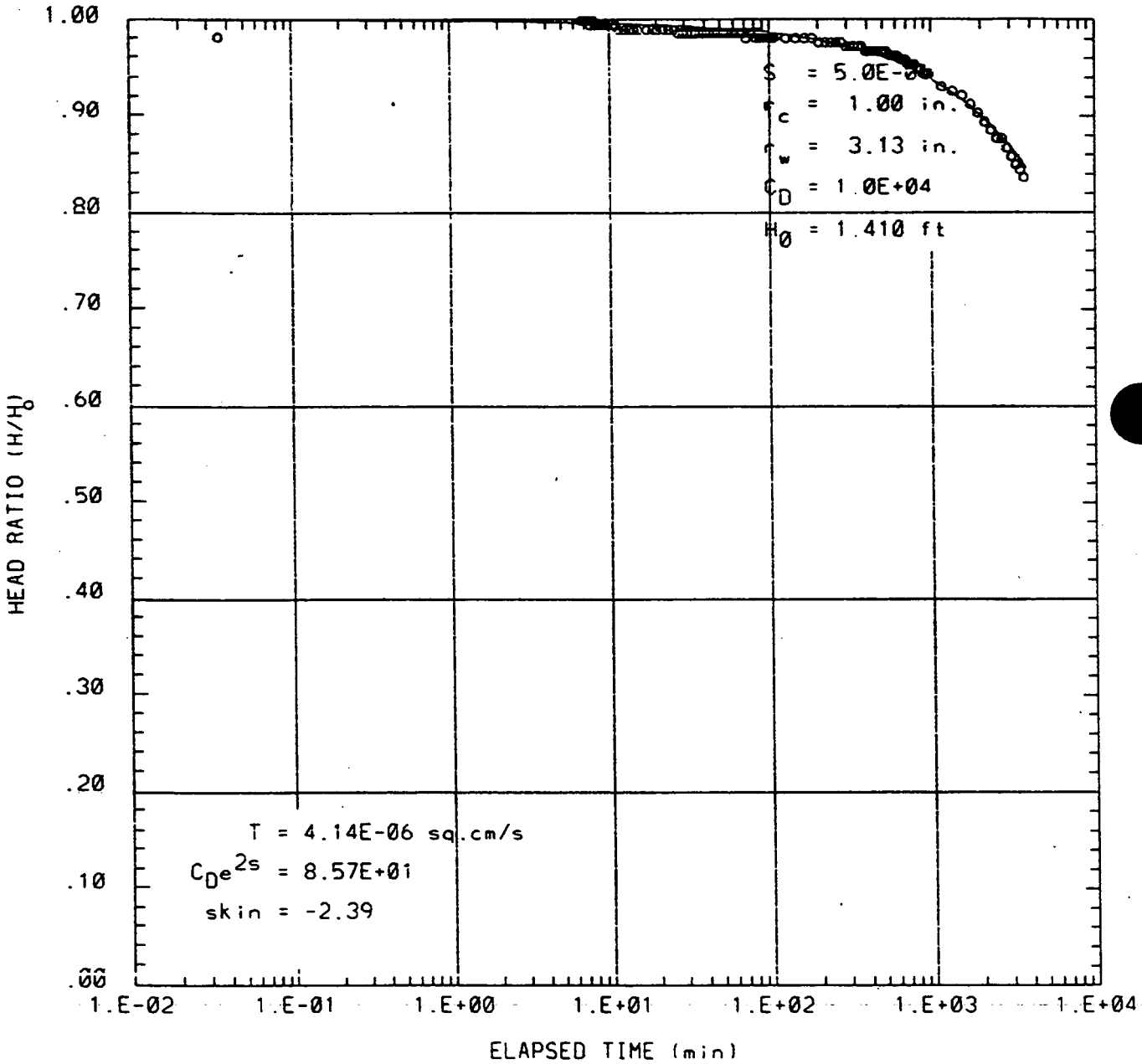
000104

Well 11503 Falling Head Test

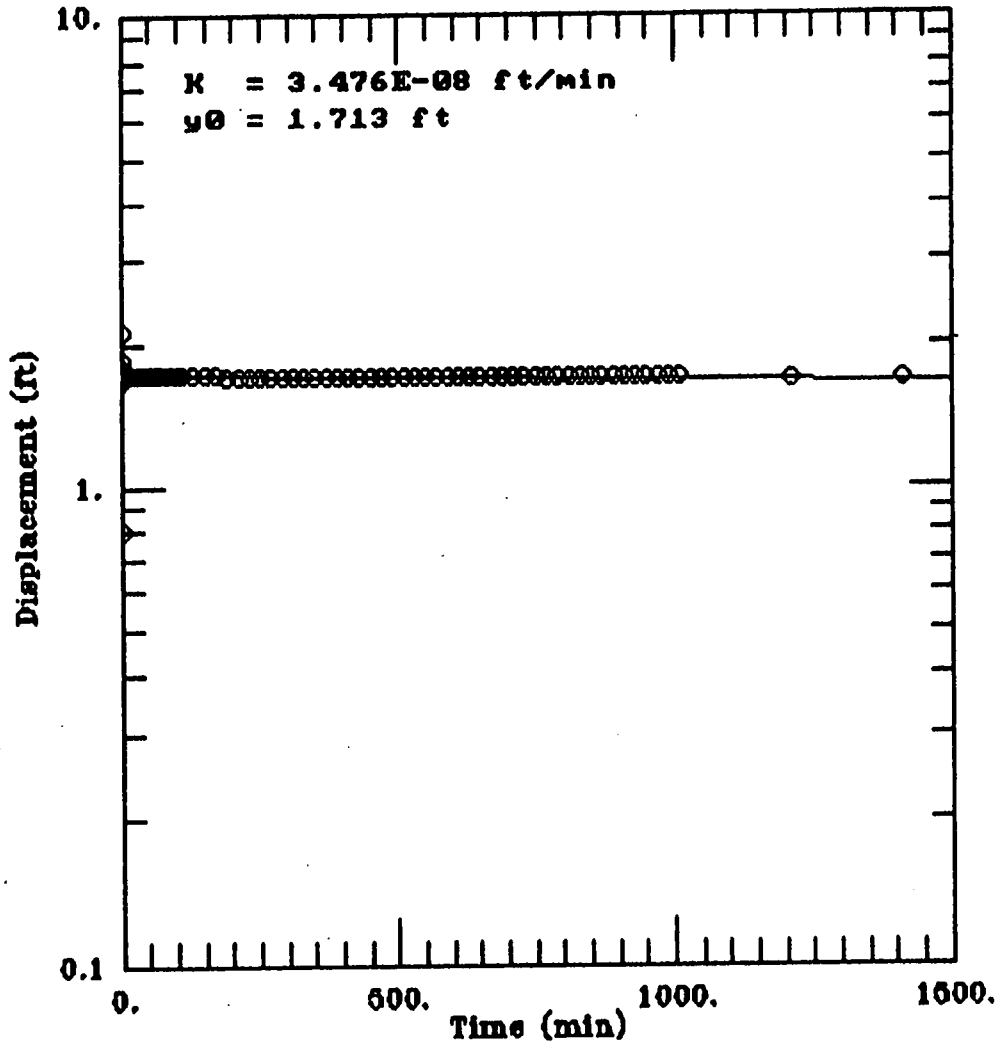


Well 11503 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11503 Rising Head Test



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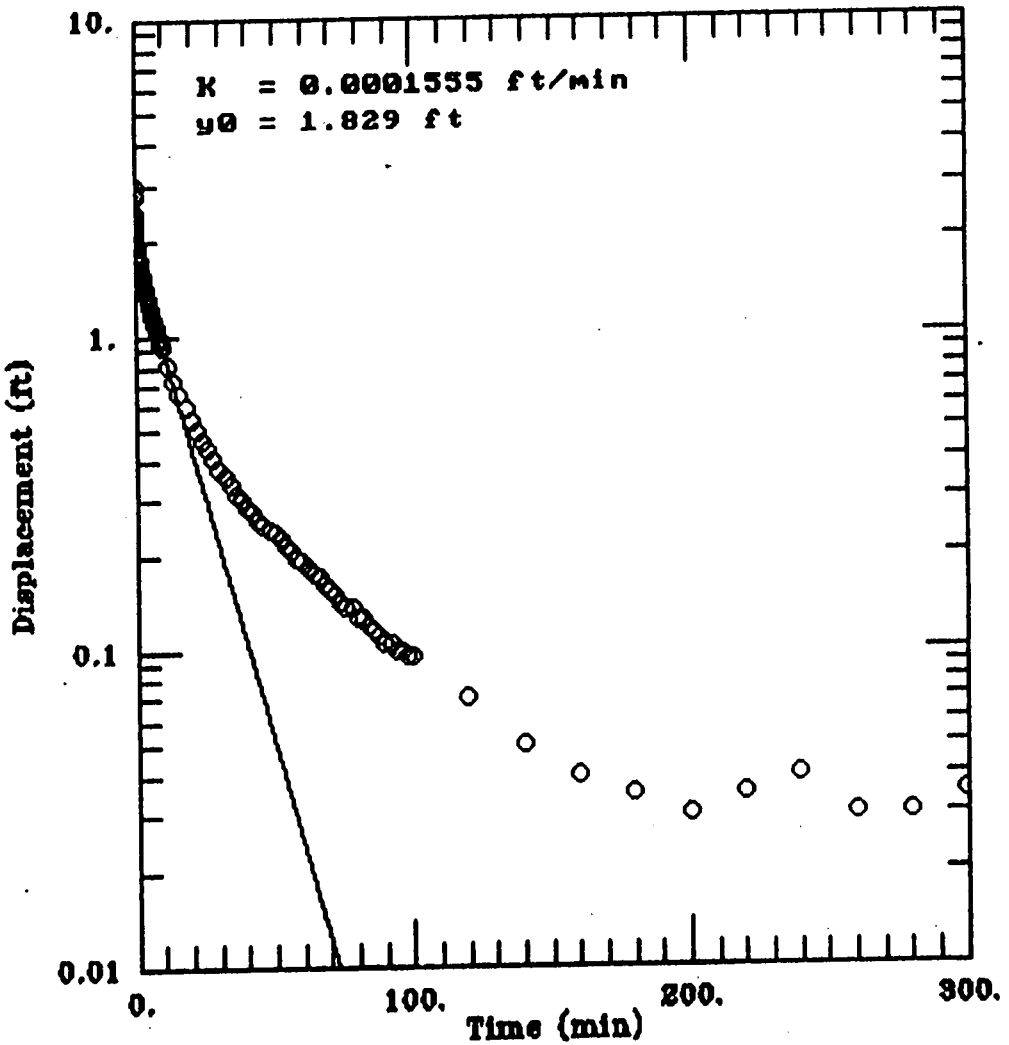
Well 11504 Falling Head Test



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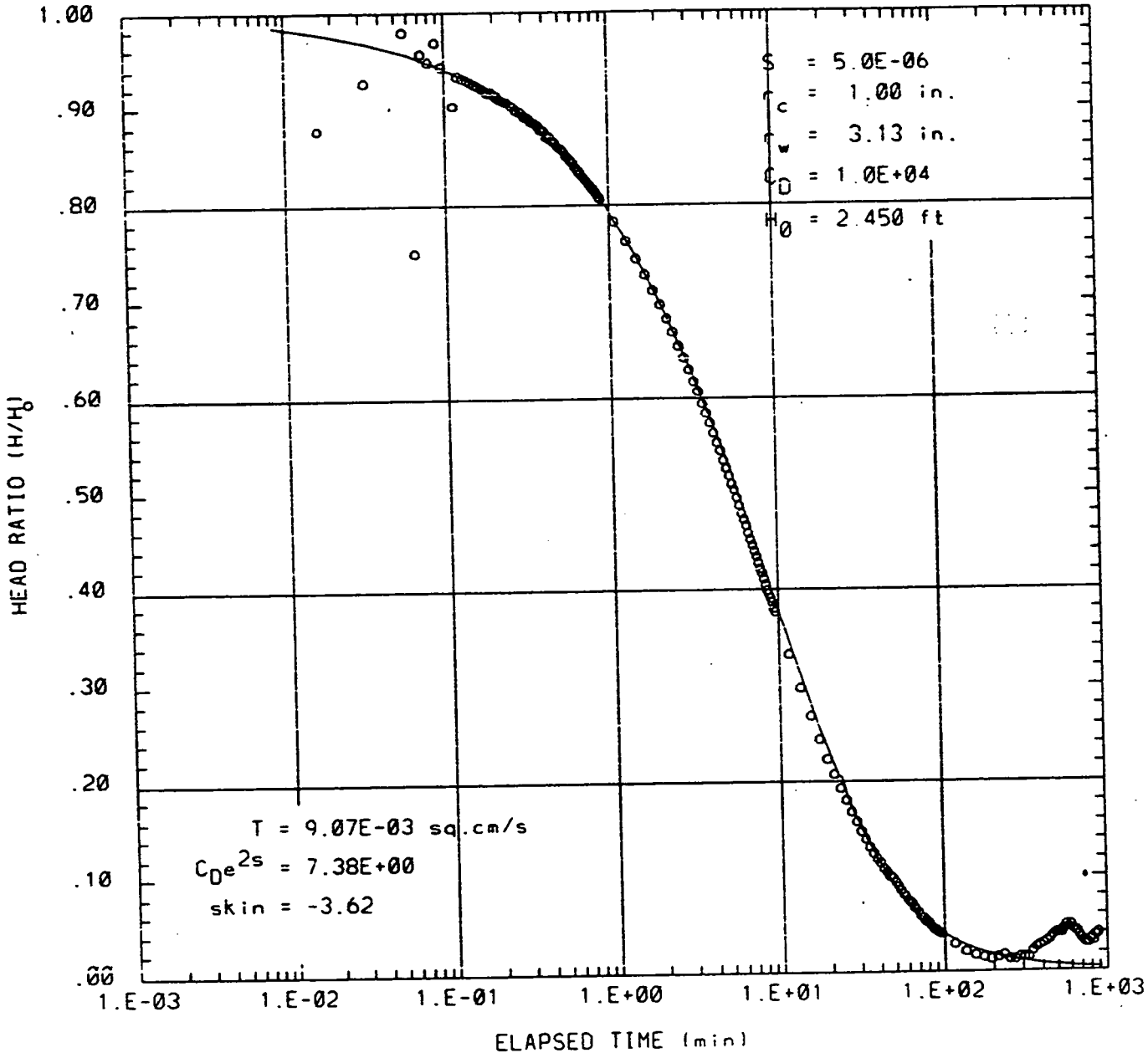
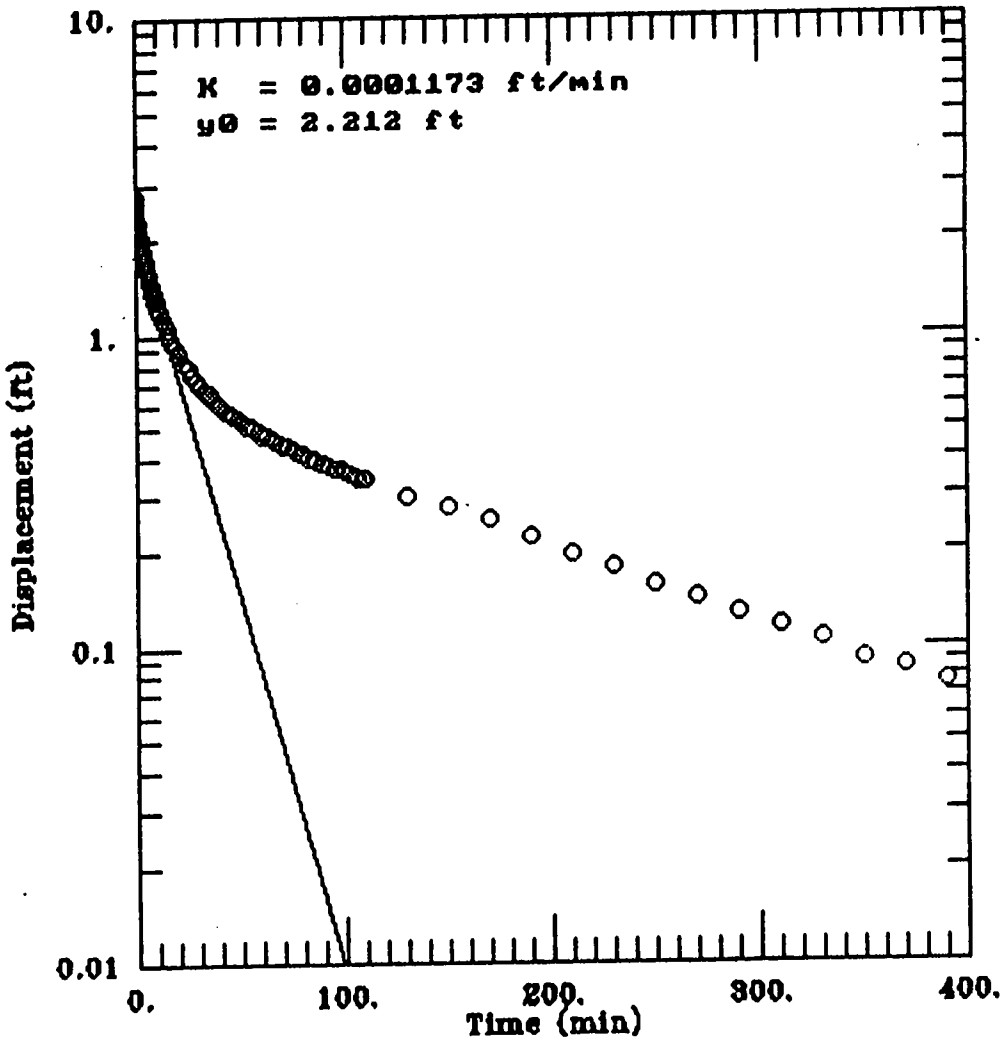
Well 11504 Falling Head Test

STEP (Slug) Test Automated Type-Curve Match (V1.2)



Well 11504 Rising Head Test



Well 11504 Rising Head Test

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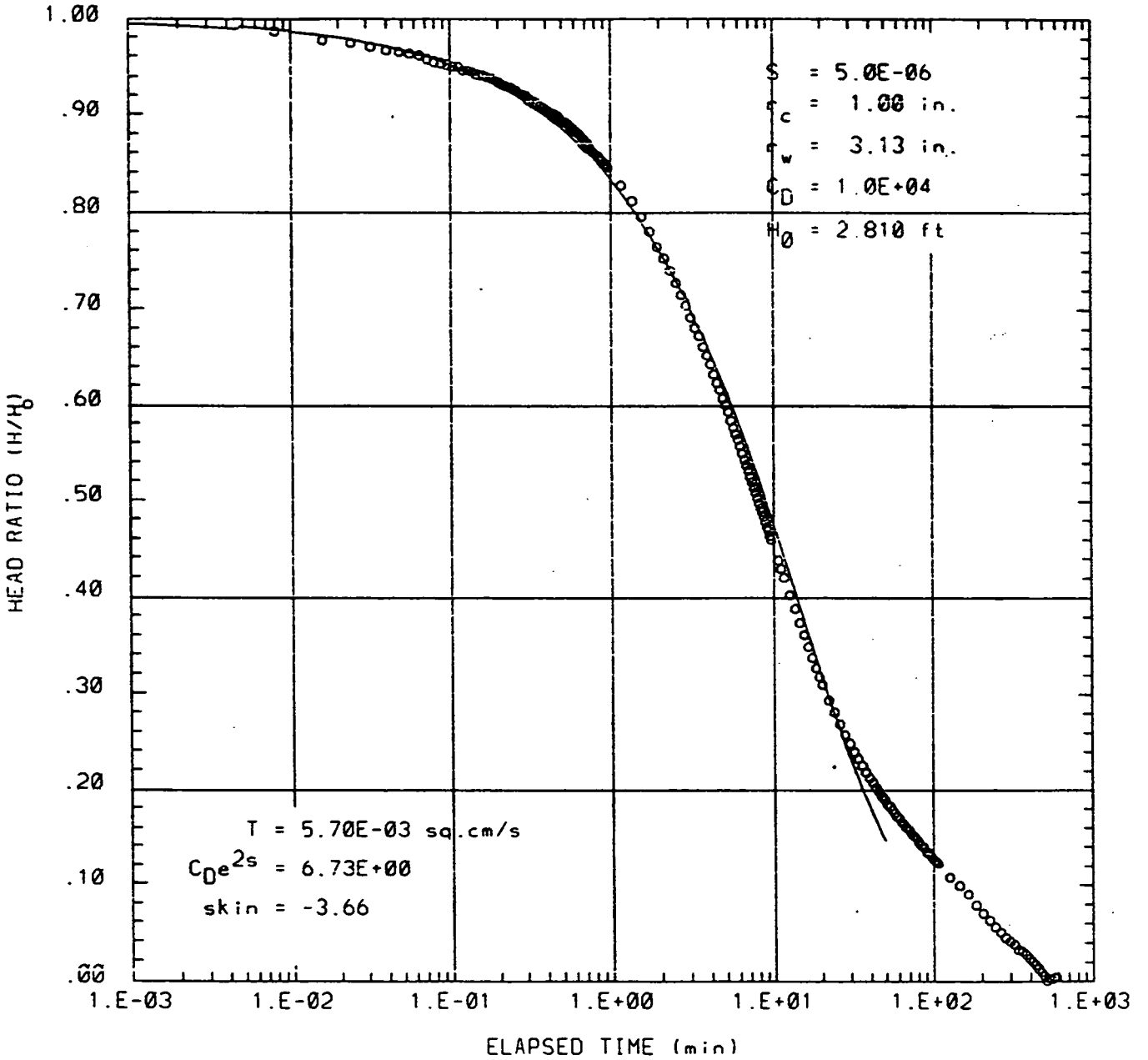

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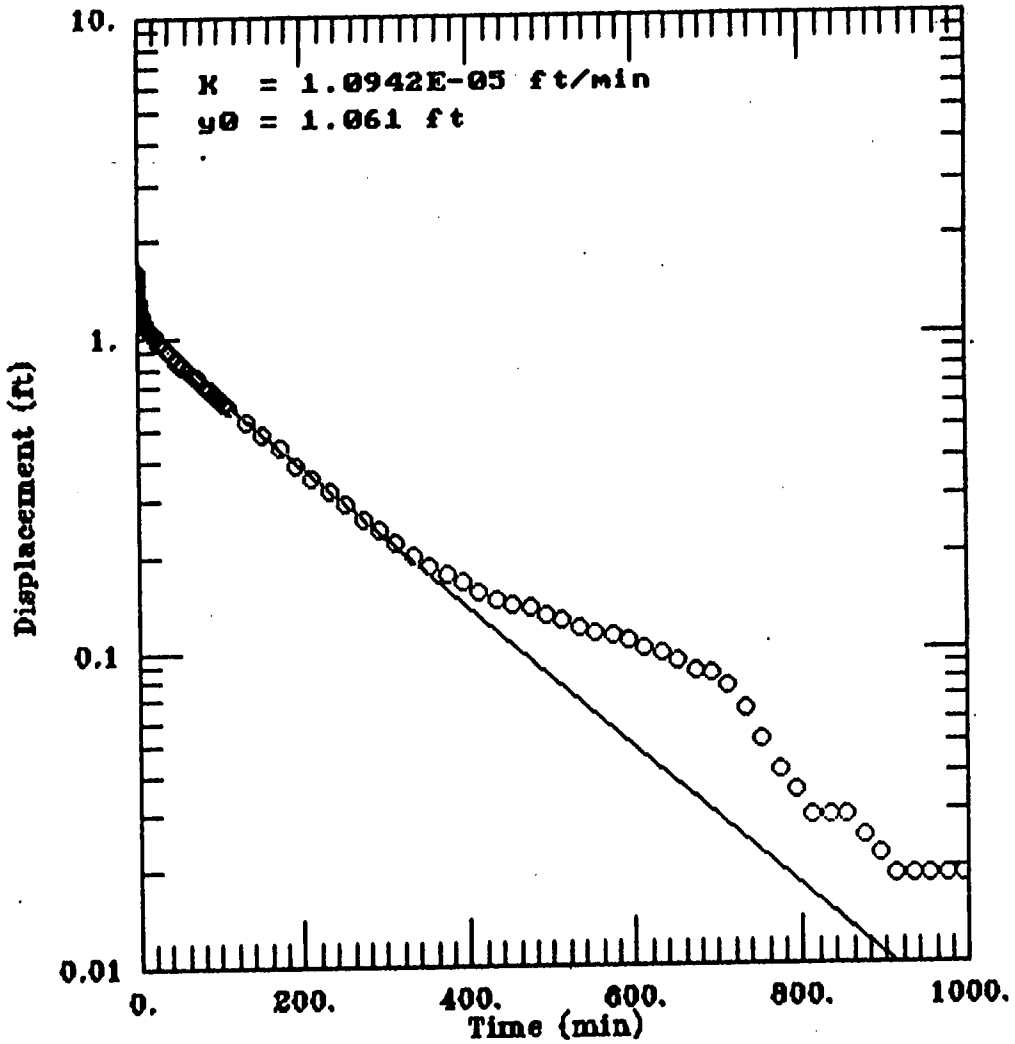

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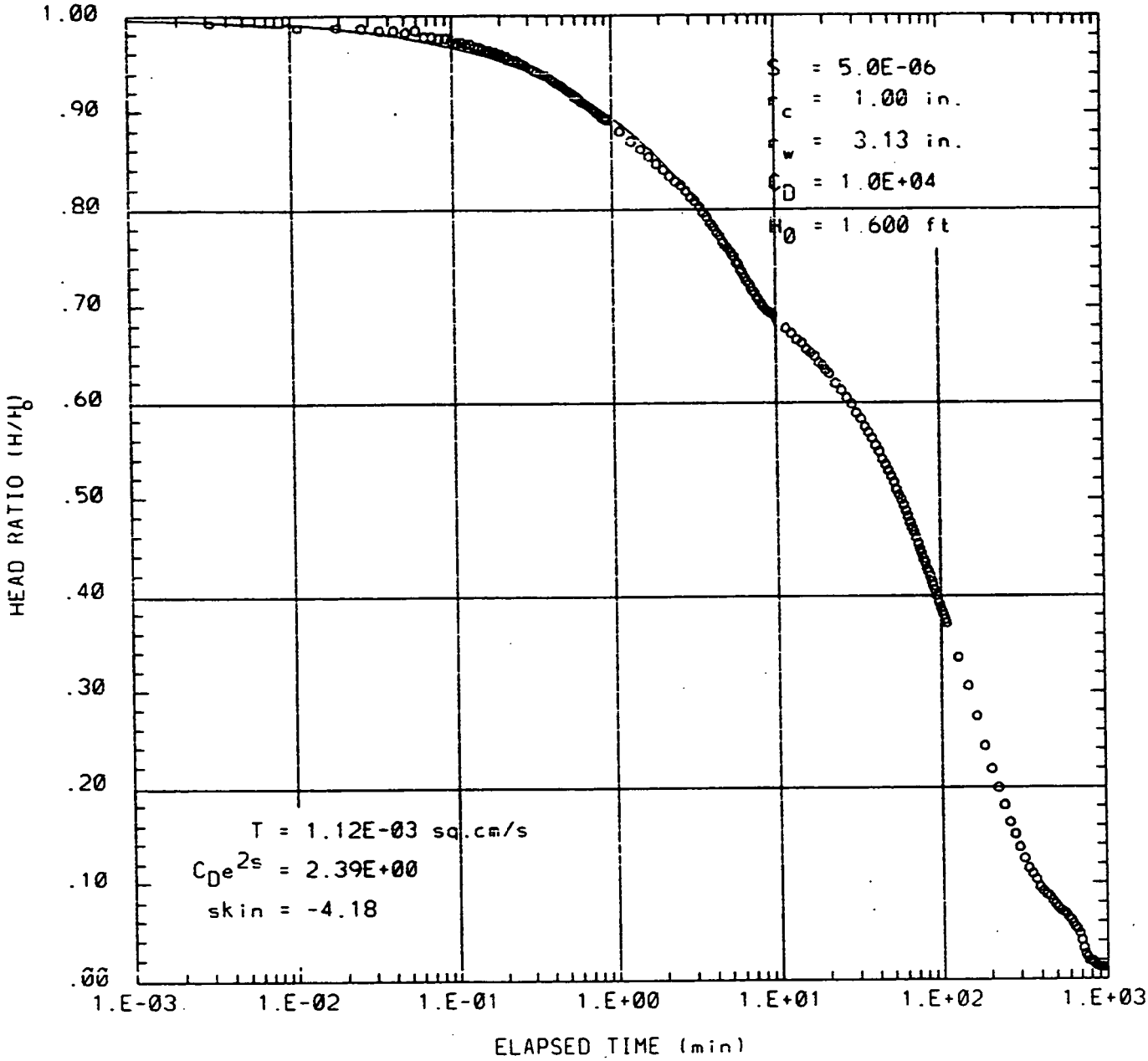

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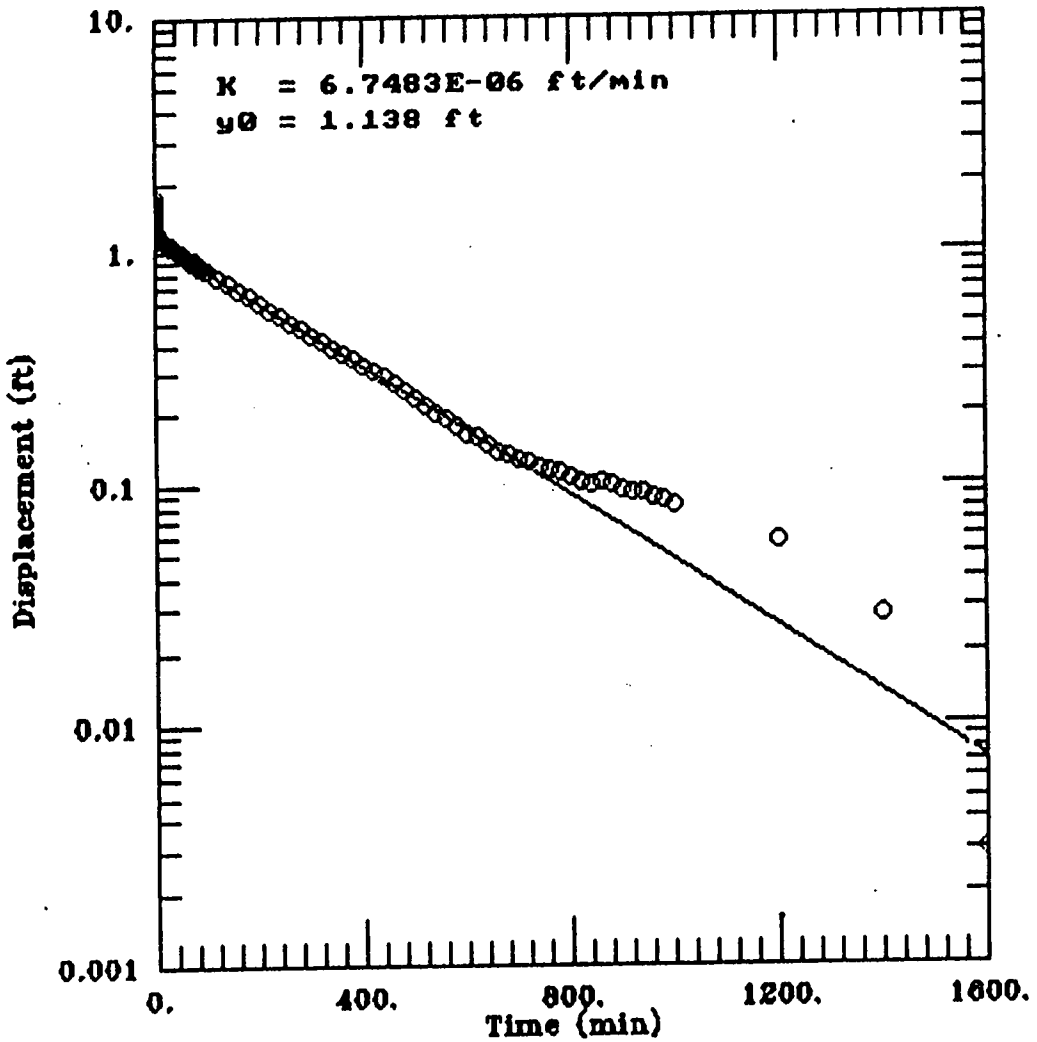

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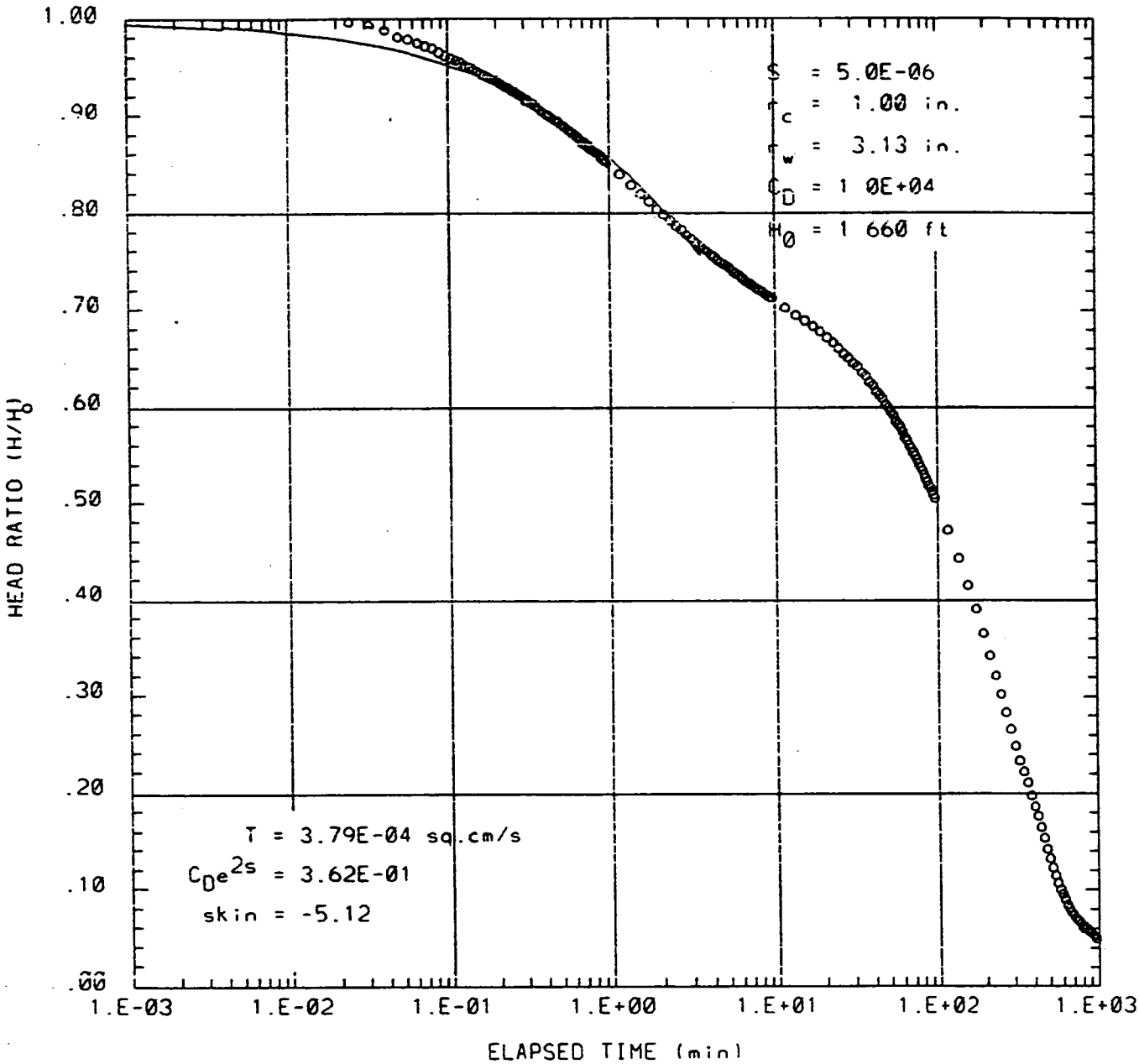

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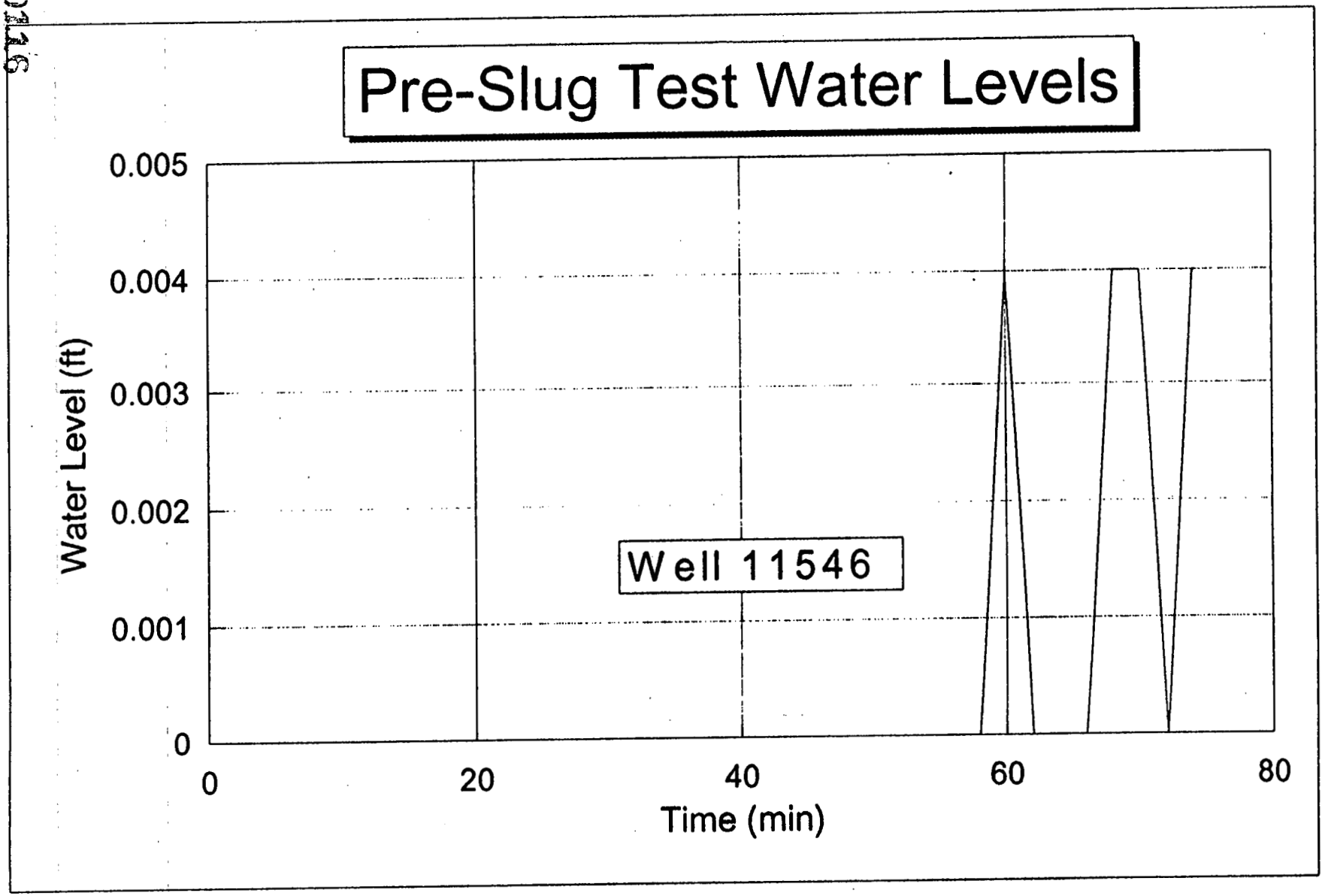
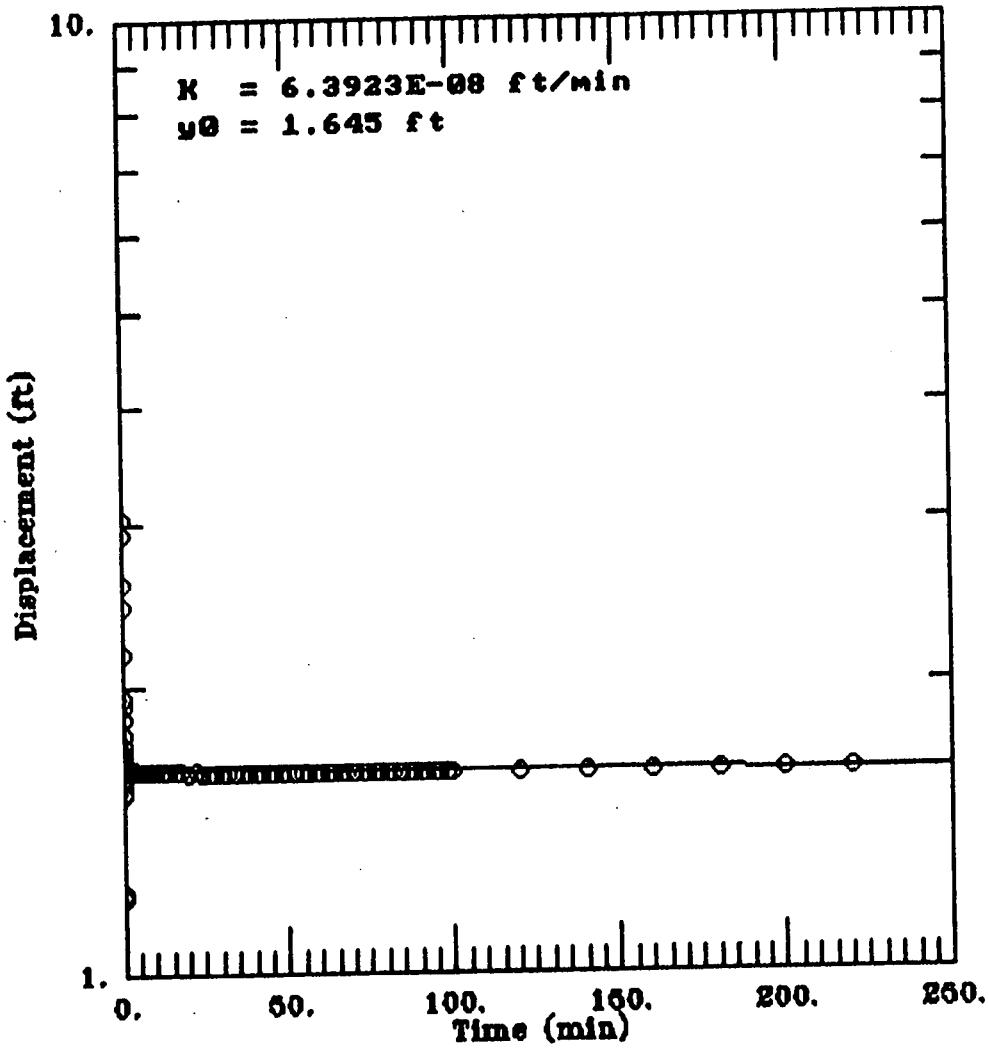

Pre-Slug Test Water Levels
Water Level (ft)
0.005
0.004
0.003
0.002
0.001
0
0
20
40
60
80
Time (min)
Well 11546

Well 11546 Falling Head Test



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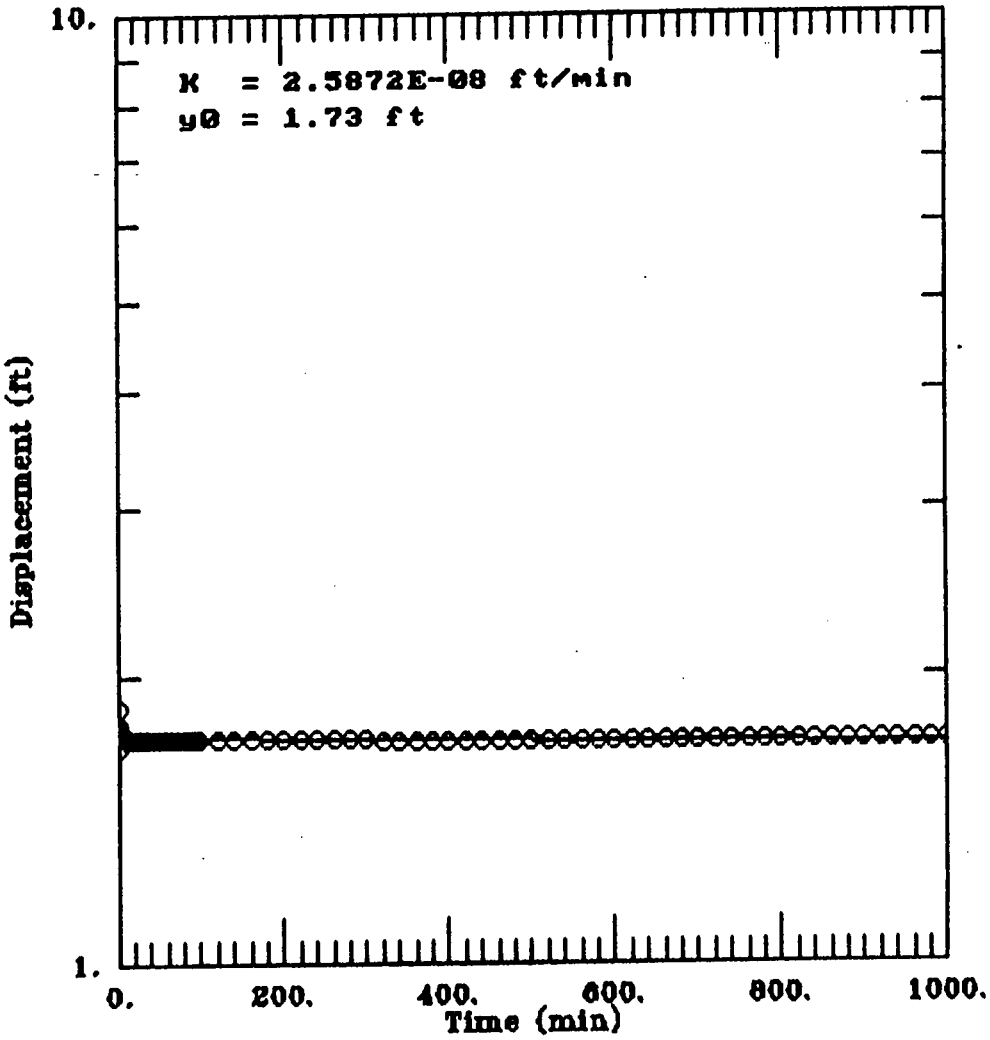

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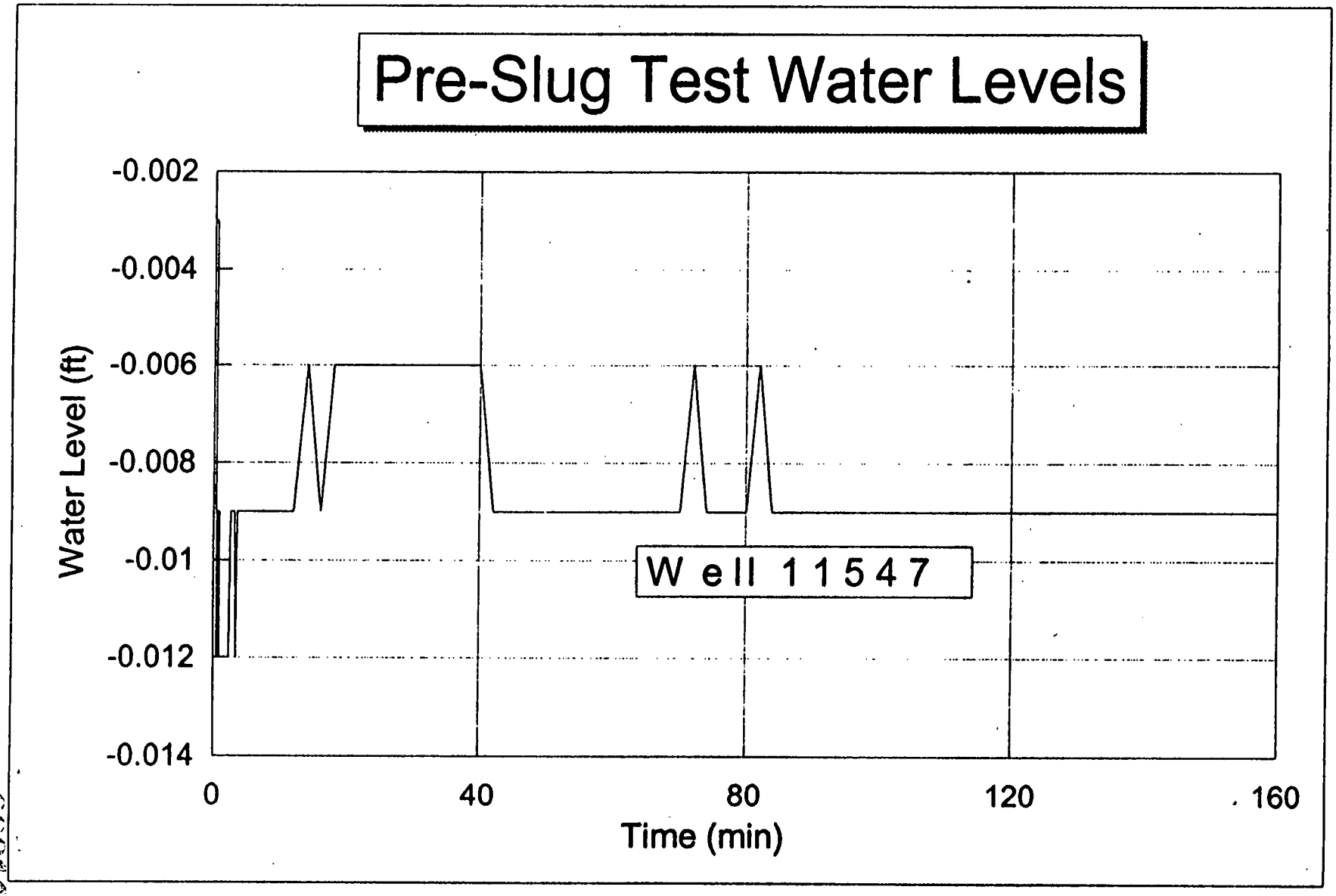
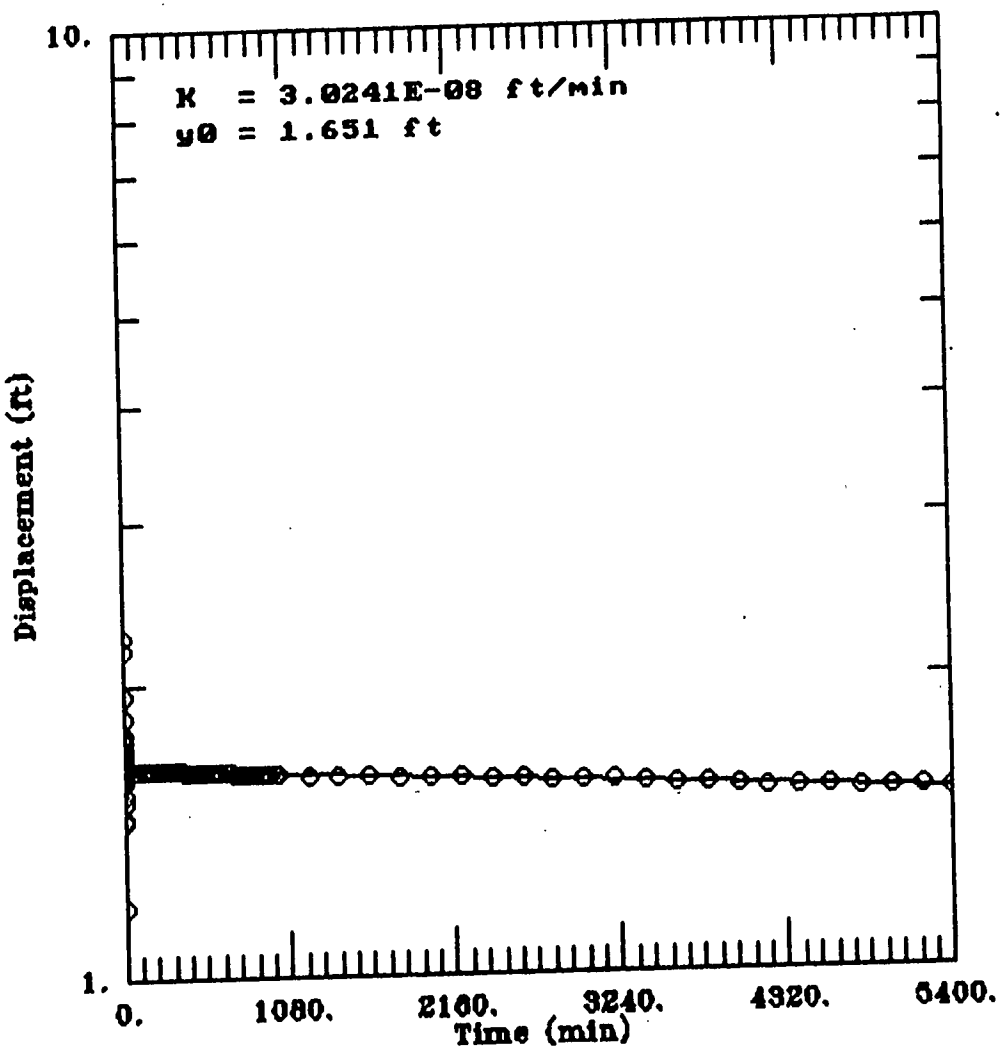

Pre-Slug Test Water Levels
Water Level (ft)
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
0
40
80
120
160
Time (min)
Well 11547

Well 11547 Falling Head Test



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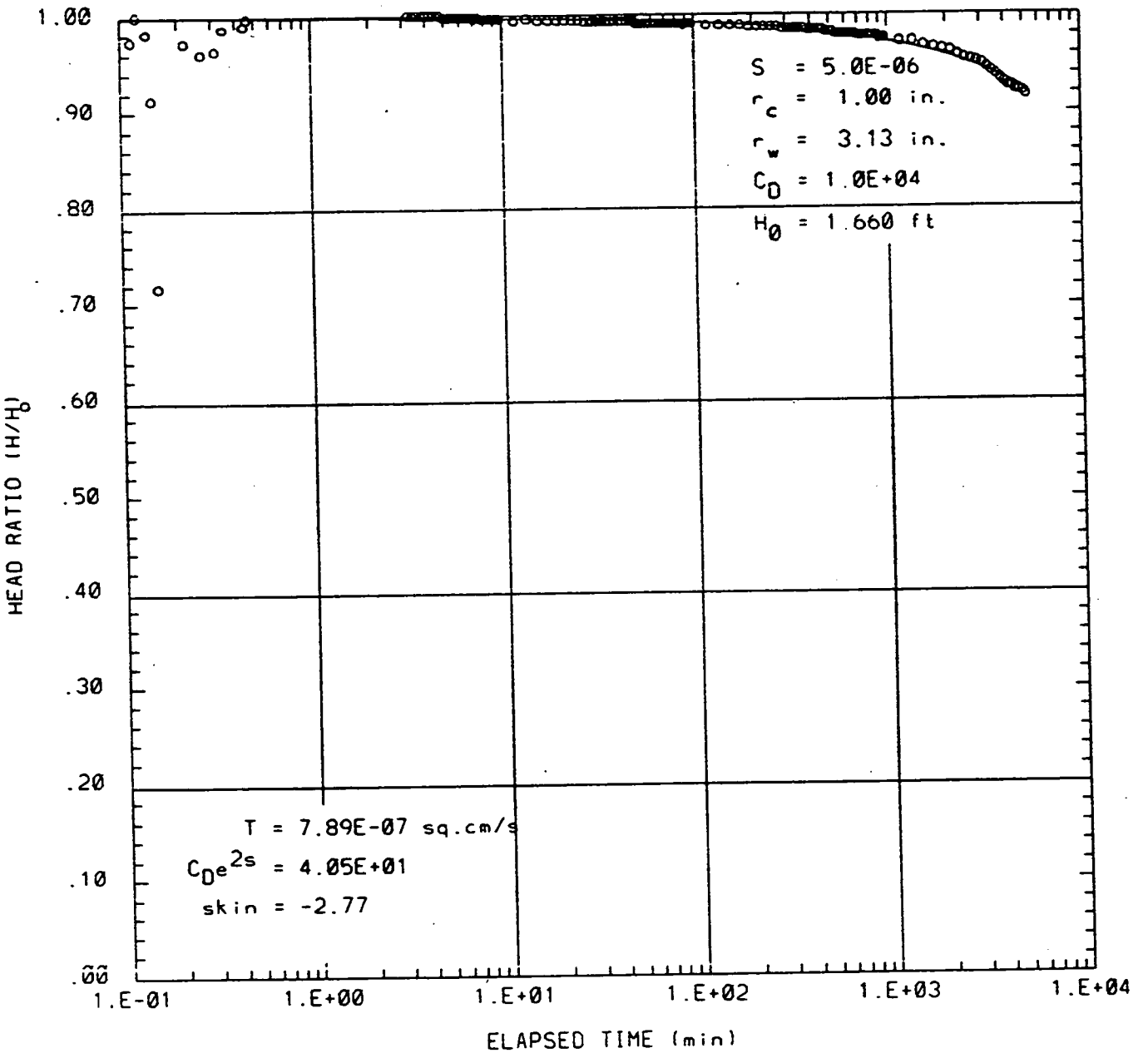

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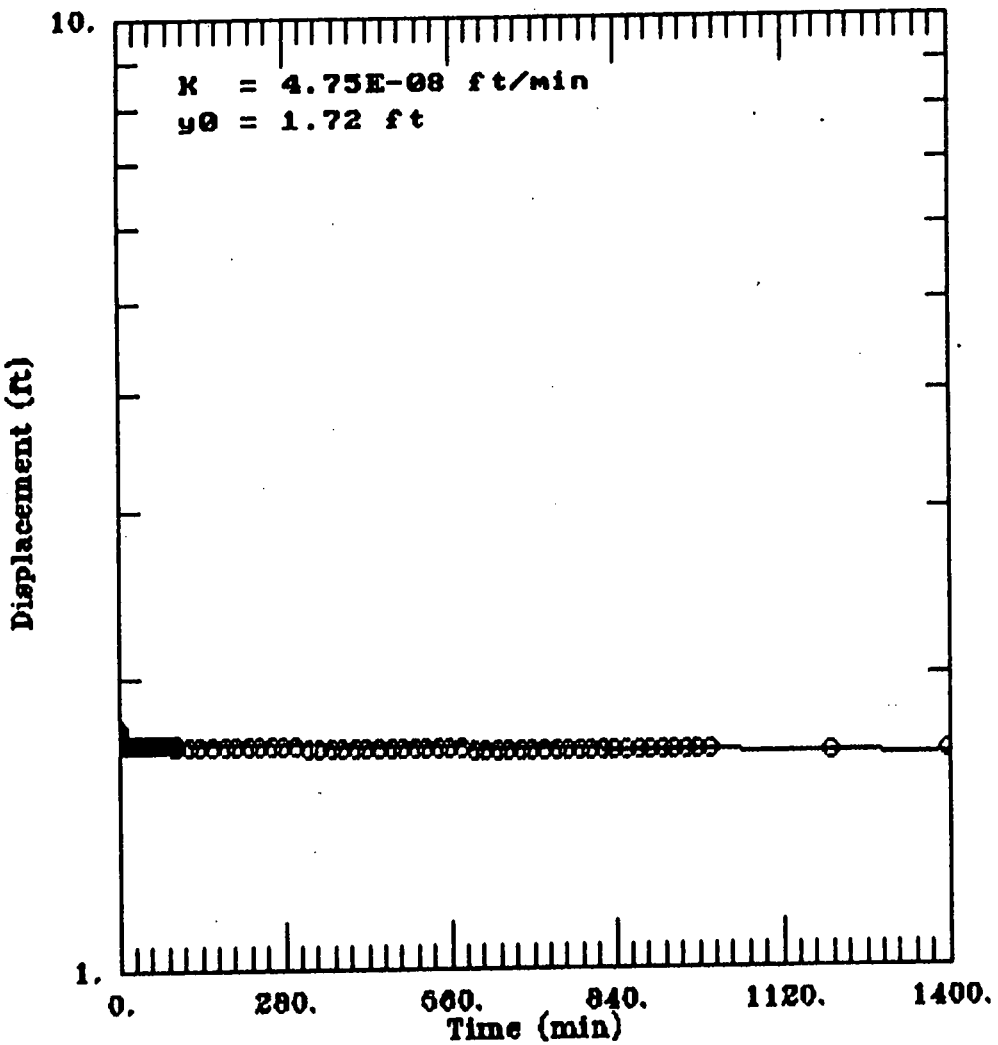

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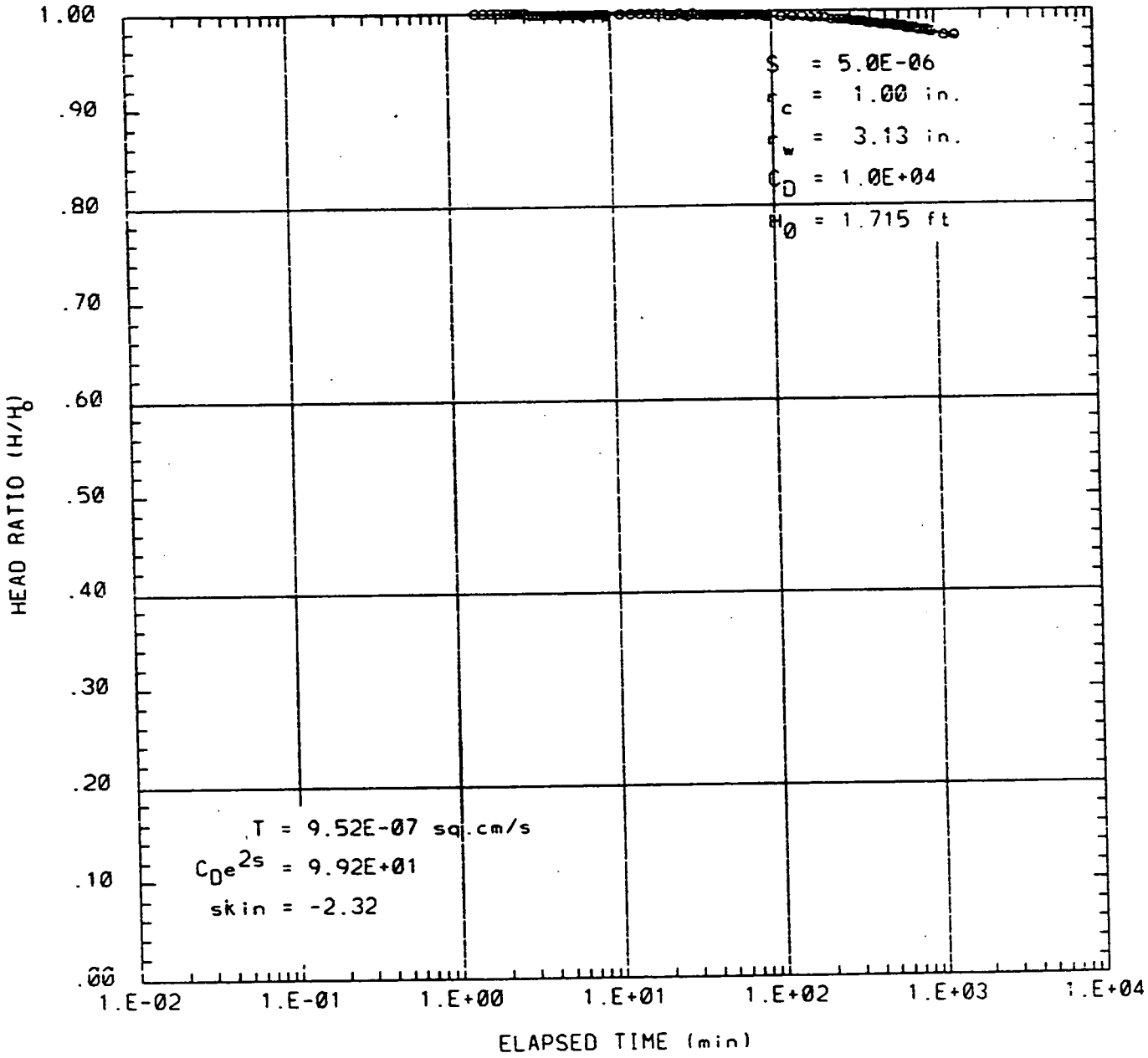
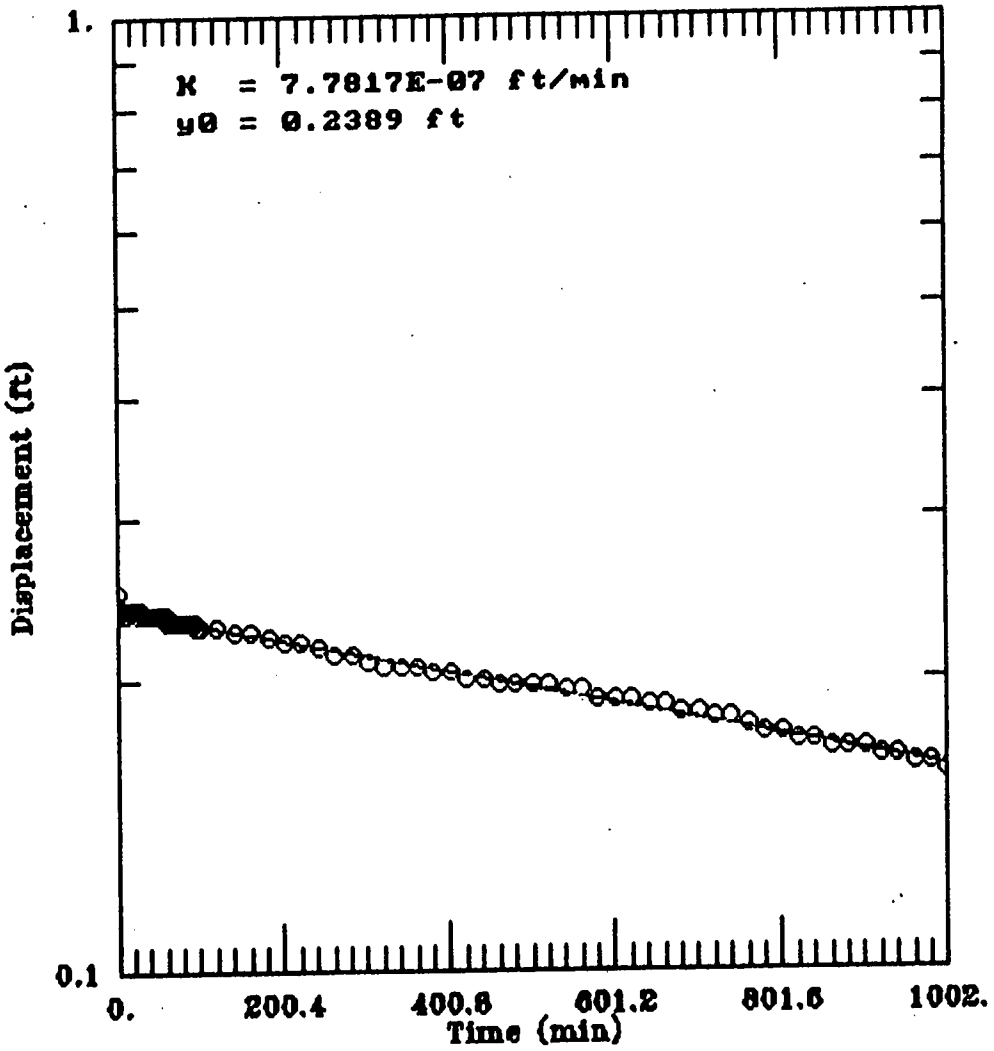


Well 11548 Response to Transducer



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Well 11548 Response to Transducer

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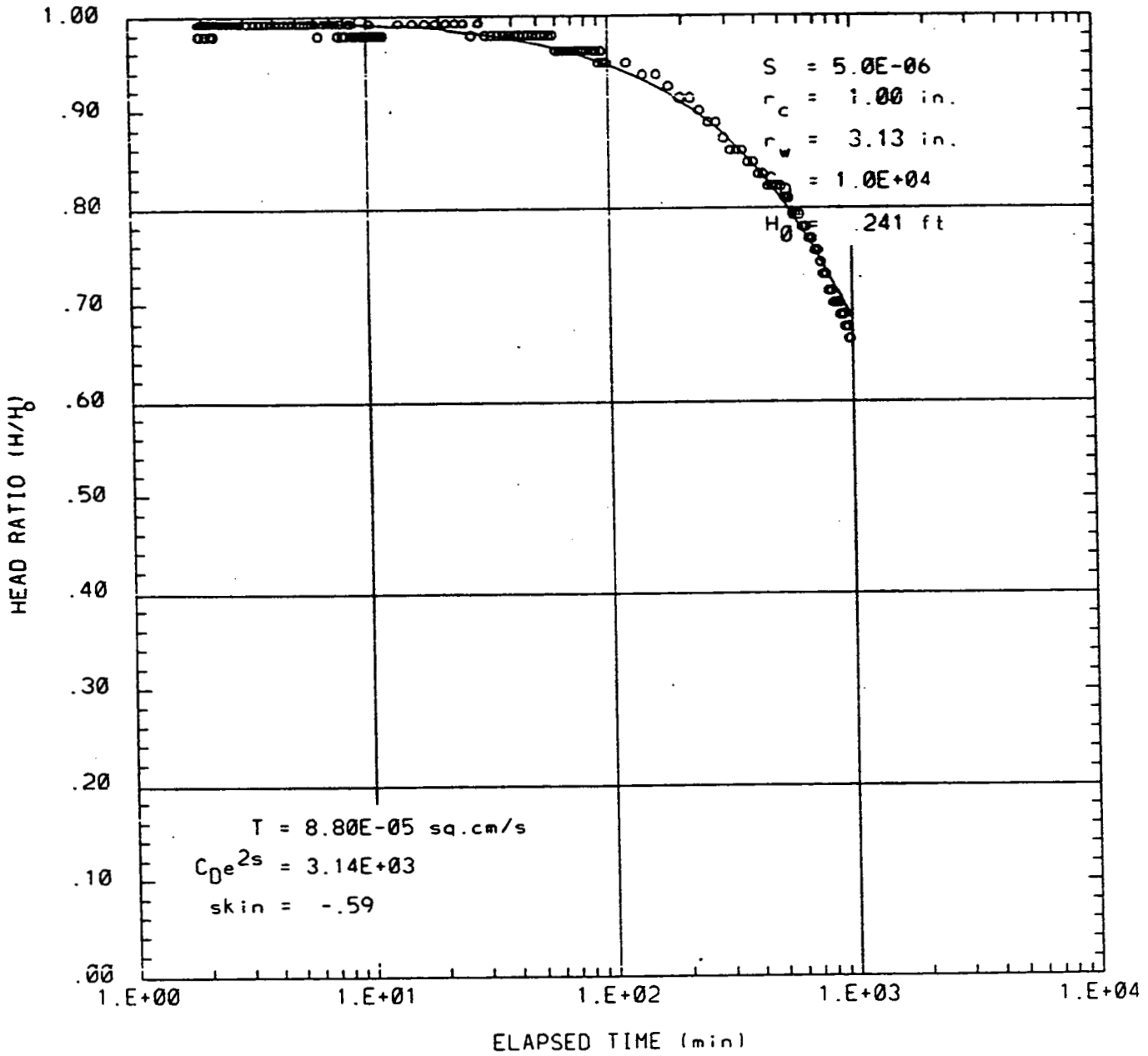
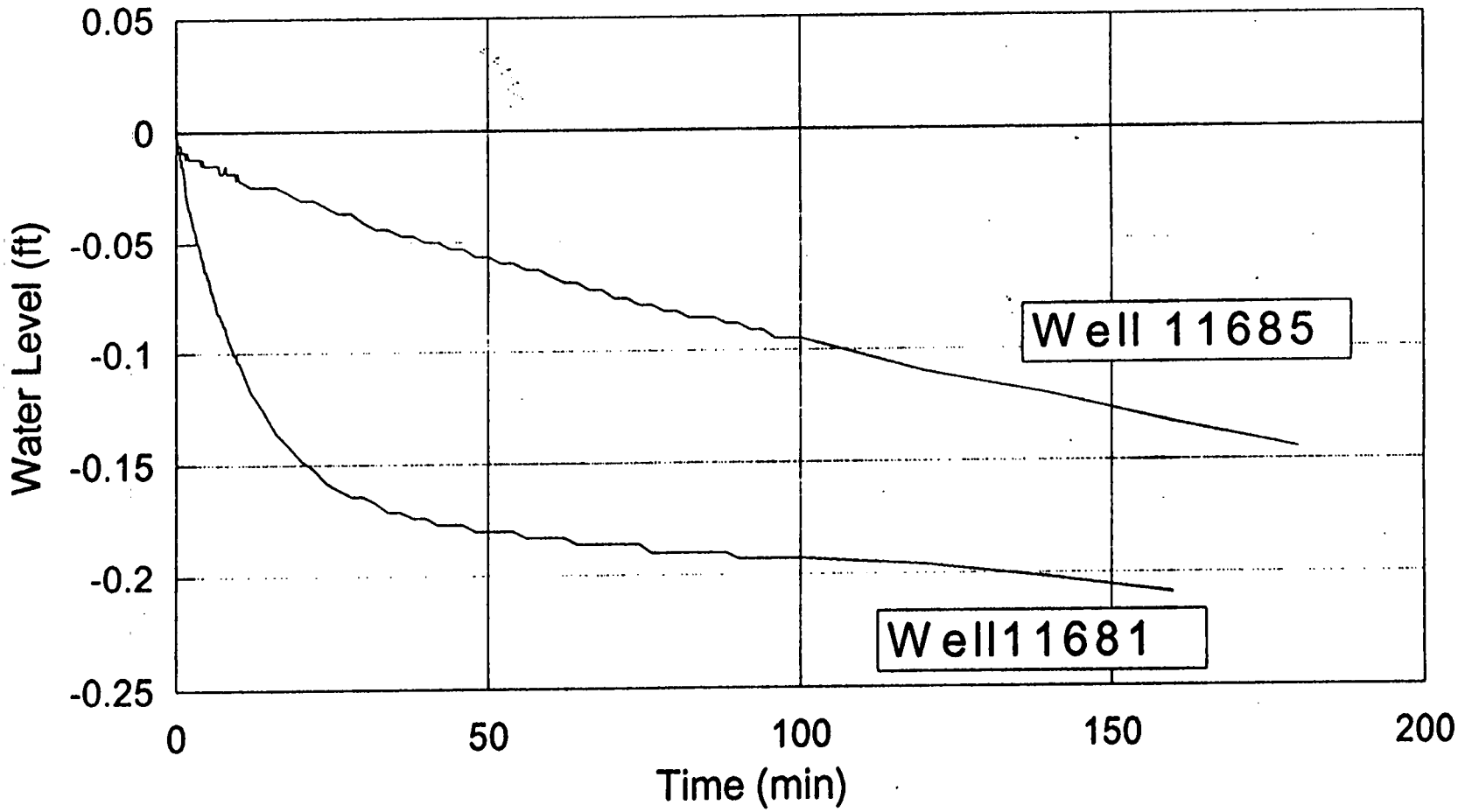
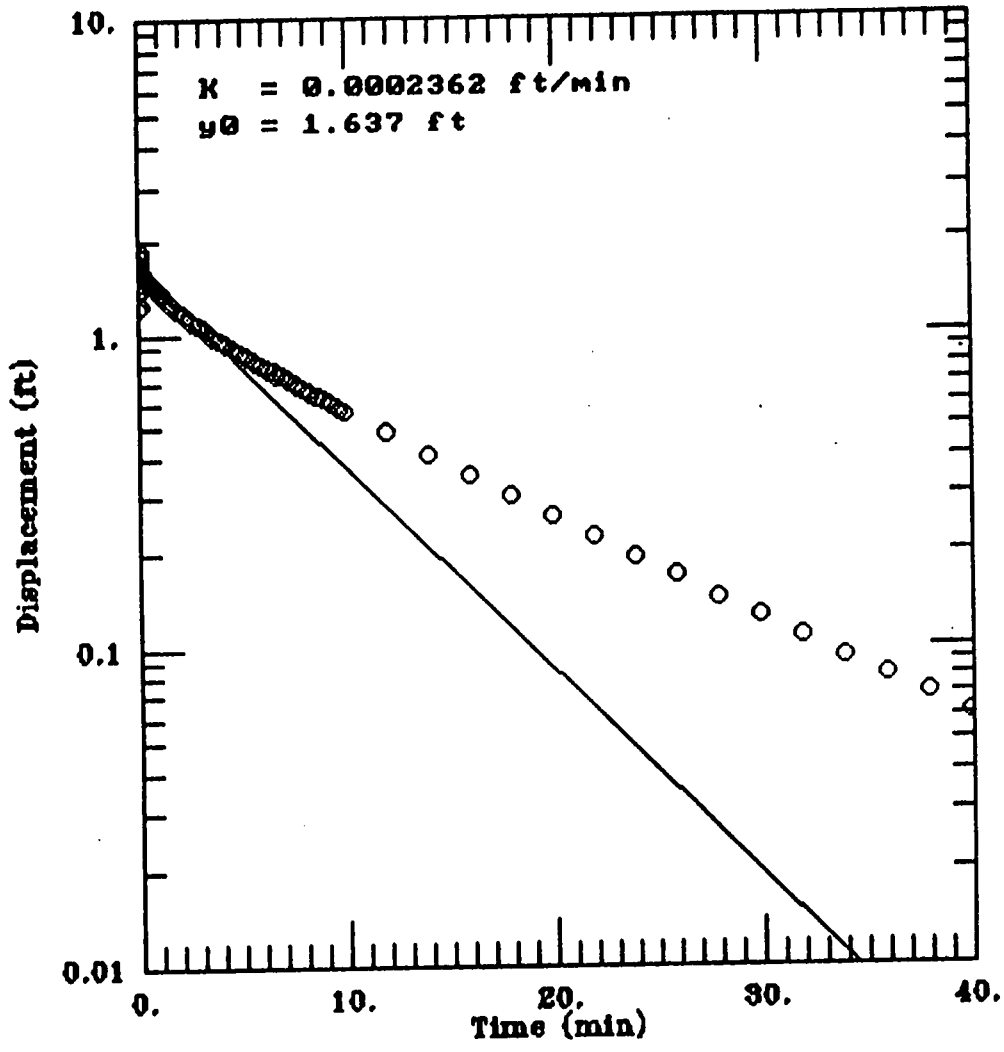


000226

Pre-Slug Test Water Levels



Well 11681 Falling Head Test



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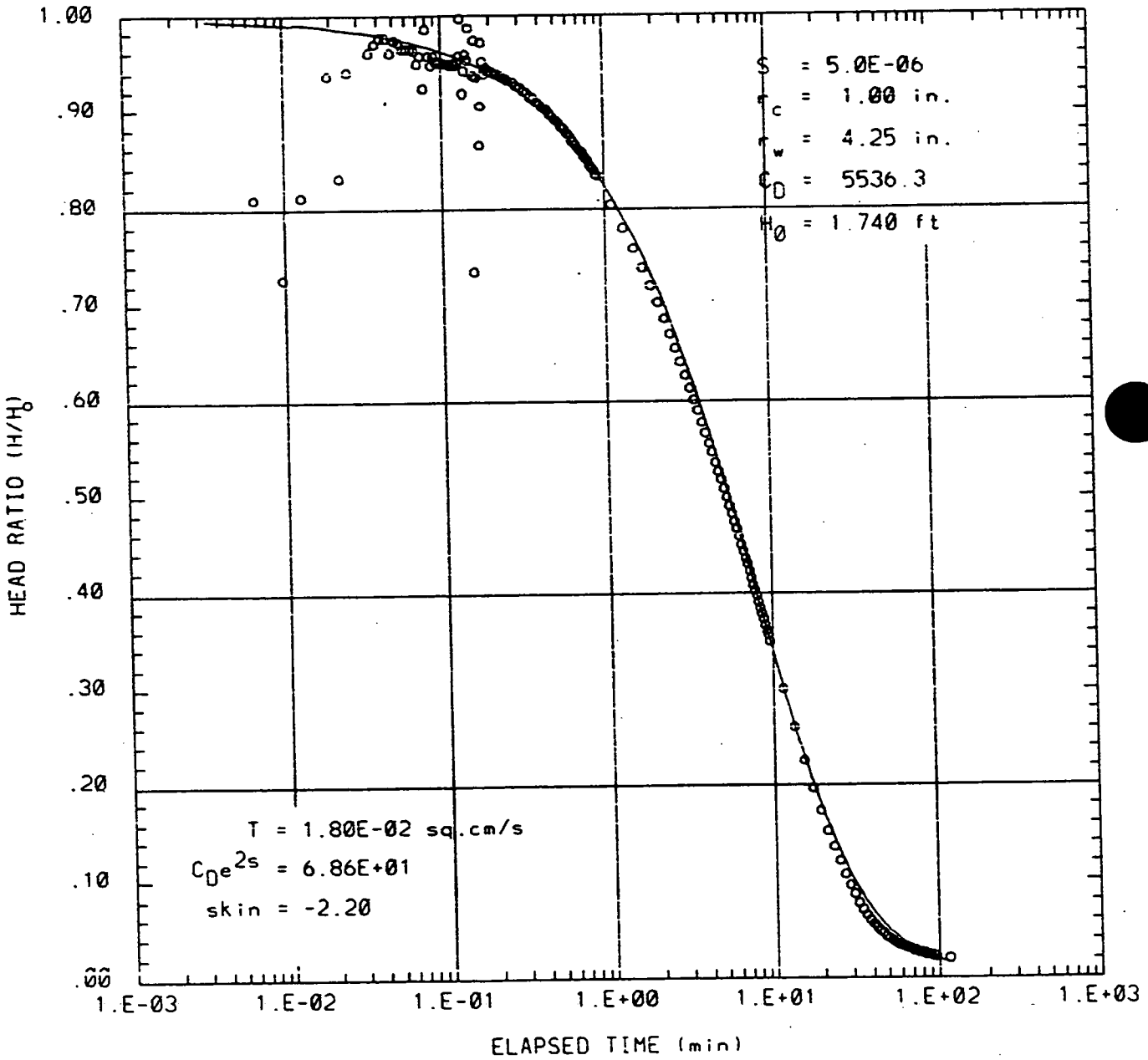

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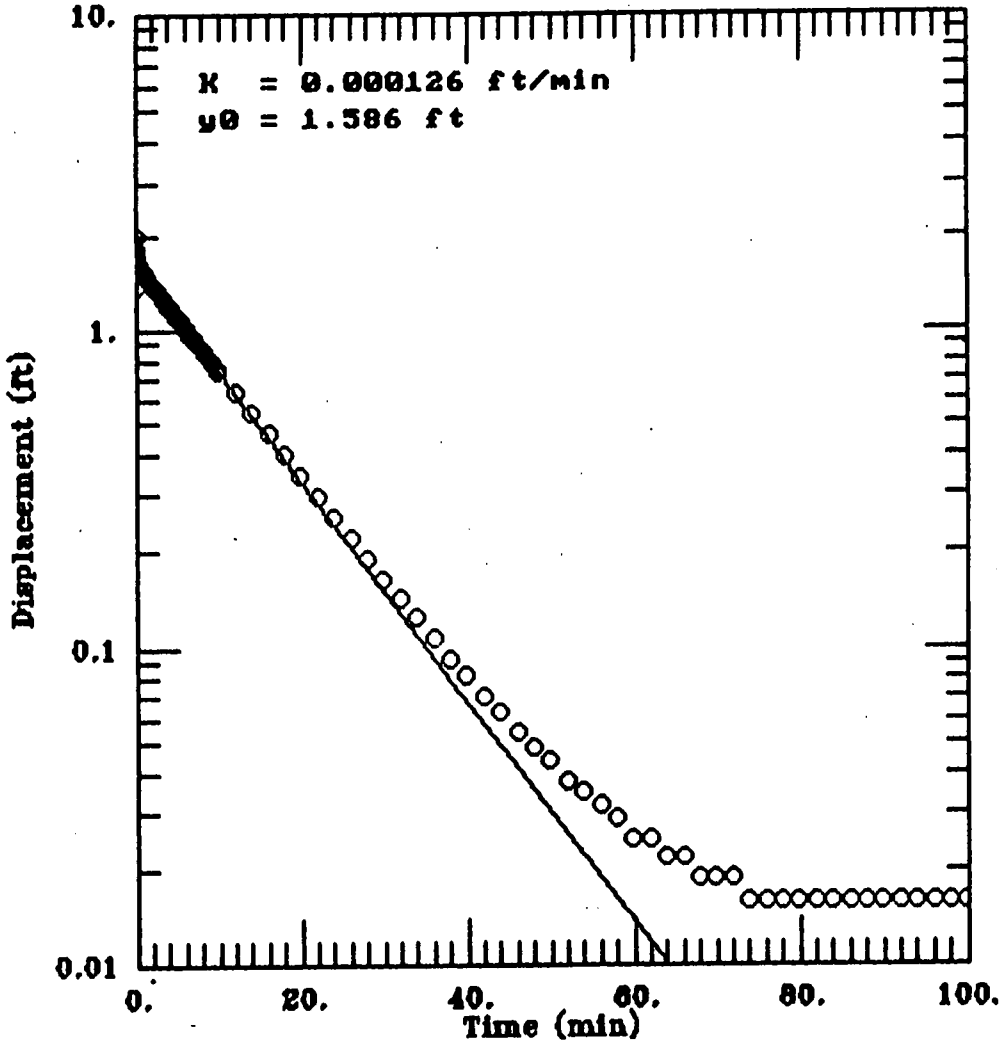
Well 11681 Rising Head Test



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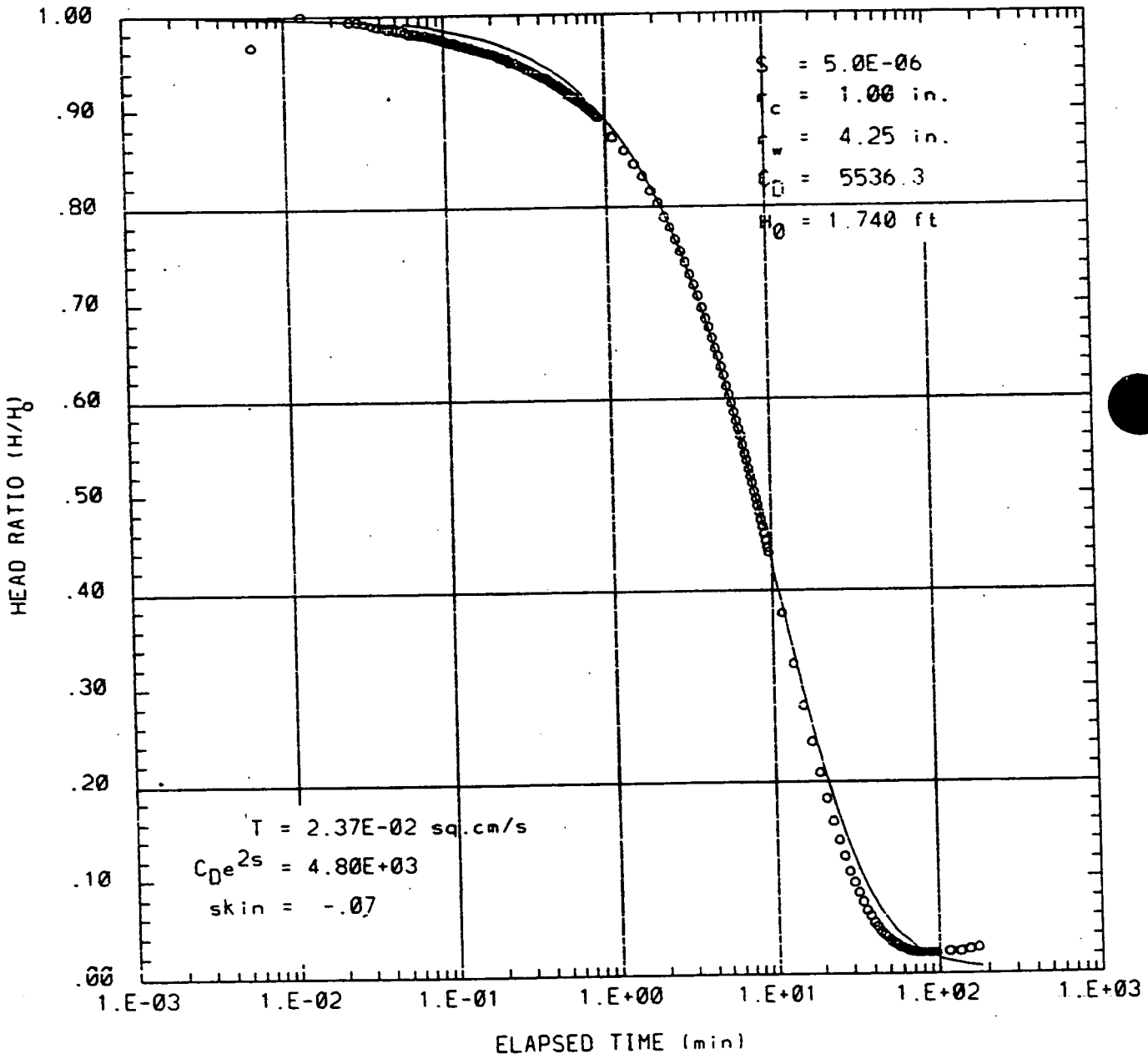

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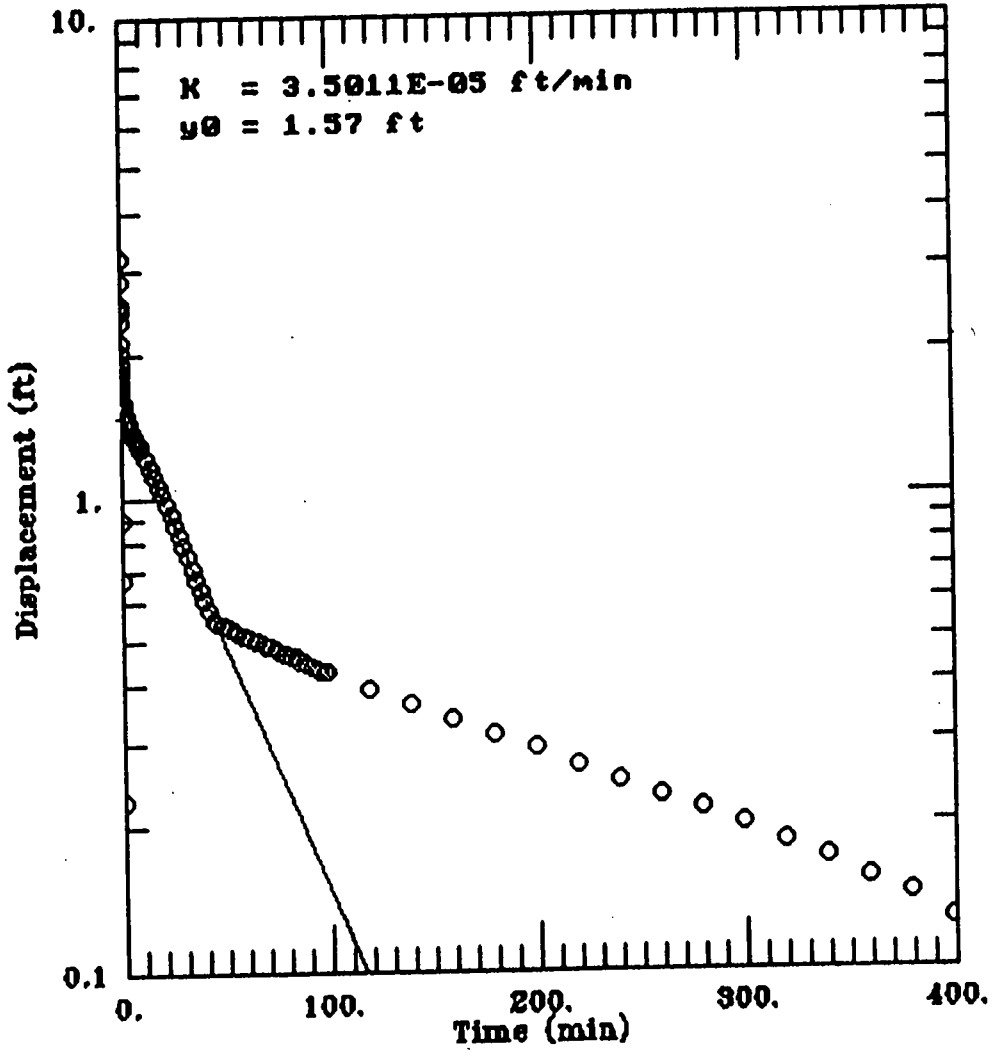
Well 11685 Falling Head Test



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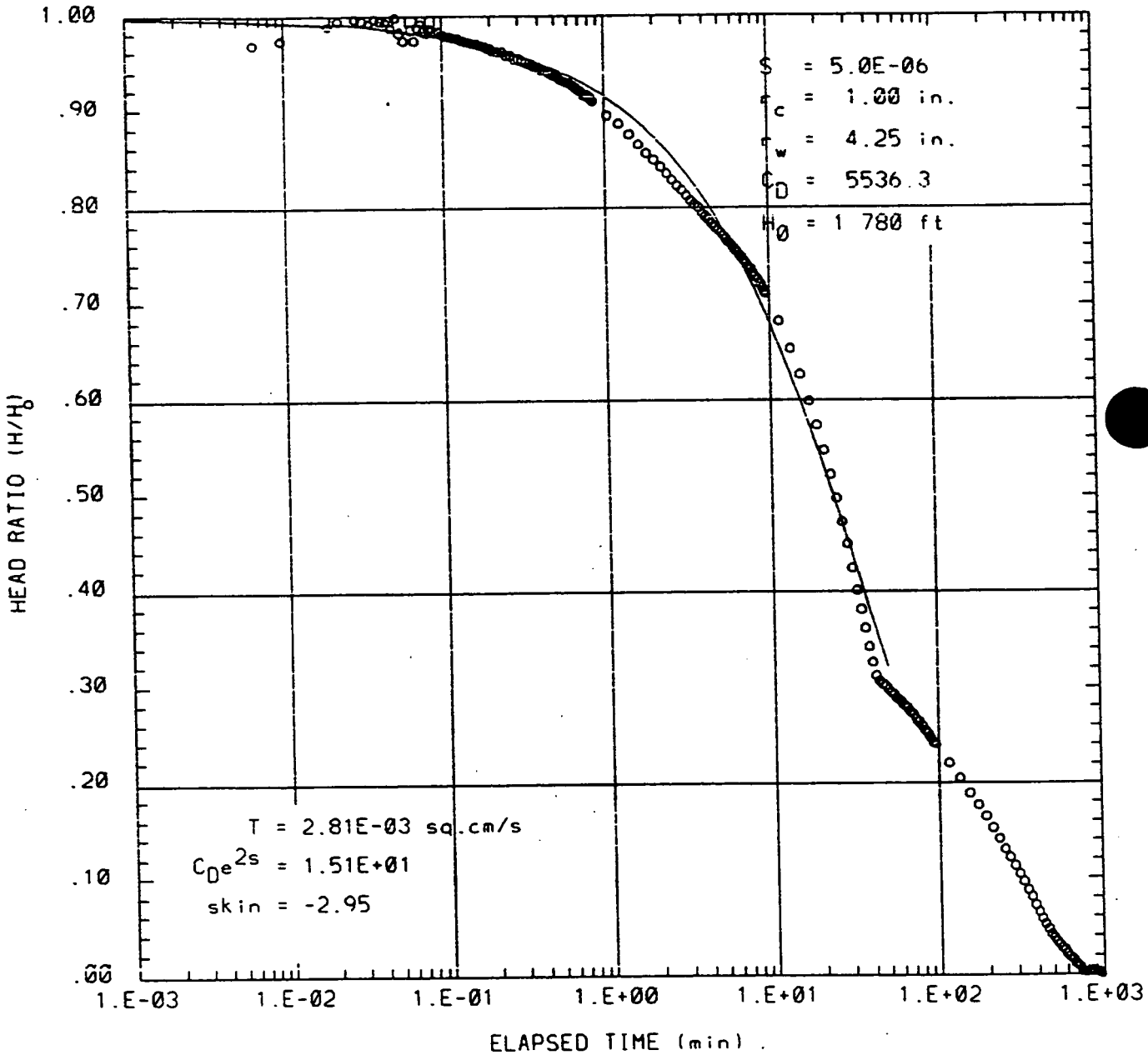

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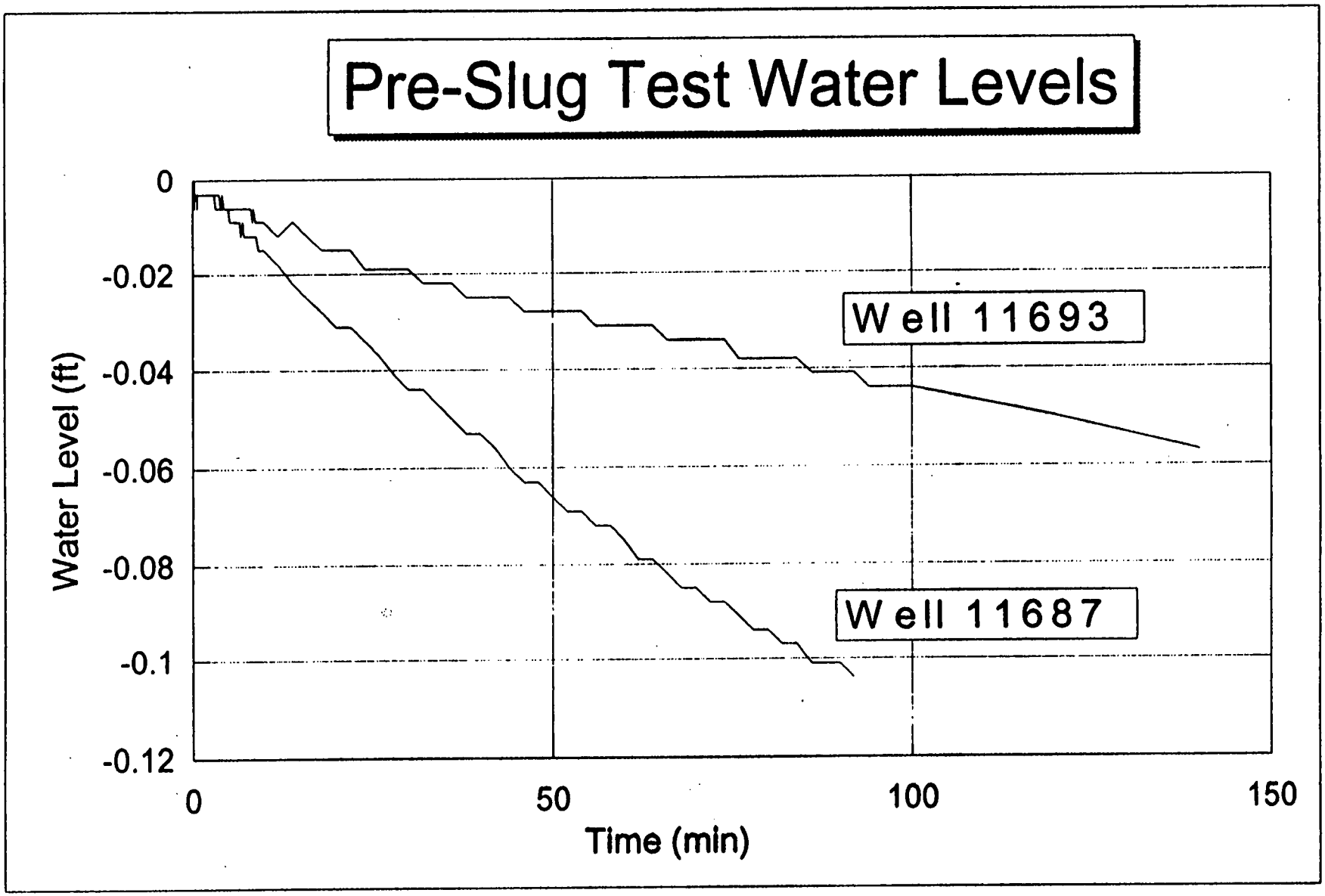
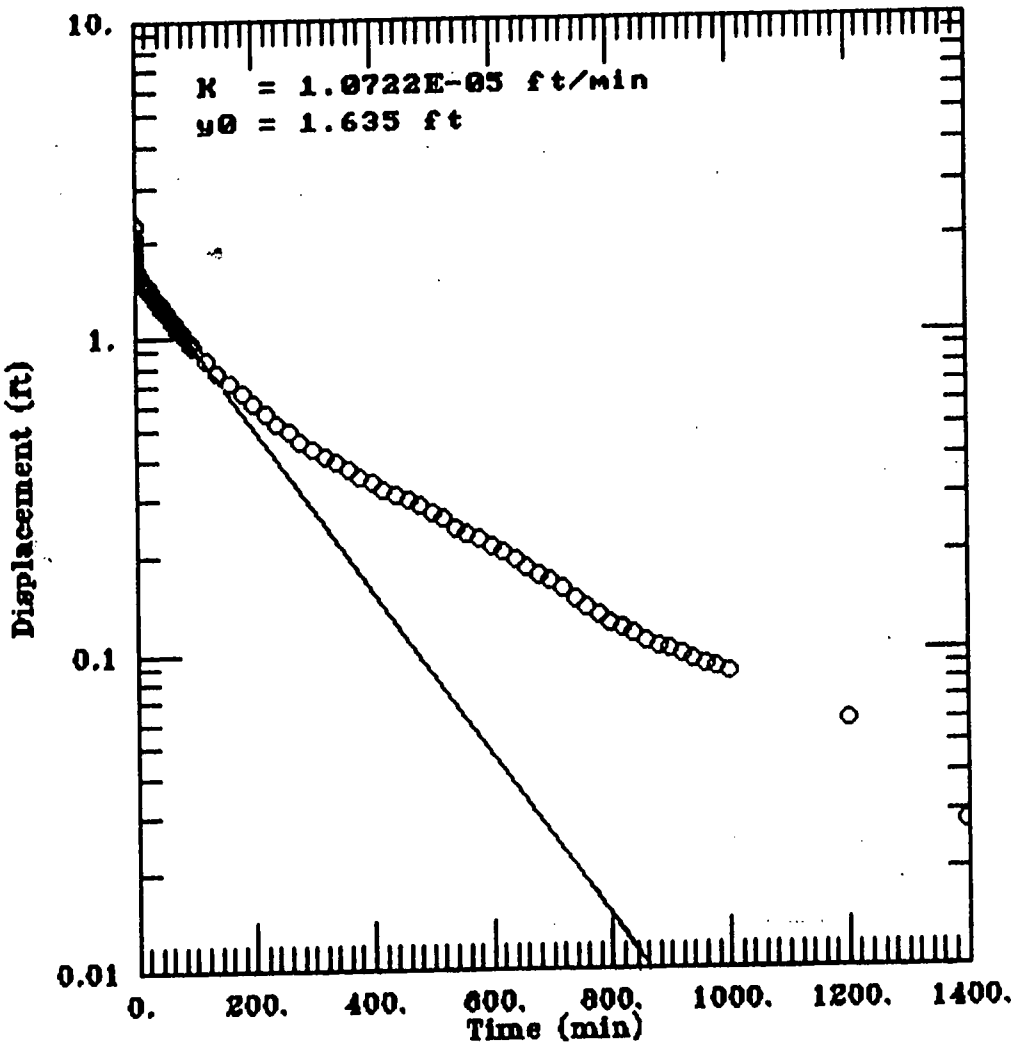

Pre-Slug Test Water Levels
Water Level (ft)
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
0
50
100
150
Time (min)
Well 11693
Well 11687

Well 11687 Falling Head Test



Well 11687 Falling Head Test

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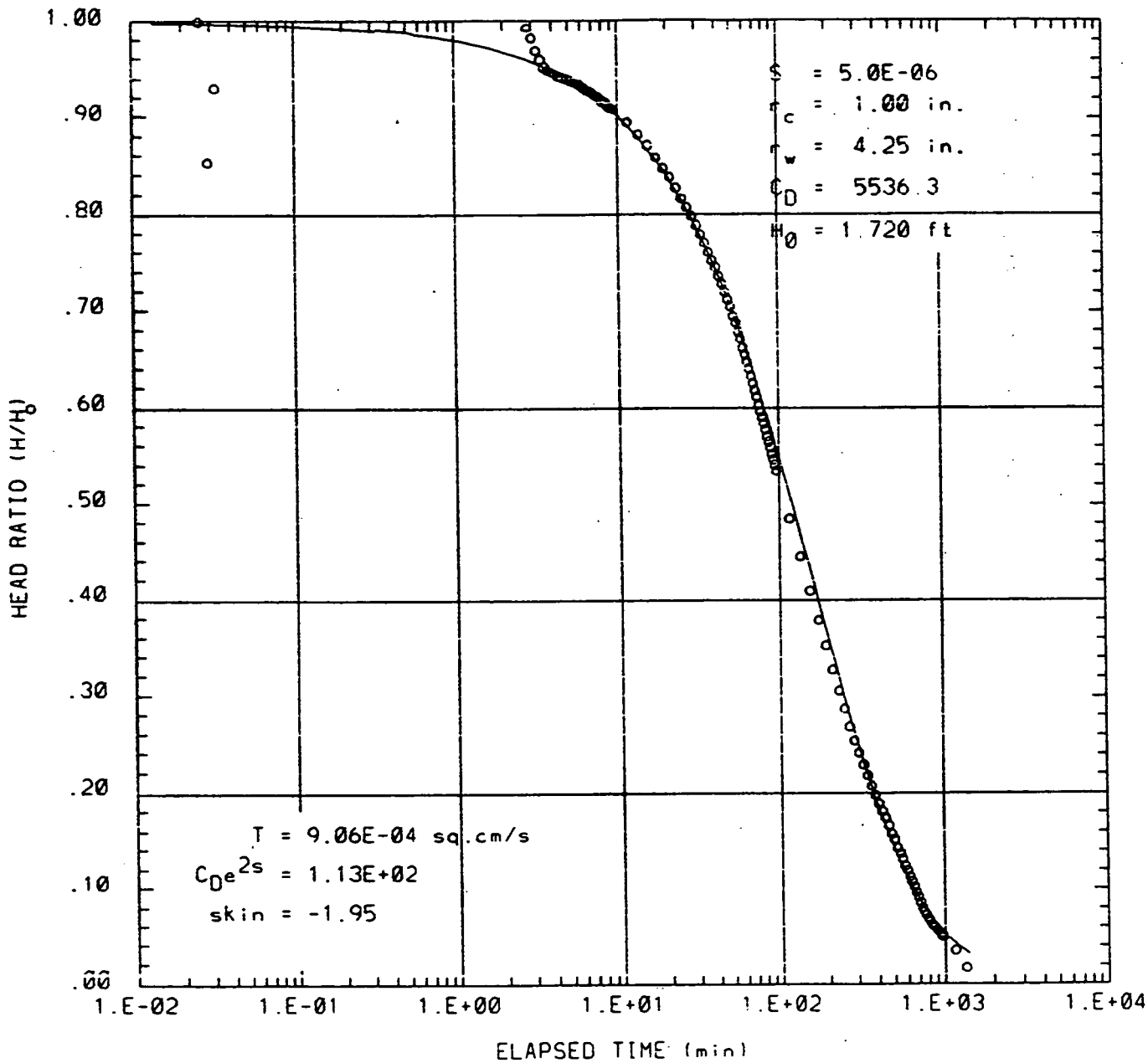
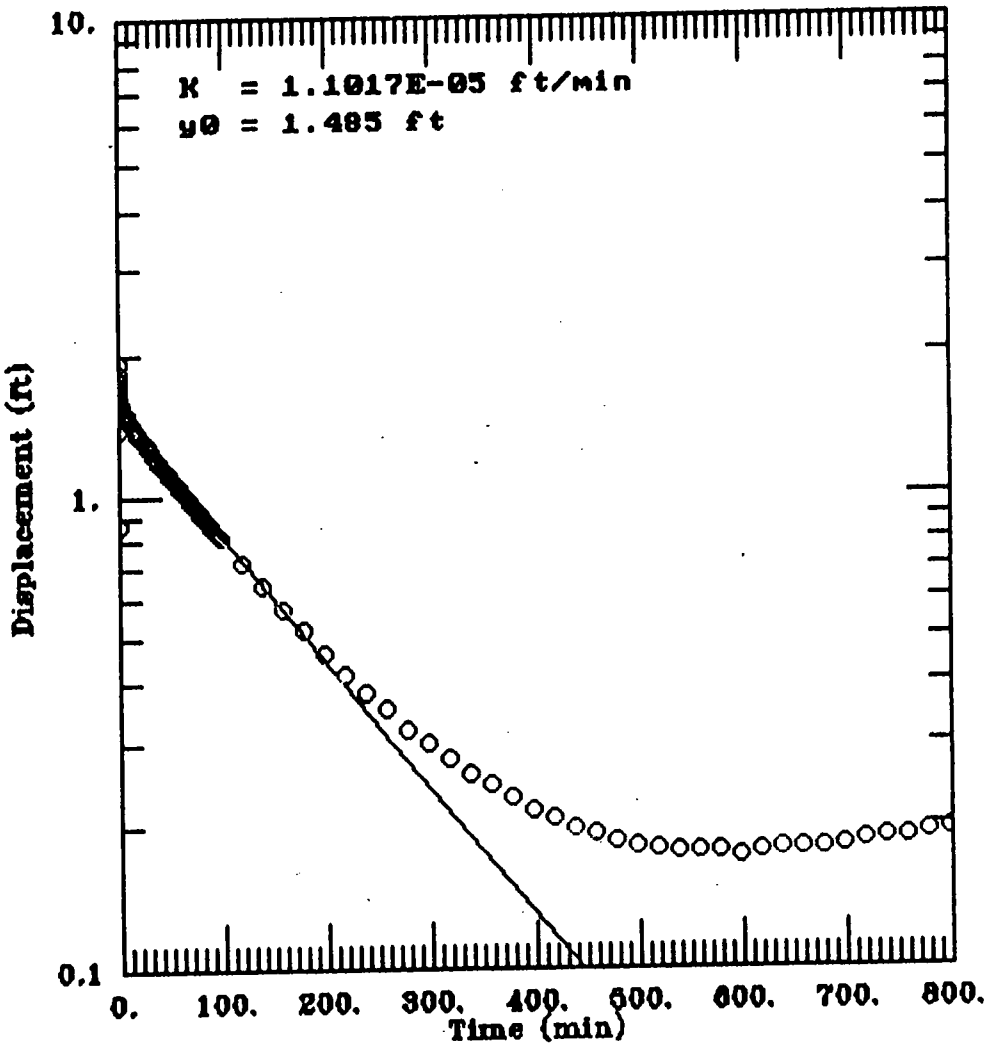


Well 11687 Rising Head Test



0001136

Well 11687 Rising Head Test

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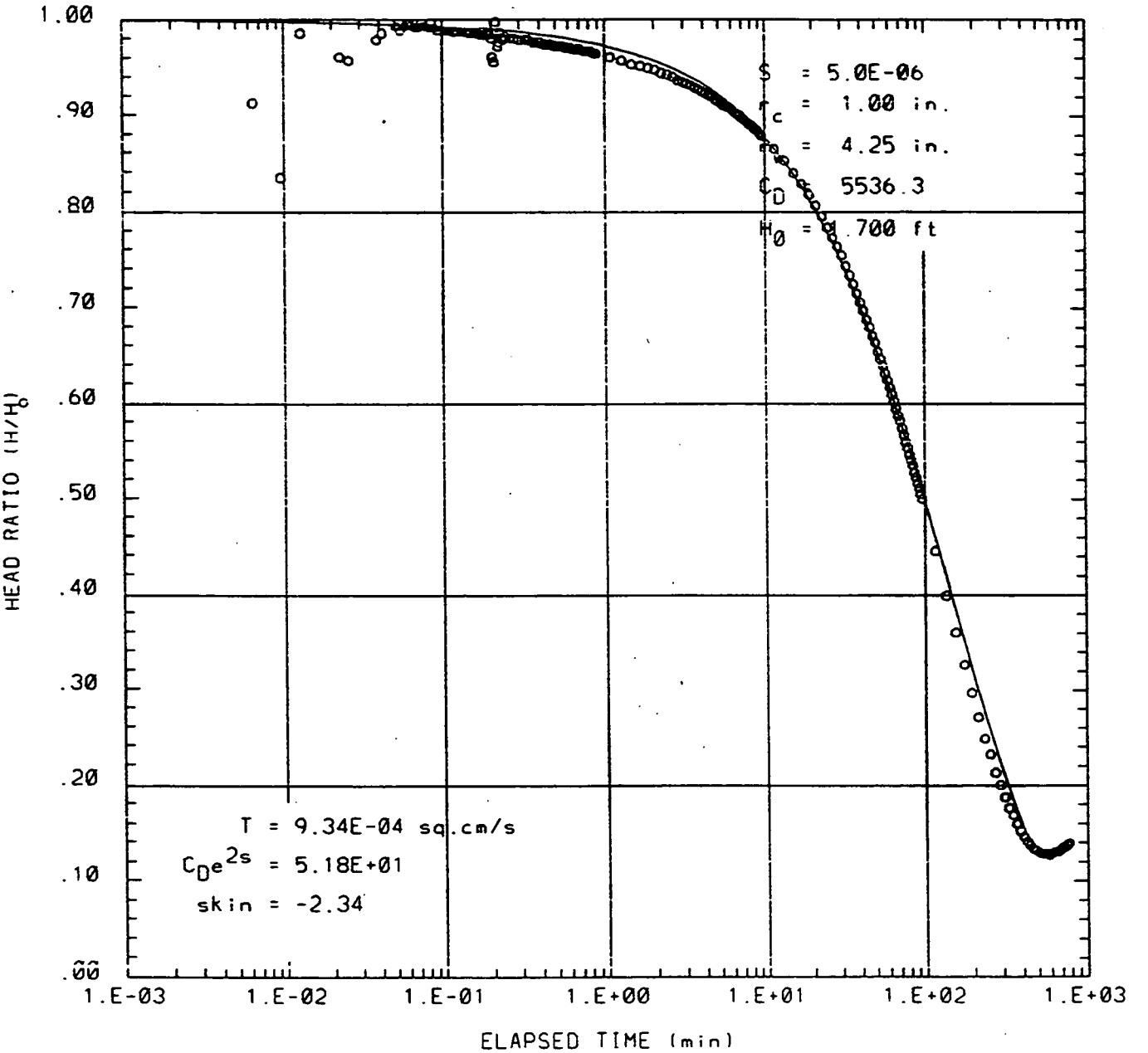
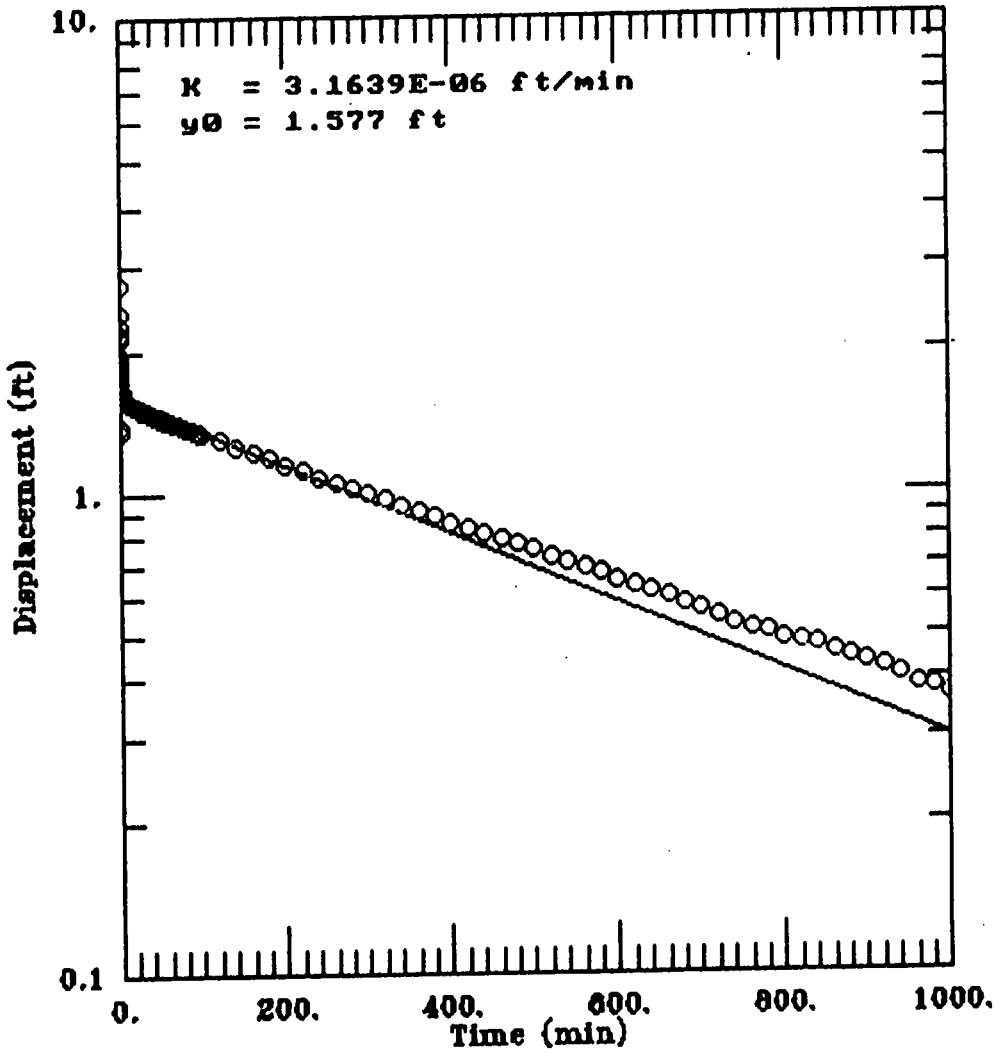


Well 11693 Falling Head Test



000138

Well 11693 Falling Head Test

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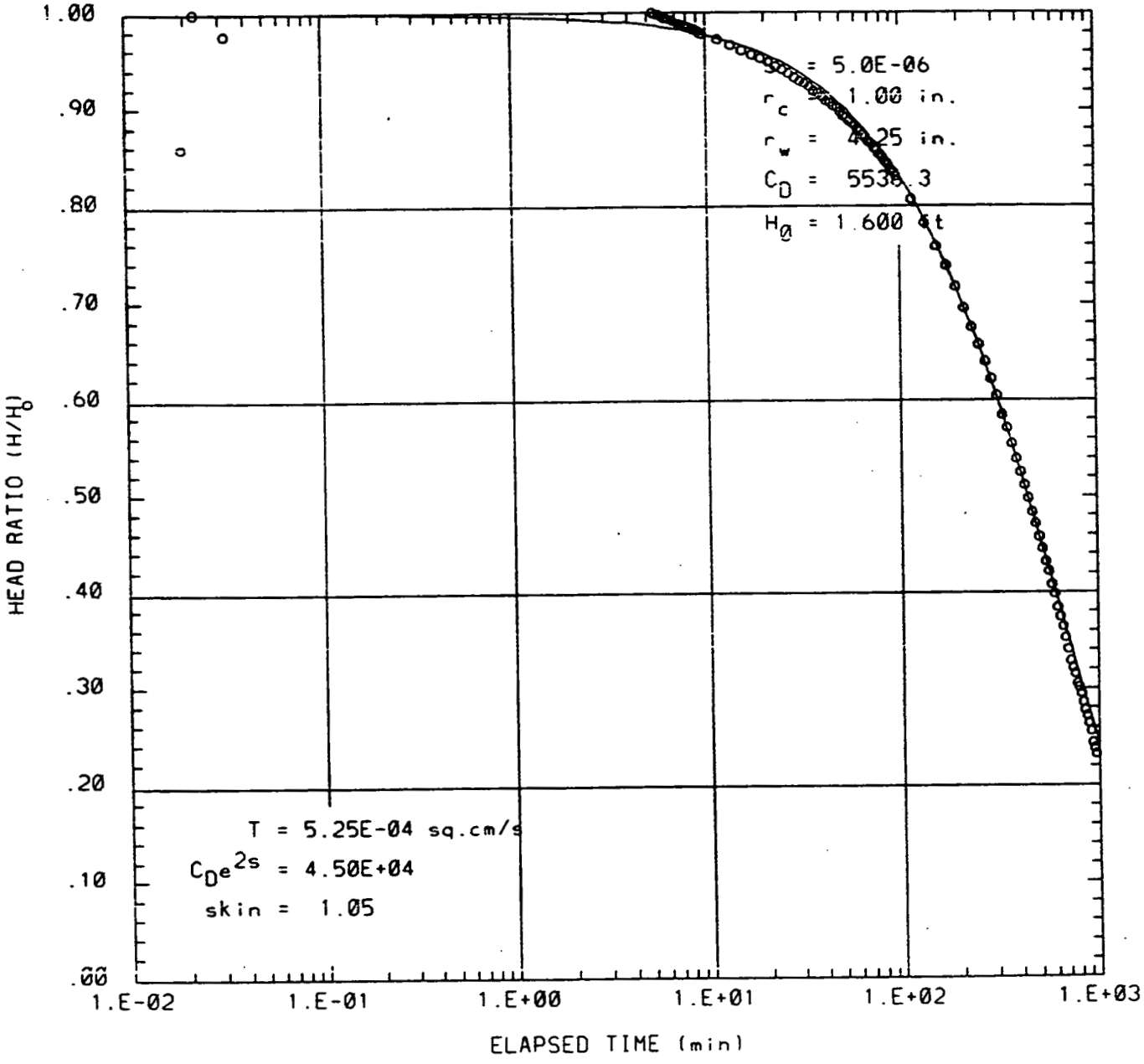
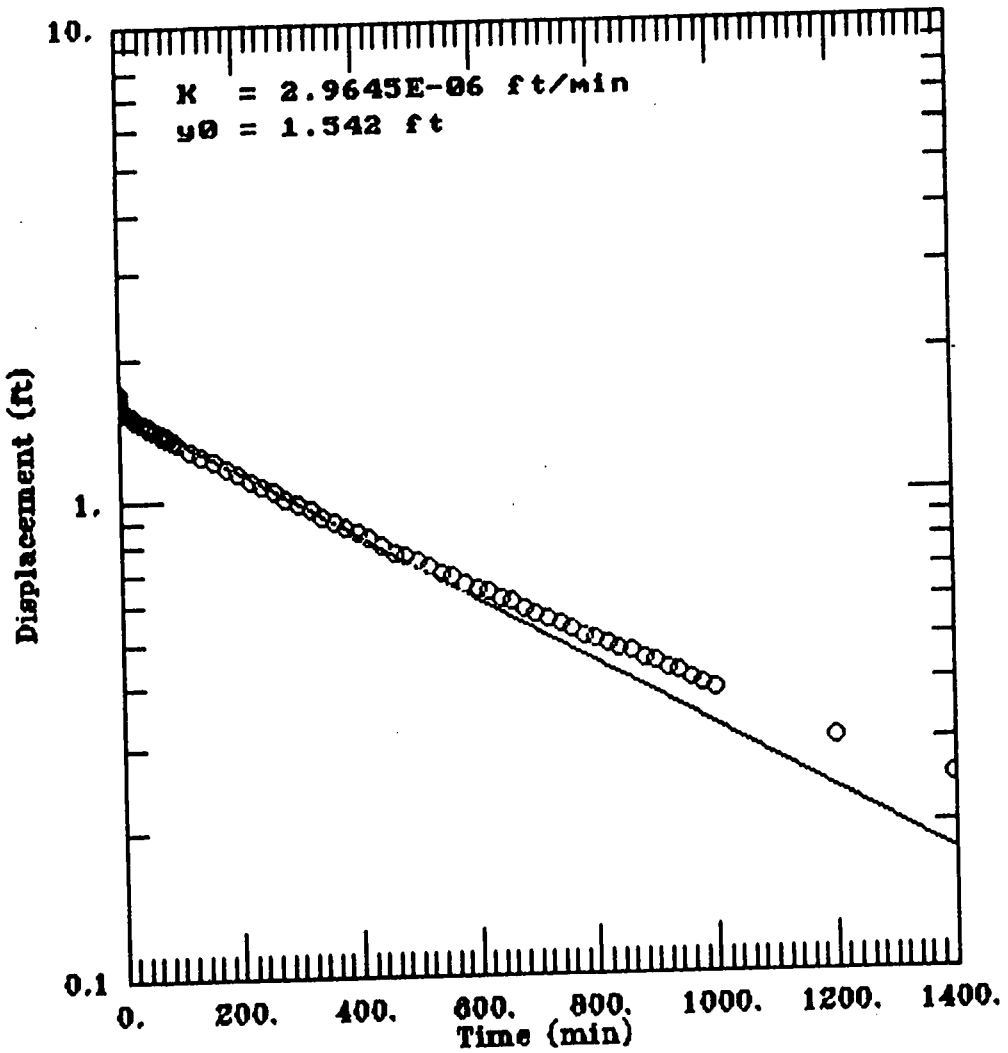


Well 11693 Rising Head Test



000140

Well 11693 Rising Head Test

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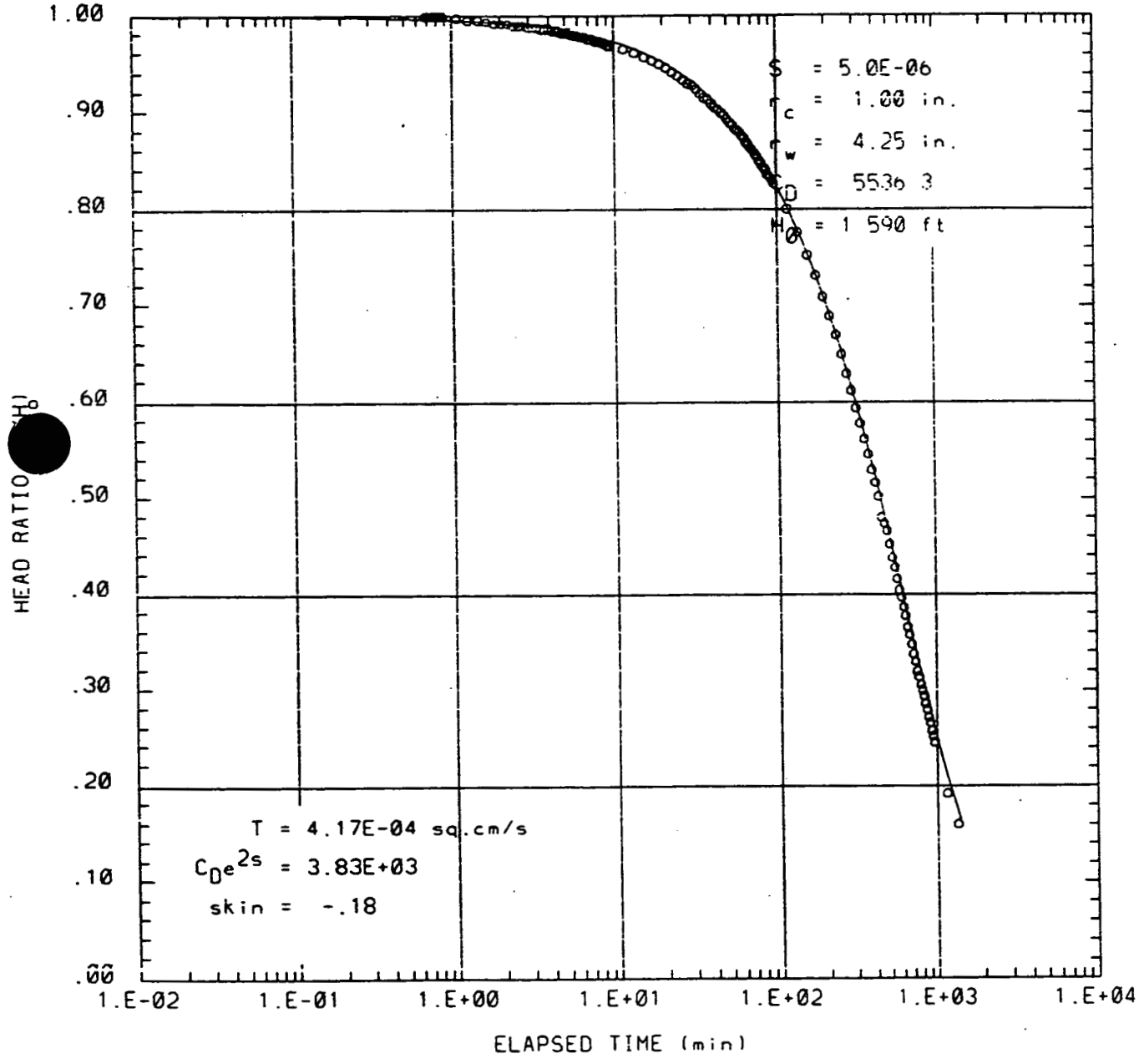

APPENDIX B

APPENDIX B

KV FLOWMETER

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B.0 KV FLOWMETER CALIBRATION

B.1 Introduction

This report has been developed to document the calibration and verification efforts for the KV Flowmeters. The KV Flowmeters are being used at the FEMP to determine the rate and direction of groundwater flow in groundwater monitoring wells. The calibration and verification process is defined by manufacturers manuals and guidance.

B.1.1 KV Flowmeter

The KV Flowmeter is a portable self-contained instrument for measuring the direction and rate of groundwater through permeable soils. The system uses thermal pulses and thermistors to measure the spread of heat in the monitoring well. The heat spreads more rapidly downgradient than upgradient, thus producing a measurable variation in temperature which can be transferred into direction and rate of groundwater flow.

B.1.2 Calibration and Verification

Instrument calibration is necessary to determine if the instrument is measuring accurately and is functioning within specifications. Instrument verification is necessary to determine if the instrument is measuring correctly the data it is designed to measure. For the KV Flowmeter, instrument calibration has to be considered for the electrical components (battery, LCD, timer, and ammeter), the probe, and the compass. Instrument verification for the KV Flowmeter requires measuring the probe against established flow rates and direction.

B.2 Calibration and Verification

The following is a description of the calibration and verification tests that are performed on the KV Flowmeter to ensure that the instrument measurements are accurate and representative. The calibration and verification tests are defined in the manufacturers manual which is included as Attachment I to this report.

B.2.1 Instrument Calibration

The KV Flowmeter is made up of two major components, the control box and the probe. The control box contains rechargeable batteries, an LED display, a timer, and an ammeter. The probe contains a heater circuit, thermistors, and a compass.

B.2.1.1 Electrical Systems Calibration

The electrical system used by the KV Flowmeter is intended to provide 2.0 amps to the heater in the probe in order to generate the heat pulse. The ammeter is used to determine if the electrical system is delivering the proper amperes to the probe. Each time the flowmeter is used to take a measurement the reading on the ammeter is written down to document that the electrical system is delivering the required current. The timer can be routinely checked with a watch.

B.2.1.2 Probe Calibration

The probe contains two parts that require calibration, the compass and the thermistors. The compass can be routinely checked for accuracy with another compass. The thermistors in the probe are calibrated every time the probe is used by rotating the probe 180 degrees and repeating the measurement. If a thermistor introduces a bias in a reading by its response to the heat pulse, the bias will be reversed when the probe is rotated. By using the reversed readings to determine an average the thermistor bias can be removed.

B.2.2 System Verification

The KV Flowmeter is used to determine the rate and direction of groundwater flow. In order to ensure that the flowmeter is accurate and representative, the manufacturer has defined a system verification process that requires testing the flowmeter readings with fabricated flow directions and rates. The intent of this verification is to establish the validity of the flowmeter readings and develop a correlation factor for the meter units.

B.2.2.1 Verification Setup

The flowmeter verification process requires a simulated groundwater flow system that can be used to test the flowmeter. This simulated groundwater flow system is created in a flow chamber. A detailed description of the verification equipment and process is provided in section C of the manual in Attachment I. The flow chamber is designed to achieve flows in a geologic medium representative of the site. These simulated groundwater flows can be controlled to accurately measured rates. A well screen of the type used at the site is installed in the flow chamber. A metering pump is used to draw water out of one end of the chamber and pump it into another, thus creating a gradient in the flow chamber. The verification system is then set up for verification of the flowmeter readings.

B.2.2.2 Verification Procedure

The verification of the flowmeter readings begins with placing the flowmeter in the prepared flow chamber. The metering pump is turned on at a specific flow rate and the system is left to reach equilibrium. Once in equilibrium the flowmeter is used to take a measurement. The flow direction is determined by plotting the vectors defined by the thermistor output. Verification of the flow direction is achieved when the flowmeter results match the direction of flow in the chamber. A $\pm$ uncertainty can be developed for the direction measurements as a results of multiple measurements in the flow chamber.

The flow rate is measured in meter units by the flowmeter. The meter units are correlated to the actual flow rate by varying the metering pump flow and plotting it against the meter units measured with the flowmeter. An example plot is provided in Attachment II. A detailed description of this procedure is provided in Attachment I. This plot provides a correlation between meter units and actual flow through the geologic medium and the well screen. Verification of the actual flow rate in this manor compensates for the borehole effects that occur when you disturb a geology with a monitoring well. Using the verification plot from this procedure, flow rates in the field can be estimated as true aquifer flows because the

borehole effects are subtracted from the flowmeter measurements. If the hydraulic conductivity of the aquifer or the well construction materials vary significantly from those used to develop the verification plot then an new plot should be generated.

B.3 FEMP Verification Results

The flowmeter verification process was completed for both of the flowmeters owned by FERMCO as part of the Pre-Design Investigation for the On-Site Disposal Facility (OSDF). The verification was performed from April 12 to May 24, 1995 and is documented in a field log (a copy is provided as Attachment III). The flowmeters were designated to measure flow directions and rates in twenty four monitoring wells in the footprint where the OSDF is to be constructed. Before field work is performed the flowmeters had to be calibrated and verified. The calibration process is routine and can be performed each day before field work begins. The verification process is more complicated and required laboratory efforts. The following section describes the verification effort and the results of the verification.

A flow chamber was set up using screen material of the type used in the monitoring wells to be measured. The chamber was packed with materials consistent with what the monitoring wells are screened in. Some assumptions had to be made about the geology being monitored do to its heterogeneity. The monitoring wells are screened in glacial till deposits consisting mainly of silt and clay with sand and gravel inclusions. There is no way to put silt and clay materials in the flow chamber and obtain flow readings because of the hydraulic conductivity of the material. It was assumed that the flow in the glacial till is predominantly through the sand and gravel inclusions. Based on that assumption a medium sand was mixed with some of the silt and clay from the well cuttings to produce a dirty sand medium. This material was packed into the flow chamber around the well screen section and water was added.

With the flow chamber set up, the metering pump was connected and a flow rate was established across the flow chamber. The flowmeter was placed in the chamber and initial

readings were taken. The initial readings (taken between 4/12 and 4/13/95) were close to true flow directions but the flow rate was too low compared to what was expected based on manufacturers recommendations. The potential for preferential flow around the well screen was a concern, so the flow chamber was repacked, but the results did not improve. After trying several other times to improve the readings the well screen was removed and the flowmeter was placed directly into the sand. Measurements without the well screen were at expected meter units, approximately 5 times as high as meter units with the well screen, and the flow direction was highly accurate. As a result of this study it was determined that the well screens were creating a resistance to flow through the well.

This was an important determination because it documented that the KV Flowmeter was measuring the flow correctly, even though the flow was less than expected. This effect was further supported by ASTM Special Technical Publication 963 (Attachment IV), which documented that wrapped screens of the type used at Fernald have at least a 48% resistance to flow. The ASTM report also discusses a change in flow direction through monitoring wells. Realizing that the slowed flow rates measured in the flow chamber were an artifact of the monitoring well and not the flowmeter, the verification process was restarted.

An iterative series of tests were performed from 4/17 to 4/27/95; repacking the flow chamber, increasing the flow rate, changing the flowmeter, and adding sand to the chamber to increase the conductivity in an effort to produce representative conditions in the flow chamber. Also, flowmeter unit 1 needed to be repaired by the manufacturer. On 4/27/95 the verification of flowmeter unit 2 was initiated. Tests were conducted at 10 ft/day, 5.4 ft/day, and 1.8 ft/day. The results were plotted and are presented in Attachment II. On 4/28/95 the screen was removed and the flowmeter was used to measure flow at 1.8 ft/day, 0.45 ft/day, and 0.3 ft/day. The measurements with the well screen removed were plotted in comparison to the measurements with the well screen (Attachment II). On 5/3/95 the well screen was repacked into the flow chamber in preparation for the KV Flowmeter 1 verification. The

flow chamber needed to be set up similar to the way it was with flowmeter 2, so the iterative measurement process had to be performed again until the chamber was representative. Adjustments were made until 5/17/95 when flowmeter 2 was used to verify that the chamber was representative to the verification measurements made earlier. Flowmeter 1 was placed in the flow chamber on 5/17/95 and its verification test began. Measurements were taken at 4.6 ft/day, 2.3 ft/ day, and 1.2 ft/ day, and the data was plotted (Attachment II).

The verification process to determine the validity of the flowmeter measurements and the meaning of the flowmeter flow units was difficult. The flow chamber does not produce the exact flow conditions that would be expected in the field, and the chamber was sensitive to outside factors (e.g. preferential flow channels). The resulting plots indicate that the verification process was successful, however, because the relationship of meter units to flow rates was linear, which was expected. The verification process indicated that there were many factors that effect the flow rate through a monitoring well, monitoring well construction being one of the major factors. The plots used to generate flow rates appear to have a precision of ± 0.2 ft/day.

B.4 Field Procedure

The well access procedures used by Groundwater Monitoring (SOP SC-GWM-FO-201 "Groundwater Sampling Activities") are used to open the well and decon anything going in and coming out of the monitoring well. The flowmeter operation procedures were learned through manufacturer's training. The major steps of flowmeter operation are listed below.

Flow measuring plan:

A flow measuring plan needs to be developed for each monitoring well prior to installation of the flowmeter. This plan can be kept in the field log, does not have to be formal, but should document what depth the screened area is that will be monitored, how many measurements in

the screened area will be taken (the manufacturer suggests every one to two feet), and what depths below the top of the well the flowmeter will be lowered. The boring log of the monitoring well should be observed to determine if there are any depths of interest, such as sand lenses. The plan should have contingencies if measurements at a specified depth find no flow or vertical flow conditions. Any changes in the field should be documented in the field log.

Flowmeter installation:

Water elevation measurements should be made a couple of times before anything is put in the monitoring well to determine the baseline water elevation. The baseline water elevation should be written in the field log. The flowmeter probe is washed with deionized water prior to placing it in the monitoring well. Aluminum rods are connected to the probe using the pop connectors at the ends of the rods. The probe is lowered into the monitoring well using the aluminum rods to the desired depth. The cable connecting the probe to the control box can be fixed to the aluminum rods with plastic ties. The aluminum rods come in 5 and 10 foot lengths and the probe is 1.5 feet long, so the depth of the probe can be determined by how much rod is protruding above the top of the well. The aluminum rod is held in place at the desired depth using a vise grip clamp. The compass is attached to the top of the aluminum rod protruding from the well, it should be at least 2 feet above the well casing so that the steel casing does not interfere with the compass reading. The compass should be aligned to magnetic north for the first readings. The flowmeter can be twisted in the well until the compass is aligned with north. Warning: Some monitoring well screens have ribs that do not allow the probe to rotate inside the screen. If resistance is felt while trying to rotate the probe, the probe must be lifted out of the screened area before it is turned. Once the probe is aligned to north and it is at the proper depth the probe cable should be connected to the control box. The flowmeter is then ready to take readings.

Flow measurement:

Water elevation readings should be conducted on a periodic bases (typically 2 to 5 minutes) and written in the field log with the time of the reading until the same water elevation is measured three consecutive times. These readings are used to determine when the monitoring well has come to hydraulic equilibrium. At the same time water elevation readings are taken the probe readings for each channel should be read and written in the field log with the time of the reading. The probe channel readings should be taken until they are consistent (within ± 2 units) three consecutive times. These probe channel readings are used to determine that the monitoring well is in thermal equilibrium.

Once the monitoring well reaches hydraulic and thermal equilibrium, the reading can be taken. Fill out the groundwater flow worksheet operator, date, time, station, location, and depth and write the start probe channel readings on the worksheet. Ensure that the batteries are connected prior to starting the reading. Start the reading by pressing start and write the start time and reading direction (N or S) in the field log. The reading light should come on and the ammeter should read approximately 2.0 amps. The ammeter reading should be written in the field log or on the worksheet. This indicates that the probe is releasing its thermal pulse. The timer will go off after approximately 3 minutes, at which time the readings for each of the four channels should be taken and written on the worksheet. The end reading should be subtracted from the start reading for each channel to obtain the net thermistor reading.

Once a north and south reading are taken for a specified elevation the flow worksheet can be completed. Subtract the south net thermistor reading from the north net thermistor reading and divide by two. This process removes any inherent bias in the thermistors of the probe. The highest channel reading is then used to normalize the channel readings to one. Divide the highest reading into all four channel readings. The results can be plotted on the circular graph on the worksheet. The direction of the vectors indicates the direction of flow,

however the vectors should form a circle with the largest vector in the middle. If this arrangement is not achieved then uniform flow has not been obtained in the monitoring well. The test should be redone to confirm the non-uniform flow condition prior to moving on to the next elevation. Further interpretation of the meter results cannot be defined in a procedure.

Flowmeter rotation:

Once a north reading is taken the probe should be rotated to south. To do this simply turn the aluminum rod until the compass arrow lines up with south. If the well screen does not allow the probe to be turned in the screen it must be lifted out of the screened area and then turned. Once the probe is rotated the flowmeter reading procedure can be repeated.

Flowmeter extraction and cleaning:

When the probe is removed from the well the aluminum rods and the probe should be wiped down with deionized water. The probe should be placed in a container and emersed in deionized water. The probe fuzzy packer should be rubbed to remove any silt or other deposits from the monitoring well.

Attachment I

GROUNDWATER FLOWMETER SYSTEM*
Operations and Maintenance Manual

Model 40L Geoflo®

KVA ANALYTICAL SYSTEMS

281 Main Street

Falmouth, Massachusetts 02540

(508) 540-0561

January 1989

*U.S. Patent # 4,391,137
Canadian Patent # 1,172,872
European Patents Pending

* Registered Trademark

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-- Caution--

Instrument probe contains a resistance heating tip which, when activated, may reach temperatures exceeding 500° if not immersed in glass bead packing or water.

Read operating instructions prior to use.

GENERAL INFORMATION

Application

The Groundwater Flowmeter System is a portable self-contained instrument for measuring the direction and rate of very slow flow of groundwater through permeable soils. The system is designed as a practical tool for groundwater hydrological measurements, most commonly applied to environmental monitoring of groundwater plume migration, where battery powered operation is required. The Model 40 L can take measurements in shallow aquifers or deeper water-bearing zones through suspension of its submersible probe down 2, 4, or 6 inch inner-diameter plastic screened well casings. Emplacement of smooth-walled plastic casings and screens (free of internal obstructions) is the major preparatory step required for down-hole use.

Initial Inspection

The Model 40L Groundwater Flowmeter System consists of the following major components:

- Reel Box with 250 feet of cable; with probe attached.
- Deck Box control unit with battery pack included.
- Calibration Kit: flow chamber, pump, two graduated cylinders (10cc and 50cc), 5 pounds of glass bead material.

Note: Unpack each item carefully and inspect for serviceability.

Warranty and Return of Goods

The Groundwater Flowmeter instrument is warranted to the original purchaser against defects in both workmanship and materials under normal use for a period of one year from date of shipment. Heating tips and bent thermistors are not guaranteed. System accessories are warranted for a period of 90 days from date of shipment.

If there is need to return the instrument to the factory for repair, obtain authorization and packaging instructions from the factory service department in advance. Ship instrument post paid. Customer will be billed only for non-warranty parts and labor and return freight costs.

GENERAL SPECIFICATIONS - Model 40L

Power: Model 40, 12 vdc, 95 mA for general electronics
2.0 A for probe heater circuit
(Two sealed rechargeable batteries, 6 v, 6.0 Ah, (12 v total)

Model 40L, 12 vdc, 96 mA for general electronics
(Two sealed rechargeable batteries, 6v, 6 Ah)
18 vdc, for probe heater circuit, 2.0 A
(Three sealed rechargeable batteries 6v, 6.0 Ah, 18 v)

Rechargers: 12 v (120 vac, use with European converter)
18 v (120 vac, use with European converter)

Fuse: Model 40 (1) 5A fuse in 12v supply
Model 30L (1) 1A in 12v supply

Pump: 120 vac (220 vac European)

Heater: 14 watts typical

Readout: 3.5 digit LCD display

Heat Pulse Time: 25 seconds

LED on-time: two minutes 15 seconds

Operating Temperature: 2-25° C groundwater ambient

Thermistors: 8 at 45° intervals

Dimensions:

Probe diameter: 1.75 inches
Thermistor extension: 1.5 inches
Cord length: depends on the model
Thermistor radius: 0.45 inches
Deck box: 13.0 inches x 9.0 inches x 9.75 inches
Reel box: 12.75 inches x 7.75 inches x 16.0 inches
Aluminum rods: 3/4 in. x 5 ft.
5/8 in. x 5 ft.
3/4 in. x 10 ft.
5/8 in. x 10 ft.
(Pop Connectors)

Materials:

Case: Delrin
Thermistors: stainless steel
Heater tip: stainless steel
Cord connector: thermoplastic
Cable jacket: PVC

OPERATING CONTROLS

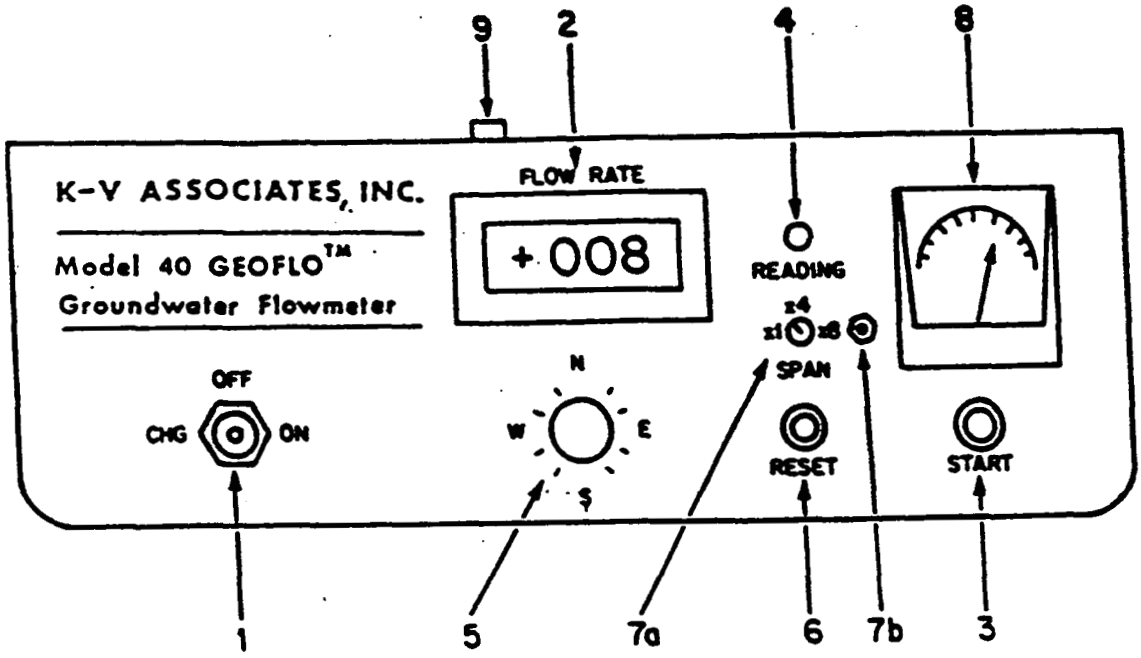
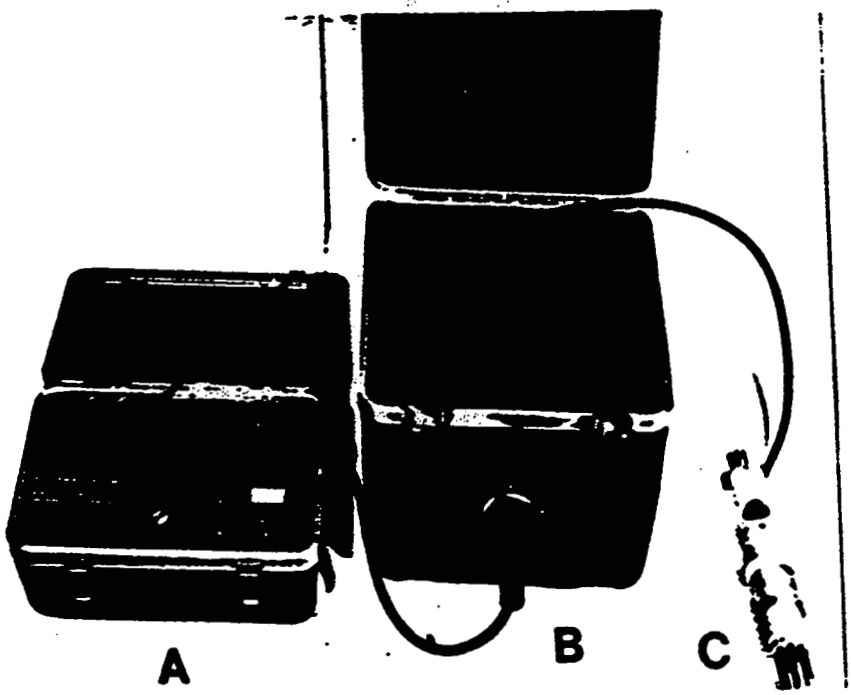


Figure 1. Deck Box Operating Controls and Indicators

1	On/off and external battery charger switch	Push toggle to right to power instrument. Push toggle to left to charge battery.
2	Channel display	Differential reading.
3	Measurement cycle and heat pulse.	Push to start when probe is in place.
4	LED on during reading time and off at end of measurement cycle.	Do not disturb probe during measurement cycle.
5	Rotary channel selector	Record readings for each position before and after measurement cycle.
6	Timer reset button	Push to reset buzzer or to interrupt a measurement cycle in process.
7	a. Span adjustment b. Sensitivity potentiometer	a. 1X = low; 4X = medium; 8X = high sensitivity. b. Turn clockwise to increase sensitivity.
8	Ammeter indicator of meter current	Use to confirm heater current flow and to check battery condition.
9	Connector to battery supply	

MODEL 40L 3-D Geoflo®



A. Control Box B. Reel Box C. Probe

Note: 1.) Plug in power jack to 18 volt supply.

2.) For laboratory test connect control box cable to reel box. Disconnect for restart.

3.) Do not connect control box cable to reel box until probe and rods are at the desired depth down the well.

GENERAL THEORY

Concept of Groundwater Velocity

The Groundwater Flowmeter measures the velocity v or Average Near Velocity (Darcy velocity) of interstitial water flow through saturated porous media. If a cross section is taken, any porous substrate, e.g. sand, has an area of void space (A_v) and solid space (A_s) which make up the total area (A_t). The porosity (p) for the cross-sectional can be defined by $p_A = A_v/A_t$. In a porous mass of three-dimensional structure, the solid is penetrated by flow paths in pore spaces. While the flow through the individual channels may be quite variable in direction and rate on a microscopic level, the average linear flow ($\bar{v}$) must equal the volume of water Q transmitted per area. The specific discharge (v) divided by the porosity equals Q/A divided by porosity (P). See Figure below.

$$\bar{v} = (Q/A)/P = v/P$$

(For more detailed discussion of macroscopic velocities, see Groundwater Prentice-Hall, Inc., Freeze and Cherry, 1979.)

Thus a mathematical expression may be derived between the volumetric transmission rate per cross-sectional area and porosity, useful in calibrating the flowmeter.

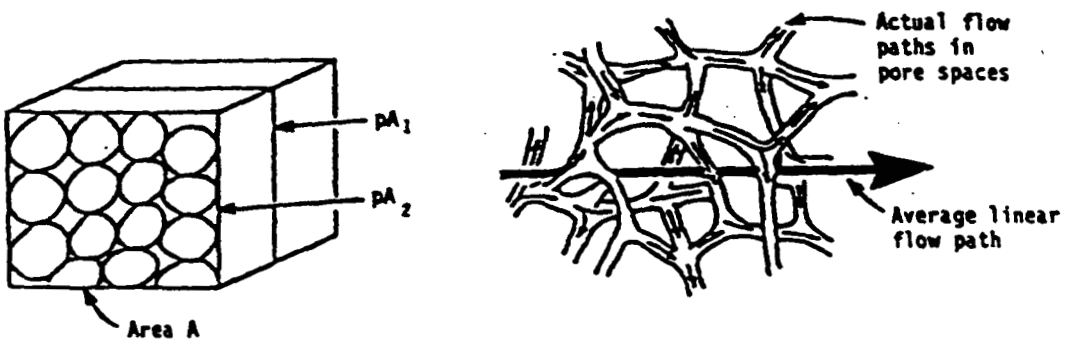


Figure 2. Concept of flow through pore spaces in soil.

Flow Rate and Direction

The submersible probe creates a transient, short duration point source of heat. The rotary switch selects one of four pairs of opposed thermistors surrounding this heat source. The relative thermal difference is displayed, the sign (- or +) of the value indicating which of the two thermistors is reading the higher temperature. With the heat source in the center of a circle of thermistors, flow of water is in the direction of temperature rise in any given pair of thermistors. The set of 8 sensors (4 pairs) has been grouped into two halves. The first group consists of thermistors 1 through 4, and the second group 6 through 9. The convention of the LCD display is that the second group's values are always electronically subtracted from those of the first group. (See figures 3A, 3B, and 4.)

For example, if thermistor 1 is hotter than paired thermistor 6, the display will be a positive value indicating flow (heat) in the direction of 1. Should thermistor 9 be hotter than 4, then flow is shown by a negative value display indicating flow towards thermistor 9. By scanning all thermistor pairs one gains information on the polar component of flow in all directions.

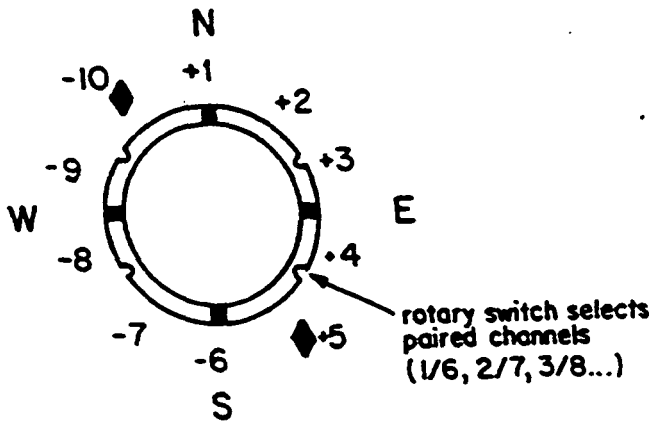


Figure. 3a

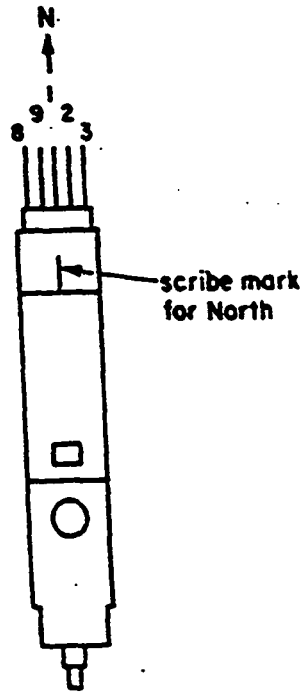


Figure. 3b

For data consistency, the convention is to always orient thermistor #1 in the magnetic North direction using compass provided.

In the NO FLOW condition (i.e. there is no water head potential), Fig. 4a, the center of the expanding heat ring remains stationary. All thermistors see the same temperature rise with time and there is no net difference between opposed pairs of thermistors.

In the FLOW condition, Fig. 4b, the center of propagation is displaced in the direction of flow, at the flow rate of the water. The propagation rate of the heat wave is much faster than the water; its rise and decay short lived also. The effect of even a very slow flow rate is thus magnified greatly. A quantitative value varying linearly with the flow may be acquired after a specific time interval. The optimal time interval for a given heater output and thermistor radius is based upon the heat conductivity of the glass bead packing material, i.e. the time when each thermistor pair sees its temperature peak.

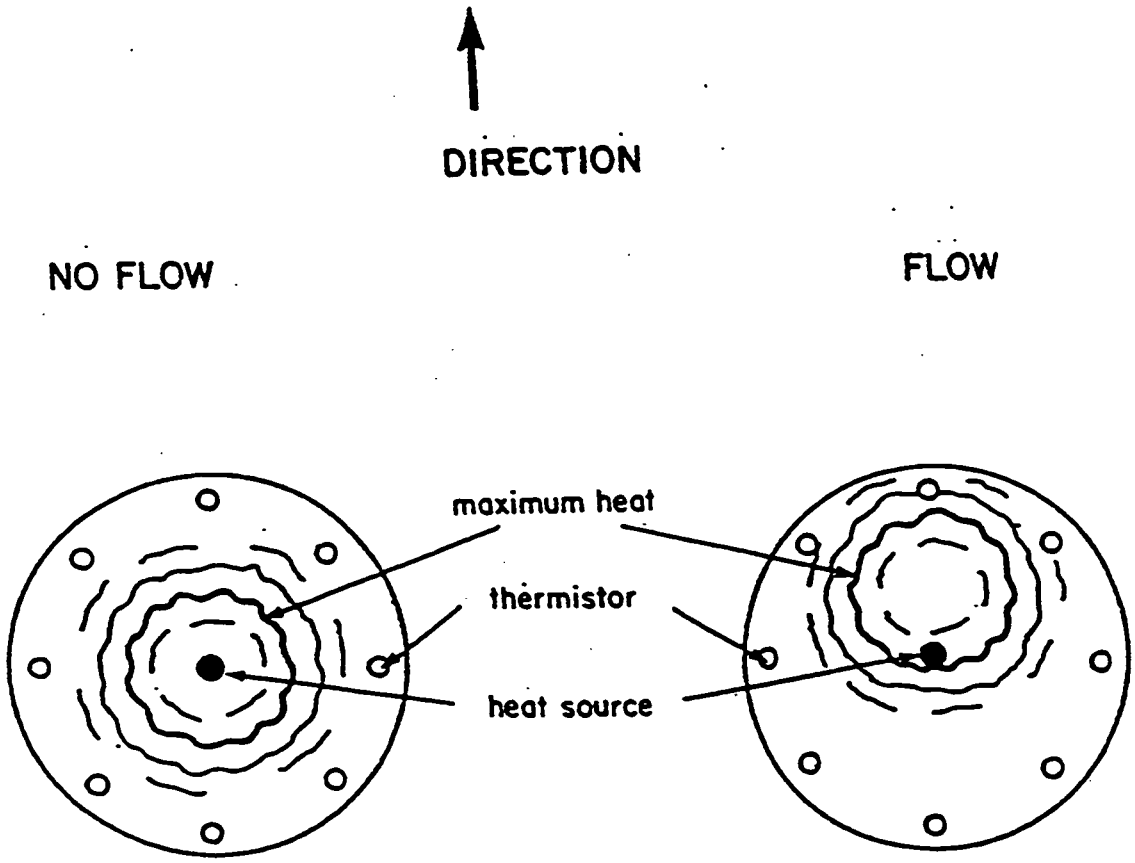


Figure 4a.

Figure 4b.

Uniformity of Flow

With steady horizontal flow, the net change in each vector readout represents a fraction of the magnitude of the flow in the principle direction, proportional as the cosine of the sensor's angular displacement from the inline flow direction. Other channels off the main axis of flow will show some symmetry in a uniform soil matrix and may deviate from symmetry when placed in non-uniform matrices where even flow is diverted by rocks, debris or recharging water flow in a freshly pumped well-casing (Figure 5). Directional results are most valid when stable water levels are maintained in the well.

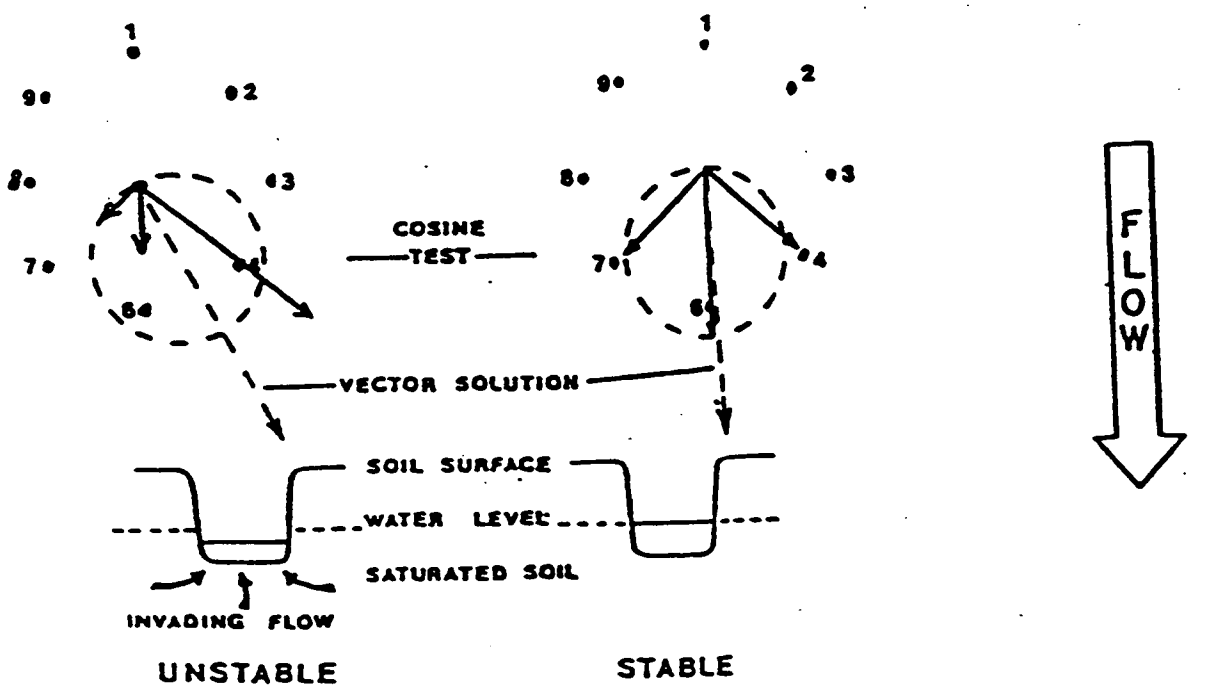


Figure. 5

Note: For 3-D probe, positions 5 and 10 are used for vertical flow.

WELL SCREEN EFFECT ON FLOW MEASUREMENT

The sensitivity and accuracy of groundwater flow measurements can vary greatly in different types of well screens. Variations in well screens such as the number of rows of slots and slot width cause the groundwater flow meter to respond differently because of differences in their resistance to uniform flow.

FLOWMETER CALIBRATION

A 6-inch or 8-inch diameter PVC flow chamber, metered flow pump, 2 graduated cylinders (10cc & 100cc), two 2", 4", or 6" fuzzy packers and glass beads are supplied for calibration and field use of the equipment.

Calibration of the instrument should precede each field study. First obtain a sample of the major soil type to be encountered or a similar one. This instrument is intended for use with permeable sandy soils. A 'SPAN' knob allows user to adjust the slope of instrument's response line. Using the calibration kit (a flow chamber etc., see Fig. 6) the user relates instrument response to preferred units of flow such as feet/day or gallons/day.

EQUIPMENT

A flow chamber and recirculating water system of low, adjustable flow rate are supplied for calibration of the instrument. See figure 6. KVA supplies a 6" or 8" diameter chamber for use in simulating groundwater flow through 2", 4" or 6" well screen (chamber may be used without well screens).

This compact flow chamber has removable end plates with #165 O ring seals and a nylon mesh screen barrier at either end to hold back sand from the inlet and outlet. The nylon screen is replaceable if necessary. A stone filter has been installed in the withdrawal side of the tube (connect this end to pump inlet) and is permanently attached to a length of 1/4" silicon tubing. This filter protects the metering pump and should be treated carefully. If you suspect filter degradation, the PVC elbow fittings are easily unscrewed and removed for replacement. The chamber is marked with a large arrow to indicate the direction of flow to be applied.

The metering pump has three speed ranges with continuously adjustable flow rates. The total range is from 0 to 30 ml/min. Use of this pump generates a steady state water flow between inlet and outlet of the flow chamber. Within each of the three flow ranges the pump rate can be adjusted by turning the vernier dial on the pump head. Measure actual drip rate in the 100 or 10 ml graduate cylinder. Measurement time may be one minute for 5 ml/min or more; two or three minutes for very low volume rates to achieve accuracy to about 0.1 ml/min. Use stop watch for timing.

Use this volume flow rate (Q) to compute flow chamber average velocity through soil matrix, assuming plug flow. Details on the calibration of flow rate are found on p.C-6.

$$\bar{V} = .146 \frac{Q}{P}$$

$\bar{V}$ = linear velocity (ft/day) Q = pump flow (ml/min) P = porosity

Note: Before beginning calibration 1. Make sure battery power is connected to unit (plug 9 into battery power jack). 2. Make sure cable is securely connected to cable box.

Setting up the Flow Chamber:

1. Pack flow chamber tightly with representative sand or soil to within 3 inches of top of chamber opening.

2. Completely fill cross section of chamber to prevent a short-circuited water path. Subsiding sand may leave open arch. (Caution: Use water at temperature of soil. Recirculating water with a noticeable temperature difference will create an unstable -constantly changing- temperature in chamber.)

3. Saturate the soil with room temperature water (the less trapped air or dissolved gases the better). Shake chamber or stir with a rod to evenly distribute soil as it is filled. Let stand to allow for subsidence, then with firm hand pressure check tops of arches of tube to assure compaction of soil in tops of tube ends. Make sure that the sand surrounding the well screen is well packed to the proper height and no short-circuit paths exist for the direct water flow between inlet and outlet. (See Fig. 6.)

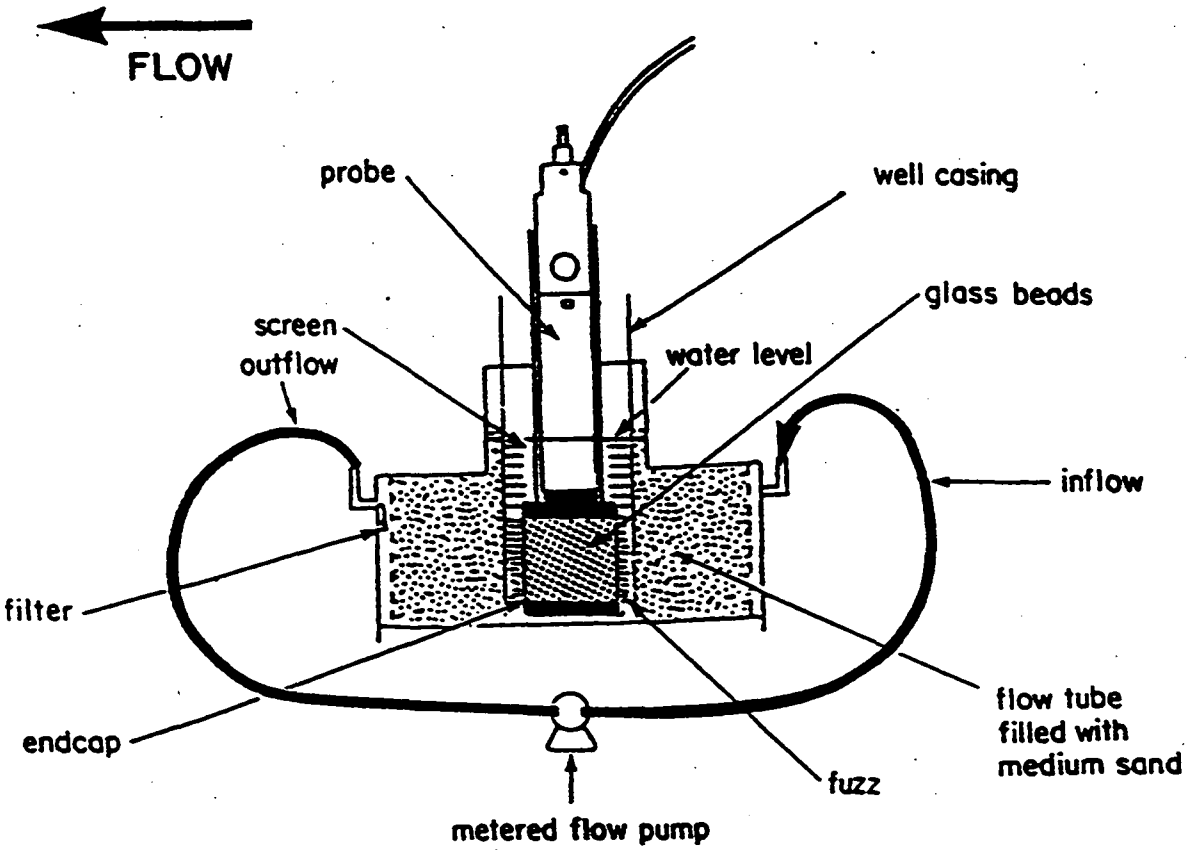


Figure 6. Calibration Kit: Flow chamber is packed with sandy soil. Water is circulated through the tube at predetermined flow rates.

4. A well screen influences the natural flow of groundwater passing through it in two primary ways: it may diminish the rate of flow (resistance) and it may modify slightly the direction of flow (deflection). Calibration of the probe for down-the-well use must then incorporate the well screen in the procedure. Obtain a short 10" to 12" length of your well screen which should have a smooth-walled interior and be of the same slit width and slit frequency as you will be encountering in your actual field well installations. Insert this section of well screen in the center port of flow chamber until it touches the bottom of the chamber. The screen may be installed by twisting it into the sand and bailing out the interior of the screen as you press it down (Use a spoon or small trowel.).

5. Fill the interior of the fuzzy packer with packing material (beads) and attach it to probe.

6. Insert probe into flow chamber as shown in Fig. 6. Orient arbitrary pair of sensors in line with axis of the chamber. To make it easier, orient N-S (1-6) in line.
   Turn instrument ON.
   Set SPAN to 4X basic calibration (see page C-11 for further explanation).

7. Allow at least 30 minutes for soil and water to come to thermal equilibrium. The height of this layer of water should be about 1/4" above the soil in the neck of the chamber. (For less permeable soils you may add tube extensions to the inlet and outlet elbow fitting to permit higher water levels to be established.

8. Set up the adjustable water recirculation system to pump water out of one end of the flow chamber and discharge into the other. A filter is attached to a length of tygon tube coming from the down-gradient end of the chamber. Connect this tube to the INLET of the metering pump. (See Fig. 6.) Flow rate can be variable between 0-30 ml/min. Switch to FWD (forward) to commence pumping. Never use REV (reverse) at the risk of sucking sand into the pump through the non-filtered tube end.

9. At a known flow rate, a measurement cycle consists of the following steps:

   a. Observe readings for each channel. Monitor at one minute intervals until a stable display or change of less than 2 units per minute is observed. Values should be within +/- 010.

   b. Record values for the four channels on a Groundwater Flow Worksheet - - Form 104 in column A. Press START button. The reading (red) light will indicate that a measurement cycle is in progress. (Note: Reading cycle can be aborted by quickly hitting "Reset")

c. When the beeper sounds, (at 2 minutes 45 seconds from the start for 40L - 3D) immediately record the values from respective channels in the 'end' column, B. Do not forget to record sign either (+) or (-). Press RESET button to silence buzzer.

d. Subtract column A ('start') from column B ('end'). The difference (column C) represents the component of flow in that sensor direction.

For the next step you should rotate the probe 180° and repeat the procedure: a,b,c, but recording values in columns D, E, and S, respectively.

Subtract column D from E. The difference (Column S) represents the component of flow in that sensor direction. (The procedure of 180° rotation corrects for thermal bias. If any thermistor is too close to the heater, it would give a reading of being hotter. This is not due to flow but to static position.

For correcting bias, subtract column S from C and enter the result divided by 2 in column F. Column F is the bias-corrected value for flow. This is used with calibration curve to give true velocity (v). Take the highest value of the 4 pairs as the strength of the flow velocity. The channel it corresponds to should be aligned with the axis of the flow chamber. Using G values plot them on the polar graph portion of the work sheet, paying proper attention to sign (positive/negative values). The arrows always should be pointing to the number with the correct sign (+ or -). Radii 1,2,3,4, are assigned positive values, radii 6,7,8,9, are assigned negative numbers. The direction is solved geometrically by plotting a line from the origin through the center of the circle formed by the vectors. (For details, see p. C-8, Fig. 8, vector resolution.) To determine flow rate, match the value from column F for the diameter of the circle, (machine reading value), to the corresponding flow rate on your calibration curve. (For detail, see calibration curve, p. C-7.)

You may use the HP-41C or TI-58/59 program "4 VADD" (optional) to get a more precise computation of angle and rate, using vector addition (see vector resolution, p.C-8).

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	-6	+128	+134
+2/-7	+15	+98	+83
+3/-8	+24	+38	+14
+4/-9	+23	-91	-114

Operator: L.K. Date: 12/12/88

Station: 206 Time: 3:00 P.M.

Location:

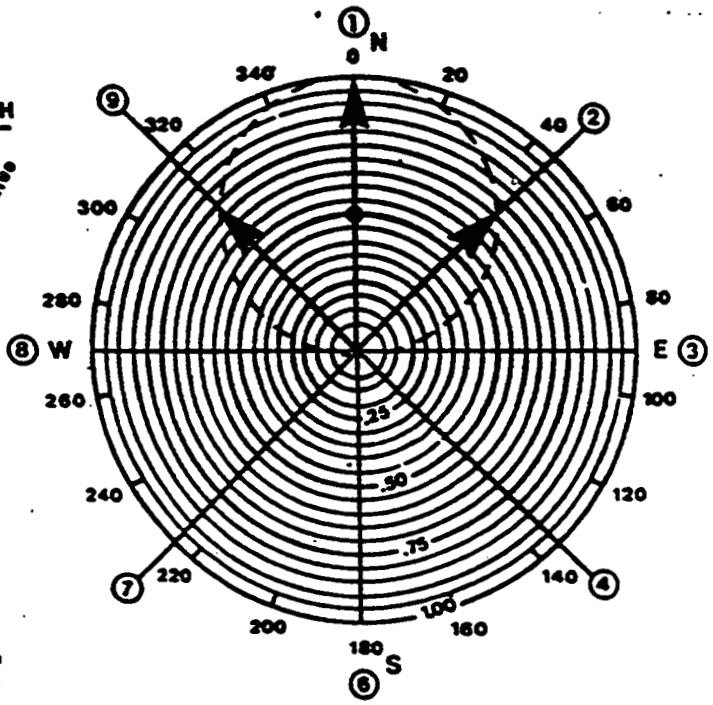
Soil Conditions: Annular

Depth to Measurement: 6" flow chamber

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	+5	-164	-169	+151	1
+2/-7	+14	-120	-134	+108	.72
+3/-8	+14	+14	0	+7	.05
+4/-9	+7	+96	+89	-101	.68

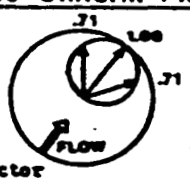


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: 1.5° Velocity: 4 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

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PREPARATION OF CALIBRATION CURVE

COMPUTE POROSITY or void volume of representative soil.

a. Place 25 ml water in a graduated cylinder.

b. Add dry soil to the water in the cylinder, tap sides to pack to the 25 ml level and dislodge air bubbles.

c. Record water level (V = ml) which is now greater than 25 ml.

porosity = void fraction = $1 - \left(\frac{V-25}{25}\right)$

COMPUTE FLOW CHAMBER VELOCITY, using the formula:

$$\text{lateral velocity (ft/day)} = \frac{Q \times K}{\text{Porosity}}$$

Where Q = pump flow (ml/min)
K = conversion constant for the 6" flow chamber = 0.26
for the 8" flow chamber = 0.146

CONSTRUCT A CALIBRATION CURVE. Observe the instrument response with at least three different flow rates through the flow chamber, covering the range of groundwater flows anticipated (commonly 0-25 feet/day). See Figure 7. In order to draw the curve, measurements from at least 3 different flow rates are required.

Begin the calibration curve from the highest value of flow rate and work downwards. We suggest a flow rate near 10 ft/day for the first value.
In a similar manner, perform measurements of flow at the mid range and the low range of flow desired.
The instrument should be back to equilibrium at 15 minutes from reading time (start).

Helpful Hints

Learn to take readings quickly at the sound of the beeper, remembering 3 or 4 values before writing them down.

Do not forget to rotate the probe 180° for a bias-subtracted reading. Ignore the reading on channels 5 and 10 during horizontal flow calibration.

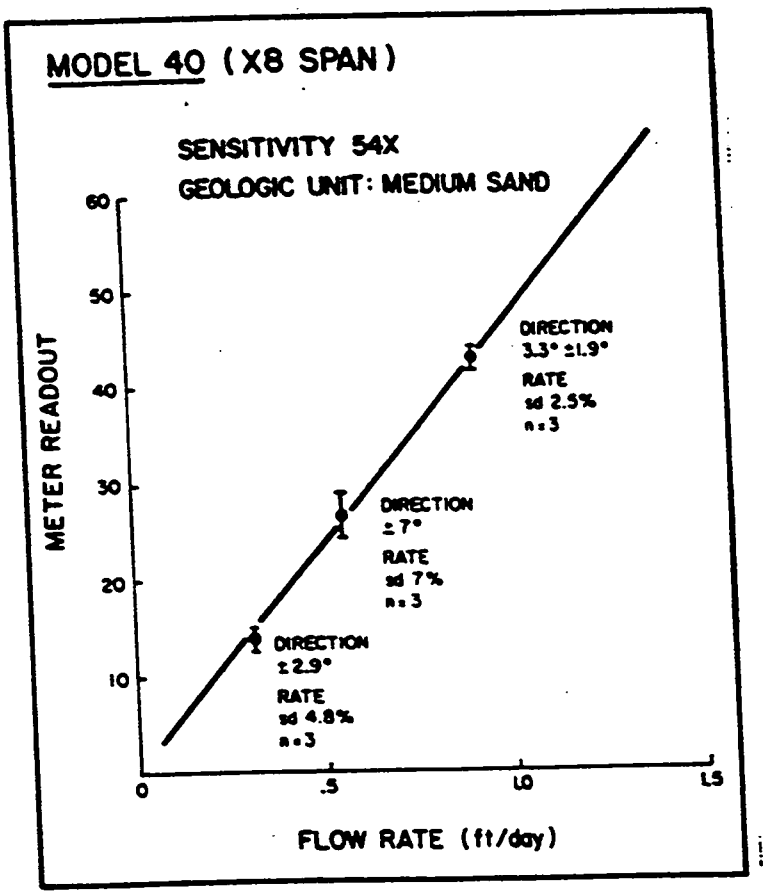

Figure 7.

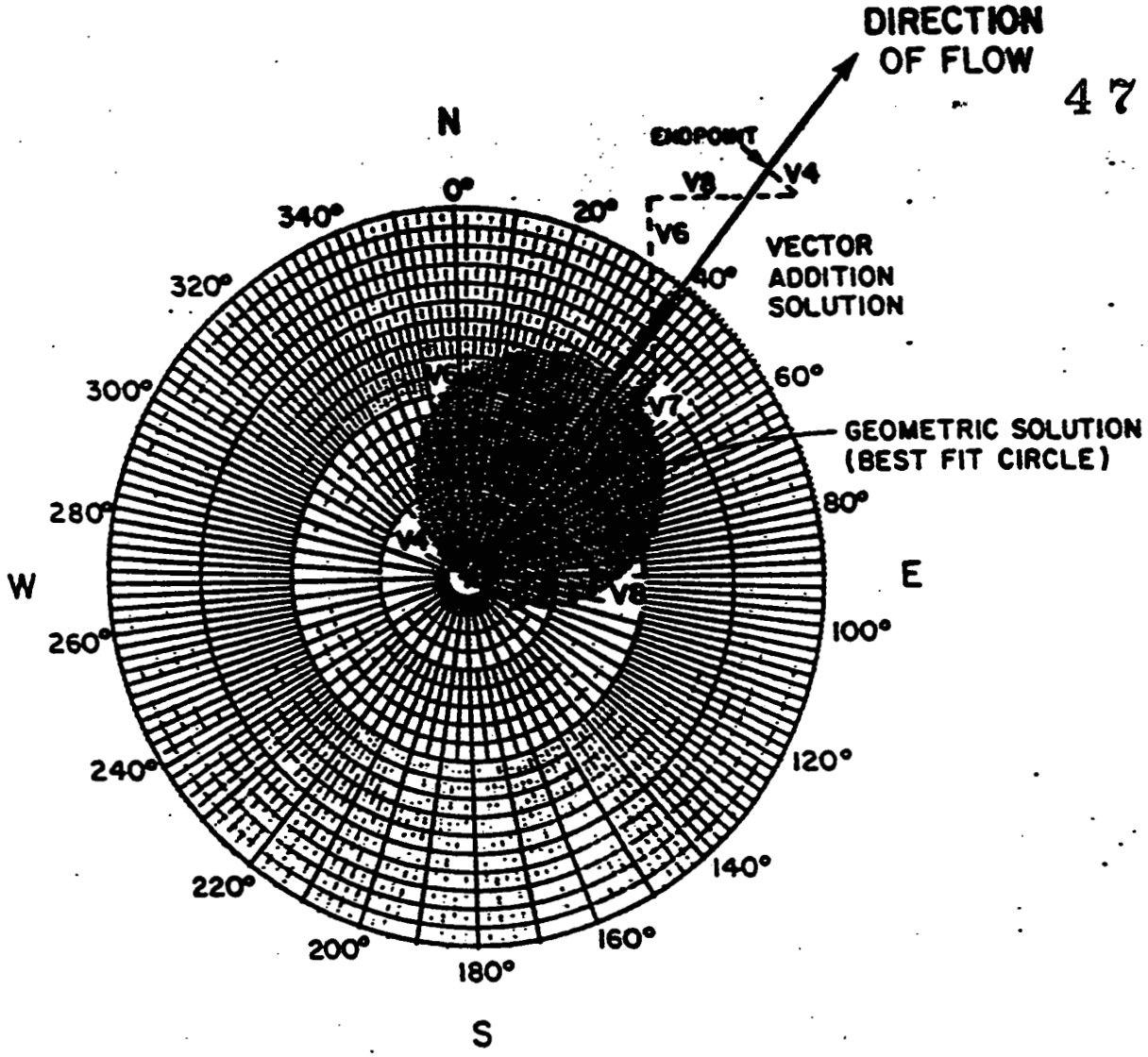

Figure 8.

VECTOR RESOLUTION

To solve graphically, plot the various vector lengths from Column F of the Groundwater Flow Worksheet on polar graph paper.

Starting at the end of the longest vector, in this case channel 7, draw the vectors head to tail, keeping their respective lengths and directions the same.

After redrawing the 3 other vectors, a line drawn from the center through the head of the last vector will intersect the outermost circle of the paper at a degree reading representing the principal direction of flow, in this case 39° northeast.

Divide the total length of the 4 vectors by 2.0 to obtain mean vector length along main axis of flow. This is equal to the diameter of the circle in the geometric solution.

SPAN ADJUSTMENTS

The SPAN switch can be set to accommodate different field flow conditions:

1X: measurements of relatively high flow rate (e.g. greater than 10 feet per day).
lakeshores, dam bases, near pump tests

4X: measurements of medium flow rate (e.g. 1 to 10 feet per day).
monitoring wells

8X: measurements of slow flow rate (e.g. less than 1 foot per day).
wells in tight soil (silt and clay), flow near groundwater divides, top of freshwater lens

By calibrating on 4X, you are then free to lower sensitivity to 1X (1/4 as sensitive) or raise it to 8X (twice as sensitive) according to field conditions.

Do not adjust the sensitivity potentiometer.
This is used by the manufacturer for instrument adjustment of different probes.

MAINTENANCE

Only simple routine maintenance is required.

* Rinse probe and cable free of sand, dirt and debris after use and prior to repacking into case.

* Inspect probe sensors regularly for straightness. This is important because precision of readings is related closely to uniform spacing of sensors.

* Keep batteries charged.

* Probe is filled with mineral oil for pressure protection. After extensive use, oil may have to be added to bring up to original volume.

Battery and Heater Circuit Condition

Monitoring your ammeter on the instrument panel will indicate the status of battery and heater circuits. With the heating element not activated, the circuit draws about 85mA (not reflected on the ammeter). When heater is activated the panel ammeter should read about 2 amps for proper operation. A higher reading may indicate a malfunction of the heater tip. Lower reading indicates a need for battery recharge. Recording the amperage of the heater during measurement allows a quick notification of the need for recharge.

Battery Charging

* Recharge only with charger supplied with equipment in which the batteries are to be used. Other chargers may reduce battery life.

* 12 - 20 hrs. is usually sufficient to bring the battery to full charge.

* Recharge as soon as possible after each use.

* Preferred storage temperature is 70° F or below. The battery should be fully charged before storing and be recharged at six-month intervals. Higher temperatures required more frequent charging. Storage at temperatures above 100° should be avoided.

* When operating time after a full charge is no longer satisfactory, it is time to replace the battery.

Both 12v and 18v battery chargers have been provided and may be plugged into their appropriate jacks. (Fig. 11 and 12.) To charge the 12v batteries in the deck box, the main power switch must be moved to the CHG (charge) position. The instrument will not operate in the charge mode, nor charge in the ON mode.

There is no switch associated with the 18v charger jack in the deck box lid.

Fuse and Battery Access

* Remove four panel screws and lift up panel (POWER SHOULD BE OFF!)
  1 amp AGC fuse is mounted in a fuse block on the right rear of the panel. It can be easily removed by a fuse puller tool.

* Battery can be lifted out if necessary.

Transporting Instrument and Accessories

For best protection during cargo shipment, thoroughly pack the instruments. Formica instrument cases are not adequate protection against the hazards of cargo handling. Five heavy batteries are mounted inside the deck box and must be cushioned against shock.

APPENDIX

USING COMPUTER PROGRAM LABELED "4VADD" FOR HP-41C for 1988

SCOPE: For use with the K-V Associates, Inc. Model 40 series Groundwater Flowmeters, this program takes as input the (bias corrected) net change for each of the four vector inputs of a flow measurement, and computes the vector addition resultant angle and normalized resultant vector length. Following display of these results, the program may be called for display of individual values of each of the four vector inputs normalized to the resultant vector length.

OPERATION:

1. Using magnetic card reader, read card program into HP-41C calculator. the program consists of one magnetic card comprising two tracks.

2. For convenience, assign the program "4VADD" to a USER defined key (e.g. "1/x").

3. To run, press USER defined key. (Then exit from USER mode.)

4. Program will prompt with a beep tone for each of the five vector input values in turn, starting with "R1=" (this is the 1/6 channel). The value input should be the net change after a flow reading as corrected by any zero offset (bias) value. Be sure to enter the correct polarity sign. After entering number, press "R/S" to continue.

5. After "R4" has been entered and "R/S" pressed, the program will compute the resultants. The display will first show "velocity=" and after 4 seconds, show "ANGLE=". All decimal places will be suppressed.

6. Press "R/S" key to display the individual vector fractions of the resultant. Labeled "R1=" through "R4", they will appear to 2 decimal places, about 2 seconds apart. This information is useful in graphing results on Groundwater Flow Worksheet Form 104, for assessing symmetry.

NOTE: For consistency in data handling, use either this program or hand processed graphical results. Estimates derived from use of the Groundwater Flow Worksheet may e less precise than the computer program, where such precision of data computation is less important.

Normalized resultant vector length means that the resultant of 4 vector additions is divided by 2.0 which is the length of the resultant of 4 perfectly cosine distributed vectors whose longest (middle) vector is of unity length (See diagram on Groundwater Flow Worksheet). This process yields a more credible result processing nonsymmetrical vector distributions than does the simpler manual method.

HP-55 Program Form

Title "4VADD" ADDITION PROGRAM FOR 4 CHANNEL PROBES Page 1 of 1

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Press [BST] in RUN mode, switch to PRGM mode. Then key in the program.

DISPLAY LINE	DISPLAY CODE	KEY ENTRY	X	Y LINE	Z	T	COMMENTS LINE	COMMENTS
00.				50	TVELOCITY =		100	/
01.		LBL T4VADD		51	ARCL X		101	TR4 =
02.		BEEP		52	AVIEW		102	ARCL X
03.		FIX 0		53	STO 12		103	AVIEW
04.		0		54	PSE		104	PSE
05.		STO 01		55	PSE		105	PSE
06.		45		56	PSE		END	REG 47
07.		STO 02		57	PSE			
08.		72		58	X<>Y			
09.		90		59	X<0?			
10.		STO 03		60	XEQ 03			
11.		108		61	X<>Y			
12.		135		62	TONE 5			
13.		STO 04		63	TANGLE =			
14.		RCL 01		64	ARCL Y			
15.		ΣREG 11		65	AVIEW			
16.		CLΣ		66	GTO 01			
17.		TONE 7		67	LBL 03			
18.		TR1		68	360			
19.		PROMPT		69	+			
20.		STO 06		70	RTN			
21.		P-R		71	LBL 01			
22.		Σ+		72	STOP			
23.		RCL 02		73	FIX 2			
24.		TONE 7		74	RCL 06			
25.		TR2		75	RCL 12			
26.		PROMPT		76	/			
27.		STO 07		77	TR1 =			
28.		P-R		78	ARCL X			
29.		Σ+		79	AVIEW			
30.		RCL 03		80	PSE			
31.		TONE 7		81	PSE			
32.		TR3		82	RCL 07			
33.		PROMPT		83	LAST X			
34.		STO 08		84	/			
35.		P-R		85	TR2 =			
36.		Σ+		86	ARCL X			
37.		RCL 04		87	AVIEW			
38.		TONE 7		88	PSE			
39.		TR4		89	PSE			
40.		PROMPT		90	RCL 08			
41.		STO 09		91	LAST X			
42.		P-R		92	/			
43.		Σ+		93	TR3 =			
44.		RCL 13		94	ARCL X			
45.		RCL 11		95	AVIEW			
46.		R-P		96	PSE			
47.		2.0		97	PSE			
48.		/		98	RCL 09			

REGISTERS: R0, R1, R2, R3, R4, R5, R6, R7, R8, R9, R.0, R.1, R.2, R.3, R.4, R.5, R.6, R.7, R.8, R.9

000277

p. E-2

HEWLETT PACKARD

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

Table of LCD Readout

1→N

Probe pair	A (start)	B (end)	C (B-A)
+1/-6	+2	+102	+100
+2/-7	+2	+70	+68
+3/-8	+14	+28	+14
+4/-9	+8	-58	-66

Operator: L.K. Date: 1/12/89

Station: L06 Time: 3:00 P.M.

Location: M40-3D special packer

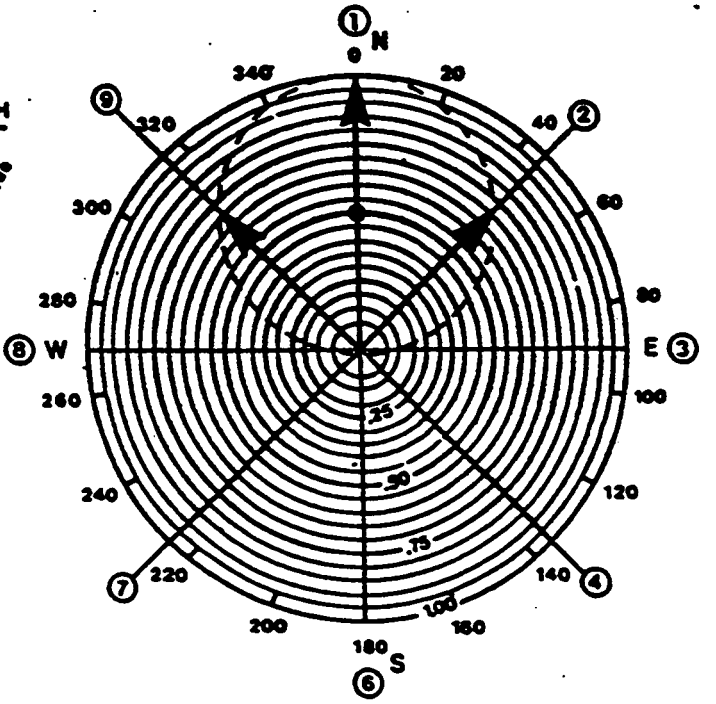
Soil Conditions: med. sand

Depth to Measurement: 8' chamber

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D (start)	E (end)	S (E-D)	F (N-S)/2	G (F/max. value)
+1/-6	0	-88	-88	+94	1
+2/-7	0	-64	-66	+67	.71
+3/-8	+10	+15	+5	+4.5	.05
+4/-9	+12	+76	+64	-65	.69

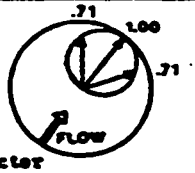


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 calculators
OR
2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: 1.5° Velocity: 7 ft/day

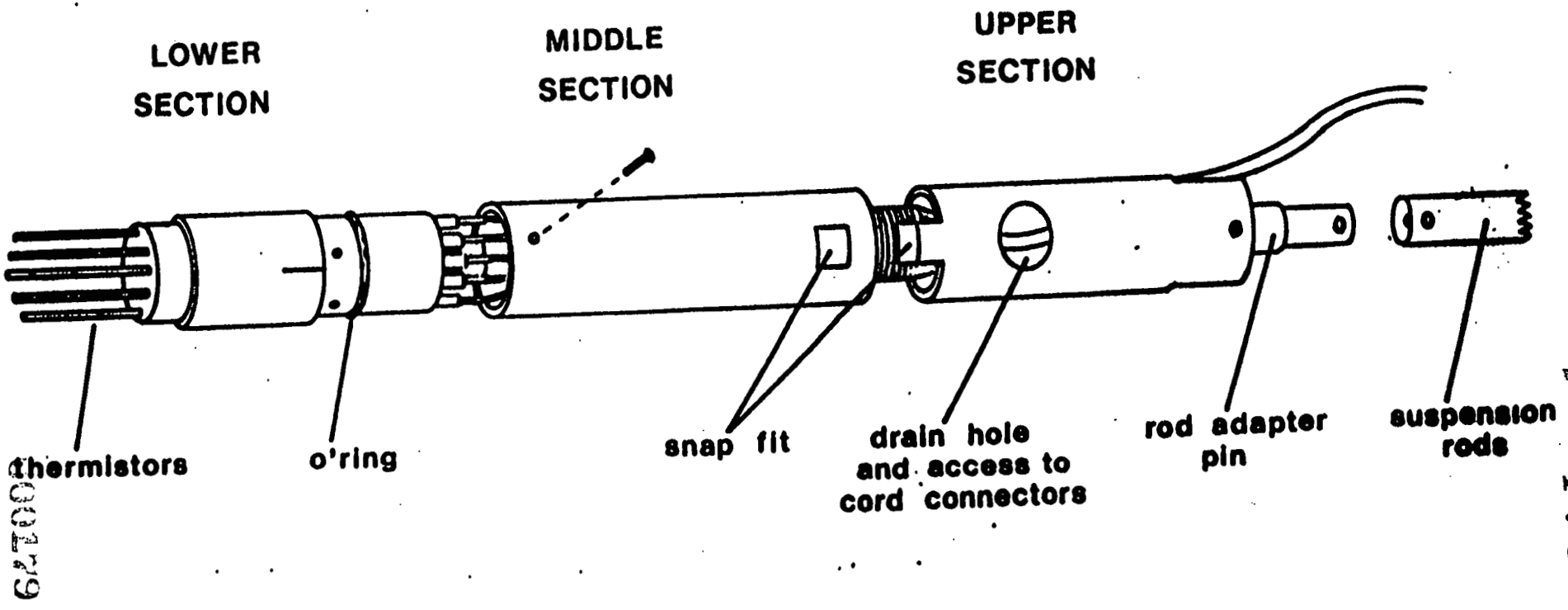
Form 104 available from your local K-V Associates, Inc. dealer.

Copyright 1981 K-V ASSOCIATES, INC., Falmouth, MA 02540 9/82

000178

Figure 11.

MODEL 40L PROBE ASSEMBLY



00179

MONITORING WELL PREPARATION

The Model 40 probe is used to measure water flow in the water zone down to 250 feet below the groundwater surface. It is useful to pack with pea gravel or coarse sand outside the well to stabilize flow through the well screen. (Fig 12.) The interior of the well casing should be smooth, with flush fitting joints. It is possible to verify that well bore is free of obstructions by lowering a clearance test plug, such as a metal cylinder or reamer. This will ensure that the probe will travel freely up and down the well casing.

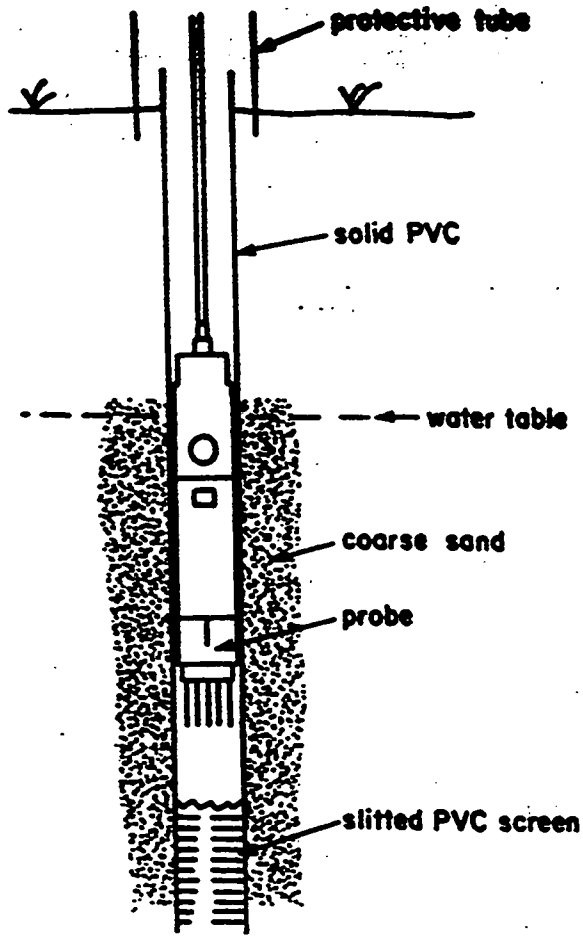


Figure 12.

FUZZY PACKERS ASSEMBLY

For down well use, the Model 40 probe is fitted with a fuzzy packer filled with uniform glass beads. The mesh screen of the fuzzy packer retains the glass beads matrix equal or more permeable than that in which you will be taking measures (See Fig. 13). Fill fuzzy packer just above the bottom of the upper PVC collar. Fit fuzzy packer to the probe.

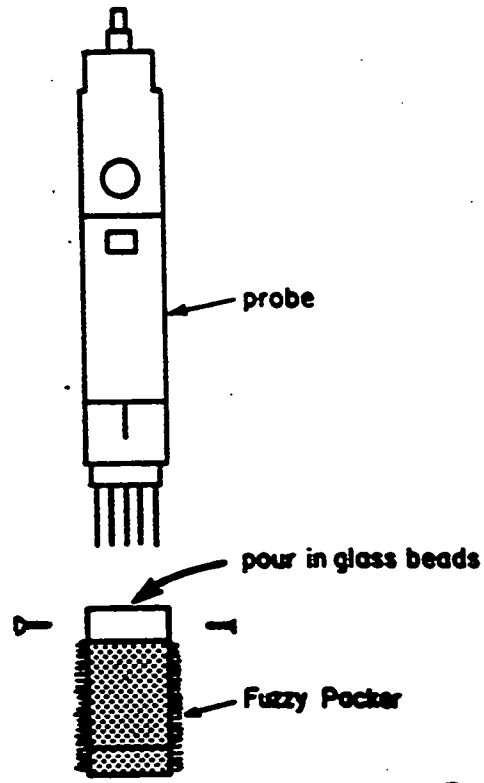


Figure 13.

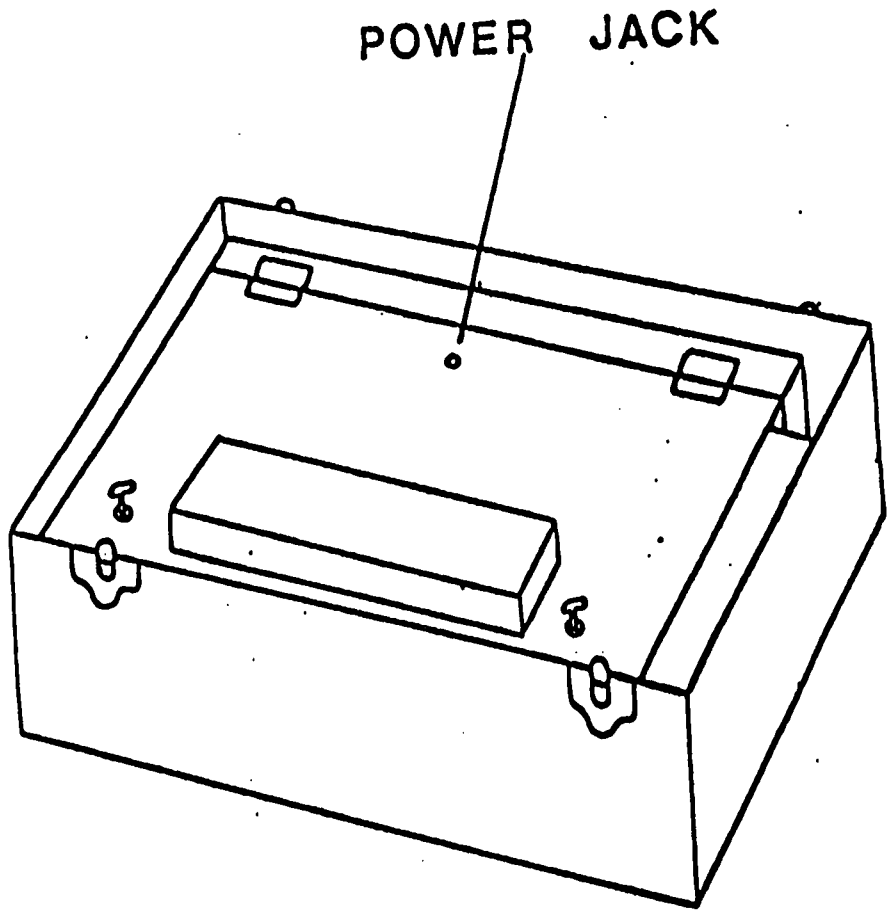


Figure 14. Model 40L, 18 volt battery pack located in deck box lid. Line cord from deck box plugs in here for 18 v power supply. Use same jack for charging 18 v battery pack with 18 v table top battery charger.

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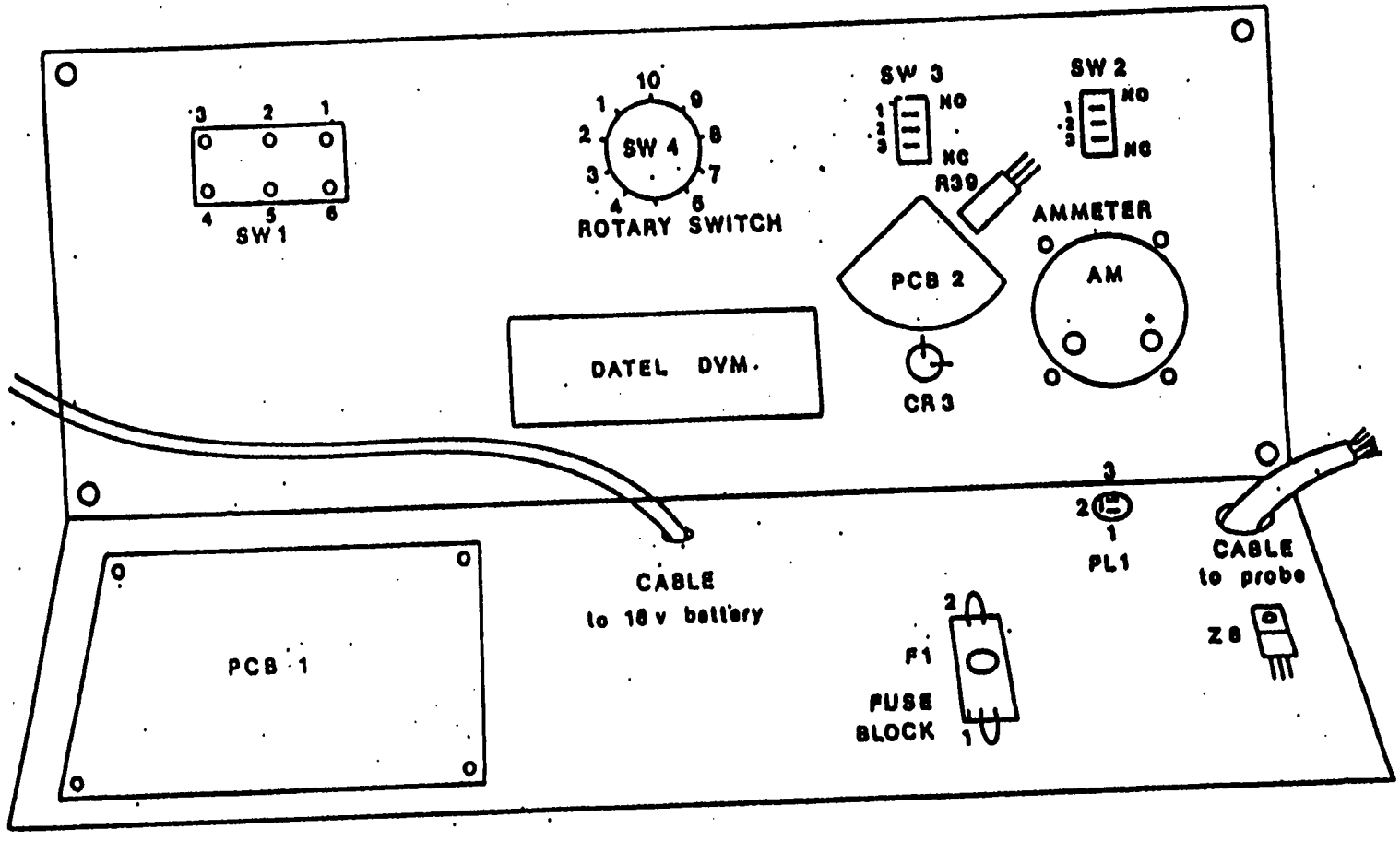
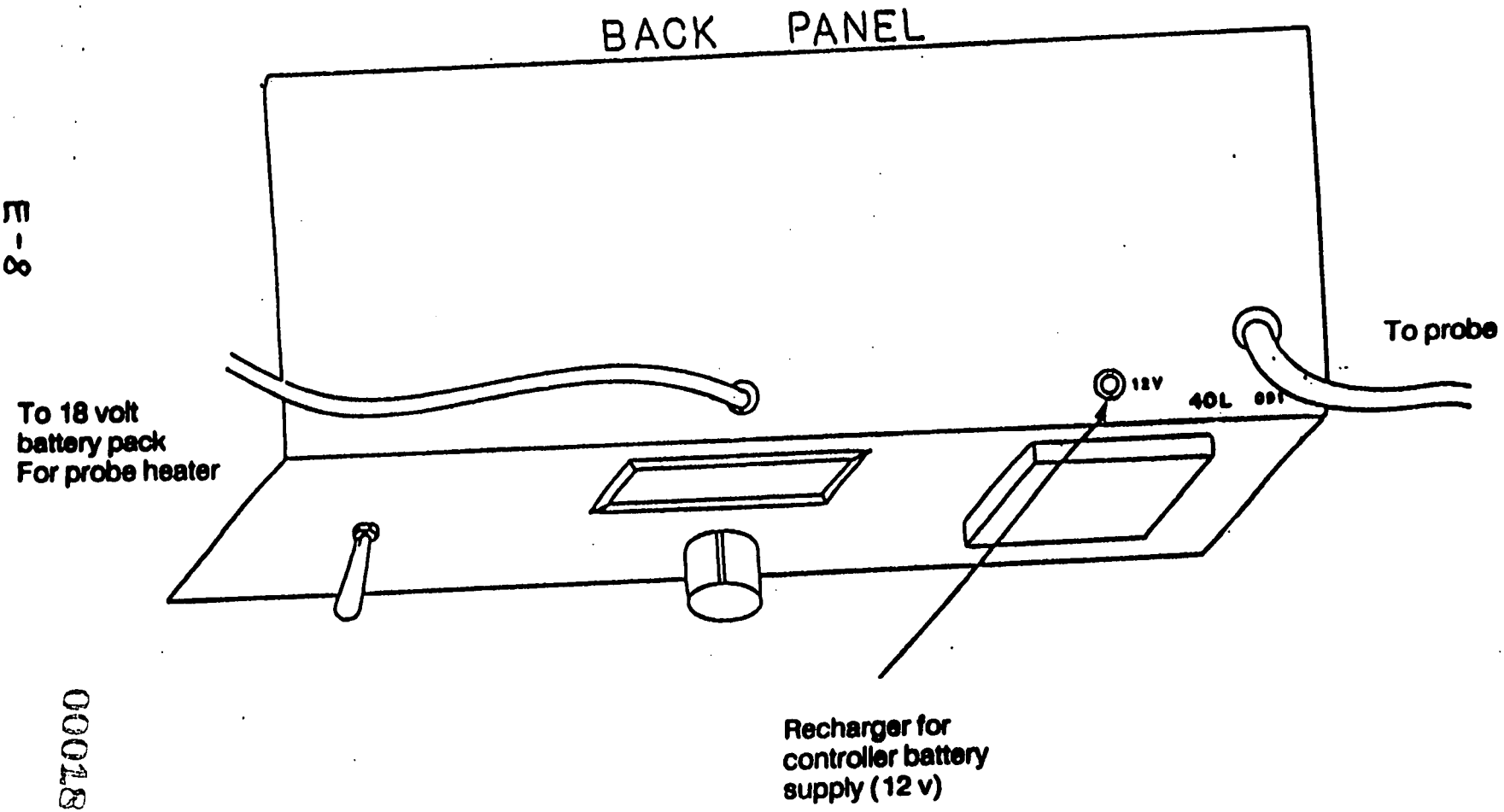
Figure 15. INSIDE PANEL VIEW - MODEL 40L



000182

4 2 5

Figure 16. Access to 12 v battery charger port is on back panel.



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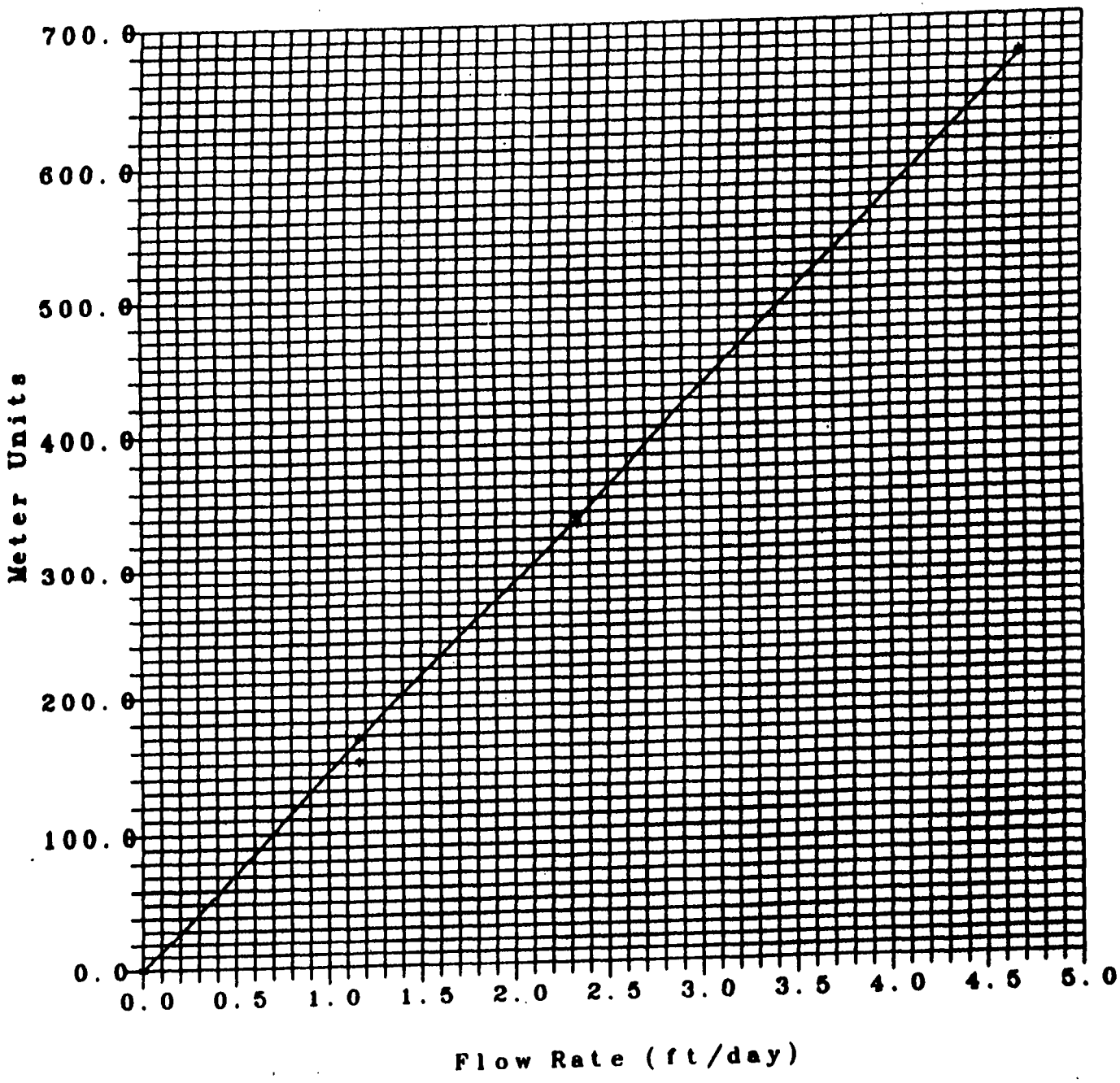
Attachment II

Flow Calibration Curve Unit 1

Meter + Box 1
Based on porosity of 0.25

$X = \frac{Y}{143.479}$

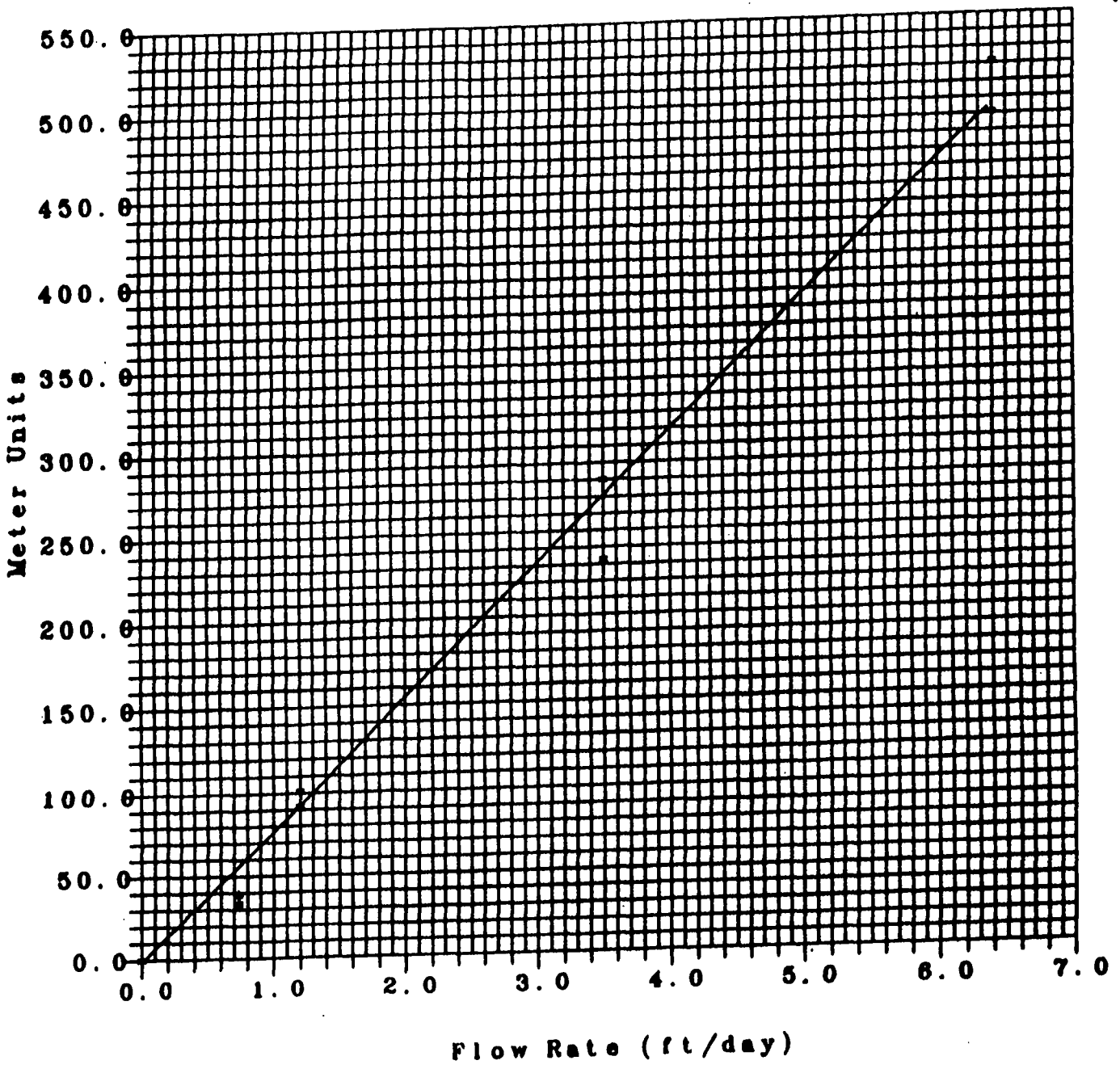


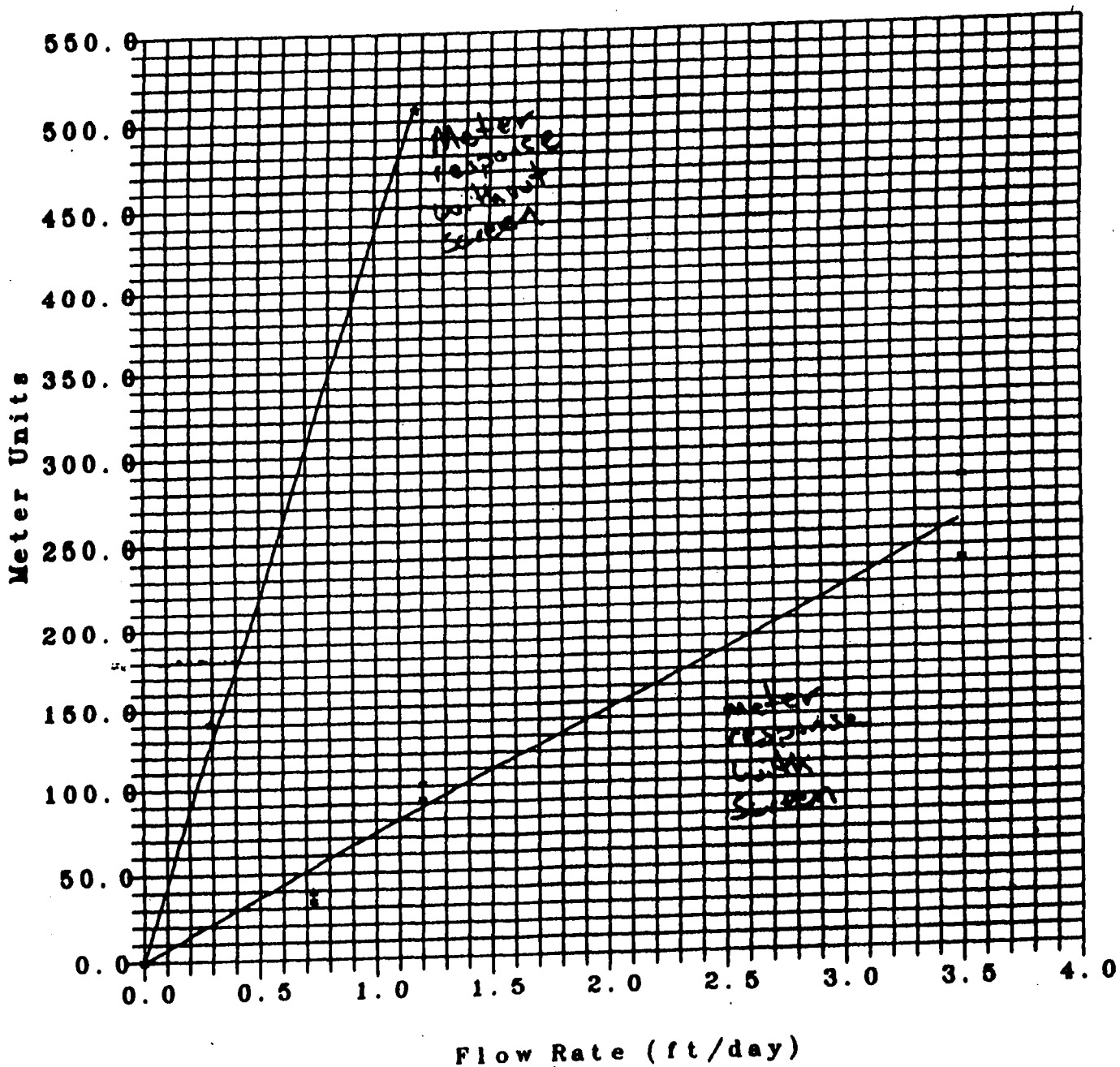
000285

Flow Calibration Curve Unit 2

Meter & Box 2
Based on porosity of 0.25

$X = \frac{Y}{77.77}$




550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Meter Units
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Flow Rate (ft/day)
Meter response without screen
Meter response with screen

1

2

3

4

Attachment III

5

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A Start	B End	C B-A
•1/-6	+32	+70	+48
•2/-7	+20	+49	+29
•3/-8	+15	-37	-52
•4/-9	+14	-66	-80

Operator: JOHN J. BEZARE Date: 4-18-96

Station: #1 Time: 9:53

Location: 11681

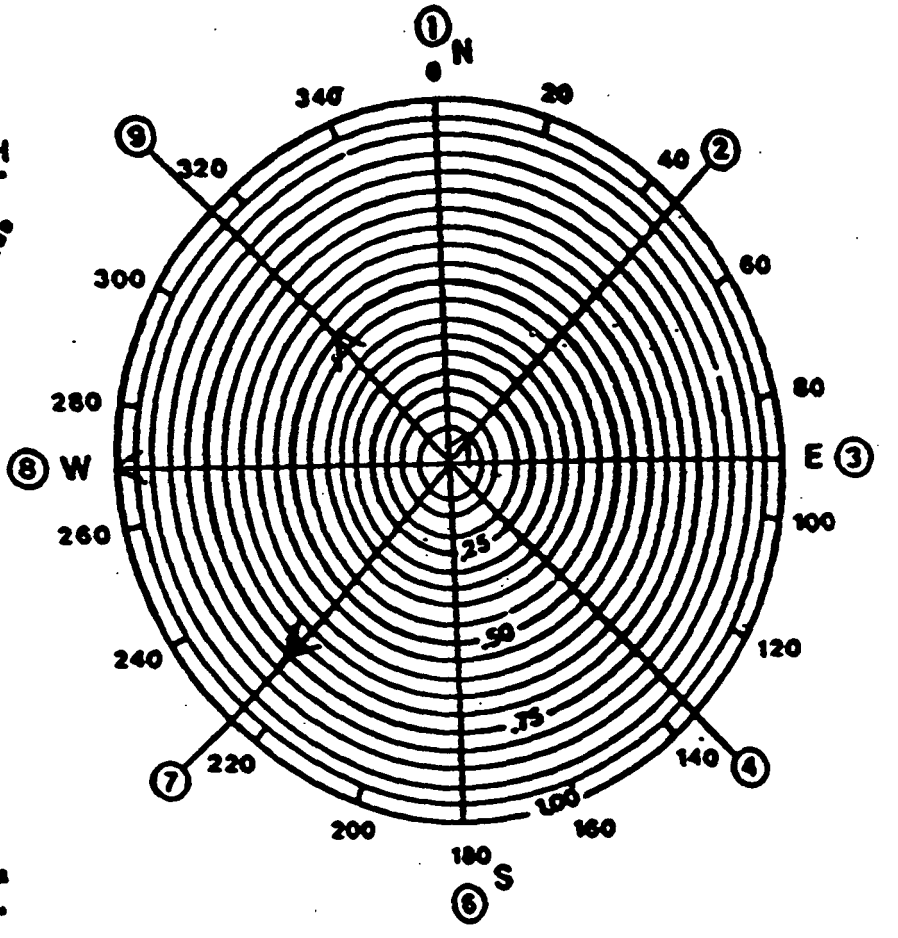
Soil Conditions:

Depth to Measurement: 13' TOW

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D Start	E End	S E-D	F N-S/2	G F/max. value
•1/-6	+33	+76	+43	+25	
•2/-7	+30	+86	+56	-13.5	
•3/-8	+28	+12	-16	-18	
•4/-9	+23	-39	-62	-9	

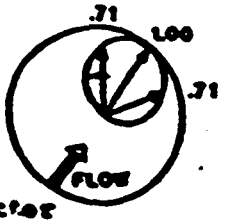


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program for calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: W Velocity: .12 ft/day

44 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
•1/-6	0	-12	-12
•2/-7	+20	+43	+23
•3/-8	+15	+79	+64
•4/-9	+15	+54	+39

Operator: DAVID BERRETZ Date: 4-16-96

Station: A-2 Time: 2'20

Location: 11685'

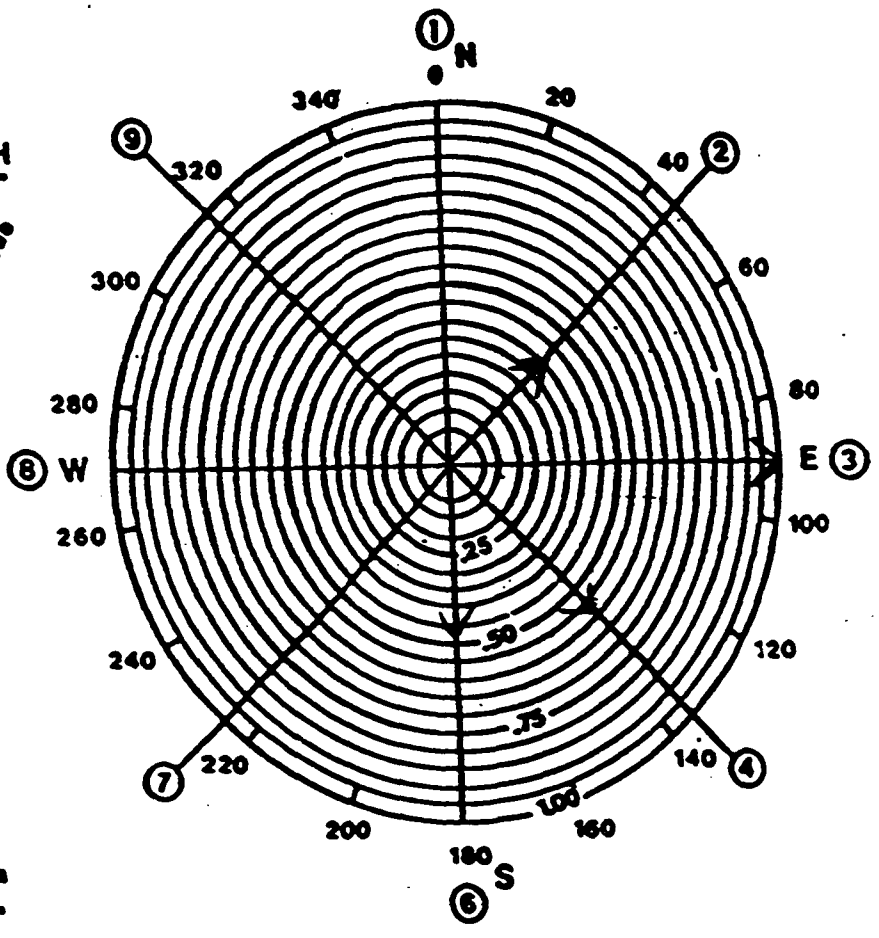
Soil Conditions:

Depth to Measurement: 17.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
•1/-6	0	+1	+1	-6.5	
•2/-7	+7	+23	+16	+3.5	
•3/-8	0	+37	+37	+13.5	
•4/-9	+4	+22	+18	+10.5	

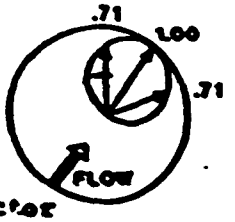


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: E Velocity: .17 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

000190

62 ft/yr

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	-15	-27	-12
+2/-7	0	+21	21
+3/-8	-14	+55	69
+4/-9	+7	+53	46

2.15 Amps

Operator: Brett Smith Date: 4/17/96

Station: 11685 Time: 9:30

Location: #2

Soil Conditions:

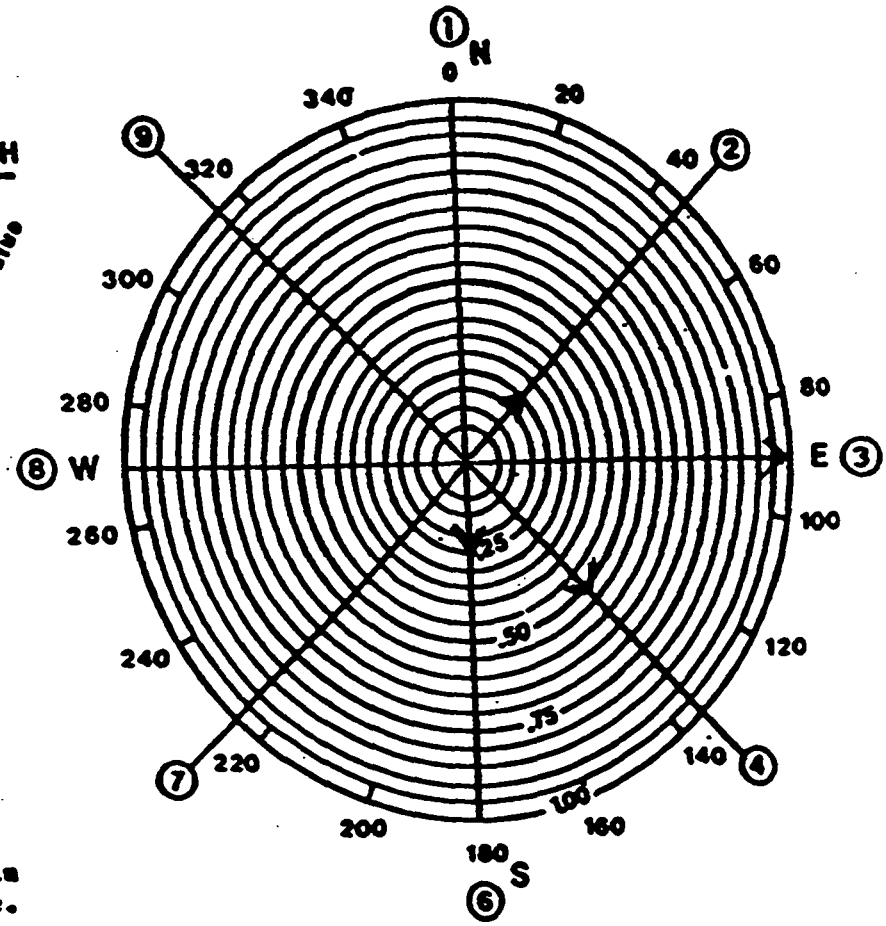
Depth to Measurement: 175'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F (N-S)/2	G F / max. value
+1/-6	+1	0	-1	-5.5	
+2/-7	+20	+30	10	+5.5	
+3/-8	+12	+52	40	19.9	
+4/-9	+11	+38	27	10.5	

2.1 Amps

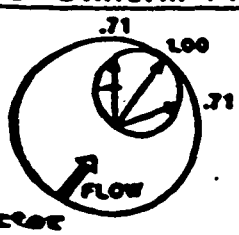


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths [illegible] right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/59 programmable calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: E Velocity: .25 ft/day

000191

Form 104 available from your local K-V Associates, Inc. dealer.

91 ft/yr

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	0	1	1
+2/-7	40	50	40
+3/-8	0	87	87
+4/-9	5	63	58

2.2 Amps

Operator: Brett Smith Date: 4-16-96

Station: 11685 Time: 9:18

Location: #2

Soil Conditions:

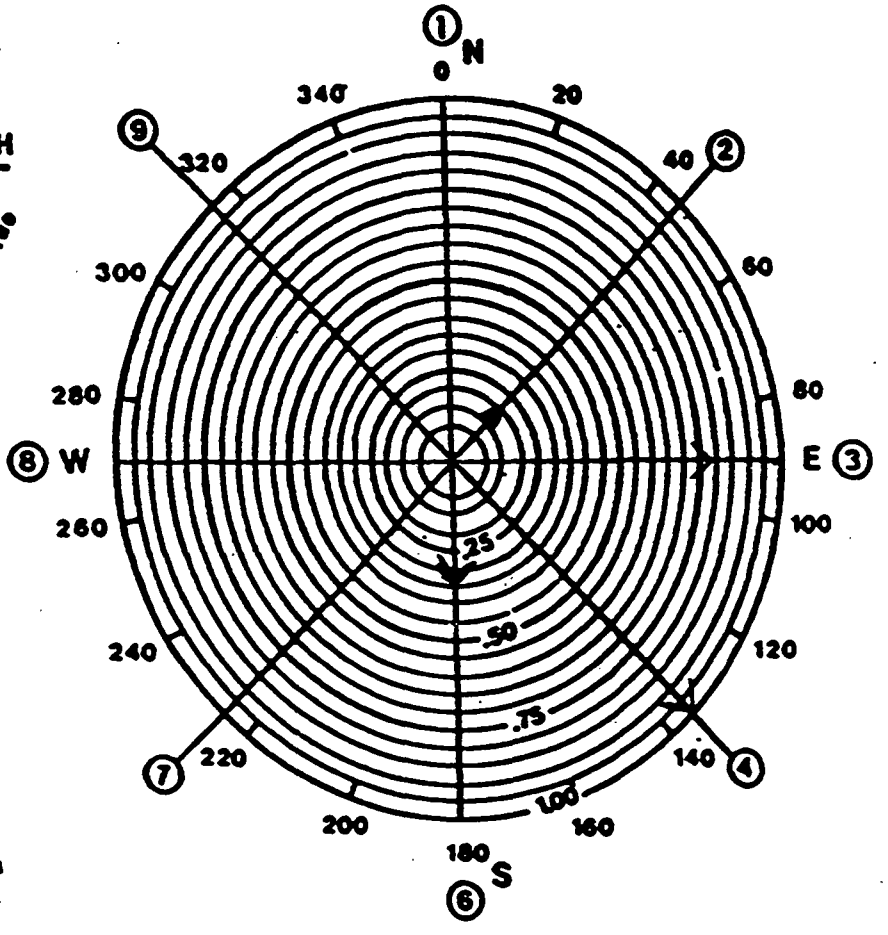
Depth to Measurement: 17.5' TOW

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	0	13	13	-6	
+2/-7	+5	46	31	4	
+3/-8	+8	60	52	125	
+4/-9	+10	32	22	18	

2.2 Amps

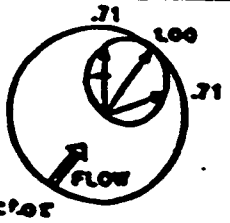


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths almost right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: ESE Velocity: .16 ft/day

000192

58 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	0	+17	+17
+2/-7	+15	+71	+56
+3/-8	+6	+84	+78
+4/-9	+7	+44	+37

2.2 amp

Operator: JOHN BERRETT **Date:** 4-11-95

Station: #2 **Time:** 9:30

Location: 11687

Soil Conditions:

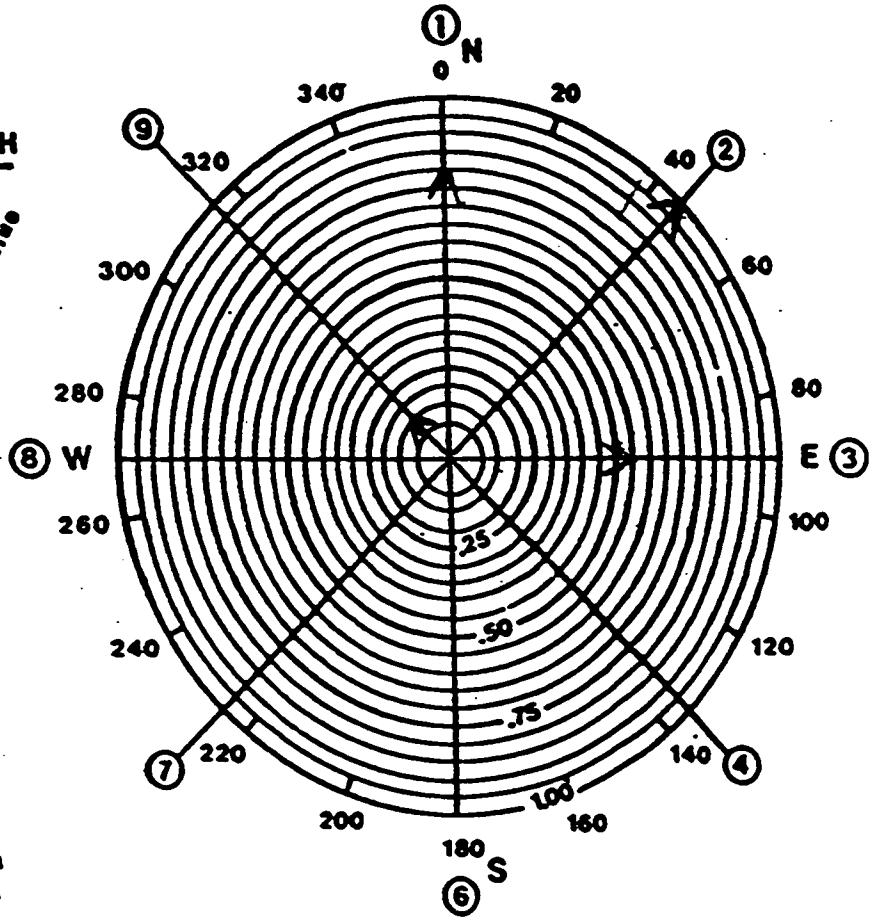
Depth to Measurement: 13.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F / max. value
+1/-6	+0	-15	-15	+16	
+2/-7	+16	+33	+17	+19.5	
-8	+6	+63	57	+10.5	
+4/-9	+6	+49	41	-2	

2.2 amp

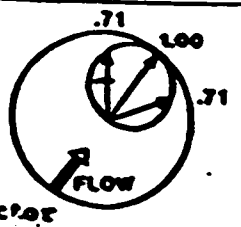


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NE **Velocity:** .25 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

91 ft/yr

000193

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	+25	-29	-54
+2/-7	+13	-33	-46
+3/-8	+18	-50	-68
+4/-9	+23	0	-23

2.2 amps

Operator: JOHN J. BERRETZ Date: 4-12-96

Station: #1 Time: 8:37

Location: 11693

Soil Conditions:

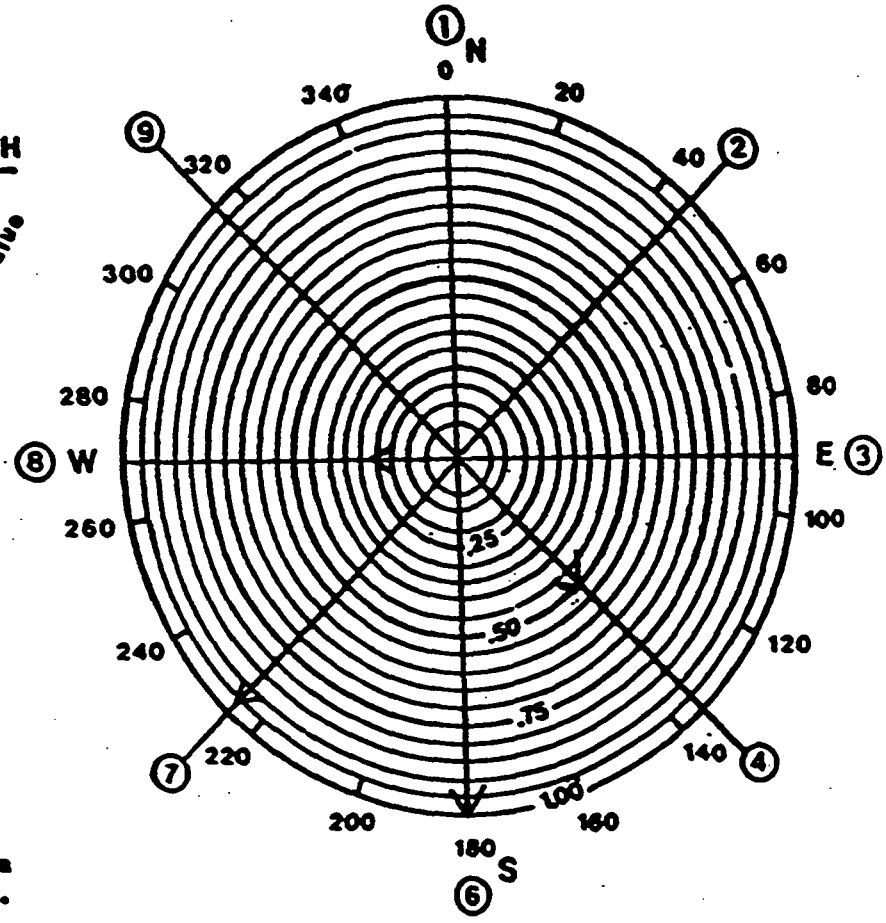
Depth to Measurement: 15' TOW

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F max. value
+1/-6	+30	+98	+68	-61	
+2/-7	+20	+85	+65	-55.5	
+3/-8	+23	-17	-40	-14	
+4/-9	+22	-65	-87	+32	

2.2 amp

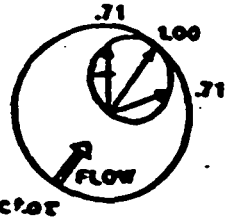


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 programmable calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: ~~SSE~~ SSW Velocity: .39 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 142 ft/yr

000294

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	0	+20	20
+2/-7	17	+68	51
+3/-8	7	+95	88
+4/-9	11	+54	43

2.3 Amps

Operator: B Smith Date: 4/1/96

Station: 11491 Time: 9:47

Location: A2

Soil Conditions:

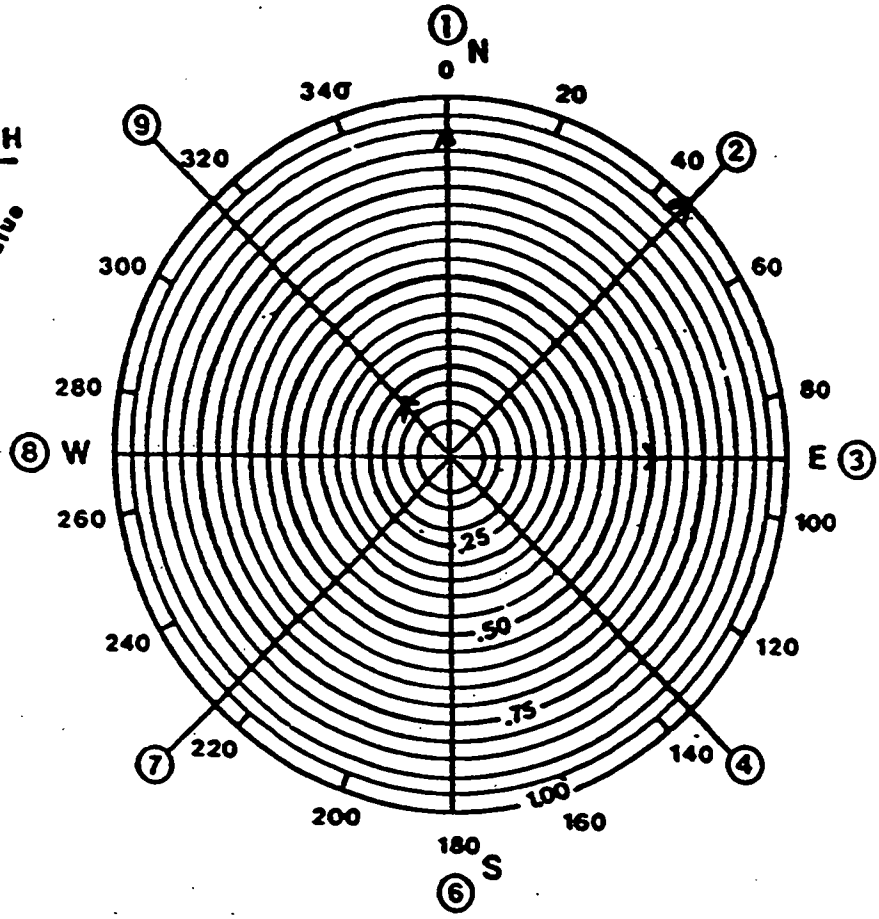
Depth to Measurement: 28.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	0	-37	-39	29.5	
+2/-7	18	+55	+13	32	1
+3/-8	9	+58	+49	19.5	
+4/-9	11	+64	+53	-5	

2.3 Amps

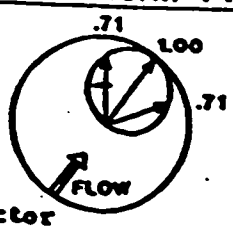


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNE Velocity: .4 ft/day

146 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

000195

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Operator: [illegible] Date: 4/1/96

Station: 11491 Time: 1:0

Location: #2

Soil Conditions:

Depth to Measurement: 28.5'

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	+14	+16	+12
+2/-7	+24	+62	+38
+3/-8	+17	+89	+72
+4/-9	+15	+54	+39

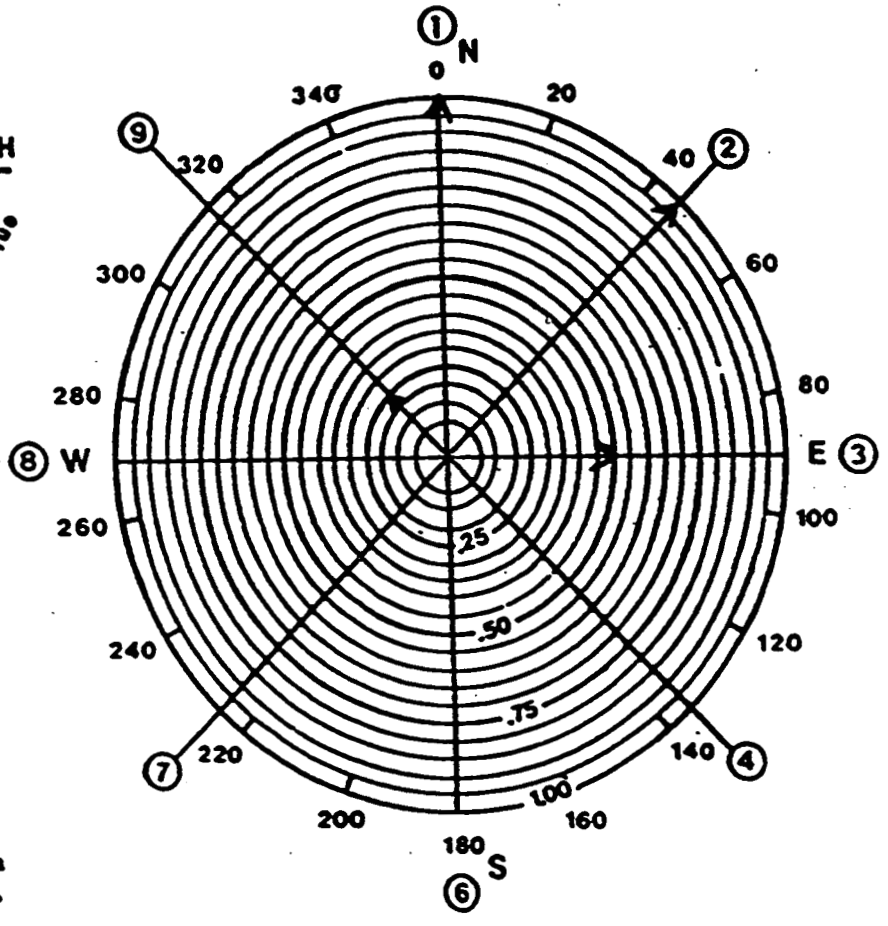
2.25 Amps

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F / max. value
+1/-6	+1	-35	-36	+24	1
+2/-7	+16	+7	-9	+23.5	
-8	+5	+53	+48	+12	
+4/-9	+9	+60	+51	-6	

2.25 Amps

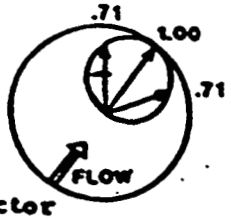


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-67/97) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNE Velocity: 0.3 ft/day

000296

Form 104 available from your local K-V Associates, Inc. dealer.

109 ft/yr

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	0	6	6
+2/-7	15	58	43
+3/-8	5	88	83
+4/-9	10	58	48

2.25 amps

Operator: Brett Smith Date: 4/2/96

Station: 11491 Time: 9:31

Location: Az

Soil Conditions:

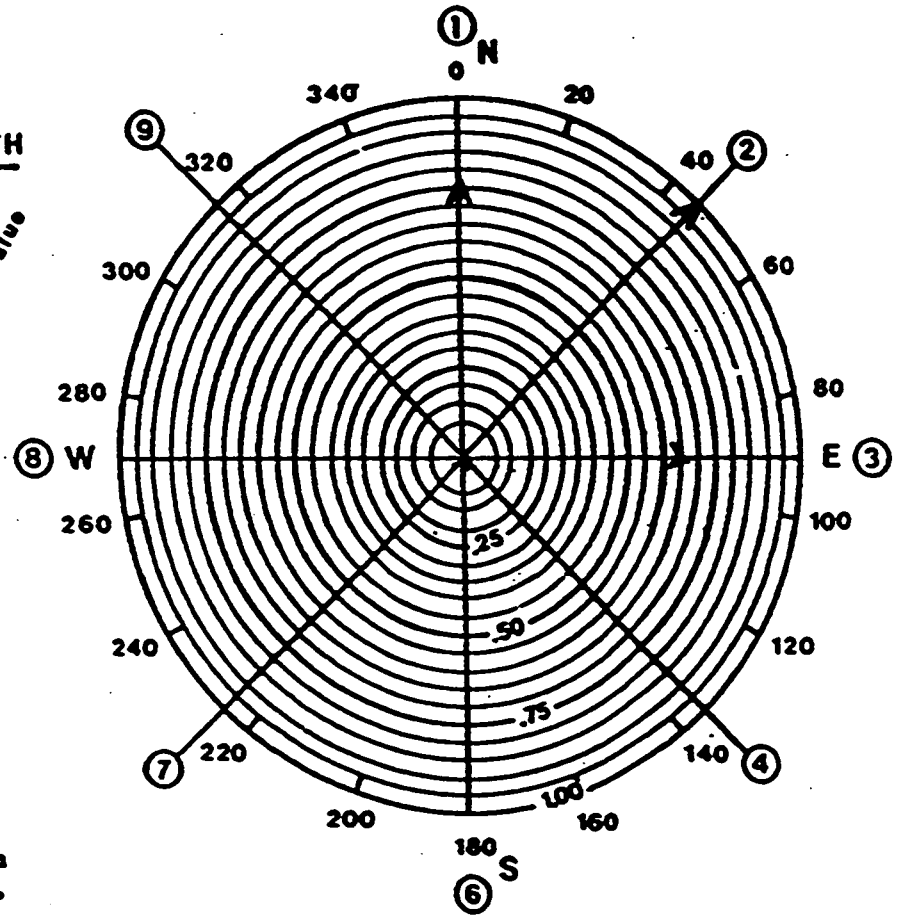
Depth to Measurement: 275'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	0	-35	-35	25	
+2/-7	19	+10	-9	26	
+3/-8	11	58	47	18	
+4/-9	13	59	46	1	

2.25 amps

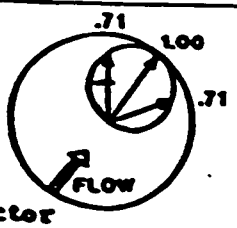


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NE Velocity: .33 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

120 ft/yr

000197

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	+23 0	+27	+4
+2/-7	+30 13	+58	+28
+3/-8	+5 5	+3	-32
+4/-9	7	-28	-52

~~+1 4 Amps~~
+1 2.2 Amps

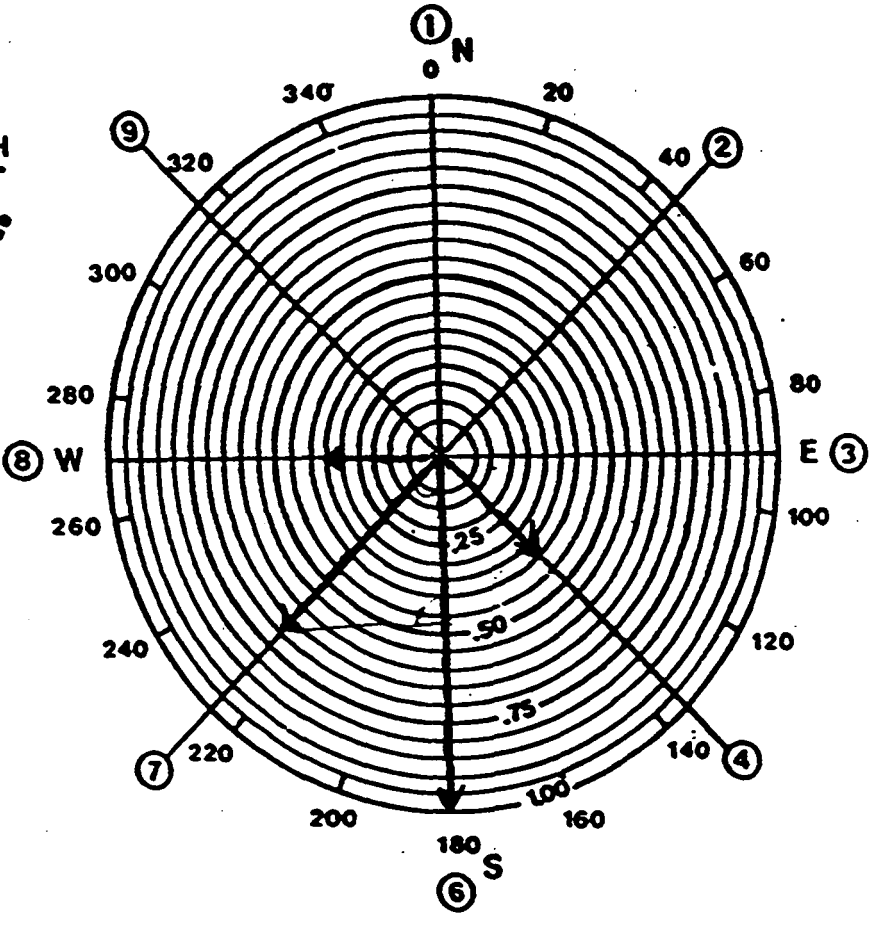
Operator: Pat Smith Date: 3/25/96
Station: ~~11462~~ 11492 Time: 9:21
Location: A1
Soil Conditions:
Depth to Measurement: 20.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	+22	+87	+65	-30.5	-1
+2/-7	+24	+93	+69	-20.5	0.67
-8	+30	+18	-12	-10	0.33
+4/-9	+23	-53	-76	+12	0.40

2.2 Amps

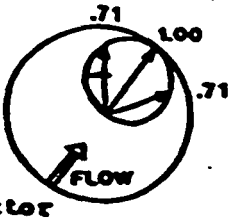


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths when a right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-67) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: 16° W of S Velocity: 0.21 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

76. ft/yr

000198

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Operator: Brett Smith **Date:** 3/29/96

Station: 11492 **Time:** 12:28

Location: #1

Soil Conditions:

Depth to Measurement: 20.5'

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	+21	+26	+5
+2/-7	+37	+80	+43
+3/-8	+37	+40	3
+4/-9	+23	-16	-39

2.2 amps

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D
+1/-6	+22	+79	+72
+2/-7	+38	+120	+82
[illegible]-8	+40	+36	-4
+4/-9	+23	+60	+37

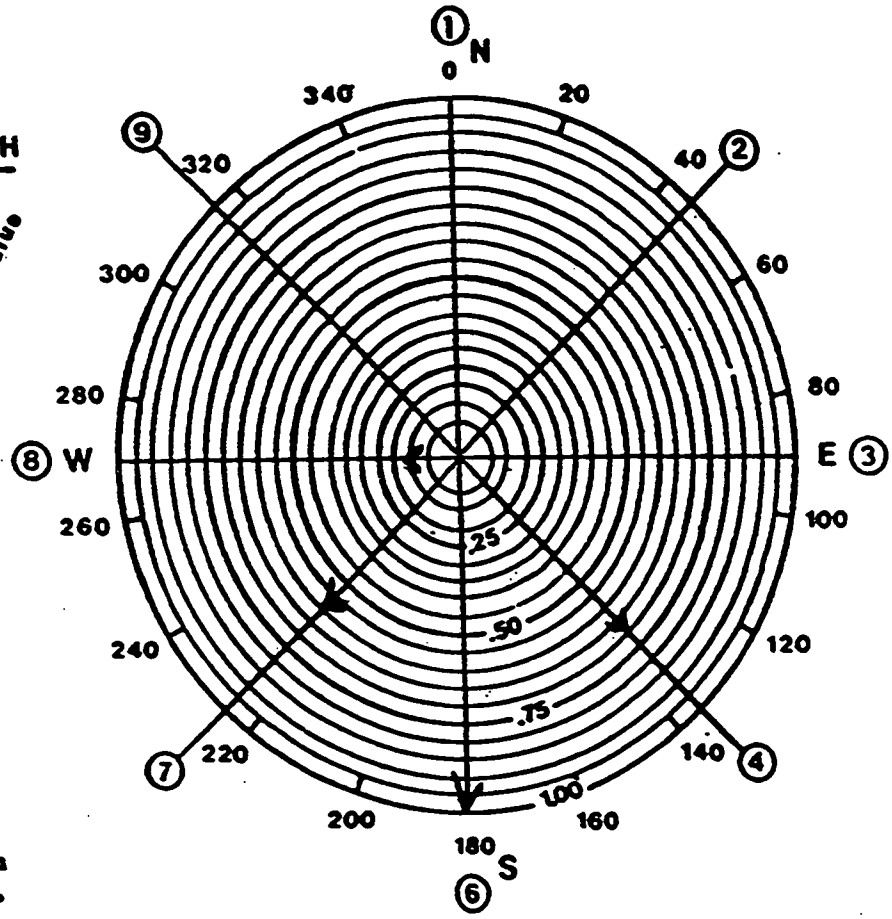
2.2 Amps

-83

Questionable

N-S / 2	F max. value
-33.5	1
-19.5	0.58
-3.5	0.1
-30	

+22 0.66

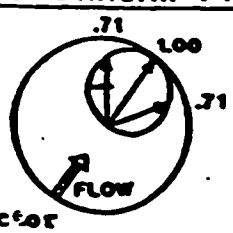


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59-HP-67) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: S **Velocity:** .23 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

84 ft/yr

000199

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

[redacted]-N

Probe pair	A start	B end	C B-A
+1/-6	20	19	-1
+2/-7	32	60	28
+3/-8	33	20	-13
+4/-9	25	-20	-45

2.3 Amps

Operator: B. Smith Date: 4/1/96

Station: 11492 Time: 9:56

Location: #1

Soil Conditions:

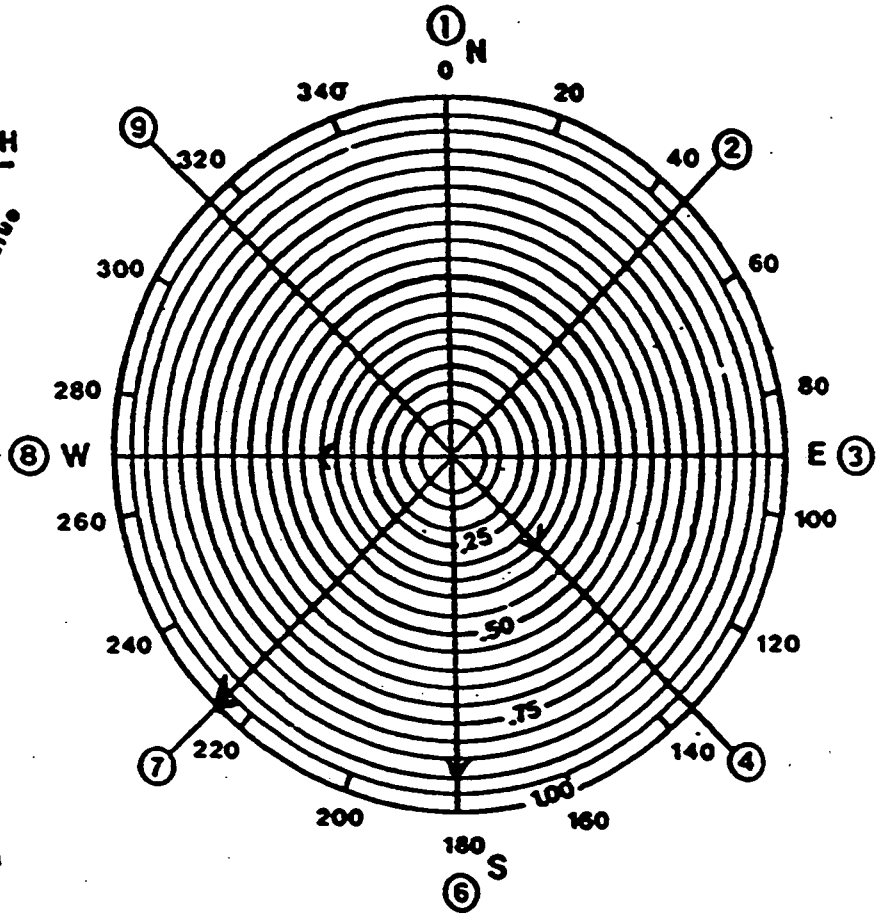
Depth to Measurement: 20.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	27	88	61	-31	
+2/-7	37	40	103	-37.5	1
[redacted]-8	37	50	13	-13	
+4/-9	25	-51	-76	+15.5	

2.3 Amps

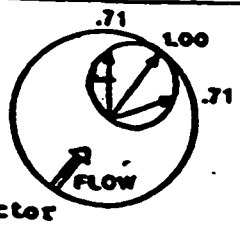


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: SSW Velocity: .26 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

000200

95 ft/yr

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	24	+47	23
+2/-7	36	120	84
+3/-8	35	60	25
+4/-9	25	-23	-48

2.2 degs

Operator: Brett Smith Date: 4/1/96

Station: 11492 Time: 2:16

Location: #1

Soil Conditions:

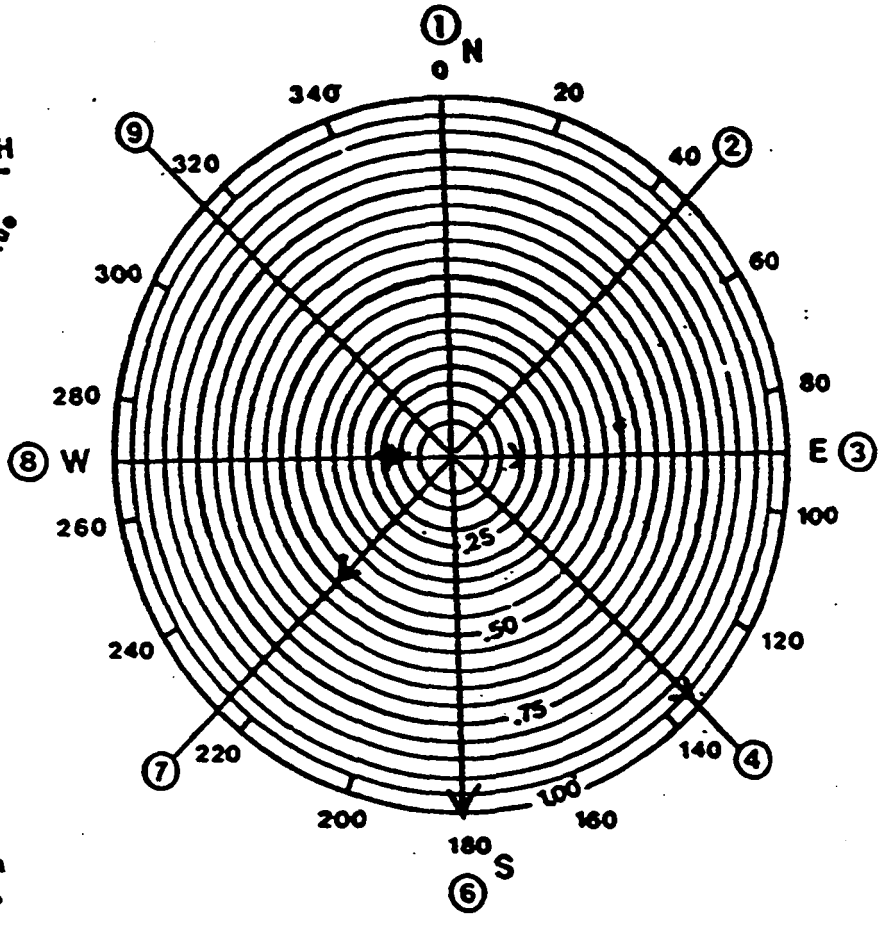
Depth to Measurement: 20'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	24	+94	70	-23.5	
+2/-7	45	160	116	-10.5	
[illegible]/-8	43	60	17	4	
+4/-9	23	-70	-93	+22.5	

22 degs

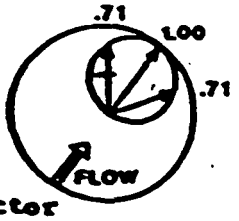


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-54/59/HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: SSE Velocity: .16 ft/day

58 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

[redacted]-N

Probe pair	A start	B end	C B-A
+1/-6	32 ~~24~~	+42	20
+2/-7	62 ~~40~~	+152	90
+3/-8	69 ~~56~~	76	-10
+4/-9	26 ~~82~~	-19	-44

2.2 Amps

Operator: Brett Smith Date: 4/2/96

Station: 11492 Time: 9:35

Location: #1

Soil Conditions:

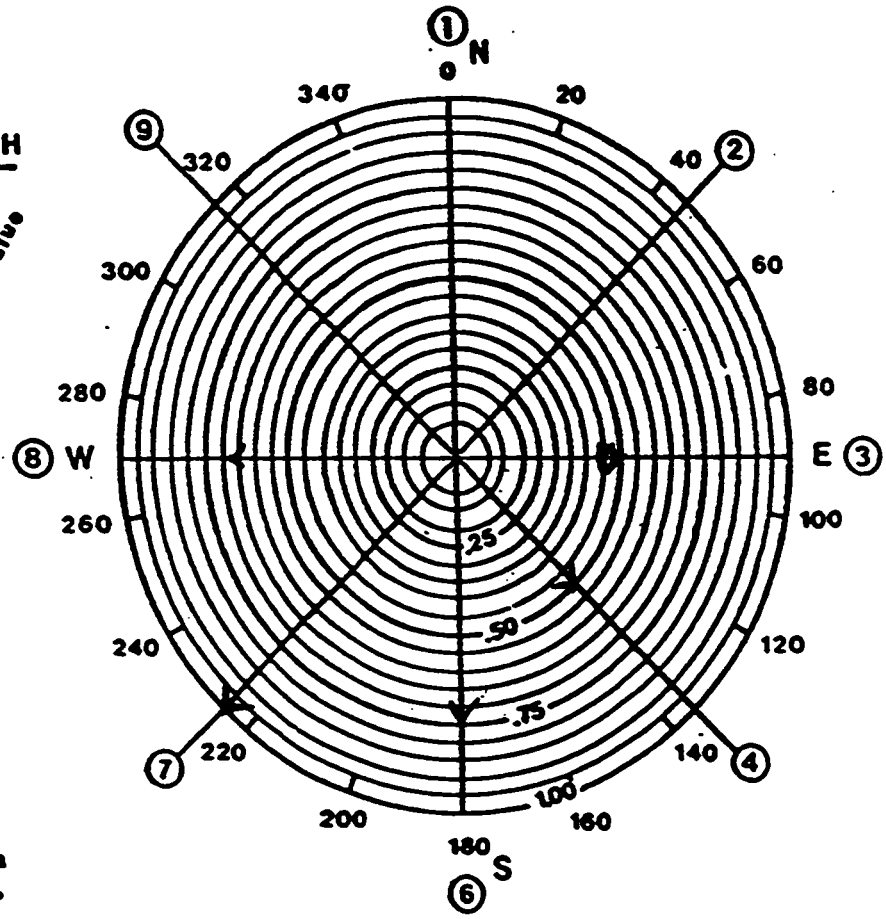
Depth to Measurement: 20'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	21	83	62	-21	
+2/-7	40	185	145	-22.5	
+3/-8	36	60	24	-17	
+4/-9	22	-52	-74	15	

2.2 Amps

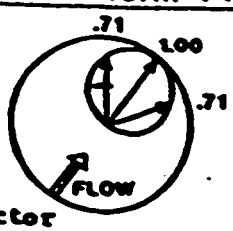


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59-HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: S.W. Velocity: .19 ft/day

000202

Form 104 available from your local K-V Associates, Inc. dealer.

69 ft/yr

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	1	0	-1
+2/-7	16	9	-7
+3/-8	9	29	20
+4/-9	10	22	17

2.2 Amps

Operator: [illegible] Date: 4/2/96

Station: 11493 Time: 1:09

Location: #2

Soil Conditions:

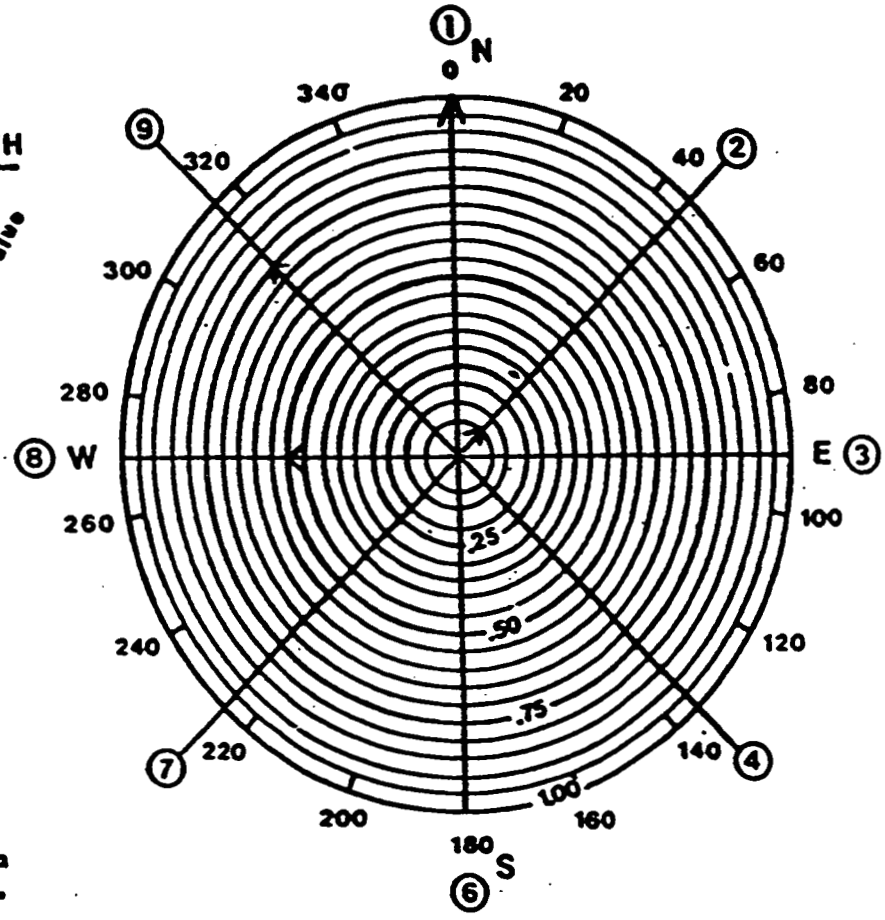
Depth to Measurement: 23.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	+3	-42	-45	22	
+2/-7	13	0	-13	3	
+3/-8	9	50	41	-20.5	
+4/-9	12	63	51	-17	

2.2 Amps

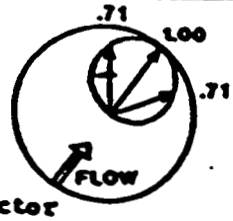


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNW Velocity: .28 ft/day

102 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

000203

GROUNDWATER FLOWMETER

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	0	1	1
+2/-7	10	11	1
+3/-8	9	28	19
+4/-9	91	22	11

2.2 Amps

Operator: Brett Smith Date: 4/2/96

Station: 11493 Time: 1:32

Location: #2

Soil Conditions:

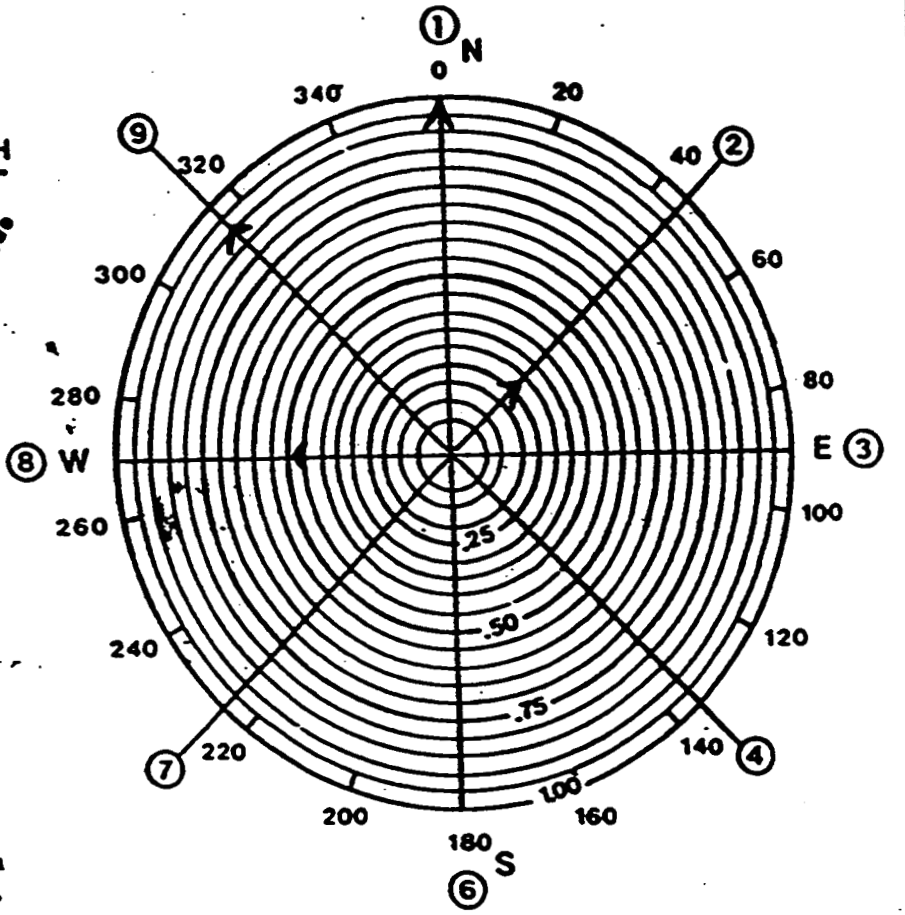
Depth to Measurement: 23.5

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F / max. value
+1/-6	0	-43	-43	22	
+2/-7	11	0	-11	6	
+3/-8	10	50	40	-10.5	
+4/-9	15	65	50	-19.5	

2.2 Amps 5/2

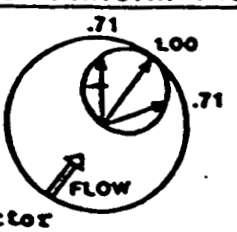


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNW Velocity: .28 ft/day

000204

Form 104 available from your local K-V Associates, Inc. dealer.

102 ft/yr

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

[redacted]-N

Probe pair	A start	B end	C B-A
+1/-6	4	-8	-12
+2/-7	14	13	-1
+3/-8	11	38	27
+4/-9	10	34	24

22 Amps

Operator: Brett Smith Date: 4/2/96

Station: 11493 Time: 3:17

Location: #2

Soil Conditions:

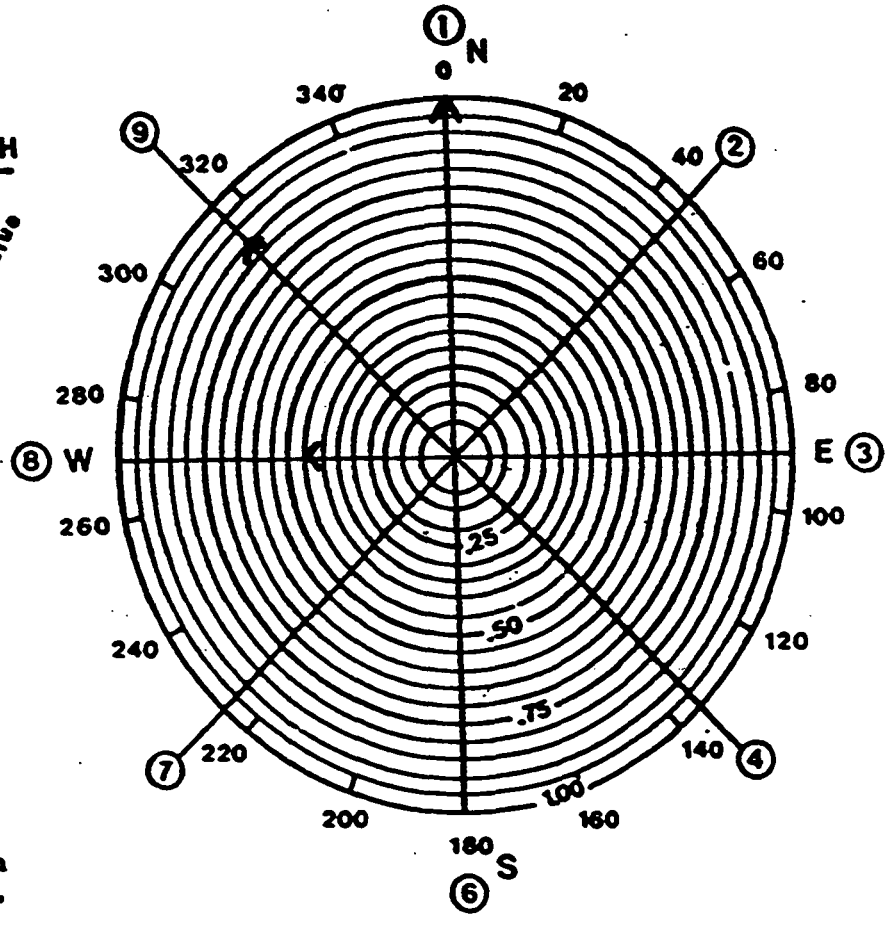
Depth to Measurement: 22.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	0	-60	-60	24	
+2/-7	11	-12	-1	0	
[redacted]-8	13	60	47	-10	
+4/-9	16	79	63	-19.5	

2.2 Amps

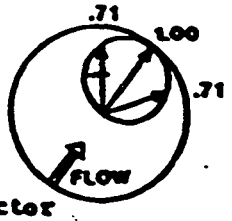


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNW Velocity: .3 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

109 ft/yr

000205

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

[redacted]-N

Probe pair	A start	B end	C B-A
+1/-6	32	33	1
+2/-7	20	66	46
+3/-8	22	28	6
+4/-9	22	0	-22

2.2 Amps

Operator: Brett Smith Date: 4/2/96

Station: 1149 Time: 12:57

Location: #1

Soil Conditions:

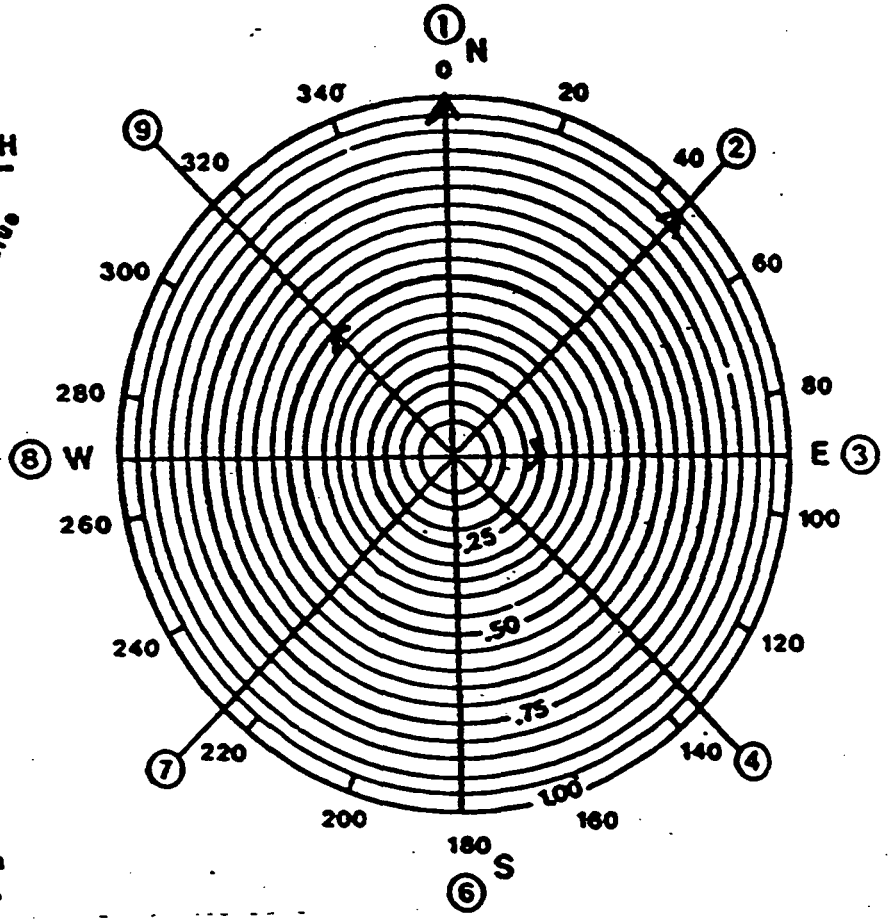
Depth to Measurement: 15.5

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F / max. value
+1/-6	29	4	-25	13	
+2/-7	19	40	21	12.5	
[redacted]-8	24	23	-1	3.5	
+4/-9	23	16	-7	-7.5	

2.26 Amps

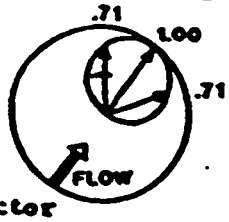


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 and HP calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNE Velocity: .09 ft/day

000206

Form 104 available from your local K-V Associates, Inc. dealer.

33 ft/yr

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	31	38	7
+2/-7	16	44	28
+3/-8	16	3	-13
+4/-9	16	-26	-40

22 Amps

Operator: Brett Smith Date: 9/2/96

Station: 11499 Time: 1:22

Location: #1

Soil Conditions:

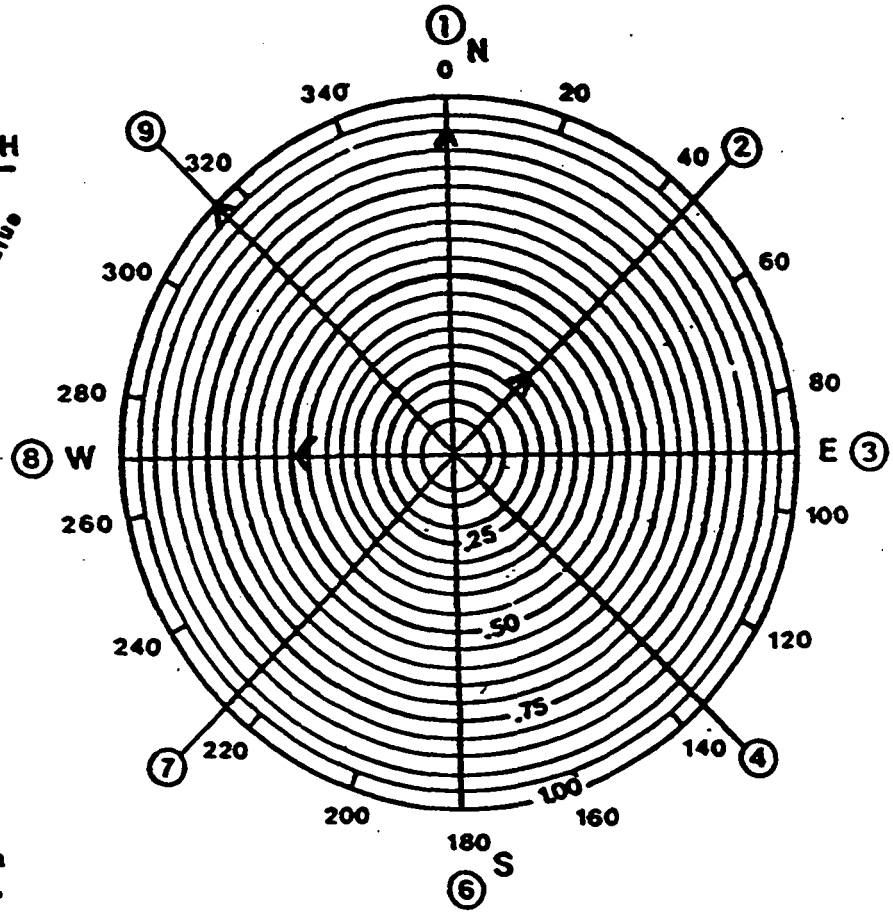
Depth to Measurement: 15.5

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	24	6	-18	12.5	
+2/-7	17	36	19	4.5	
[illegible]8	23	23	0	-6.5	
+4/-9	25	14	-11	-14.5	

22 Amps

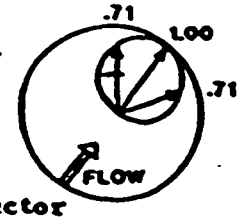


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNW Velocity: .10 ft/day

32 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

000207

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Operator: Brett Smith **Date:** 9/2/96

Station: 11492 **Time:** 3:20

Location: #1

Soil Conditions:

Depth to Measurement: 14.5'

Table of LCD Readout

[redacted]→N

Probe pair	A start	B end	C B-A
+1/-6	31	35	4
+2/-7	24	43	19
+3/-8	26	0	-26
+4/-9	24	-24	-48

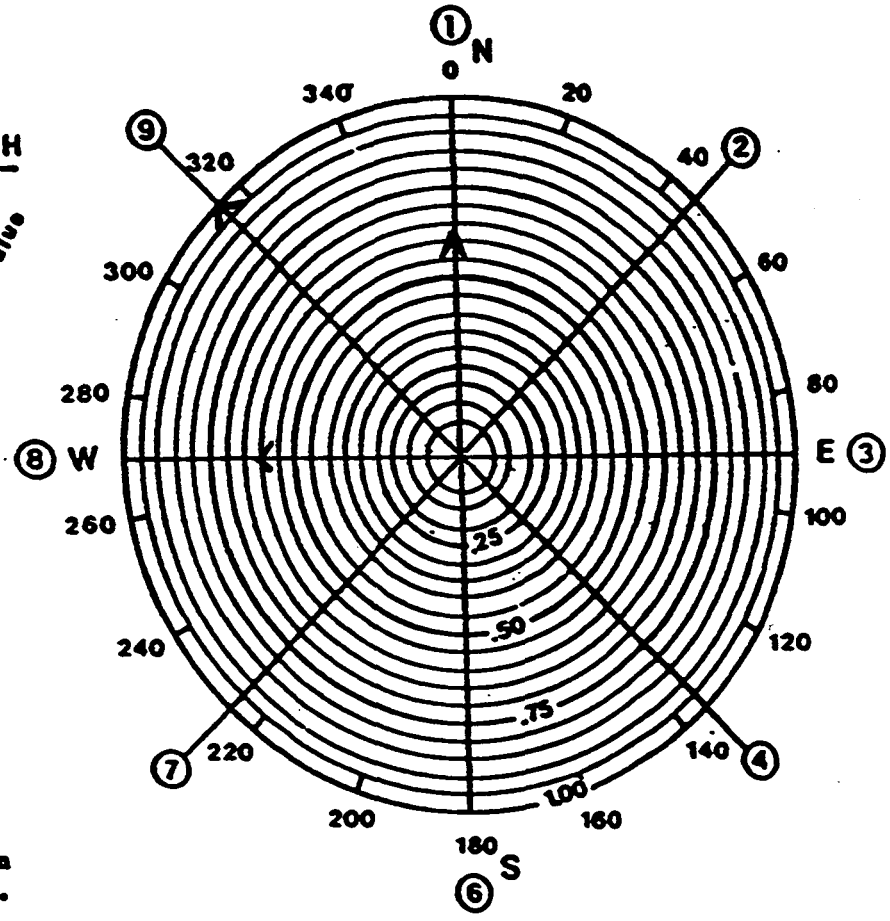
2.2 Amps

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	27	18	-9	65	
+2/-7	18	37	19	0	
[redacted]-8	24	12	-12	-7	
+4/-9	23	0	-23	-126	

2.2 Amps

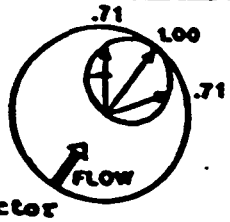


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NW **Velocity:** .097 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

32 ft/yr

000208

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Operator: Bret Smith **Date:** 4/3/96

Station: 11496 **Time:** 1:50

Location: #1

Soil Conditions:

Depth to Measurement: 16'

Table of LCD Readout

[redacted]-N

Probe pair	A start	B end	C B-A
+1/-6	30	61	31
+2/-7	17	94	77
+3/-8	17	44	27
+4/-9	17	-22	39

2.2 Amps

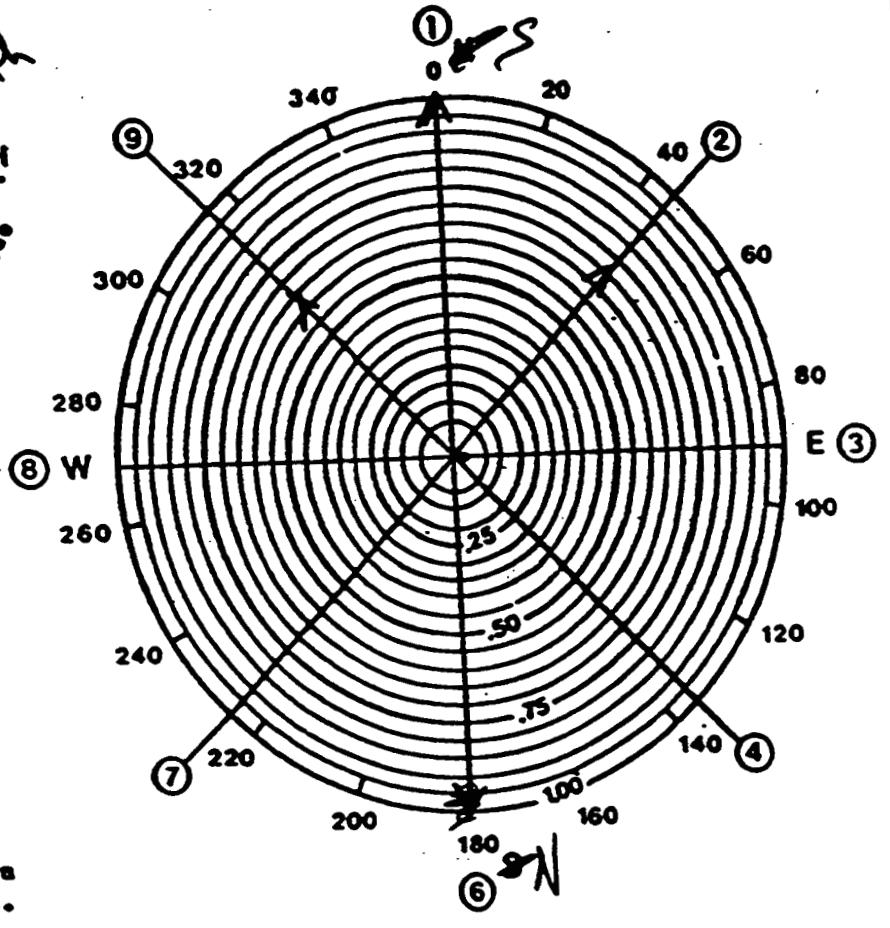
Measurement Reversed North is South

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F / max. value
+1/-6	26	7	-19	25	1
+2/-7	18	60	42	17.5	
+3/-8	21	47	26	0.5	
+4/-9	21	17	-4	-17.5	

2.2 Amps

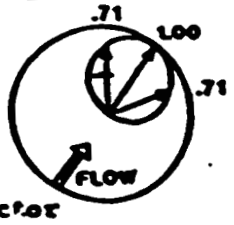


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: ~~N~~ S **Velocity:** .17 ft/day

62 ft/yr

000309

Form 104 available from your local K-V Associates, Inc. dealer.

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

N → A B C

Probe pair	start	end	B-A
+1/-6	25	28	3
+2/-7	14	70	56
+3/-8	19	50	31
+4/-9	22	7	-15

2.1 Amps

Operator: Brett Smith Date: 4/3/96

Station: ~~11/99~~ 1496 Time: 9:30

Location: #1

Soil Conditions:

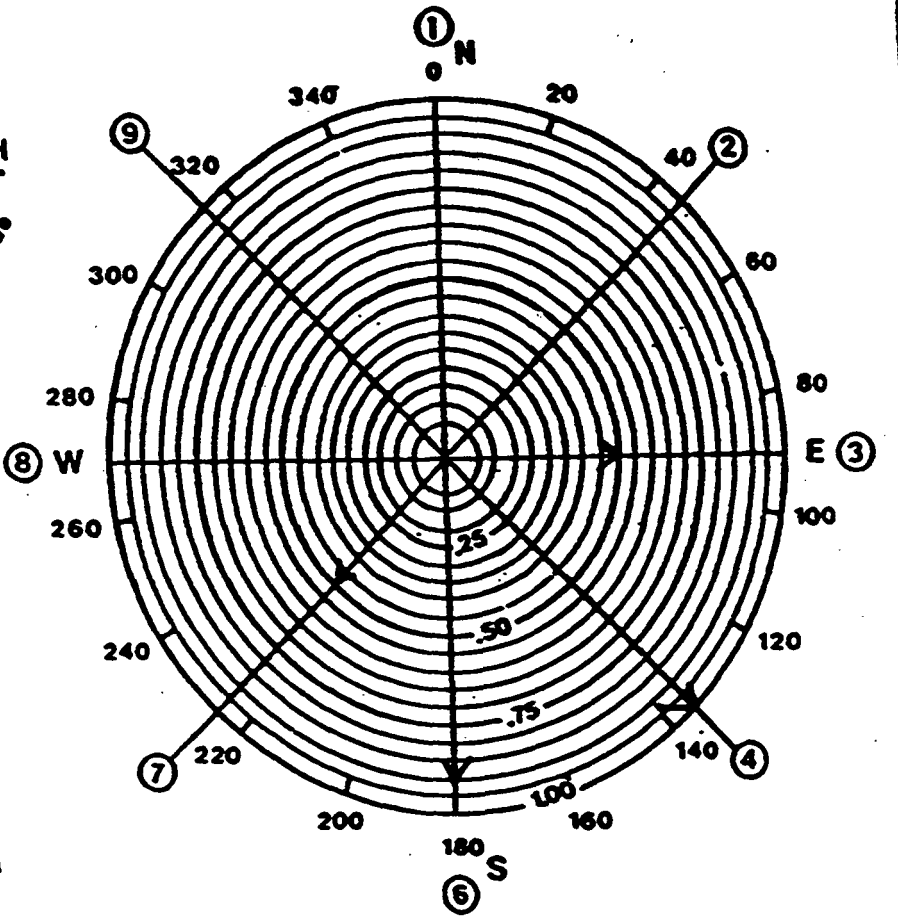
Depth to Measurement: 16'

ROTATE PROBE 180° AT SAME DEPTH

1 → S D E S F G

Probe pair	start	end	E-D	N-S / 2	F / max. value
+1/-6	34	73	39	-18	
+2/-7	20	92	72	-8	
-8	17	30	13	9	
+4/-9	15	-41	56	20.5	

2.1 Amps

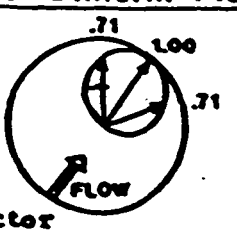


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: SSW Velocity: .14 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

.51 ft/gpd

000210

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

[redacted]N Probe pair	A start	B end	C B-A
+1/-6	+1	-6	-7
+2/-7	13	36	23
+3/-8	6	73	67
+4/-9	9	58	49

2.1 hours

Operator: Brett Smith Date: 4/3/96

Station: ~~11423~~ 11497 Time: 9:25

Location: #2

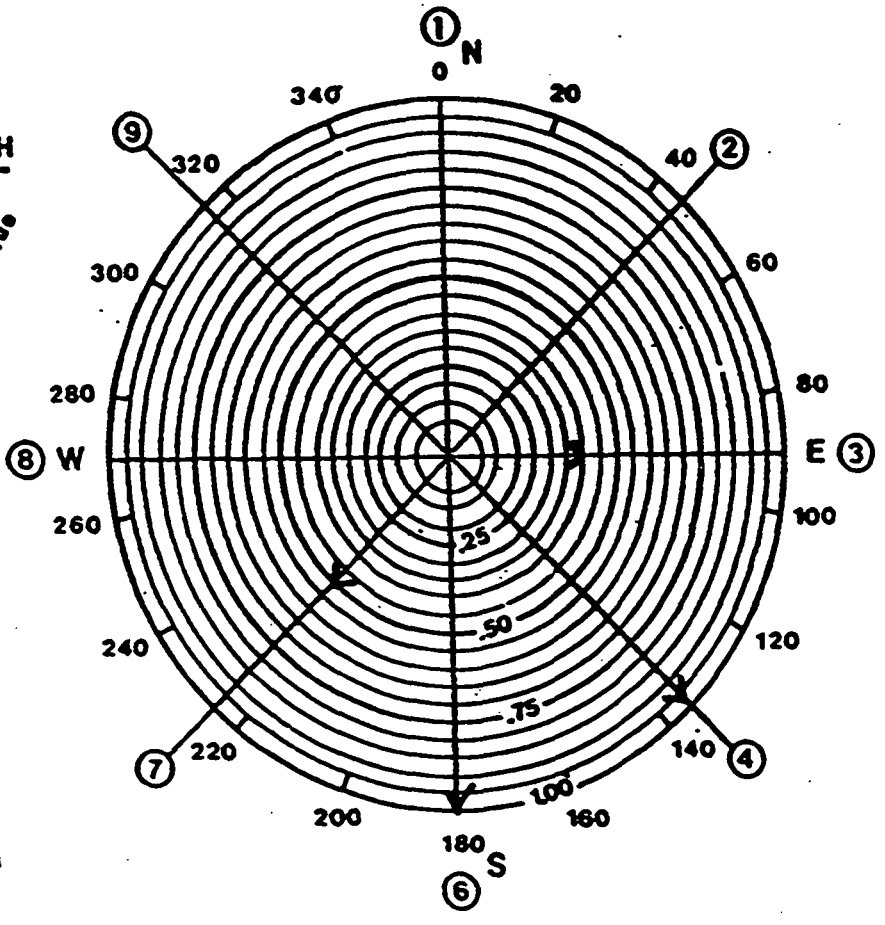
Soil Conditions:

Depth to Measurement: 33.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	0	26	26	-16.5	
+2/-7	12	51	39	-8	
[redacted]8	13	68	55	6	
+4/-9	17	34	17	16	

2.1 hours

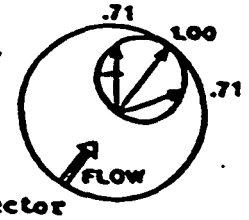


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-54/59+HP41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: S Velocity: .20 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

73 ft/yr

000211

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	1	-7	-8
+2/-7	17	33	16
+3/-8	13	71	58
+4/-9	15	55	40

2.1 Amps

Operator: Brett Smith Date: 4/3/96

Station: 11497 Time: 9:51

Location: #2

Soil Conditions:

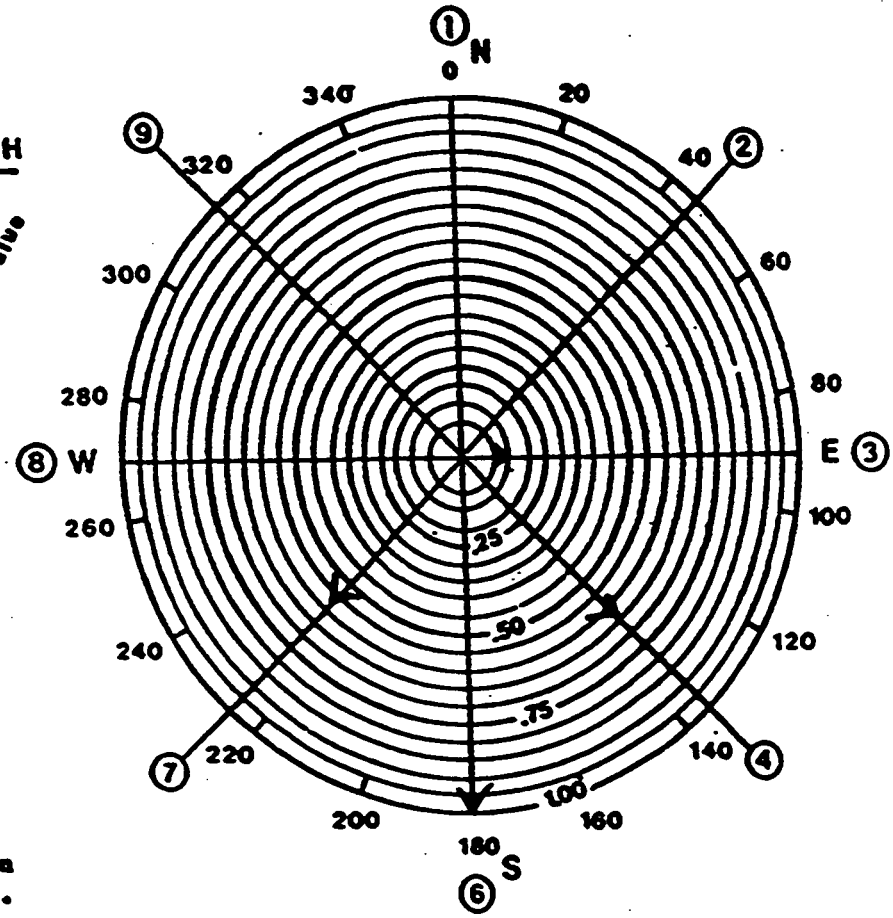
Depth to Measurement: 33.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	E-D	S	F N-S	G F/max. value
+1/-6	0	24	9	21	-16	
+2/-7	12	46	33	34	-9	
+3/-8	11	64	77	53	25	
+4/-9	13	32	45	19	15	

2.1 Amps

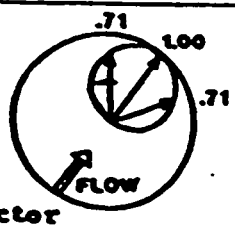


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: S Velocity: .20 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

73 ft/yr

000212

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Operator: Bob Smith **Date:** 4/3/96

Station: 11497 **Time:** 1:50

Location: A2

Soil Conditions:

Depth to Measurement: 83.5

Table of LCD Readout

N → A B C

Probe pair	A start	B end	C B-A
+1/-6	0	1	1
+2/-7	15	10	-5
+3/-8	5	30	25
+4/-9	9	35	26

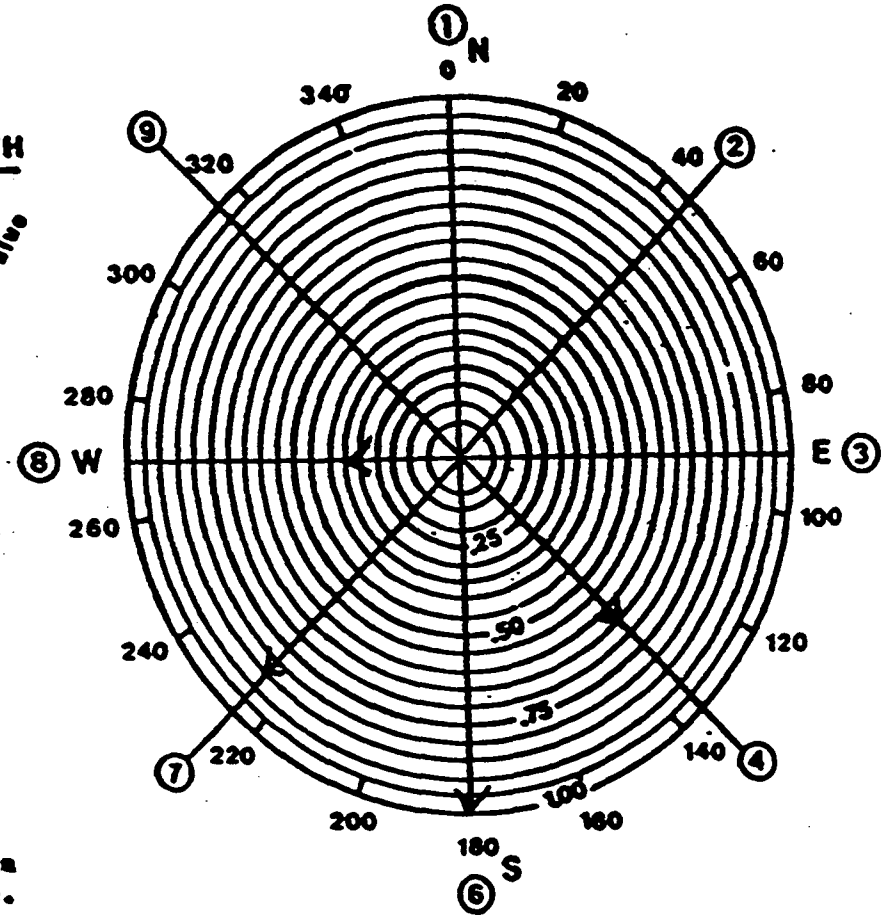
2 Amps

ROTATE PROBE 180° AT SAME DEPTH

1 → S D E S F G

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	2	27	25	-12	
+2/-7	14	30	16	-10.5	
[illegible]-8	7	40	33	-4	
+4/-9	9	20	11	-7.5	

2 Amps

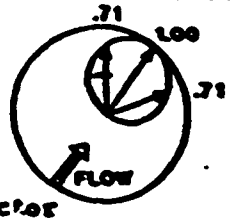


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41 calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: S **Velocity:** .15 ft/day

000213

Form 104 available from your local K-V Associates, Inc. dealer.

55 ft/yr

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475.

Operator: Brett Smith **Date:** 4/8/96

Station: 11498 **Time:** 10:10

Location: #1

Soil Conditions:

Depth to Measurement: 30.25

Table of LCD Readout

●→N

Probe pair	A start	B end	C B-A
+1/-6	+30	+47	17
+2/-7	+21	66	45
+3/-8	+23	17	-6
+4/-9	+23	-21	-44

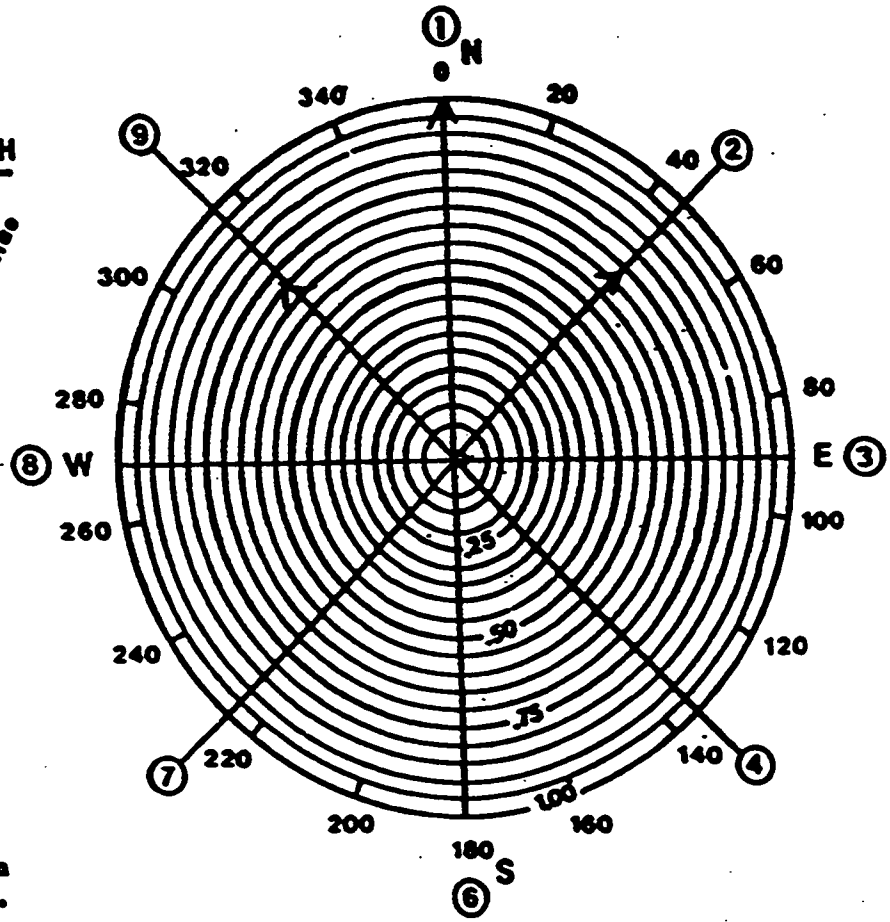
2 intervals

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	27	8	-19	18	
+2/-7	16	36	20	12.5	
+3/-8	19	14	-5	-0.5	
+4/-9	20	0	-20	-12	

2 intervals

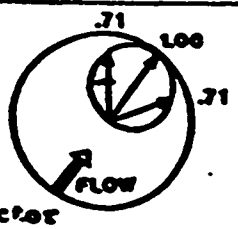


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Value in column G will approximate vector [illegible] at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP calculators
OR
2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: N **Velocity:** .12 ft/day

000214

Form 104 available from your local K-V Associates, Inc. dealer.

44 ft/yr

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

N → A B C

Probe pair	A start	B end	C B-A
+1/-6	29	30	1
+2/-7	20	41	21
+3/-8	22	-12	-34
+4/-9	21	-30	-51

2.1A-ps

Operator: Brett Smith Date: 4/3/96

Station: 1/4/98 Time: 2:37

Location: #1

Soil Conditions:

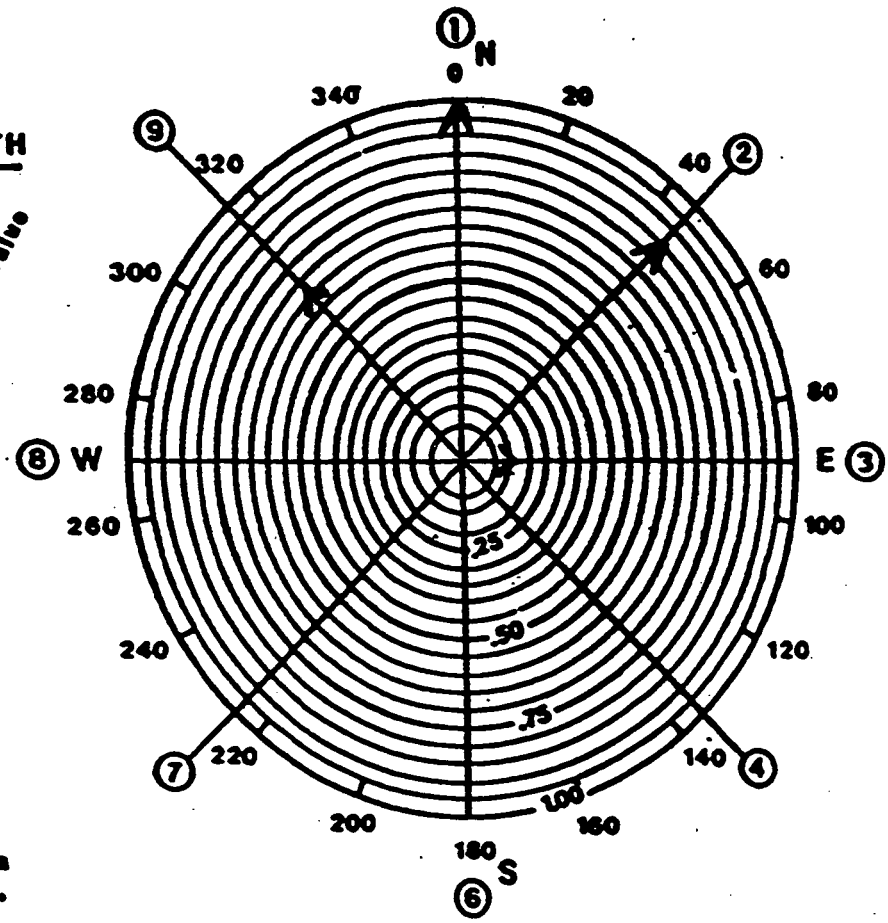
Depth to Measurement: 30.25'

ROTATE PROBE 180° AT SAME DEPTH

1 → S D E S F G

Probe pair	D start	E end	S E-D	F N-S	G F / max. value
+1/-6	29	-6	-35	18	
+2/-7	13	2	-11	16	
+3/-8	13	-25	-38	2	
+4/-9	14	-9	-23	-14	

2.1A-ps

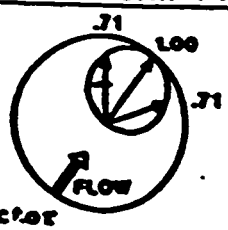


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 programmable calculators)

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: N Velocity: .12 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

000215

44 ft/yr

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

N

Probe pair	A start	B end	C B-A
+1/-6	0	4	4
+2/-7	9	35	26
+3/-8	0	40	40
+4/-9	4	14	10

2.1 steps

Operator: Brett Smith Date: 4/8/96

Station: 11499 Time: 10:12

#2

Location:

Soil Conditions:

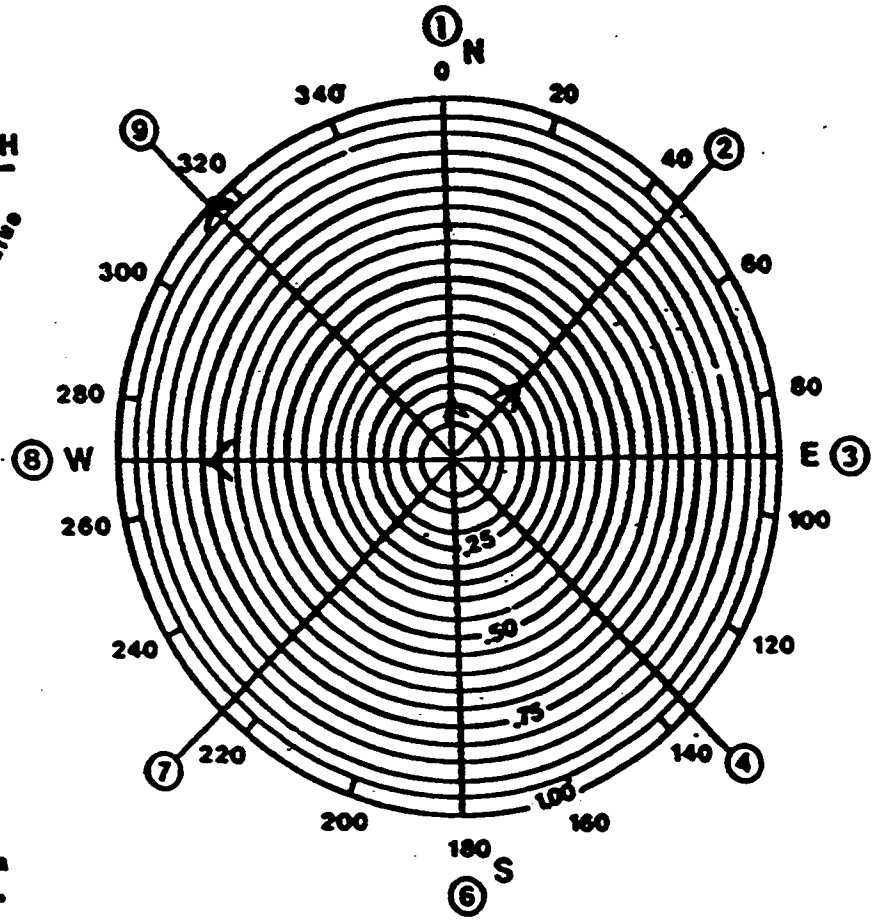
Depth to Measurement: 18.25'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	0	8	0	2	
+2/-7	15	33	18	4	
-8	7	67	60	-10	
+4/-9	10	55	45	-7.5	

2.1 steps

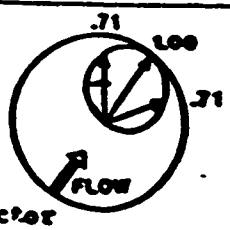


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41 calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NW Velocity: .22 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

80 ft/yr

000216

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Operator: Brett Smith **Date:** 4/2/96

Station: 11499 **Time:** 3:35

Location: #2

Soil Conditions:

Depth to Measurement: 18.25'

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	0	40	40
+2/-7	16	62	46
+3/-8	7	61	54
+4/-9	8	7	-1

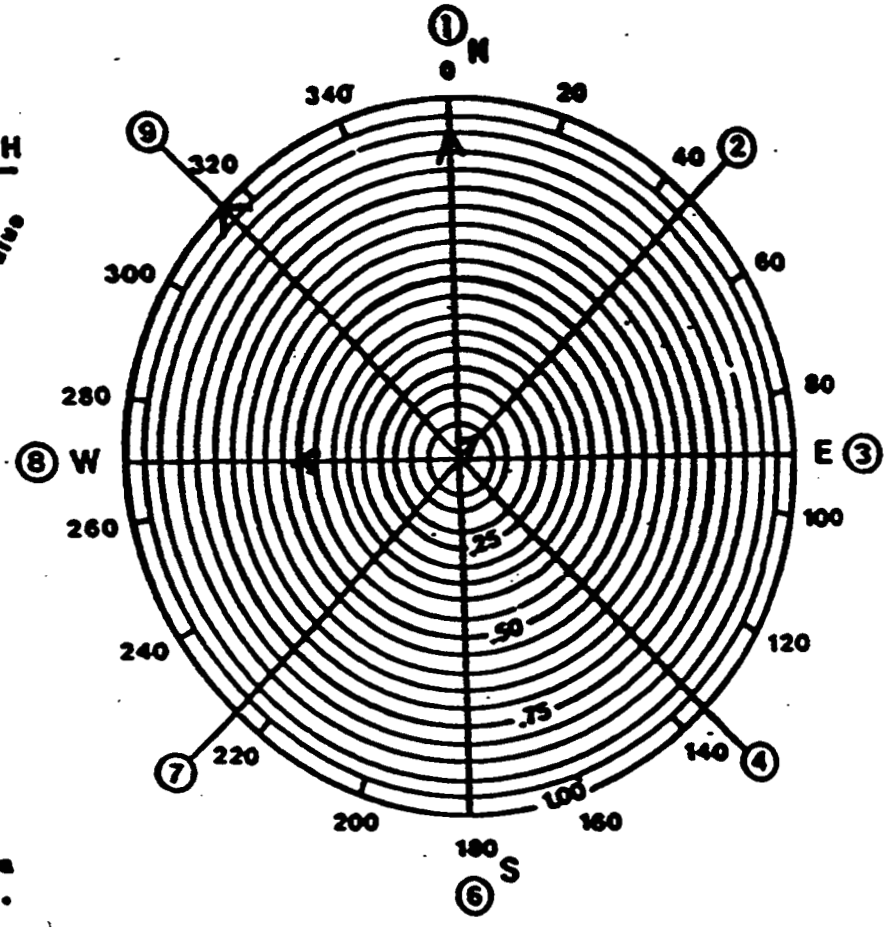
2.1 Amps

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	G E-D	F N-S / 2	G F / max. value
+1/-6	0	1	1	9.5	
+2/-7	15	54	39	3.5	
+3/-8	12	86	74	-10	
+4/-9	12	55	43	-22	

2.1 Amps

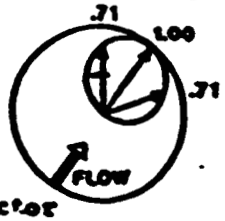


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NW **Velocity:** .28 ft/day

102 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

[redacted]-N

Probe pair	A start	B end	C B-A
+1/-6	0	-35	-35
+2/-7	7	2	-5
+3/-8	0	48	48
+4/-9	9	59	50

20 amps

Operator: Brad Smith Date: 4/9/96

Station: 11500 Time: 10:30

Location: #2

Soil Conditions:

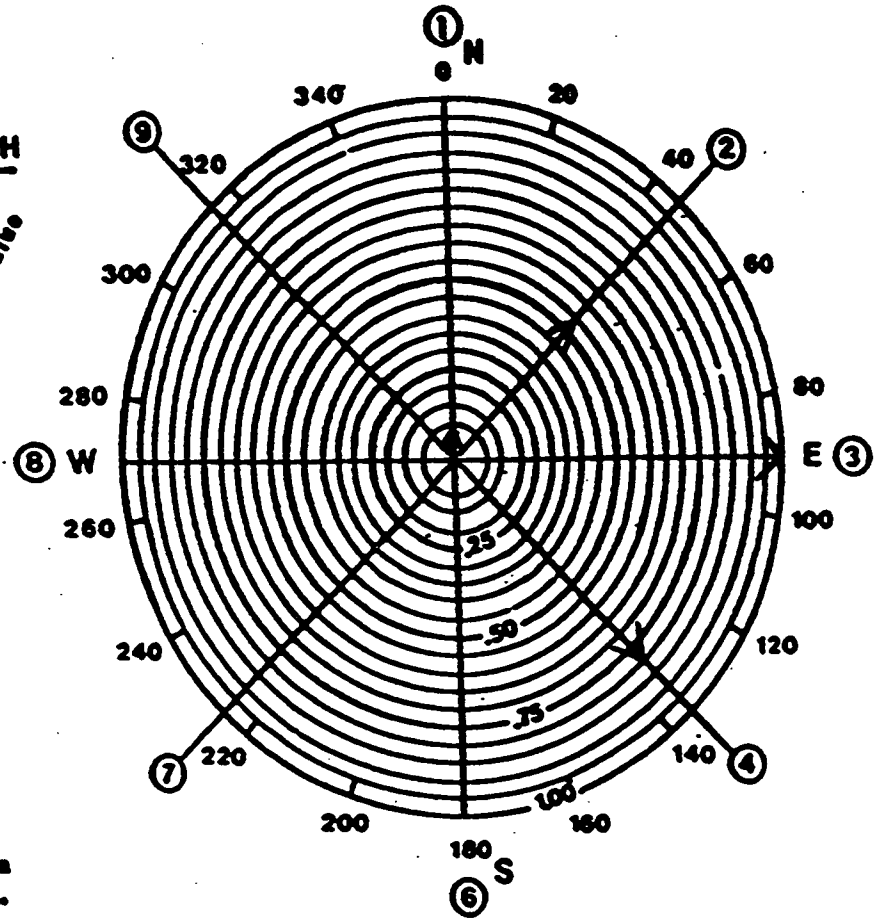
Depth to Measurement: 24'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	0	-33	-33	1	
+2/-7	10	-23	-23	9	
[redacted]-8	0	13	13	17.5	
+4/-9	6	29	23	13.5	

20 amps

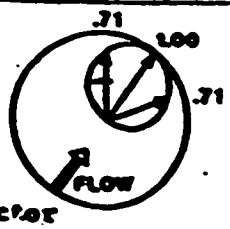


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/39 calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout vs. preferred units of flow (e.g. feet per day).

Direction: E Velocity: .17 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 62 ft/yr

000218

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

●→N

Probe pair	A start	B end	C B-A
+1/-6	0	12	12
+2/-7	10	77	67
+3/-8	5	126	121
+4/-9	7	74	67

2.25 Amps

Operator: Brett Smith Date: 4/10/96

Station: 11501 Time: 10:05

Location: probe 2

Soil Conditions:

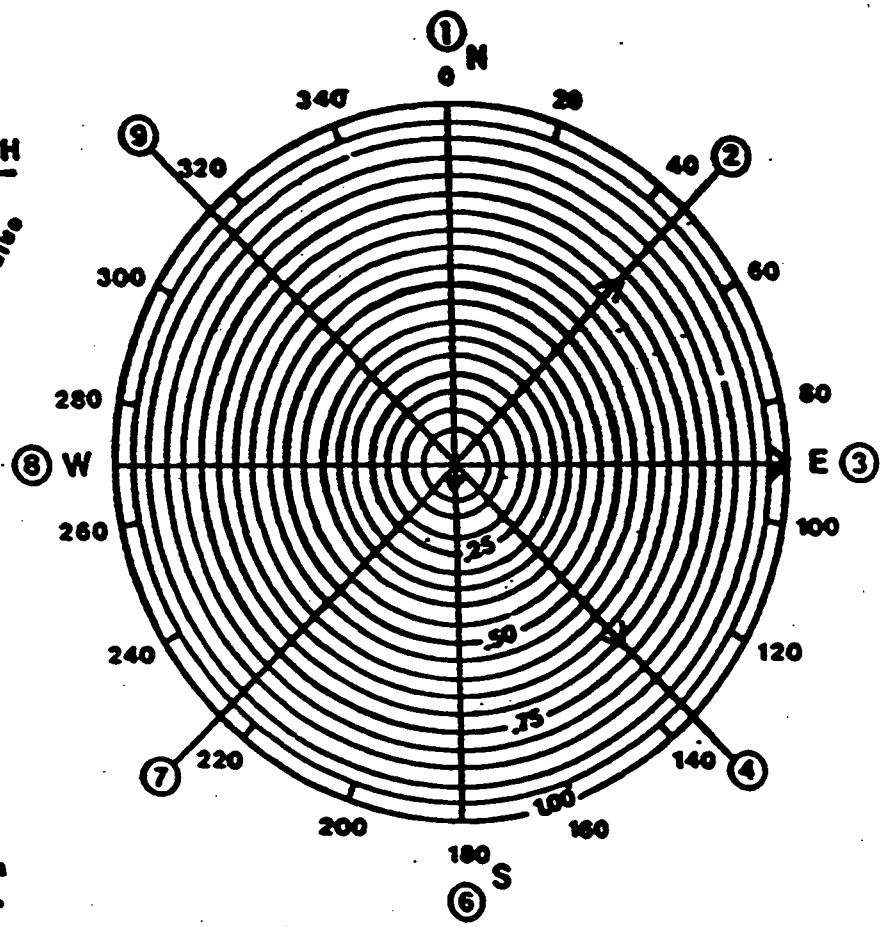
Depth to Measurement: 36'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F/max. value
+1/-6	0	+17	17	-25	
+2/-7	9	+20	11	33	
+3/-8	8	+41	33	44	
+4/-9	12	+11	-1	34	

2.25 Amps

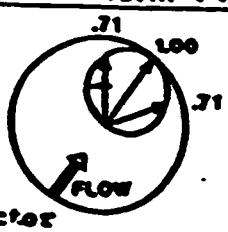


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: E Velocity: .56 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 204 ft/yr

000219

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C Δ
•1/-6	0	-16	-16
•2/-7	+12	+46	+34
•3/-8	+7	+91	+84
•4/-9	+7	+72	+65

Operator: JOHN L BECKETT Date: 4/9/96

Station: #2 Time: 8:21

Location: 11501

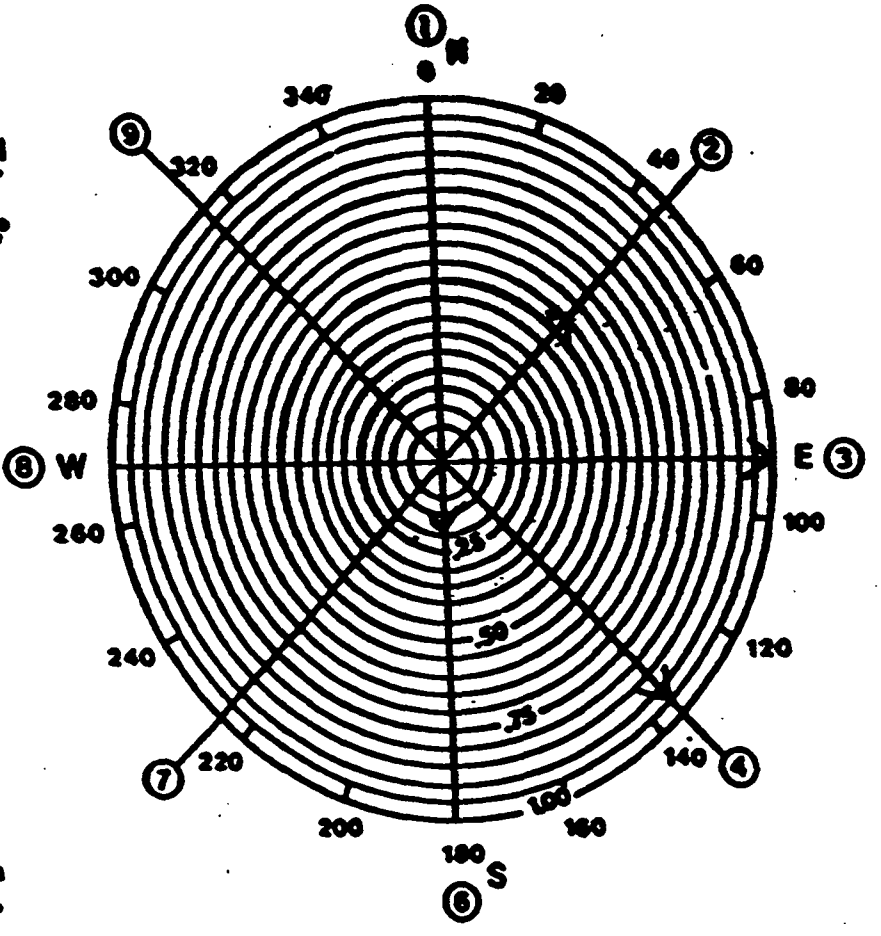
Soil Conditions:

Depth to Measurement: 30'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
•1/-6	0	0	0	-8	
•2/-7	+13	+8	-5	+19.5	
•3/-8	+7	23	+16	34	
•4/-9	+12	+19	+7	+29	

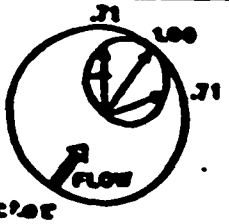


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/35 scientific calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: E Velocity: .44

Form 104 available from your local K-V Associates, Inc. dealer.

000220

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
•1/-6	+1	+20	-21
•2/-7	+15	+56	+41
•3/-8	+7	+100	+93
•4/-9	+11	+81	+70

Operator: John J Bera Date: 4-14-90

Station: 42 Time: 10:43

Location: 11501

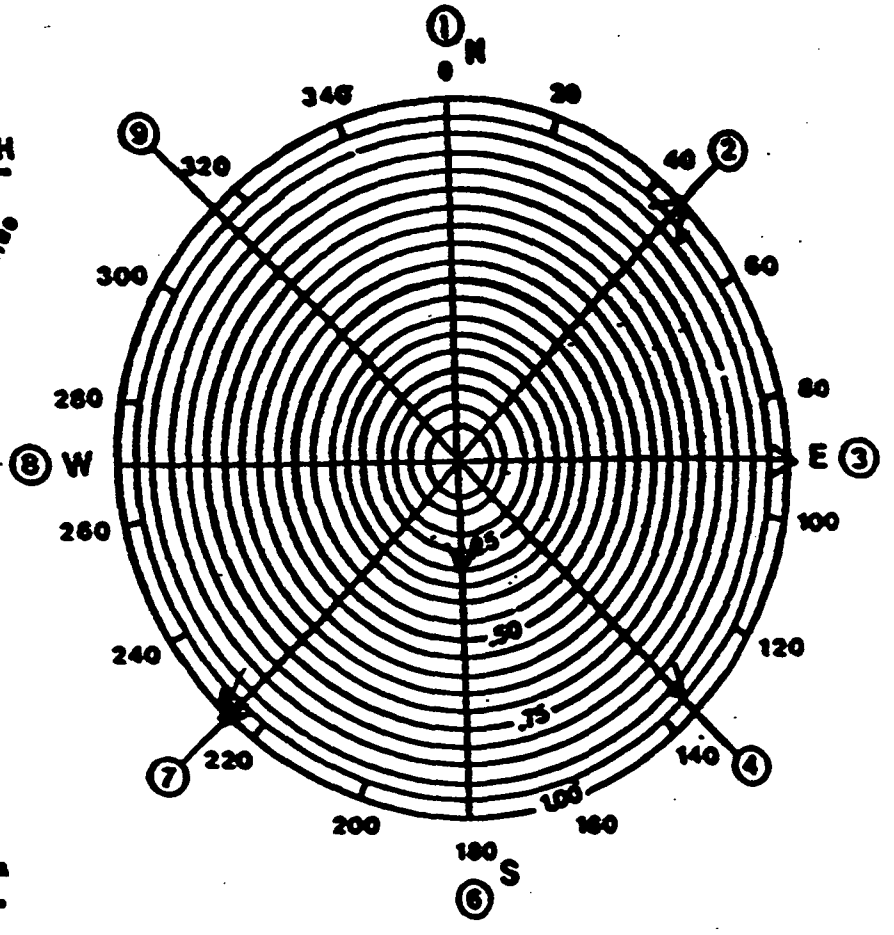
Soil Conditions:

Depth to Measurement: 35.5'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F (N-S)/2	G F / max. value
•1/-6	+1	+4	+3	-12	
•2/-7	+14	+14	0	355	
•3/-8	+9	+22	+13	+35	
•4/-9	+9	+12	+3	335	

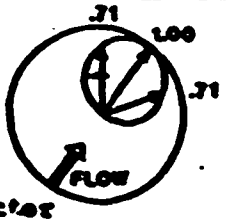


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C calculators
OR
2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: N.D. Velocity: N.D.

Form 104 available from your local K-V Associates, Inc. dealer.

000221

Table of LCD Readout

1→N

Probe pair	A start	B end	C end
•1/-6	+1	+2	+1
•2/-7	+13	+57	+44
•3/-8	+8	+83	+75
•4/-9	+10	+59	+49

Operator: John J. Keller Date: 4-19-96

Station: #2 Time: 1:55

Location: 1450'

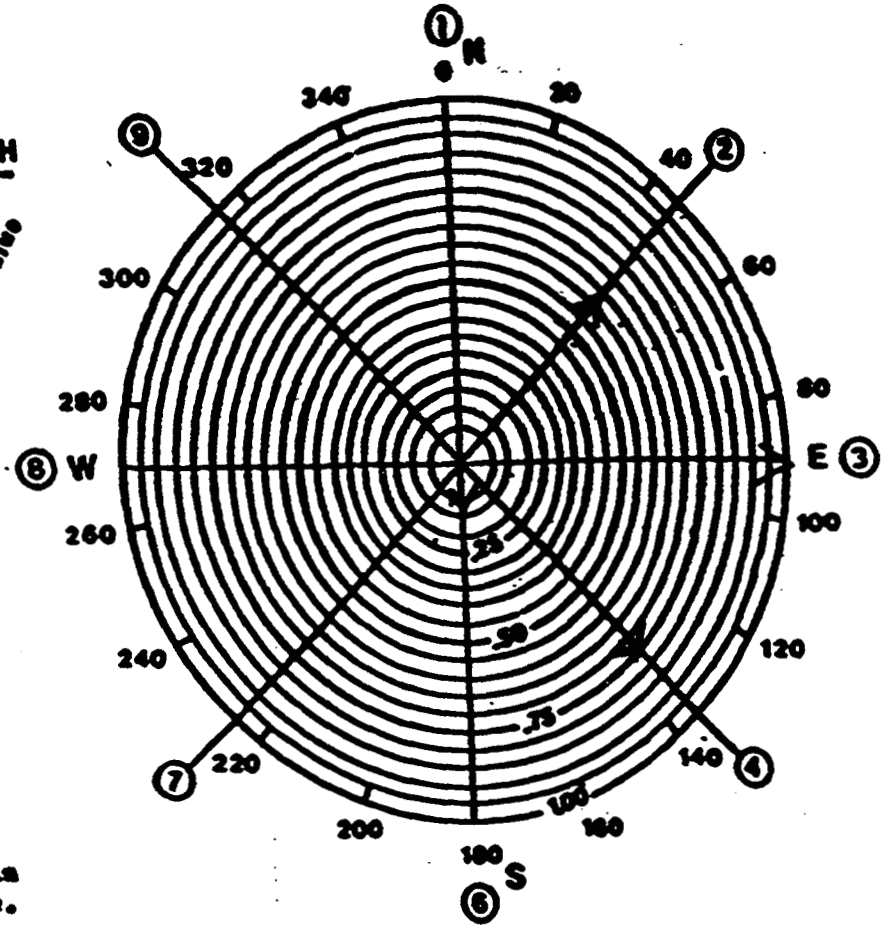
Soil Conditions:

Depth to Measurement: 35.

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F (N-S)/2	G F max. value
•1/-6	0	+6	+6	-3	
•2/-7	+20	+25	+5	+19.5	
•3/-8	+22	+41	+19	+28	
•4/-9	+25	+25	0	+24.5	

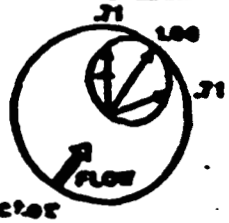


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/programmable calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: E Velocity: .36 ft/day

000222

131 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

N	A	B	C
Probe pair	start	end	B-A
+1/-6	29	22	-7
+2/-7	18	19	1
+3/-8	22	-12	-34
+4/-9	21	-12	-33

2.2 Amps

Operator: Brett Smith Date: 4/10/96

Station: 11502 Time: 10:12

Location: probe 1

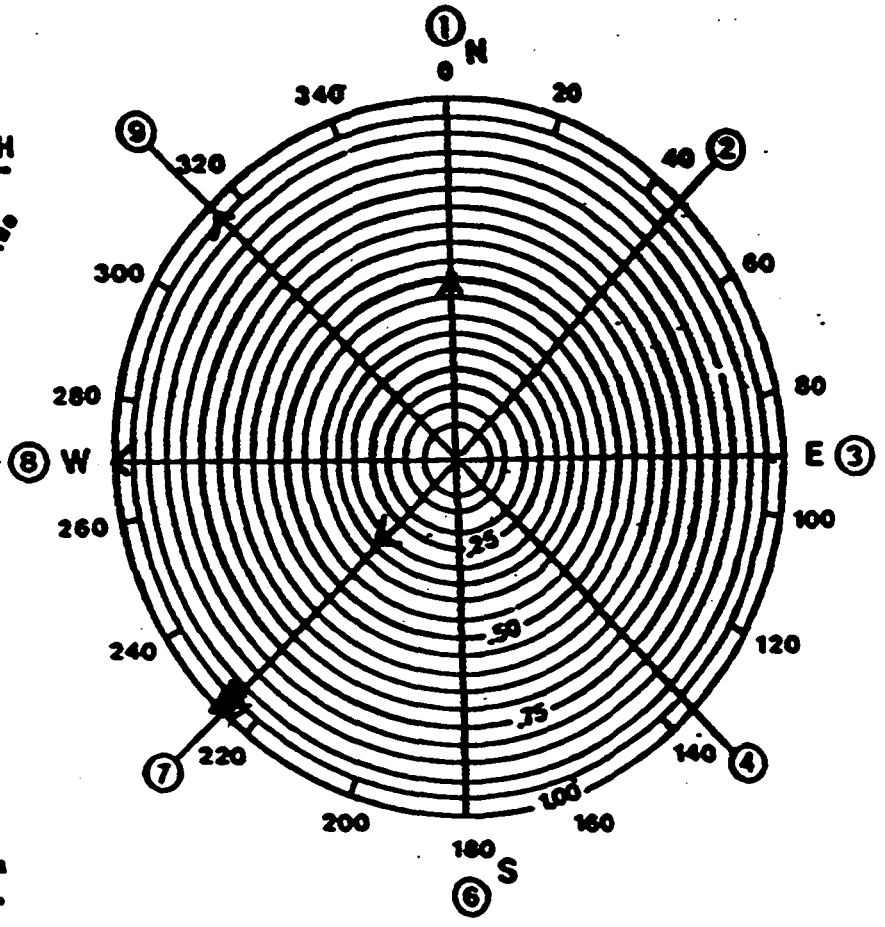
Soil Conditions:

Depth to Measurement: 21.5'

ROTATE PROBE 180° AT SAME DEPTH

1	D	E	S	F	G
Probe pair	start	end	E-D	N-S / 2	F / max. value
+1/-6	32	0	-32	12.5	
+2/-7	19	37	18	-8.5	
+3/-8	20	36	16	-25	1
+4/-9	19	35	16	-24.5	

2.2 Amps

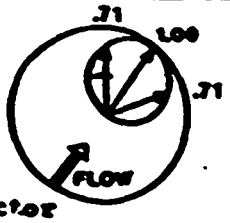


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] a at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 programmable calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NW Velocity: .17 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 62 ft/yr

000223

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

●→N

Probe pair	A start	A end	B-A	C
+1/-6	29 / 26	53	24	
+2/-7	13 / 18	56	41	
+3/-8	16 / 23	16	0	
+4/-9	16 / 26	-17	-33	

2.2 Amps

Operator: Brett Smith Date: 4/10/96

Station: 1150Z Time: 1:02

Location: probe 1

Soil Conditions:

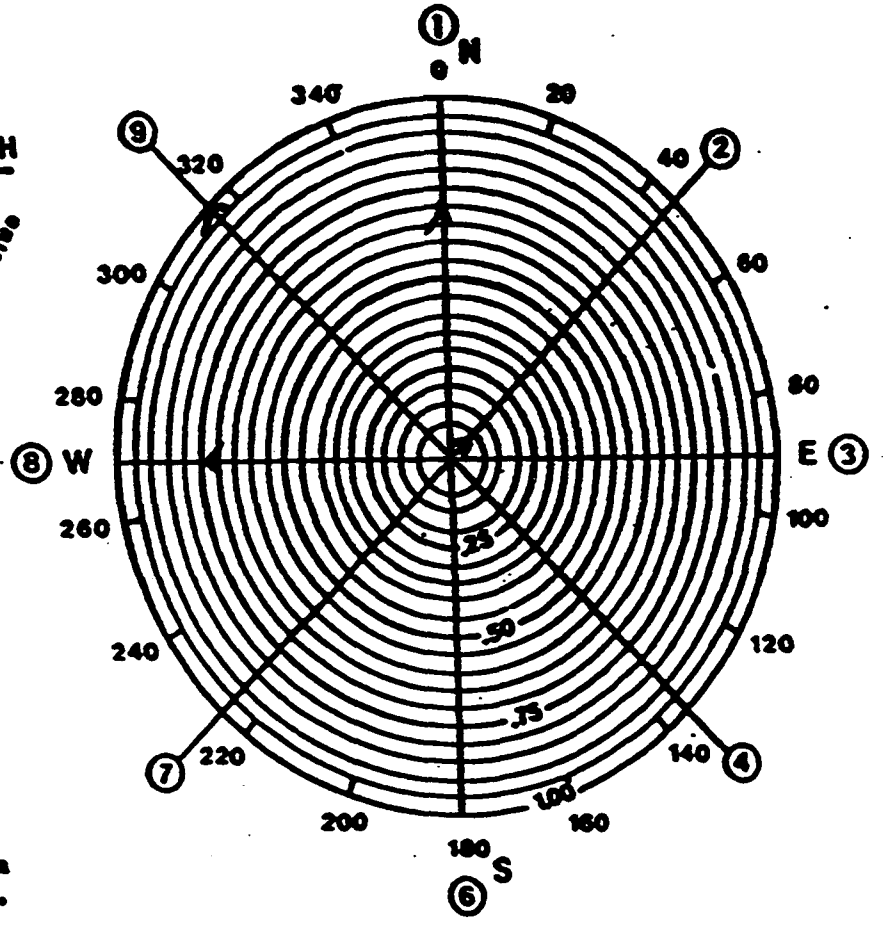
Depth to Measurement: 21'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	E-D	F N-S/2	G F/max. value
+1/-6	26	23	-3	13.5	
+2/-7	18	58	40	0.5	
+3/-8	23	44	21	-10.5	
+4/-9	26	23	-3	-15	

2.2 Amps

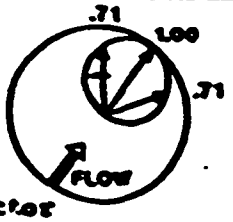


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 and HP calculators
OR
2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NW Velocity: .10 ft/day

36 ft/yr

000224

Form 104 available from your local K-V Associates, Inc. dealer.

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

[redacted]→N

Probe pair	A start	B end	C B-A
+1/-6	+29	+30	+1
+2/-7	+14	+38	+24
+3/-8	+22	+28	+4
+4/-9	+25	+13	-12

2.25 cm/s

Operator: W+N BERRER Date: 4-11-86

Station: #1 Time: 9:24

Location: 11503

Soil Conditions:

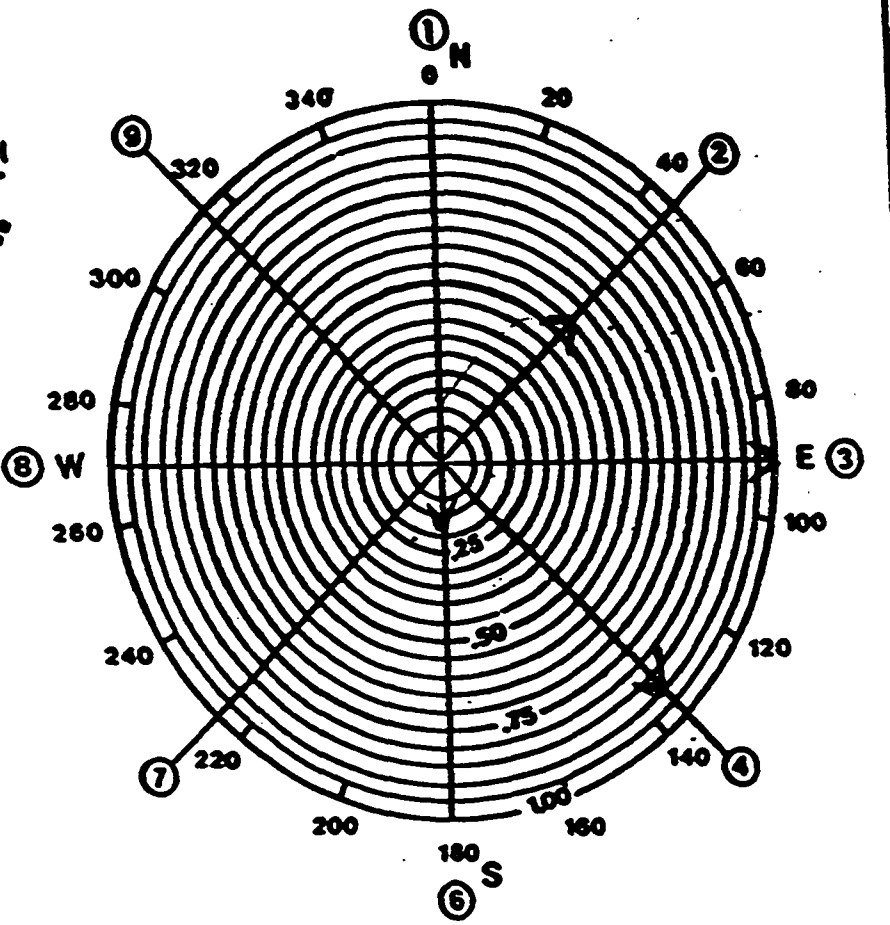
Depth to Measurement: 29.1

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F max. value
+1/-6	+28	+48	+20	-95	
+2/-7	+14	+0	-14	+19	
[redacted]/-8	+22	-45	-67	+36	
+4/-9	+23	-53	-76	32	

2.25 cm/s

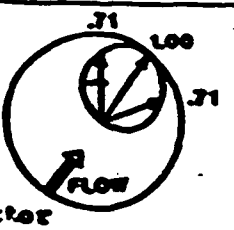


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [redacted] right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP calculators
OR
2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: E Velocity: .24 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 88 ft/yr

000225

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Operator: JOHN J. BELLETZ **Date:** 4-12-94

Station: #2 **Time:** 8:25

Location: 11504

Soil Conditions:

Depth to Measurement: 15' TOW

Table of LCD Readout

[redacted]→N

Probe pair	A start	B end	C B-A
+1/-6	+2	+6	+4
+2/-7	+14	+76	+62
+3/-8	0	+100	+100
+4/-9	0	+58	+58

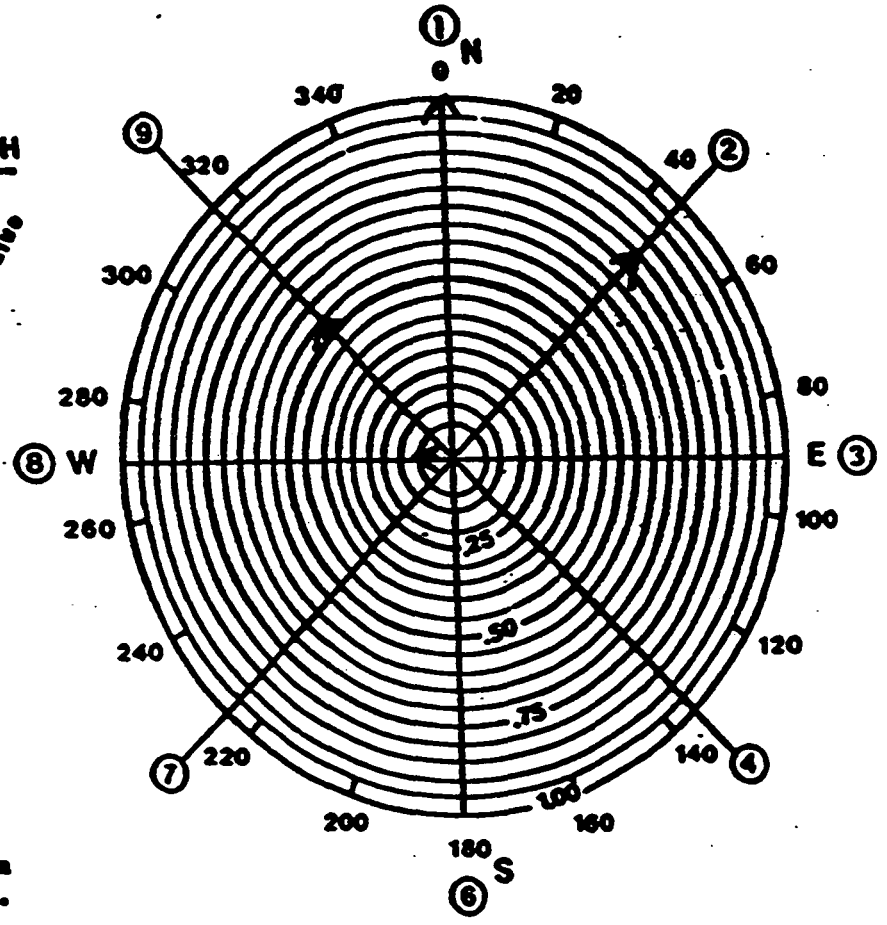
2.25 amps

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S	G F / max. value
+1/-6	+0	-20	-20	N2	
+2/-7	+17	+62	+45	8.5	
+3/-8	+12	+114	+102	-1	
+4/-9	+12	+83	+71	-6.5	

2.2 amps

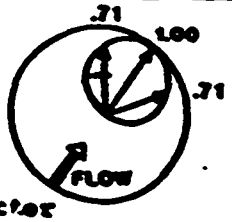


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (M-34/scientific calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: N **Velocity:** .15 ft/day

55 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A Start	B End	C B-A
+1/-6	+28	+44	+16
+2/-7	+22	+53	+31
+3/-8	+23	+5	-18
+4/-9	+31	-12	-43

2.2 amps

Operator: JOHN J. BERGER Date: 4-15-96

Station: #1 Time: 9:40

Location: 11505

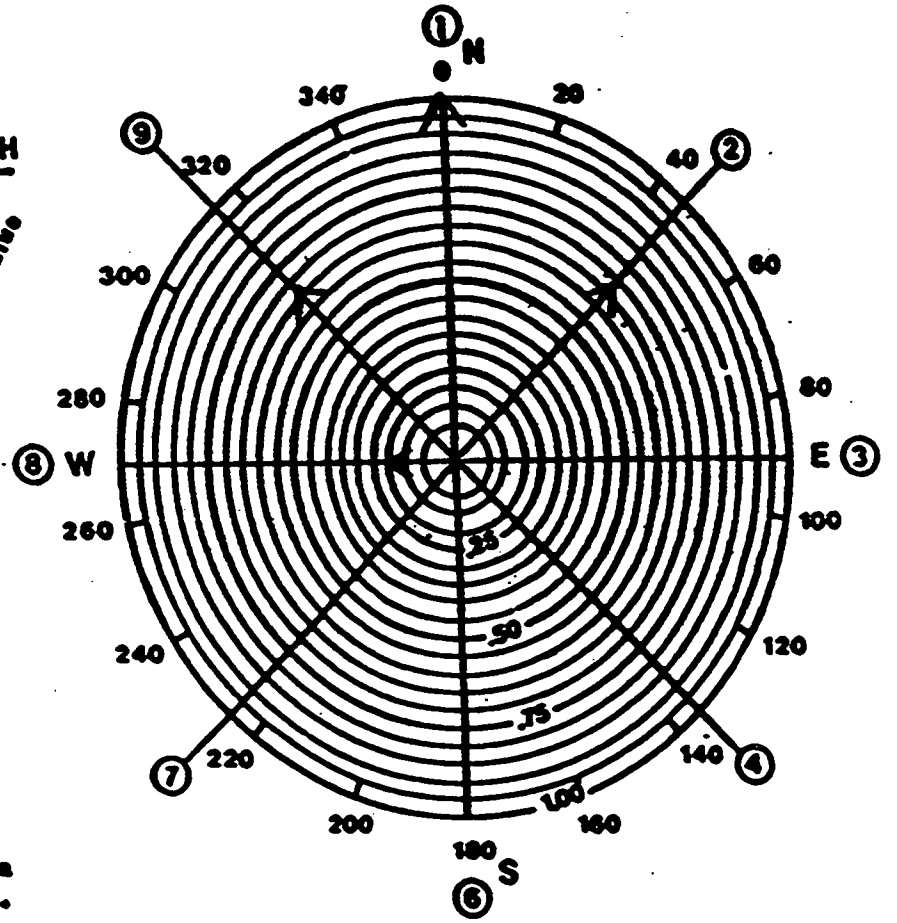
Soil Conditions:

Depth to Measurement: 28.' TOW

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D Start	E End	S E-D	F N-S / 2	G F / max. value
+1/-6	+27	+14	-13	+6.5	
+2/-7	+25	+36	+11	+10	
+3/-8	+26	+15	-11	-3.5	
+4/-9	+31	+10	-21	-11	

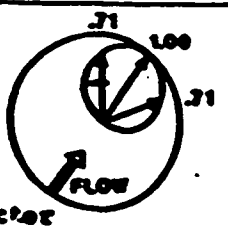


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/35 or HP-33 calculators)

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: N Velocity: .10 ft/day

36 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

GROUNDWATER FLOW WORKSHEET

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

[redacted]→N

Probe pair	A start	B end	C B-A
+1/-6	30	88	58
+2/-7	15	103	88
+3/-8	16	32	16
+4/-9	19	-42	-61

2.25 amps

[redacted]

Operator: Brett Smith Date: 4/3/96

Station: 11546 Time: 10:30

Location: #1

Soil Conditions:

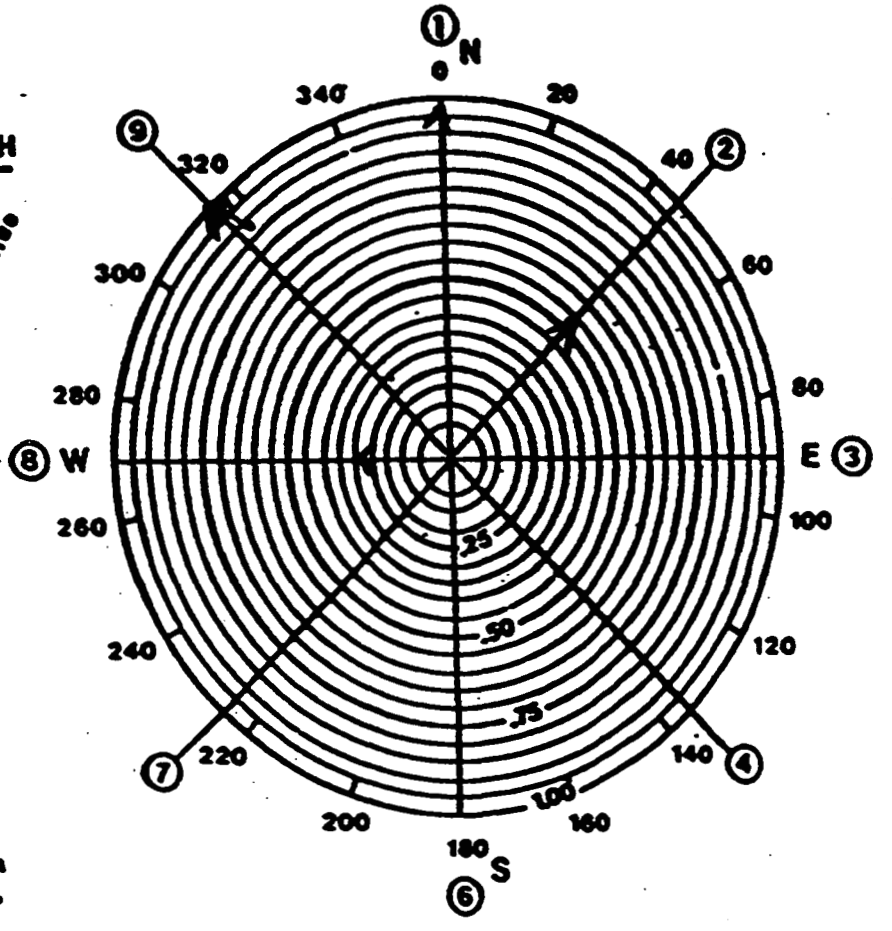
Depth to Measurement: 14'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	34	14	-20	39	
+2/-7	19	65	46	21	
[redacted]/-8	17	58	41	-125	
+4/-9	15	34	19	-40	

2.2 amps

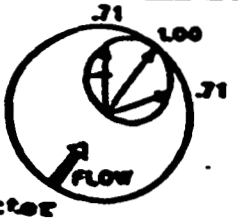


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program [illegible] calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NNW Velocity: 27 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 99 ft/yr

000228

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
•1/-6	-44	-50	-6
•2/-7	-200	-199	+1
•3/-8	-30	-69	-39
•4/-9	+26	-17	-43

Operator: JOHN J. BARRER Date: 4-16-96

Station: #1 Time: 2:19

Location: 11547

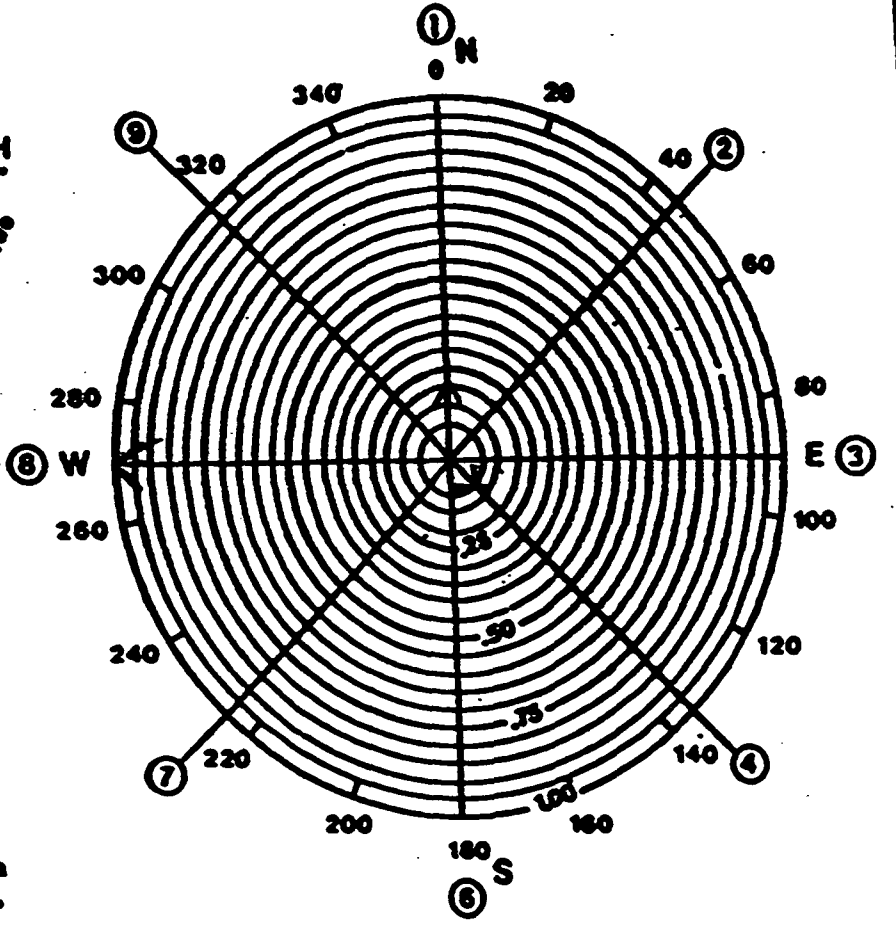
Soil Conditions:

Depth to Measurement: 14'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
•1/-6	20	0	-20	+7	
•2/-7	-110	-118	0	+.5	
•3/-8	-150	-127	+23	-31	
•4/-9	+26	-30	-54	+5.5	

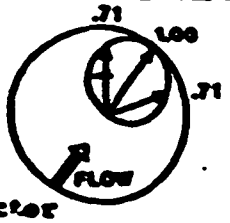


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in colum G will approximate vector lengths at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: W Velocity: .21 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 77 ft/yr

000229

For use with K-V Associates, Inc. Groundwater Flowmeters, 4 channel probe

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	+28	+7	-21
+2/-7	+8	-4	-12
+3/-8	+14	-25	-39
+4/-9	+24	-17	-41

2.2 Amps

Operator: Brett Smith Date: 4-16-96

Station: 11647 Time: 9:50

Location: #1

Soil Conditions:

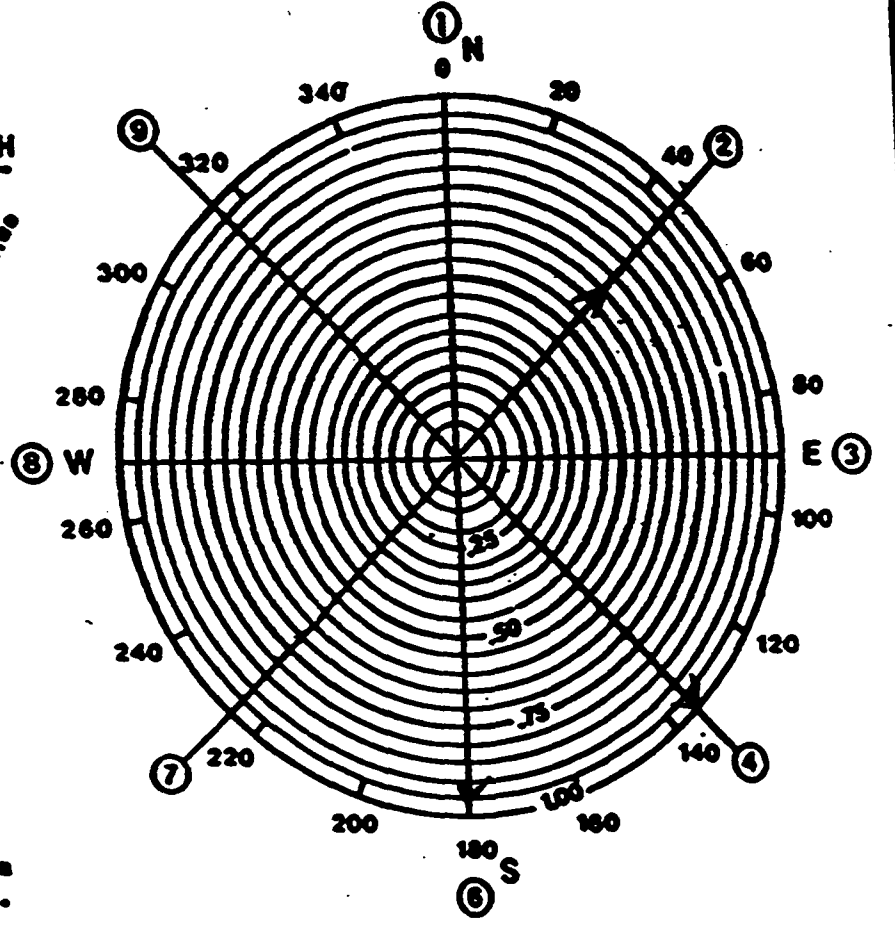
Depth to Measurement: 14' TOW

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	22	26	4	-2.5	
+2/-7	-32	-62	-30	9	
+3/-8	+7	-46	-39	0	
+4/-9	+24	-44	-68	3.5	

2.2 Amps

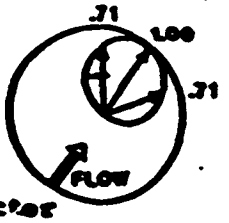


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector lengths at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: SE Velocity: .09 ft/day

Form 104 available from your local K-V Associates, Inc. dealer. 33 ft/yr

000230

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
•1/-6	+3	+17	14
•2/-7	-285	-285	10
•3/-8	-314	-326	-12
•4/-9	+29	-46	-70

2.2 Amps

Operator: Brett Smith Date: 4-17-96

Station: #1 Time: 9:10

Location: 11547

Soil Conditions:

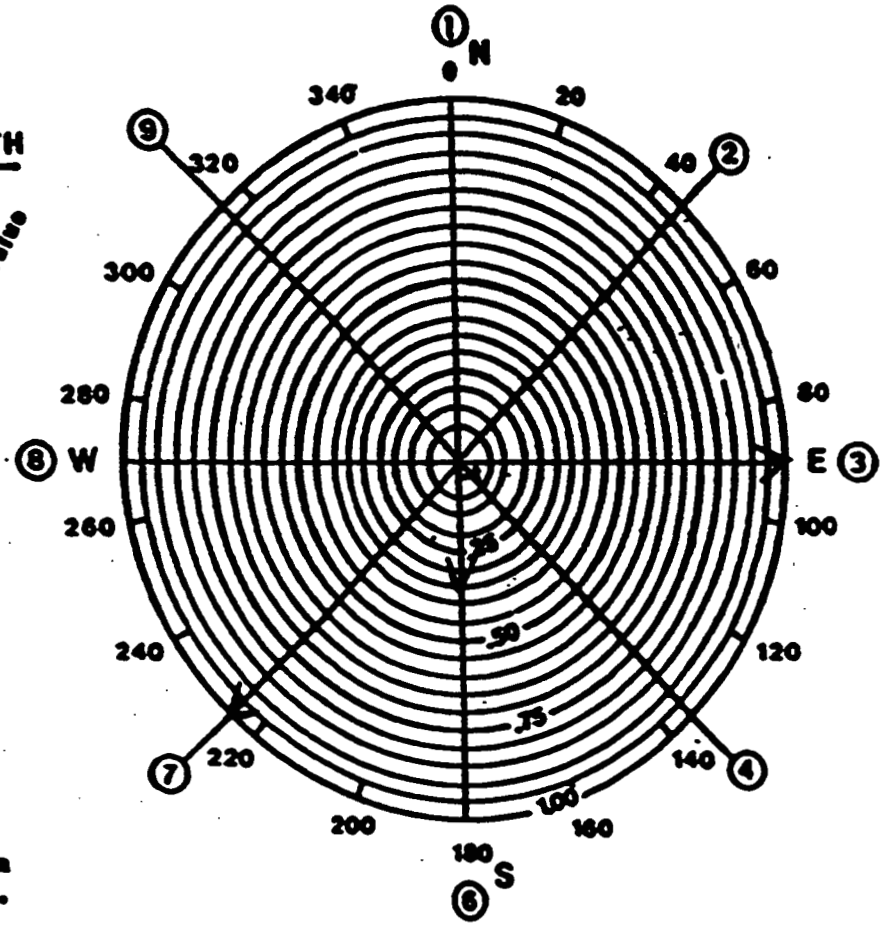
Depth to Measurement: ~~14~~ 13.5

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
•1/-6	+9	31	+22	-4	
•2/-7	-306	-269	+47	-165	
•3/-8	-237	-271	-34	+11	
•4/-9	+27	-44	-71	0.5	

2.2 Amps

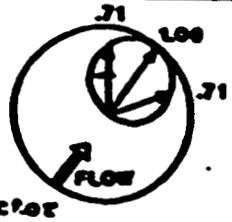


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/35 or equivalent calculators
OR
2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: Can't be determined Velocity:

Form 104 available from your local K-V Associates, Inc. dealer.

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	+1	+21	+20
+2/-7	+19	+35	+16
+3/-8	+17	+49	+22
+4/-9	+10	+15	+5

2.0 amps

Operator: John J. B[redacted] Date: 4-17-96

Station: #2 Time: 2:50

Location: 11547

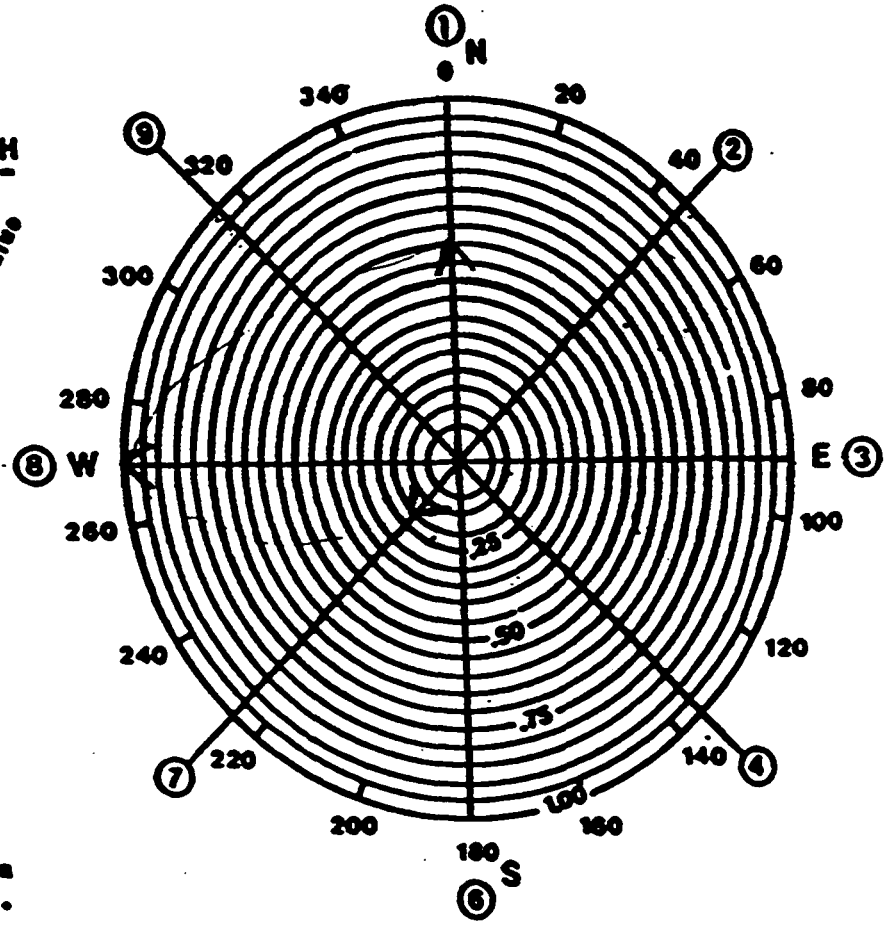
Soil Conditions:

Depth to Measurement: ~~13~~ 14'

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	+1	+14	+13	3.5	
+2/-7	+18	+37	+19	-1.5	
+3/-8	+10	+43	+33	-5.5	
+4/-9	+10	+17	+5	0	

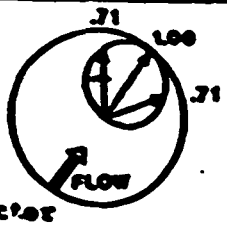


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: WNW Velocity: .07 ft/day

Form 104 available from your local K-V Associates, Inc. dealer.

26 ft/yr

000232

Table of LCD Readout

N → A B C

Probe pair	A start	B end	C B-A
•1/-6	0	+19	+19
•2/-7	+19	+40	+21
•3/-8	+15	+45	+30
•4/-9	+16	+11	-5

2 gauges

Operator: JOHN J. BERRER Date: 4-18-96

Station: A2 Time: 9:41

Location: 11547

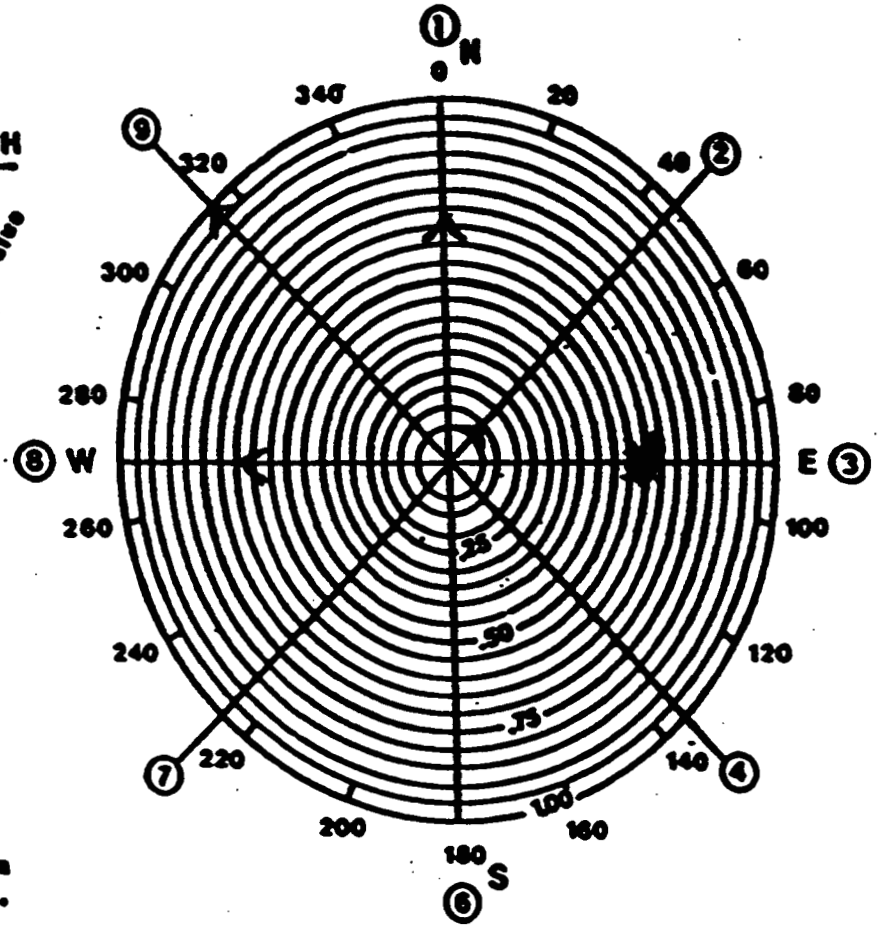
Soil Conditions:

Depth to Measurement: 14'.

ROTATE PROBE 180° AT SAME DEPTH

1 → S

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
•1/-6	0	+12	+12	+3.5	
•2/-7	+14	+33	+19	+1	
•3/-8	+7	+43	+36	+2	
•4/-9	+8	+14	+6	-5.5	

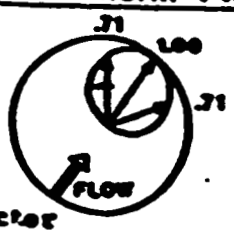


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector [illegible] right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-34/35 medical calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: NW Velocity: .07 ft/day

26 ft/yr

GROUNDWATER FLOW ...

For use with K-V Associates, Inc. Groundwater Flowmeters, **4 channel probe**

475

Operator: JOHN J. BERKETZ Date: 4-15-96

Station: A2 Time: 9:23

Location: 11548

Soil Conditions:

Depth to Measurement: 15' TOW

Table of LCD Readout

1→N

2.25 amps

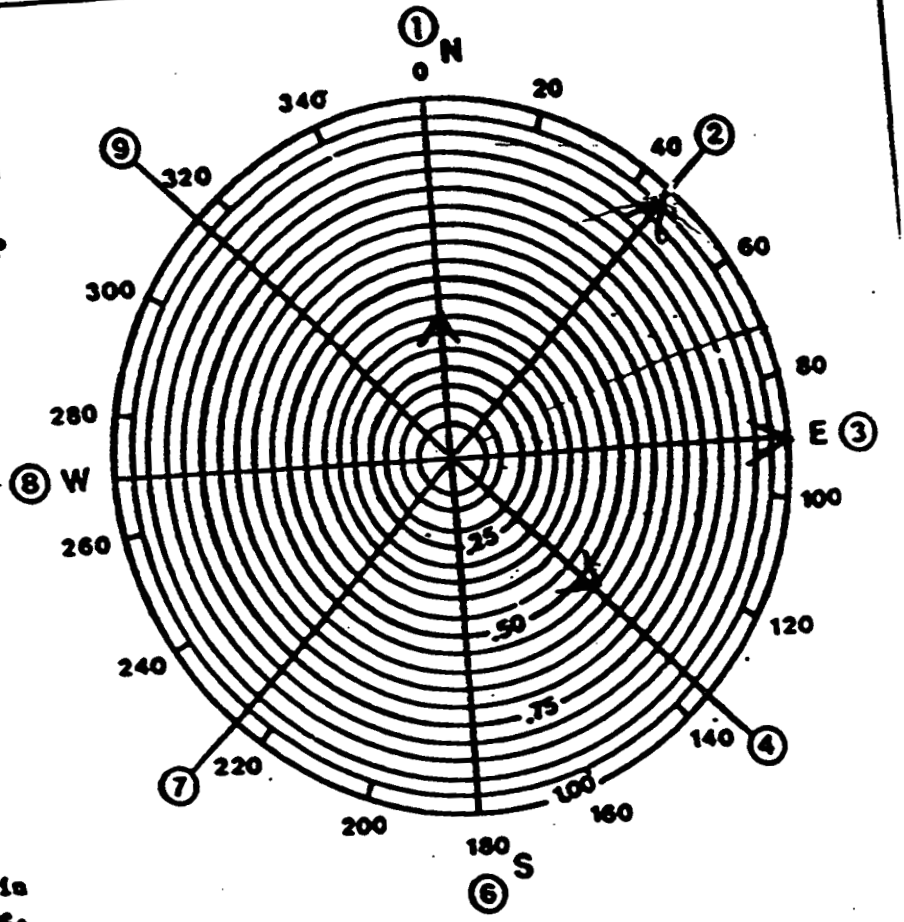
Probe pair	A start	B end	C B-A
+1/-6	+1	+6	+5
+2/-7	+16	+75	+59
+3/-8	+5	+106	+101
+4/-9	+8	+67	+59

ROTATE PROBE 180° AT SAME DEPTH

1→S

2.25 amps

Probe pair	D start	E end	S E-D	F N-S / 2	G F / max. value
+1/-6	+0	-16	-16	+105	
+2/-7	+16	+24	+8	+55	
+3/-8	+8	+55	+47	+27	
+4/-9	+11	+42	+31	+14	

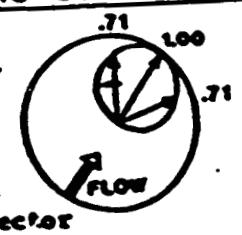


Use of Table

COLUMN G - Divide each reading in column F by the largest absolute value. Draw these 4 vectors on the circle chart according to the scale provided (i.e. strongest vector = 1.00).

Cosine Test Shows Uniform Flow

Vector end points will closely fit a circle inscribed about the longest vector. Values in column G will approximate vector mag... st ... t right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59 or HP-41C) calculators

OR

2. Solve graphically by placing 4 individual vector segments sequentially head to tail. (See manual for detailed instructions).

Velocity Determination

Refer to your calibration curve of readout versus preferred units of flow (e.g. feet per day).

Direction: E Velocity: .35 ft/day

000234

128 ft/yr

Form 104 available from your local K-V Associates, Inc. dealer.

1

2

3

4

Attachment IV

5

2:53 14.90' - WATER ELEV. 11492
2:56 CHANNEL SETTINGS +21, +33, +35, +23
2:59 +21, +37, +37, +23, START RESTING
~~3:05 RAISE PROBE 6 INCHES~~ NA BOS Questionable reading

4/1/96
9:30 arrived at 11491 & 11492
9:41 water elev 11491 16.47'
channels +0 +17 +7 +11
9:45 water elev 11492 14.78'
channels +20 +31 +33 +25
9:46 11491 channels +0 +17 +7 +11
9:47 test 11491 N started
9:48 11492 channels +20 +32 +33 +25
9:50 11491 probe 2 rotated South
9:53 11492 test started probe 1 rotate south
10:48 Arrived at wells
10:49 water elev 11491 16.49'
channels +0 +20 +13 +13
10:51 water elev 11492 14.79'
channels +27 +36 +35 +24
10:52 channels 11491 +0 +18 +9 +11
10:54 channels 11492 +27 +37 +37 +25
1:12 arrived at wells
raised 11492 to 20' rotated to N
1:13 11491 channels +1 +15 +5 +9
1:14 water elev. 11491 16.53'
1:16 water elev 11492 14.86'
1:12 11491 channels +1 +16 +5 +9
1:18 test started
1:21 11491 probe rotated N
2:07 water elev. 11491 16.53'
Channels -16 +79 +105 +75 bad reading probe [illegible] went off
2:10 water elev 11492 14.86'
channels +24 +35 +33 +25
2:15 water elev 11492 14.85
channels +24 +36 +35 +25
2:16 probe 2 test started

000236

4/1/96

2:21 channels 11491 +7 +27 +21 +16
2:25 channels 11491 +4 +24 +17 +15
2:26 test 11491 started.
2:33 probe 2 raised 1' in 11491
2:35 water elev 11492 14.85'
channels +26 +41 +41 +21
2:39 water elev. 11491 16.58'
2:41 channels 11492 +24 +45 +43 +23

4/2/96

9:25 water elev. 11491 16.57'
channels +0 +16 +4 +10
9:27 water elev 11492 14.92'
channels +22 +29 +28 +23
9:31 channels 11491 +0 +15 +5 +10 N test started
9:32 channels 11492 +21 +39 +35 +22
9:34 probe 2 rotated South.
9:36 channels 11492 +21 +40 +36 +22 S test started
9:41 probe 1 rotated to the North
9:51 channels 11491 +0 +19 +13 +15
9:52 channels 11492 +10 +49 +57 +38
9:54 channels 11491 +0 +19 +11 +13
9:57 channels 11492 +18 +
10:00 probe 2 removed from 11491
10:15 channels 11492 +22 +57 +56 +26
10:20 channels 11492 +22 +62 +60 +25 test started
10:30 probe 1 removed from 11492
11:00 probe 1 placed in 11494 at 15.5'
11:05 probe 2 placed in 11493 at 23.25'
11:10 water elev. 11494 3.45'
11:11 water elev. 11493 17.74'
12:40 water elev. 11493 ~~15.72'~~ 17.72'
12:43 water elev. 11494 3.46'
12:47 water elev. 11494 3.46'

4/2/96
12:48 channels 11494 +32 +20 +22 +22
12:51 channels 11494 +32 +20 +22 +22 test started
12:52 water elev. 11493 17.72'
1:02 water elev. 11493 17.72'
~~10~~ 1:04 water elev. 11494 3.42'
1:05 channels 11493 +0 +19 +12 +13
1:06 channels 11494 +30 +19 +23 +21
1:08 channels 11493 +1 +16 +9 +10 test started
1:10 channels 11494 +29 +19 +24 +23 test started
1:15 Channels 11493 +3 +13 +9 +12 test started
1:20 channels 11494 +24 +16 +23 +24
1:22 channels 11494 +24 +17 +23 +25 test started
1:30 channels 11493 0 +11 +10 +15
1:32 channels 11493 0 +1 +10 +15 test started
1:37 water elev. 11495 36.32'
1:41 Channels 11493 +32 +16 +16 +14
1:42 channels 11493 0 +9 +10 +15
1:43 channels 11494 +31 +16 +16 +15 test started N
1:44 channels 11493 +0 +10 +9 +11 N test started N
1:50 probes 1 & 2 raised 1'
3:05 water elev 11494 3.49'
3:07 water elev 11493 17.75'
3:15 water elev 11493 17.75' channels +4 +14 +11 +9
3:16 water elev 11494 3.50'
3:17 channels 11493 +4 +14 +11 +10 test started N
3:20 water elev 11494 3.50'
3:24 channels 11494 +31 +24 +26 +24 test started N
3:27 channels 11493 +0 +12 +15 +16
3:29 channels 11493 +0 +11 +13 +16 test started S
3:30 probe 2 removed from 11493
3:40 channels 11494 +28 +20 +21 +21
3:45 channels 11494 +27 +18 +24 +23 test started S
3:50 probe 1 removed from 11494

4/2/96

3:58 water elev. 11496 2.77'
4:00 water elev. 11497 26.06'
4:10 probe 1 set at 16' in 11496
4:12 probe 2 set at 33.5' in 11497

4/3/96

9:00 arrived at wells
9:05 water elev 11496 2.96'
9:09 water elev. 11497 25.18'
9:15 " " 25.18'
channels +2 +15 +7 +9
9:17 water elev 11496 2.94'
channels +23 +12 +17 +21
9:23 water elev 11497 25.18'
channels +1 +13 +6 +9 N test started
9:25 water elev 11496 2.94'
9:28 channels +25 +14 +17 +22 N test started
9:30 probe 2 rotated South
9:34 probe 1 rotated South
9:35 channels +1 +13 +17 +19
9:36 water elev 11497 25.18'
9:37 water elev 11496 2.94'
9:38 channels +0 +12 +13 +17 test started
9:00 channels +0 +12 +11 +13 test started
9:59 channels 11496 +34 +18 +17 +13
10:02 " 11496 +34 +20 +17 +15
10:10 channels 11497 +1 +17 +13 +15 test started
10:11 probe 1 raised 1' in 11496
10:16 probe 2 raised 1' in 11497
12:42 water elev 11496 2.94' channels +30 +17 +17 +12
12:45 water elev 11497 25.25'
12:46 channels 11497 +1 +13 +6 +9

12:47 channels 11496 +30 +17 +17 +17 test started
12:49 " 11497 +0 +15 +5 +9 test started
12:55 probes rotated to the South
1:05 channels 11496 +28 +17 +19 +19
1:06 channels 11497 +2 26 +14 +8 +9
1:10 channels 11496 +22 33 +18 +21 +21 test started
1:11 channels 11497 +2 +14 +7 +9 test started
1:25 probes removed
1:42 arrived at wells 11498 + 11499
1:45 water elev. 11498 27.84'
1:47 water elev. 11499 6.44'
2:00 probe 2 placed in 11499 18.25'
2:01 probe 1 placed in 11498 30.25'
2:02 water elev. 11499 5.19'
2:03 water elev. 11498 25.05
3:21 water elev. 11498 25.05
3:22 water elev. 11499 5.19'
3:28 water elev. 11499 5.19', channels +0 +16 +6 +9
3:30 water elev. 11498 25.05' channels +29 +20 +22 +21
3:33 channels 11499 +0 +16 +7 +8 test started
3:37 channels 11498 +29 +20 +22 +21 test started
3:50 channels 11499 +0 +17 +13 +12
3:55 channels 11499 +0 +15 +12 +12 test started
4:01 channels 11498 +29 +13 +12 +12
4:05 " " +29 +13 +13 +14 test started

4/8/96

9:50 water elev 11498 25.26'
9:52 water elev 11499 5.31'
9:54 channels 11498 +30 +21 +23 +23
9:55 channels 11499 +0 +9 +0 +4
10:05 channels 11498 +30 +21 +23 +23
10:06 channels 11499 +0 +9 +0 +4
10:10 channels 11498 +30 +21 +23 +23 test started
10:12 channels 11499 +0 +9 +0 +4 test started
10:14 probes rotated south
10:21 water elev 11499 5.31'
10:22 water elev. 11498 25.26'
10:35 channels 11498 +27 +16 +19 +20
10:36 channels 11499 +0 +17 +7 +10
10:37 channels 11498 +27 +16 +19 +20 test started
10:38 channels 11499 +0 +15 +7 +10 test started

2:15 probes removed from 11498 & 11499
~~2:30 water elev. 11546 8.75'~~ water elev. 11546 8.75'
2:35 probe 1 placed at 14' tow in 11546
2:35 probe 2 placed at 21' tow in 11500
2:39 water elev. 11546 7.96'
2:40 water elev. 11500 6.76'

4/9/96

9:52 water elev 11500 7.26'
9:54 water elev 11546 7.86'
9:56 channels 11546 +47 +156 +64 -61
9:57 channels 11500 -7 +4 +0 +8
10:20 channels 11500 +0 +4 -4 +7
10:21 channels 11546 +31 +14 +12 +14
10:27 channels 11546 +30 +15 +16 +19 test started
10:28 channels 11500 +0 +7 +0 +9 test started
10:30 probes rotated to the South

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10:45 channels 11546 +35 +17 +15 +11
10:46 channels 11500 +2 +13 +2 +6
10:56 channels 11546 +34 +19 +17 +15 test started
10:57 Channels 11500 +0 +10 +0 +6 test started
1:35 probes removed from 11546 & 11500
1:43 water elev 11501 12.81'
1:50 probe 2 set at 36' in 11501
1:51 water elev. 11501 10.91'
~~1:31~~ 1:55 probe removed from 11546
2:22 water elev. 11502 7.61'
2:22 probe 1 set at 21.5' in 11502

~~4/9~~

4/10/96

9:54 water elev. 11501 12.41'
9:56 channels 11501 +0 +10 +5 +7
10:00 water elev. 11502 6.24'
10:01 channels 11502 +32 +19 +21 +22
10:05 channels 11501 +0 +10 +5 +7 test started
10:09 probe 2 rotated South.
10:11 channels 11502 +29 +18 +22 +21 test started
10:15 probe 1 rotated South
10:23 channels 11501 +0 +9 +9 +12
10:25 " " +0 +9 +8 +12 test started
10:34 channels 11502 +33 +20 +19 +18
10:36 " " +32 +19 +20 +19 test started
10:45 probe 1 raised 0.5' in 11502
12:33 water elev 11502 6.26'
12:34 channels 11502 +25 +17 +23 +27
12:47 probe 2 removed from 11501
12:50 water elev. 11687 3.01'
1:55 probe 2 set in 11687 at 13.5'

4/10/96

12:56 water elev. 11687 2.0'
1:00 water elev. 11502 6.26'
1:01 channels +26 +18 +23 +26 test started
1:05 probe 1 rotated South
1:20 channels 11502 +36 +14 +7 +4
1:25 channels 11502 +35 +15 +11 +11
1:28 channels 11502 +32 +15 +14 +14
1:31 channels 11502 +29 +15 +16 +16 test started
1:45 probe removed from 11502
1:50 water elev. 11503 27.03'
1:55 probe placed in 11503 at 29.1'
1:57 water elev. 11503 26.62'
2:05 water elev. 11687 2.48' - well does not have cap
3:15 " " " 2.70'
3:18 water elev. 11503 26.78'
3:28 water elev. 11687 2.72'
3:41 water elev 11687 2.75'
3:44 water elev 11503 26.79'

4-11-96

8:57 Arrived at well 11503
9:00 Water level @ 11503 26.89'
9:03 Connected meter #1 with probe #1 @ 11503
9:04 Channels 11503 +30 +17 +24 +23
9:09 Water level @ 11687 3.17'
9:10 Connected meter #2 with probe #2 @ 11687
9:12 Channels 11687 +0 +15 +5 +7
9:15 Water level @ 11503 26.89
9:20 Channels 11503 +29 +14 +22 +24
9:25 Started test @ 11503 - 2.25 amps
9:28 Ended test @ 11503
9:29 Turned probe to the south
9:32 Water level @ 11687 3.17'
9:34 Channels @ 11687 +0 +15 +6 +7
9:36 Started test @ 11687
9:39 Test ended @ 11687
9:[illegible] Moved probe #2 in [illegible] south
9:45 Channels @ 11503 +29 +14 +22 +23
9:53 Channels @ 11503 +28 +14 +22 +23
9:55 Started test 11503 - 2.25 amps
9:58 Ended test 11503
10:57 Channels @ 11687 +0 +16 +6 +8
10:58 Started test @ 11687 2.2 amps
12:18 Pulled probe from 11503
12:[illegible] Pulled probe from 11687
[illegible] [illegible] well does not have [illegible]
12:37 Water level @ 11693 3.18'
12:40 Set probe #1 in 11693 at 15 feet [illegible] top of well
12:[illegible] Water level @ 11513 [illegible] 2.10'
12:45 Water level @ 11504 5.25'
12:50 Set probe #2 19' from top of well
12:55 Water level @ 11504 after setting probe 4.54
2:15 Water level @ 11504 5.04
2:20 Water level @ 11693 2.34

4-15-96

9:19 Water level @ 11548 8.11'
9:21 Channel reading @ 11548 +1, +16, +5, +8
9:22 Started Test @ 11548 2.25 amps
9:26 Ended test @ 11548
9:27 Started probe #2 in 11548 to the south
9:31 Water level @ 11505 16.98'
9:33 Channel reading @ 11505 +28, +15, +24 +31
9:38 Channel reading @ 11505 +28, +22, +23, +31
9:40 Started test @ 11505 2.2 amps
9:43 Ended test @ 11505
9:44 Started probe #1 in 11505 to the south
9:48 Channel reading at 11548 +0, +18, +9, +10
9:53 Channel reading @ 11548 +0, +16, +8, +11
9:54 Started test @ 11548 2.25 amps
9:57 Ended test @ 11548
10:1 Channel reading @ 11505 +26, +32 +29, +35
10:06 Channel reading @ 11505 +22, +25, +26, +31
10:07 Started test @ 11505 2.25 amps
10:11 Ended test @ 11505
10:30 Water level @ 11547 [illegible] 19'
10:44 Set probe #1 in well 11547 water level after probe was set 3.14'. Probe set at 14' from top of well
1:12 Water level @ 11585 6.32'
1:12 Set probe #2 in 11585 @ 17.5 from top of well
1:20 Water level in [illegible] probe 3.26
3:05 Water level @ 11547 13.15'

4-16-96

9:02 Water elev. 11686 6.42'
9:06 channels 11685 +0 +6 -11 +0
9:18 channels 11685 +0 +10 +0 +5 test started
9:22 probe rotated South in 11685
9:26 water elev. 11547 5.8'
9:29 channels 11547 +28 +10 +26 +25
9:29 channels 11712 +30 -6 +14 +23
9:50 channels 11712 +28 +8 +14 +24 test started
9:55 probe rotated South in 11547
9:59 channels 11685 +0 +16 +9 -0
10:04 channels 11685 +0 +15 +8 +10 test started
10:15 channels 11547 +18 -58 +19 +28
10:25 channels 11547 +24 -62 +0 +26
10:30 channels 11547 +22 -32 +7 +24 test started
1:08 channels 11547 +12 -138 -190 +24
2:07 Channels 11685 0, +7 0, +9
2:10 Started Test @ 11685 South
2:13 Ended test and rotated probe #2 to the north in 11685
2:17 Channels 11547 +20, -110, -150, +24
2:19 Started Test @ 11547 2.2 amps South
2:22 Ended Test @ 11547
Final Channel @ 11547 0, -110, -127, -30
2:24 Rotated Probe #1 in 11547 to the north
2:26 Channels @ 11685 0, +22, +22, +21
2:33 Channels @ 11685 0, +20, +15, +15
2:34 Started test @ 11685 2.2 amps
2:37 Ended test @ 11685
2:40 Raised probe #2 6 inches in 11685
2:45 Channels @ 11547 -22, -125, -42, -99
3:00 Channels @ 11547 -44, -200, -30, +24
3:03 Started test @ 11547 2.2 amps
3:07 Ended test @ 11547
Final Channels -50, -199 -69, -17
Raised probe #1 6 inches in 11547

4-17-96

8:49 water elev. 3.26 11547
8:51 channels 11547 -59 -140 -32 +23
9:02 channels 11547 +4 -50 -15 +23
9:05 channels 11547 +3 -215 -314 +24 test started
9:15 probe rotated South in 11547,
9:20 water elev. 11685 6.52
9:24 channels 11685 +0 +8 +0 +6
9:26 channels 11685 -15 +0 -13 +7
9:30 " " -15 +0 -14 +7 test started
9:34 probe rotated South in 11685
9:37 channels 11547 +11 -35 -280 +26
9:39 channels 11547 +9 -306 -237 +27 test started
9:50 probe 1 removed from 11547.
readings indicate the potential for vertical flow.
9:54 channels 11685 +1 +20 +10 +11
10:00 Channels 11685 +1 +20 +12 +11 test started
10:05 probe 2 removed from 11685
10:15 probe 2 set in 11547 at 14'
10:16 water elev. 11547 3.38'
10:35 water elev. 11681 4.09'
10:40 probe 1 set in 11681 at 13' TOW
10:42 water elev. 11681 3.27'
1:30 water level @ 11681 4.09'
1:40 Water level @ 11547 3.38
1:53 channels @ 11547 +1, +19, +9, +10
2:05 Channels @ 11547 +1, +19, +7, +10
2:08 Channels @ 11547 3.38'
2:16 Started test @ 11547 2.0 amps
2:13 Ended test @ 11547 +21, +45, +49, +15
2:14 Rotated probe #2 @ 11547 south
2:25 Channels @ 11681 +28, +22, +24, +23
2:30 Channels @ 11681 +28, +22, +24, +22
Started test @ 11681 2.2 amps

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4-17-91

Continued

2:33 Ended test @ 11681
Final channels +76, +42, -44, -84
2:34 Rotated Probe #1 to the South 11681
2:41 Channels @ 11547 +1, +18, +12, +13
2:41 Channels @ 11547 +1, +18, +10, +10
2:42 Started test @ 11547 2.0 amps
2:50 Ended test @ 11547
Find channels +14, +37, +43, +15
3:02 Channels @ 11681 +25, +22, +24, +24
3:02 Channels @ 11681 +26, +24, +25, +24
3:08 Started test @ 11681 2.2 amps
3:11 Ended test @ 11681
Find channels

9:4[illegible]
[illegible] Water level at 11547 3.40'
9:40 Channels 11547 0, +14, +7, +8
9:41 Started test @ 11547 Probe #2 2.0 amps to the South
9:44 Ended test @ 11547 +12, +33, +43, +14
9:45 Rotated Probe #2 north in 11547
9:52 Water level @ 11681 4.09'
9:53 Channels @ 11681 South +33, +30, +28, +23
9:54 Started test @ 11681 2.2 amps
9:57 Ended test @ 11681 +74, +86, +12, -39
9:58 Rotated Probe #1 in 11681 to the north
10:05 Channels @ 11547 North 0, +19, +15, +16
10:06 Started test @ 11547 2.0 amps
10:09 Ended test @ 11547 +19, +40, +45, +11
10:14 Channels @ 11681 North +32, +20, +15, +14
10:17 Started test @ 11681 2.2 amps
10:20 Ended test @ 11681 +70, +49, -37, -66

[illegible] Water level @ 11501 13.07'
[illegible]:11 Water level @ 11501 after probe setting 11.17
[illegible]:12 Set probe #2 in 11501 @ 38 1/2" from TOW

Water level @ 11501 12.34'
:20 Meter reading probe #2 @ 11501 0, +2, +7, +7
:21 Started test @ 11501 2.2 amps
:24 Ended test @ 11501
Final Reading North -16, +46, +91, +72
:25 Rotated probe #2 to the south
:31 Channel reading South 0, +11, +17, +20
:42 " " " 0, +12, +10, +14
:50 " " " 0, +13, +7, +12
:51 Started test @ 11501 2.2 amps
:54 Ended test @ 11501
Final Reading South 0, +8, +23, +19
:03 Raised probe #2 6" and rotated north 11501
:04 Water level @ 11501 12.39'
:40 Water " " " 12.44'
:42 Channels @ 11501 +1, +15, +7, +11
Started Test @ 11501 2.2 amp North
Ended Test @ 11501 -20, -56, +100, +81
:46 Rotated probe #2 to the South
:26 Water level @ 11501 12.50
:29 Channels @ 11501 South +1, +14, +9, +9
:30 Started test @ 11501 2.2 amps
:33 Ended test @ 11501 South +4, +14, +22, +12
:45 Rotated probe north and raised 6" 12.5
:46 Water level @ 11501 12.59'
:55 Channels @ 11501 +1, +13, +8, +10
:56 Started test @ 11501 2.2 AMPS
:59 Ended test @ 11501 North +2, +57, +83, +59
:01 Rotated probe #2 South
:15 Channels South 0, +20, +22, +25
:16 Started test @ 11501 2.2 amps
:19 End test @ 11501 +6, +25, +41, +25

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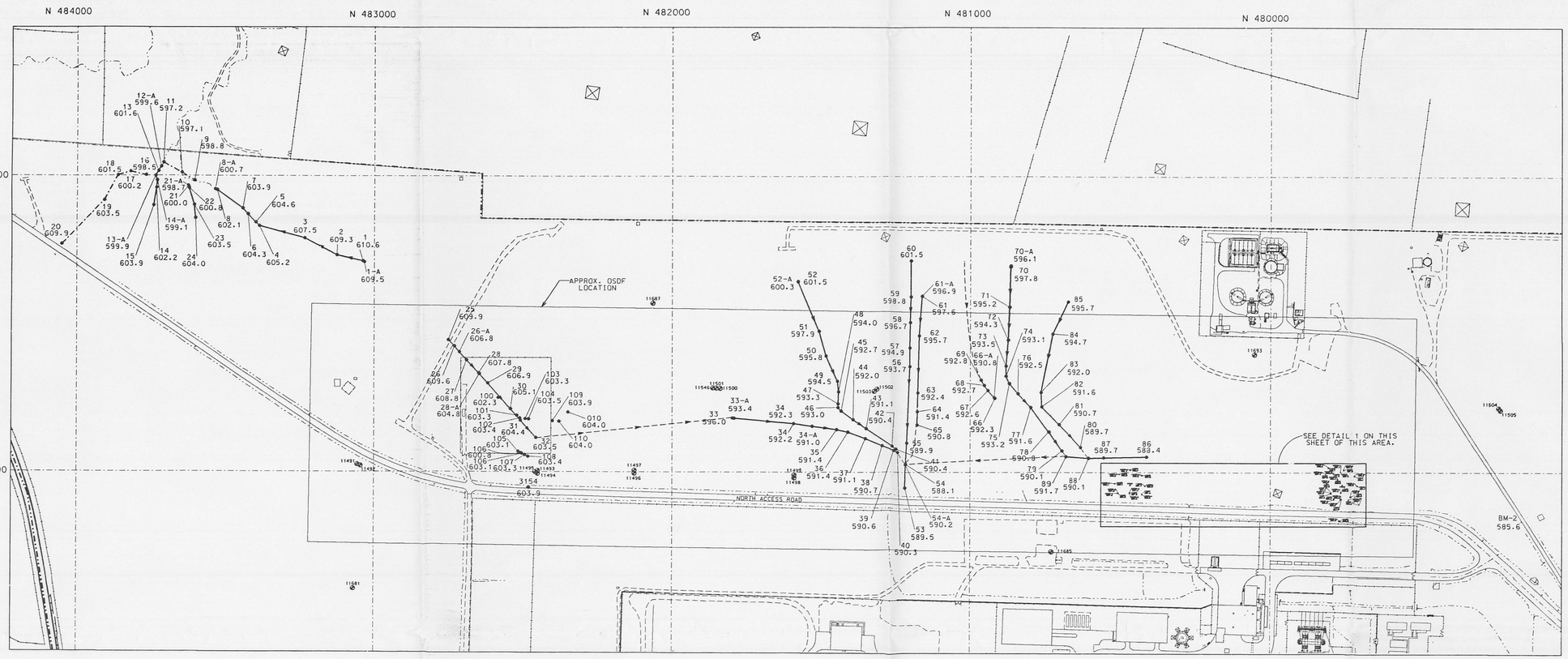

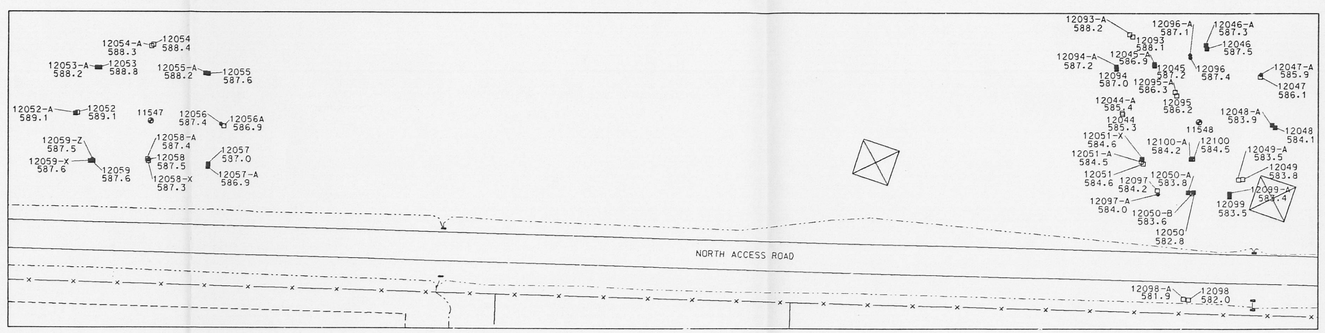

DETAIL 1
GEOPROBE GROUNDWATER AND SURFACE SOIL LOCATIONS

LEGEND

20 STATION POINT
• POINT LOCATION
609.937 ELEVATION TOP OF PIPE
FEMP BOUNDARY
DRAIN TILE
FLOW DIRECTION
STREAM BED
COMPLETE BORING
GEOPROBE CORE LOCATIONS
GEOPROBE TEMPORARY WELL SCREEN LOCATIONS
11693 MONITORING WELLS

INFORMATION ONLY
CADD SERVICES

150' 0' 150' 450'
SCALE: 1" = 150'-0"
NAD83

NO.	REVISIONS	DATE	DWN. BY	APPD.
3	UPDATED MODIFIED TITLE AND DETAIL	8-8-96	GES	GEP
2	UPDATED ADDED DRAIN TILE POINTS, JOB #02	7-9-96	GES	GEP
1	ADDED TEMP. WELL SCREEN 12056A AND ENLARGED DETAIL	5-20-96	GES	GEP

NO.	REVISIONS	DATE	DWN. BY	APPD.	REF. DWG. NO.

NOTE: FERMCO C.A.D. DRAWING NOT TO BE REVISED MANUALLY

CONFIGURATION MANAGEMENT DRAWING
SYSTEMS, STRUCTURES OR COMPONENTS DEPICTED ON THIS DRAWING ARE UNDER CONFIGURATION MANAGEMENT CONTROL. SEE NOTES.
COGNIZANT ENGINEER DATE

APPROVALS					
CIVIL & STR.			SAFETY ENG.		
ELECTRICAL			MAINTENANCE		
ENGINEER	J. BURRITZ	5-3-96	O.A.		
INSTRUMENT			FIRE PROTECT.		
MECHANICAL			WASTE MANAGE		
			SECURITY		
			CRU		
CHECKED	G.E. PAUL	5-3-96			
APPROVED	G.E. PAUL	5-3-96			

FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION
FERMCO
Fernald Environmental Management Project
U.S. DEPARTMENT OF ENERGY

CRU #2 JOB NO. 02, 13, 14, 16, 30B

FIGURE 2.1
LOCATIONS FOR GEOPROBE GROUNDWATER AND SURFACE SOIL SAMPLES, DRAINTILE, SLUGTEST, AND FLOWMETER READINGS OSDF AREA

RES 3000
DATE 5-23-96
DRAWN G. SCHWARZMAN

75X-5500-G-00453 | 3

FORMAT REVISED 4/5/96 FORM5.DGN

FILE NAME: /res3000/75xg0453.dgn

OCT 15 '96