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United States Air Force 611th Civil Engineer Squadron

Elmendorf AFB, Alaska

Final

Aquifer Test Report
Galena Airport
Alaska

October 1994

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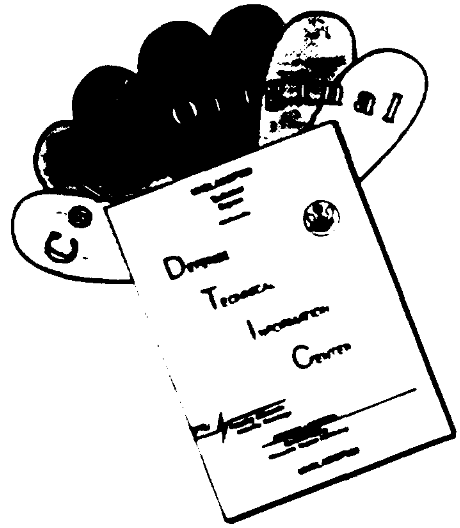

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13. ABSTRACT (Maximum 200 words)

In August 1993, the Air Force conducted aquifer tests near the POL Saddle Tank Site (ST05) at Galena Airport, Alaska. Aquifer test data was acquired in seven observation during a short-term (9.5 hour) pumping test in conjunction with downhole heat-pulse flowmeter recordings in six wells. Analysis of drawdown and recovery data from the pumping test showed the transmissivity ranges from 24,000 to 120,000 ft^2/day with an overall increase with depth consistent with the coarsening nature of the Yukon River aquifer material. The calculated storativity values range from 0.05 to 0.0006, generally decreasing with depth, indicating that shallow unconfined conditions transition to confined conditions at depth. Using an affected aquifer thickness of 100 ft, the hydraulic conductivity ranges from 241 to 1203 ft/day. Average groundwater velocity ranges from 0.31 to 1.56 ft/day. For each 10-ft aquifer zone, the flowmeter velocities were consistently 3.2 to 20 times higher than the calculated velocity from the pumping test. The objectives of the aquifer testing were met--the pumping test provided useful estimates for hydraulic parameters. In addition, the flowmeter, proved to be useful in identifying discrete aquifer zones of high velocity, although velocity estimates did not agree well with those derived from the pumping test.

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1.0 INTRODUCTION

The Galena Airport (formerly Galena Air Force Station, Alaska) is undergoing remedial investigation as part of the U. S. Air Force Installation Restoration Program (IRP). The remedial investigation/feasibility study (RI/FS) process includes characterization of aquifer properties such as hydraulic conductivity, storativity, and groundwater velocity. Once values for these properties are obtained, this information becomes an integral part of the RI/FS in the determination of contaminant fate and transport as well as optimum remedial action technologies.

Aquifer testing was conducted from 24 through 28 August 1993 using pumping test analytical techniques combined with direct borehole flowmeter measurements of groundwater velocity. This was the first occurrence of these types of tests at the Galena installations to a depth of 70 ft below ground level (bgl). Previous slug testing was limited to the shallow aquifer above 25 ft bgl. The objectives of the testing and data evaluation were to:

- Conduct a pumping test that conforms to published standards within operational constraints and satisfies assumptions concerning data evaluation;
- Obtain drawdown and recovery data that can be used in calculations of aquifer transmissivity, hydraulic conductivity, storativity and anisotropy;
- Calculate the groundwater flow velocity from values of hydraulic conductivity derived from the pumping test data and compare computed velocities to direct measurements obtained by flowmeter testing; and
- Enhance the current understanding of groundwater and hydrocarbon migration through the aquifer by using the above calculated parameters.

The aquifer testing at Galena Airport was performed in an area southwest of the POL Saddle Tank Site (ST05), (shown in Figure 1-1). This site was chosen for the following reasons:

- Hydrogeologic similarities to other Galena sites in the "installation triangle" area, allowing test results to be applied to other areas;
- Close proximity to identified groundwater contamination at Site ST05;
- Lack of aquifer disturbance from daily pumping of water supply wells; and
- Good logistics to perform all necessary testing activities.

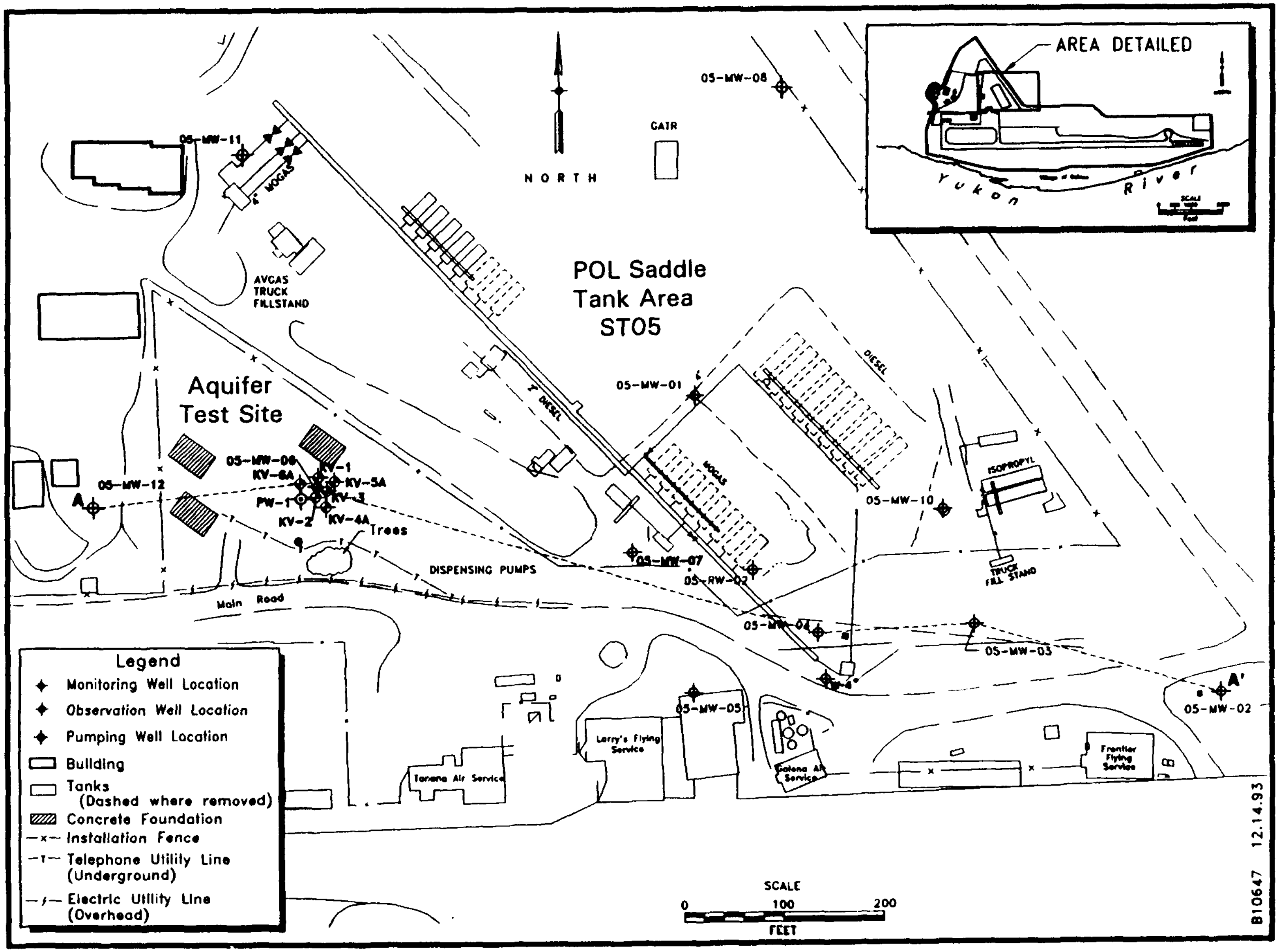

Figure 1-1. Location Map of the POL Saddle Tank Farm (Site ST05) Area and the Aquifer Test Site, Galena Airport, Alaska

2.0 SITE DESCRIPTION

Galena Airport is located on recent floodplain alluvium of the Yukon River. Present-day features in the area are the result of interglacial fluvial processes along one of the largest river systems in North America. The Yukon is unique because of its large drainage area, cold-weather climate, and the fact that there are no man-made controls throughout its length. These factors combine to create spring flooding of great magnitude along lower stretches of the river. The predominant landforms in the Galena floodplain area are abandoned meander channels, accretionary sand bar ridges, and active transverse and longitudinal channel sand bars. The entire Yukon River alluvium is over 200 ft thick and is composed of stacked layers of active channel and floodplain deposits. The overall coarse-grained nature of the Yukon River alluvium at Galena is due to the relative close proximity to high mountain ranges and the river gradient.

2.1 Subsurface Geology

The current knowledge of the aquifer at Galena has been defined from borehole soil samples collected for shallow construction (less than 20 ft depth), intermediate IRP investigation (50 ft depth), and one deep water supply well (200 ft depth) for the Galena installation. Figure 2-1 is a cross section from borehole logs from the Aquifer Test Site eastward to the POL Storage Tank Area as shown in Figure 1-1. The upper 8 to 10 ft of the aquifer consists of silts and silty sands. In some areas of the base where excavation and backfilling occurred during airfield construction, the upper few feet of the aquifer consists of sandy gravel fill material.

The aquifer from 10 to 70 ft bgl consists of a thick sequence of interbedded sands and gravelly sands with only a minor silt fraction. At this depth in the installation area, there is no identifiable silt or clay confining layer. On the basis of data obtained from one borehole log of a base water supply well (BWS-07), sands and gravelly sands continue

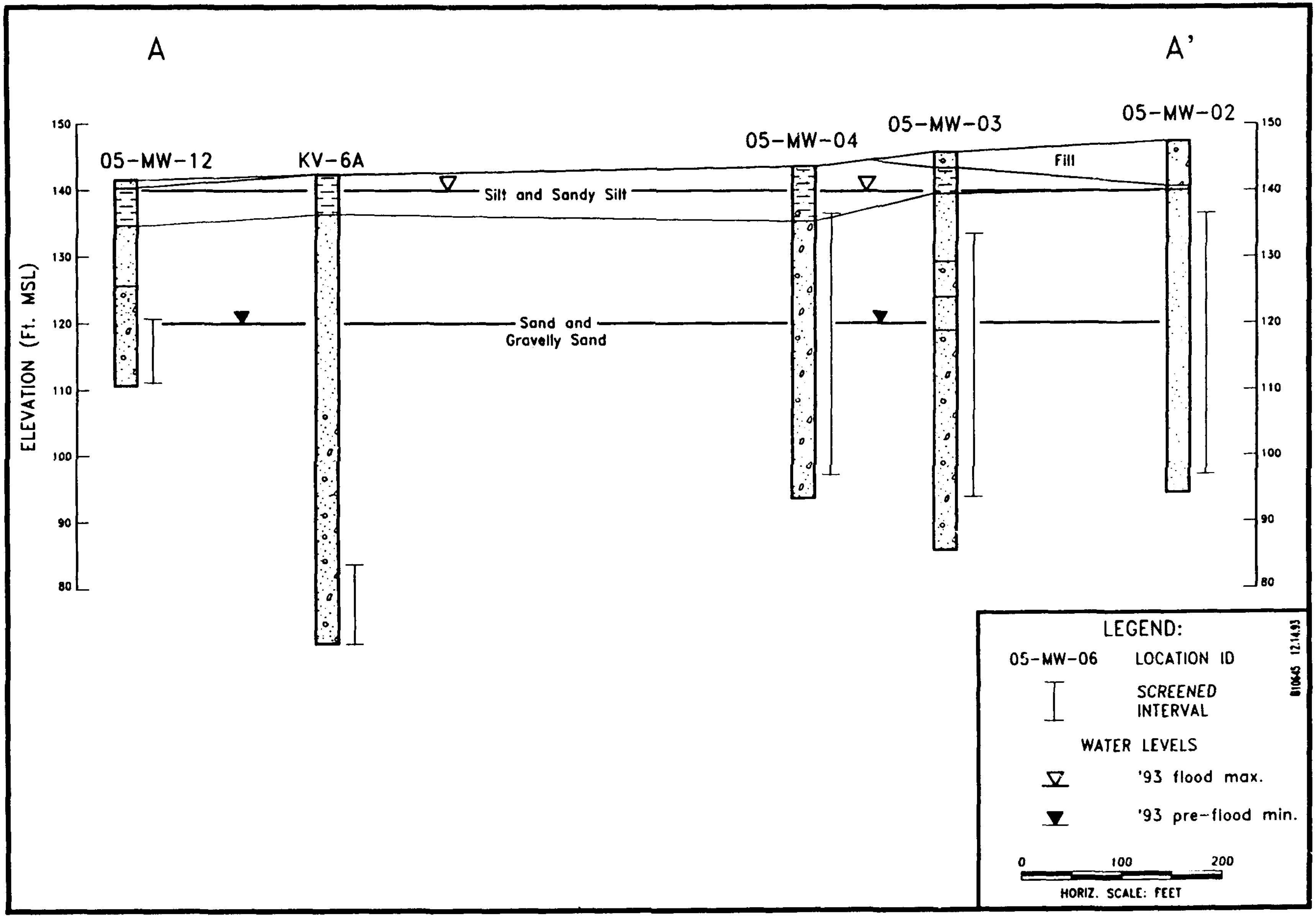

Figure 2-1. Geologic Cross Section A-A', From the Aquifer Test Site to the POL Storage Tank Area

to a depth of 200 ft bgl with only minor interbedded silt layers. Therefore, a silt or clay aquitard within the Yukon aquifer at Galena Airport has not been discovered.

2.2 Hydrogeology

The shallow groundwater in the Galena aquifer is unconfined (the water table represents an atmospheric pressure-head surface). When the Yukon River floods in spring and early summer, the groundwater saturates the upper silty sand zone. Thereafter, the water level gradually subsides into the coarser part of the aquifer and, by late summer, the silty sand upper zone is dry. This seasonal fluctuation of groundwater level is approximated in cross section in Figure 2-1.

On the basis of water level surveys and ambient flowmeter measurements, the normal summer, fall, and winter groundwater flow direction is to the south or southwest across the Galena installation. The horizontal gradients that control the rate and direction of groundwater movement at Galena reflect the elevation differences between the Yukon River and the aquifer water table. The water levels in monitor well 05-MW-06, screened to 45 ft bgl, and the Yukon River level over a period from May 1993 to November 1993 are depicted in Figure 2-2. For most of this period, the water level in the well is higher than the river level. The difference in the levels over the distance from the well to the river is the hydraulic gradient, which is the driving force for groundwater flow and can be used to determine general direction of groundwater flow.

Water level elevations within the aquifer show a maximum near 138 ft above mean sea level (amsl) during June (Figure 2-2). Flowmeter measurements collected during the spring flooding show that groundwater flow reverses and flows northward until the stream level subsides. During summer, temporary groundwater flow reversals occur during the brief river increases from heavy rains within the Yukon basin. However, from September until May, the aquifer levels subside to near 120 ft amsl due to freeze-up within the entire river basin.

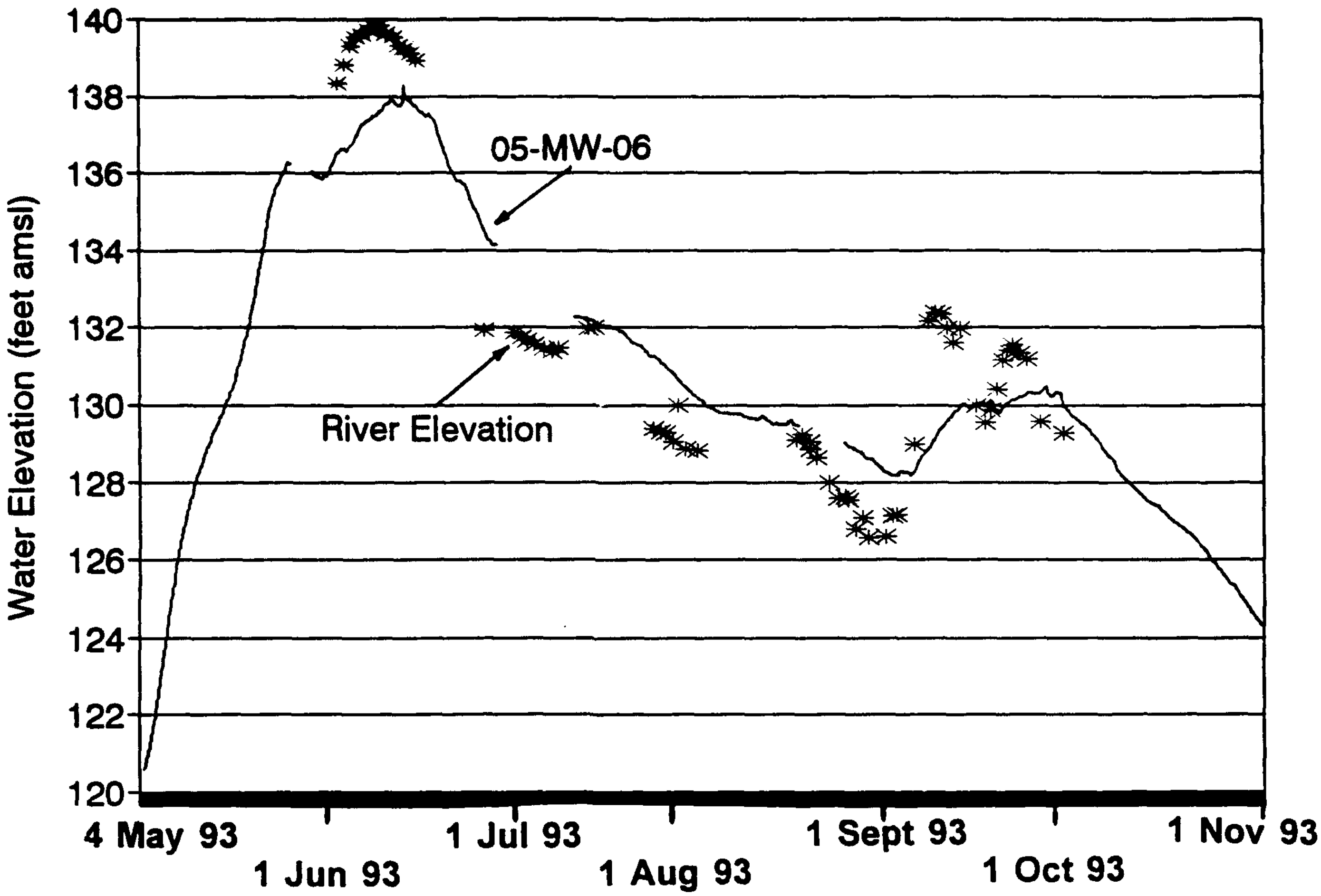

Figure 2-2. Continuous Water Level Monitoring of Well 05-MW-06 and the Yukon River From May to November 1993

A potentiometric surface contour map (Figure 2-3) shows potentiometric contours across the site based on a water level survey of all area wells on 15 August 1993. The map shows that isopotential lines trend northwest to southeast. Potentiometric contours decrease toward the south-southwest, indicating that the direction of groundwater flow is to the south-southwest at a gradient of about 0.00039.

Observation of water levels in deep (base water supply well) and shallow (10-MW-01) wells indicate that vertical gradients are in a downward direction. Continuous water-level data (Figure 2-4) have been collected since May 1993 for monitor well 10-MW-01 and the Base Water Supply Well #2, screened from 5 to 45 ft bgl and 200 to 210 ft, respectively. There is consistently about 2 ft of head difference between the deep zone and the shallow zone. This head difference provides a vertical gradient of about 2 ft per 180 ft, or 0.01 ft./ft.

In 1992, slug tests were performed on 13 wells screened in the top 10 ft of the shallow saturated silty sand material. The hydraulic conductivity calculated from these tests ranged from 0.000014 to 0.00009 cm/sec, or 0.3 to 19.1 gpd/ft^2.

During the 1992 drilling efforts to install monitor wells at the Galena installation, selected samples were collected from the coarse sands and gravelly sands from the 20 to 45 ft depth to obtain preliminary estimates for hydraulic conductivity. These samples were dry-sieved and the grain size distributions plotted. Using the method of Masch and Denny (1966), hydraulic conductivity estimates averaged 0.08 cm/sec. This average hydraulic conductivity developed from the grain size analyses was used to plan for the expected pumping test radius and the observation well distances from the pumping well.

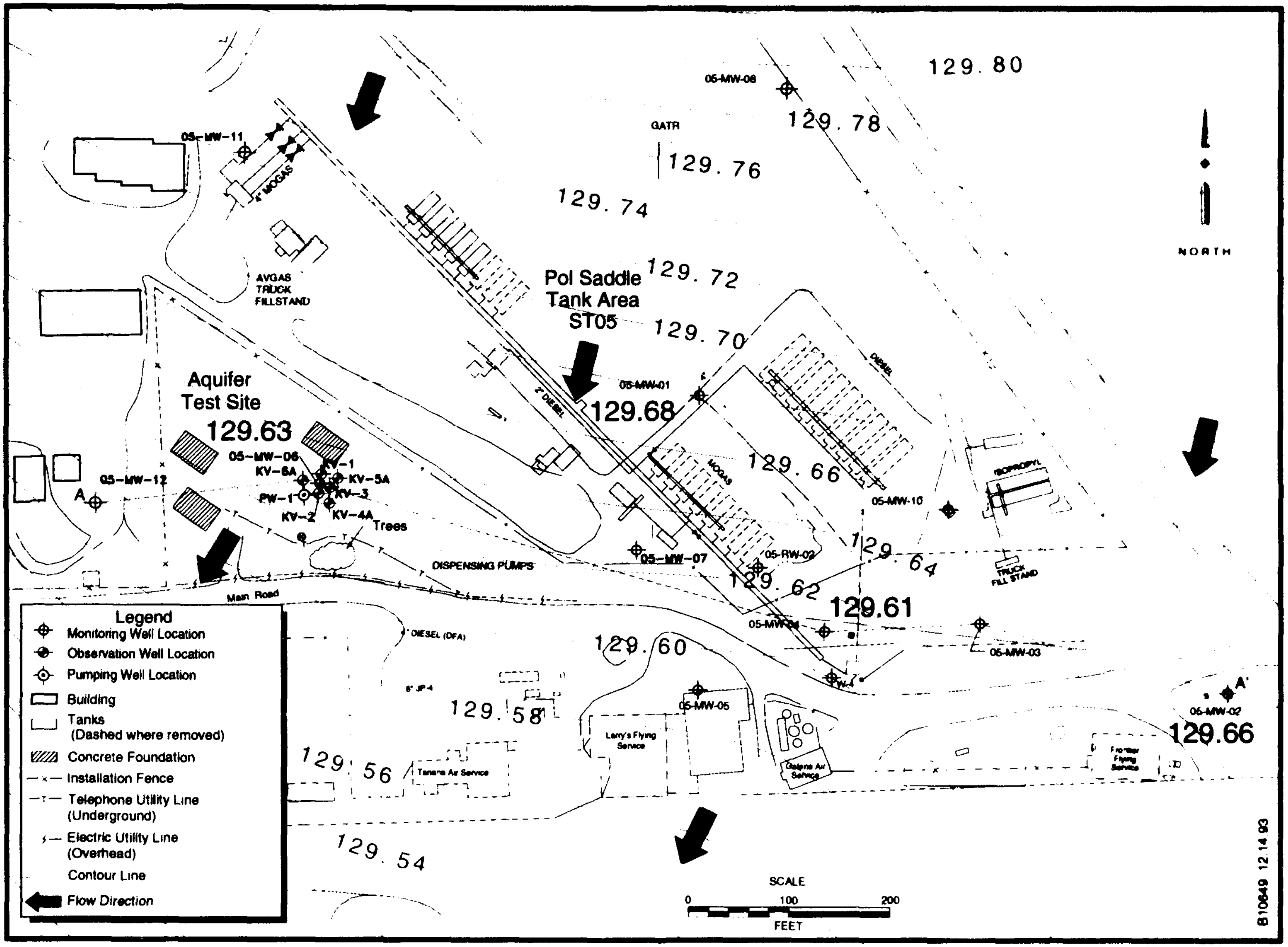

Figure 2-3. Potentiometric Surface Contour Map Based on Water Level Survey, August 15, 1993

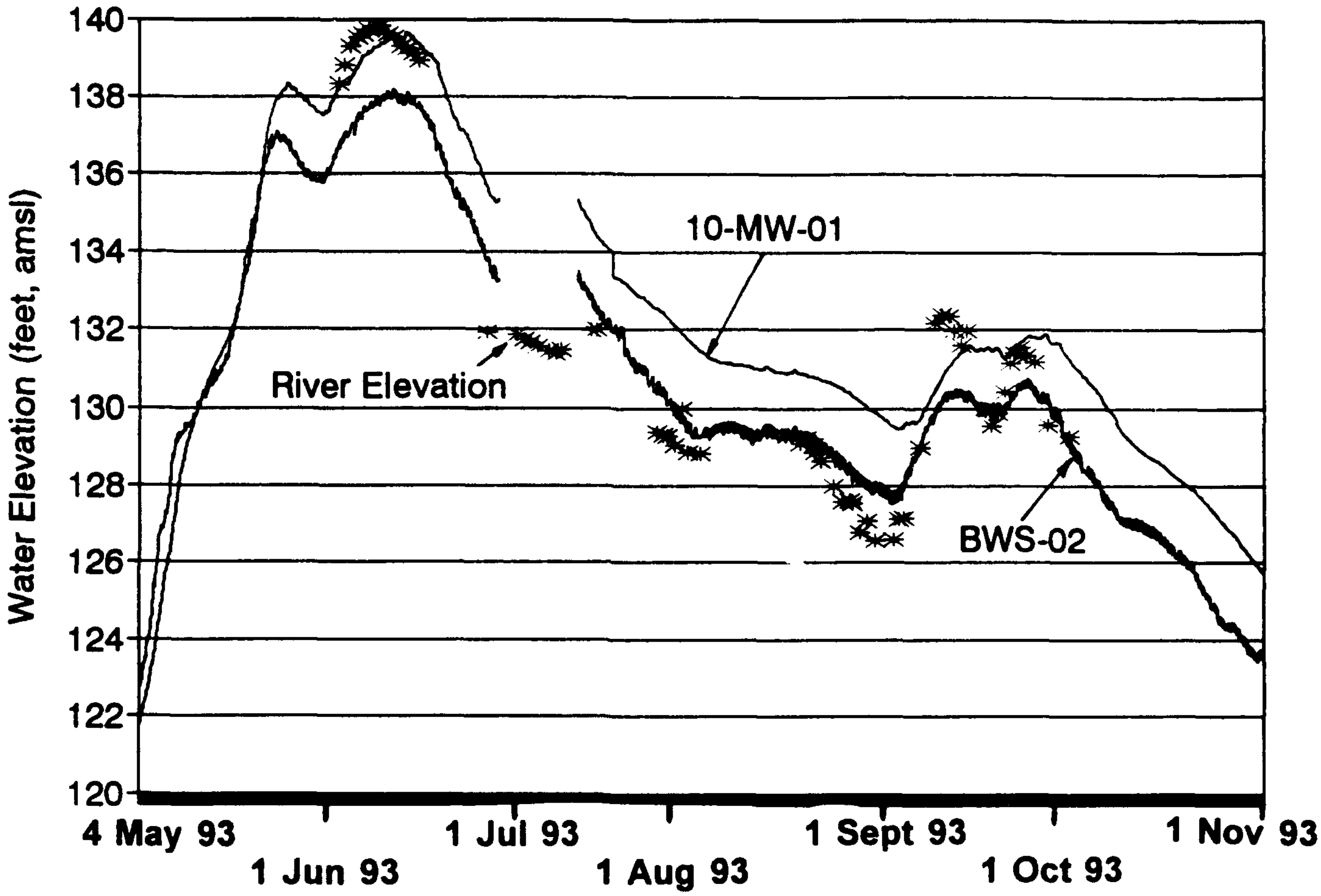

Figure 2-4. Hydrograph Comparison of Water Levels in the Shallow Aquifer (10-MW-01), Deep Aquifer (BWS-02), and the Yukon River

3.0 AQUIFER TESTING AND DATA EVALUATION PROCEDURES

This section describes general testing and evaluation procedures for the pumping test and the flowmeter test. The aquifer testing employed two main methods, a standard short-term pumping test and a borehole flowmeter test. This testing combination was chosen by screening a variety of testing methods on technical, logistical and cost criteria. The screen-testing methods included a long-term pumping test, tracer-dye tests, and packer slug tests. However, since water storage was a logistical problem, a short-term pumping test was evaluated. The combination of short-term pumping and flowmeter testing was believed to provide the least-cost solution for obtaining quality technical data.

3.1 Pumping Test

The pumping test used one pumping well and six partially-penetrating observation wells. Figure 3-1 shows both a map view of the test well locations and a schematic cross section with test well screen depths. The test wells were installed in the pattern shown for the purpose of the flowmeter testing. A pumping well was later installed nearby in a downgradient direction, since a central location to the observation wells would have been difficult to accomplish. The Aquifer Pumping Test Plan (Air Force, 1993a) provides details on the pumping and monitoring equipment. The distances of the observation wells to the pumping well ranged from 15 to 350 ft. The nearby observation wells, denoted by a KV prefix, were installed specifically for the purpose of obtaining direct groundwater flow measurements with a borehole flowmeter and to record the effect of the pumping test. Each well was screened in 10-ft increments to a depth of 70 ft bgl for the purpose of estimating hydraulic parameters within each screened interval of aquifer. Three farther observation wells were monitored during the pumping test. These wells ranged in distance from 207 to 334 ft from the pumping well, PW-1.

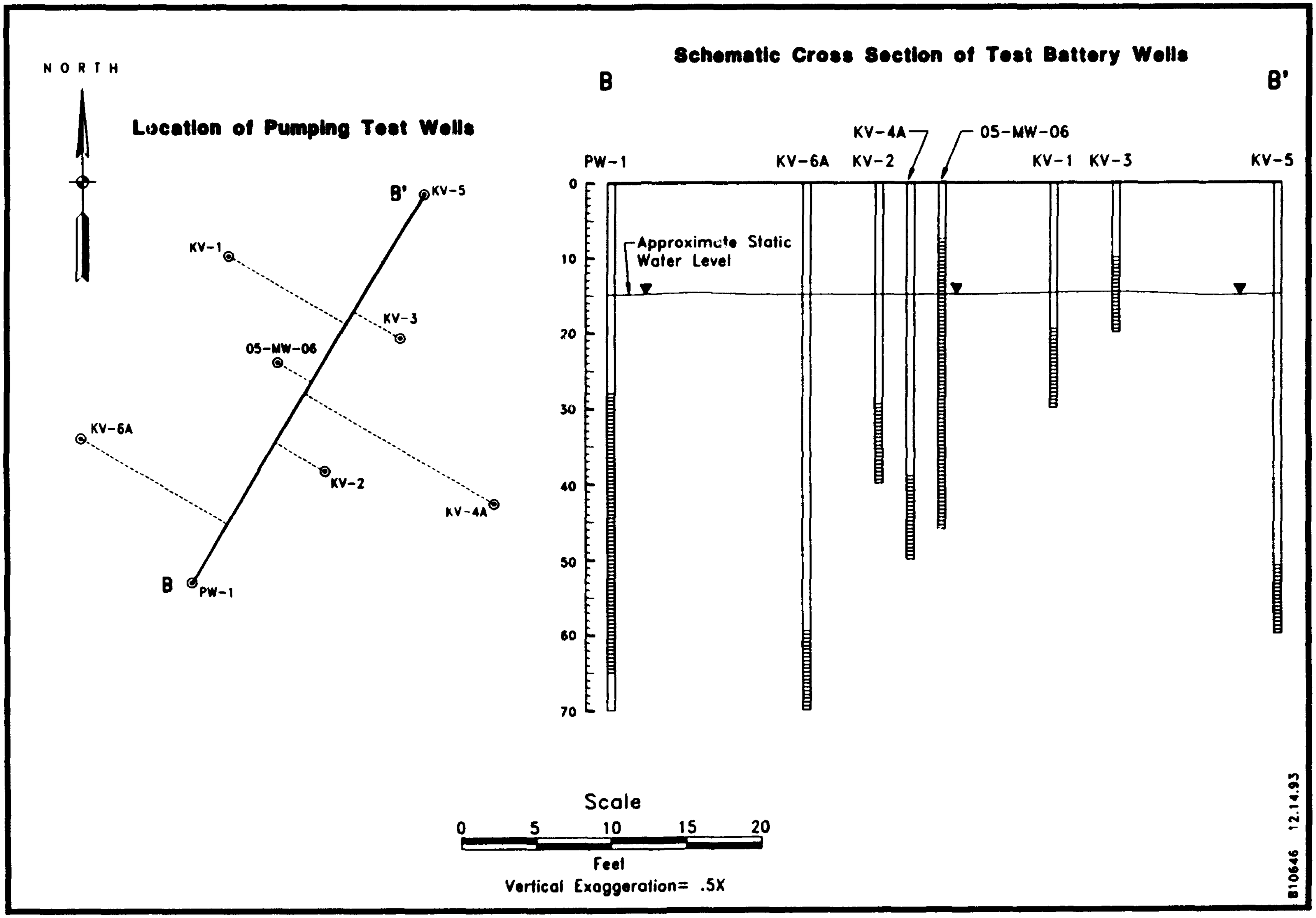

Figure 3-1. Test Well Map and Schematic Well Construction Cross Section

The pumping test actually consisted of three separate phases during which data were recorded. The test phases are summarized as follows:

1. A step-discharge test in which the pumping well was pumped at varying rates. These data are used to estimate the optimum pumping rate (and corresponding valve position) to conduct the pumping test. The step-discharge test was conducted after the pumping and monitoring equipment were installed and operational. Drawdown and recovery data from the step-discharge test were also recorded in nearby observation wells to verify propagation of the drawdown cone. For the step-test, the pumping rate was held constant at 25 gpm for 30 minutes and then increased to rates of 42, 60, and 75 gpm for 30 minutes each.

2. A drawdown pumping test in which the well was pumped at a constant discharge over a 9.5 hour period. During the drawdown pumping test, the pumping well was pumped consistently at 75 gpm to assure drawdown in the observation wells. The water was piped into a 50,000-gal. water bladder for holding until analytical tests for volatile organic compounds could be run on the water samples. Due to the constraint on water bladder capacity, the test could only be conducted for 9.5 hours. The maximum sustained drawdown in the observation wells were recorded to estimate the cone of groundwater depression, which represents the zone of pumping influence. Time-drawdown data were recorded in each observation well for plotting on water-level hydrographs and were analyzed by three analytical techniques described in Section 3.3.

3. A recovery test in which the pumped well was shut down and water-level data were recorded in the pumped well and observation wells. These data can also be used to calculate aquifer transmissivity and storativity. Data for the recovery phase were recorded until recovery of water level in the pumped well was near 95%.

The following types of data were recorded during the pumping test:

- Correction data, including ambient test-well water levels, barometric station pressure, river level, and rainfall that can affect groundwater levels during the pumping test. These data were recorded to correct, if needed, the drawdown and recovery data.

- Water level survey data, used to calculate the regional groundwater flow direction and gradient;

- Water level data in response to pumping (as described above)--recorded by a combination of pressure transducers, automatic datalogger, and hand-held water level probes during each of the three phases of testing. The pumping discharge, as displayed by a continuous in-line flowmeter, was recorded on 15-minute intervals into a field notebook.

- Flowmeter data--recorded by an Air Force hydrogeologist at specific test well depths before and during the pumping test to determine groundwater velocity changes in response to pumping.

3.2 Flowmeter Tests

Flowmeter tests were conducted on three separate occasions on test wells KV-1 through KV-6 at the pumping test site (Figure 3-1). The testing was conducted to obtain groundwater velocity and direction within discrete zones of the aquifer. The vector sum of the discrete flow zones defines the general groundwater flow within the measured portion of the aquifer. The specific testing methods at the Galena site were detailed in an Air Force work plan and memo (1993b, 1993c). The tests were conducted on the following schedules.

- Ambient-May groundwater flow--recorded during the Yukon River flood stage from 25 to 28 May 1993;
- Ambient-August groundwater flow--recorded prior to the pumping test setup from 21 through 24 August 1993; and
- Pumping-induced groundwater flow--recorded during the short-term discharge pumping test on August 26 when the aquifer was pumped at 75 gpm for 9.5 hours.

The purpose of the ambient flowmeter tests was to directly measure groundwater flow direction and velocity for discrete aquifer zones during both the spring flood and normal summer river flow. The flowmeter data provided greater resolution to identify discrete flow zones that are otherwise averaged by conventional pumping test techniques.

An Air Force hydrogeologist recorded the flowmeter measurements with a KVA Model 40 (GeoFlow) groundwater flowmeter. The meter was carefully calibrated and operated according to specifications in ASTM Method #963 (Kerfoot, 1988). The flowmeter employs a heat-pulsing technique and provides a vector reading for the direction and magnitude of groundwater velocity. In each of the test battery wells, KV-1 through KV-6, vector measurements were attempted at three separate positions in each ten-ft section of well screen. Wells KV-4, 5, and 6 were replaced by KV-4A, 5A, and 6A, respectively, when initial flowmeter recordings for those wells were not valid.

3.3 Pumping Test Data Evaluation

The conceptual model for the pumping test is described by Dawson and Istok (1991) for transient flow in an unconfined, anisotropic aquifer with partially penetrating pumping and observation wells. The model is based on an analytical solution described by Neuman (1974, 1975) for both drawdown and recovery data from observation wells. These data are plotted and analyzed by type-curve and straight-line matching methods, respectively. Both methods are used to directly calculate the aquifer parameters, transmissivity and storativity.

The assumptions governing the use of the Neuman model (Dawson and Istok, 1991) are as follows:

- The layer is bounded below by an aquiclude;
- All aquifer layers and the water table are horizontal and extend infinitely in the radial direction;
- The aquifer is homogenous and isotropic;
- Groundwater density and viscosity are constant; flow can be described by Darcy's Law;
- The pumping rate is constant and head losses through the well screen and pump intake are negligible;
- The pumping well has an infinitesimal diameter;

- The aquifer is compressible and completely elastic; pumping instantaneously releases water from storage by expansion of the pore water or compression of the soil skeleton; and

- Water table drawdown is negligible compared to the saturated aquifer thickness.

The type curves used to evaluate the time-drawdown data were developed by a computer program (Delay 2) provided by Neuman (personal communication, 1993). The steps for using type-curves to evaluate the time-drawdown data are detailed in Dawson and Istok (1991). The type curves are visually matched to the data curves and appropriate values of time and drawdown were chosen from a point lying on a matching portion of the curves. Transmissivity, T, is calculated from

$$T = \frac{0.0796\ Q\ S_D}{S}$$

where, Q is the pumping rate in gallons per minute, and s is the drawdown in ft for the data curve, and s_D is the dimensionless drawdown for the type curve.

Estimates of transmissivity and storativity were also calculated using the Cooper and Jacob (1946) method. This method can be applied in unconfined aquifers if the decline of the water table was small in comparison to the saturated thickness of the aquifer. The recovery test data from the pumping well and observation wells were used to determine aquifer transmissivity using Neuman's (1975) recovery method, which employs the Cooper-Jacob equation for transmissivity. Both the drawdown and recovery data were plotted on semilogarithmic paper and the transmissivity for both methods was calculated by the equation

$$T = \frac{0.1833\ Q}{\Delta S}$$

where ΔS is the drawdown over one log cycle on the straight-line plot. Storativity is calculated by the equation

$$S = \frac{2.25\ T\ t}{r^2}$$

where T is the calculated transmissivity, t is the time in minutes at zero drawdown, and r is the radial distance of the observation well (in ft) from the pumping well.

The true thickness of the aquifer is unknown. At a depth of 100 ft below the water table, groundwater flow is assumed to not be influenced by the pumping test. Therefore, the apparent aquifer thickness equal to 100 ft, the hydraulic conductivity, K (in ft/day), is given by

$$K = \frac{T}{b}$$

where b is the apparent aquifer thickness, in ft.

The average linear velocity of groundwater within the aquifer is defined by

$$V_{avg} = \frac{Ki}{n}$$

where V is the average linear velocity in ft/day, i is the hydraulic gradient (0.0039 ft/ft based on 15 August water-level survey data), and n is the effective porosity (approximately 30%). This groundwater velocity calculation is independent of the flowmeter measurements and allows a comparison of the pumping test and flowmeter methods. It also is an important factor for modeling the advective transport of contaminants.

4.0 PUMPING TEST AND FLOWMETER TEST RESULTS

The following sections describe the results of the hydraulic parameter calculations from the pumping and flowmeter tests performed at the Galena Airport test site.

4.1 Pumping Test Results

The collected background data were evaluated to determine whether corrections to the pumping test data were necessary. The influence of background variations on the pumping test data was sufficiently small to be neglected. The background data are presented graphically in Figure 4-1 and are described as follows:

- Barometric pressure--the measured station barometric pressure data in units of inches of mercury were converted to ft of water to allow direct comparison to aquifer head changes. The barometric pressure showed only cyclical diurnal variation ranging over 0.1 ft of water, no major barometric changes were recorded.

- Ambient aquifer test well water level--as measured beyond the pumping test influence in a selected ambient well, 10-MW-01. The well was chosen for ambient monitoring of the shallow aquifer because of its close proximity to a deep water supply well, BSW-2, which was also monitored. The proximity of the two wells was favorable for comparison of water level changes in the shallow and deep part of the aquifer while minimizing the horizontal distance between the wells. The ambient aquifer water level showed a steady rate of decrease for a total of 0.41 ft for the five day monitoring period. The water level showed no apparent response to diurnal barometric fluctuations. The ambient water level decline of 0.4 ft per five-days seen in 10-MW-01 is equivalent to a minimal 0.03-ft drop over the 9.5-hour pumping test.

- River level--a steady rate of decrease for a total of 1.08 ft over the five-day period.

- Rainfall--no rainfall occurred during the aquifer testing from August 24 to 28.

The step-discharge test verified that measurable drawdown could be propagated to nearby observation wells at pumping rates above 20 gpm. The last step of the test

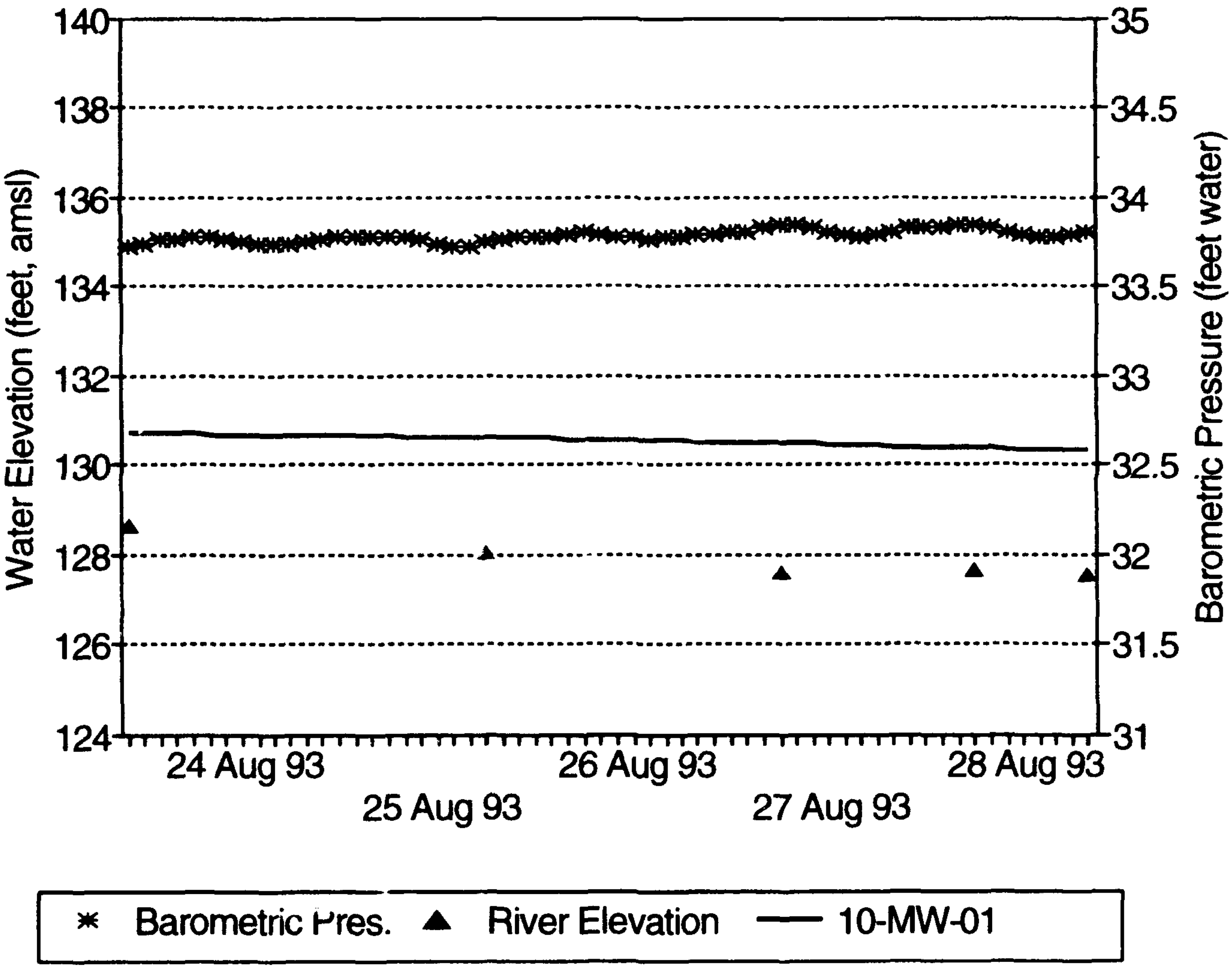

Figure 4-1. Barometric Pressure, Aquifer Water Level, and River Level Changes During the Aquifer Testing Period, August 24 to 28, 1993

showed that the maximum sustainable pumping rate of the pump was 75 gpm, which was 115% of the rated capacity at the pump depth with calculated fitting and line head losses.

During the pumping test, a constant discharge of 75 gpm was maintained for 9.5 hours. The maximum drawdown measured in each observation well is shown on the site map in Figure 4-2. The drawdown ranged from a minimum of 0.09 ft at 05-MW-12 to a maximum of 0.52 ft at KV-2 (14.1 ft from PW-1). Well KV-6A, at 15.0 ft from PW-1, showed only 0.24 ft of drawdown during the test. The low drawdown at a close distance to the pumping well suggests a high aquifer transmissivity of the zone from 60 to 70 ft bgl in which KV-6A was screened. Drawdown data for well 05-MW-06 were lost due to an electrical power surge. From extrapolation of observed drawdowns, the maximum zone of influence from the 9.5 hours of pumping at 75 gpm is probably just over 210 ft. The minimal water level drop at 05-MW-12 can be partially attributed to water table response to the river trend (see Figure 4-1, 10-MW-01).

The ratio of discharge to drawdown at the pumping well at a specified time since pumping began is called specific capacity and can be related to transmissivity under ideal conditions using the equation $T = 1500 (Q/s)$ for unconfined aquifers (where T is the transmissivity, Q is the pumping discharge, and s is the drawdown). Ideal conditions are those specified in the assumptions in Section 3.3 and also include the establishment of steady-state conditions. The calculated specific capacities for the pumping well range from 27.4 to 38.5 gpm/ft. This small range in values suggests that the conditions for the test were not far from ideal. The range in specific capacity translates to a transmissivity range of 5,481 to 7,720 ft^2/day, respectively, which is 2 to 8 times less than the pumping test calculations for transmissivity using the Neuman recovery and Cooper and Jacob methods (described further below).

Hydrographs were constructed for each well over the pumping test period and are presented in Figures 4-3, 4-4, and 4-5. For the pumping well and observation wells, the general shape of the time drawdown curves were very similar to Theis curves with gradual

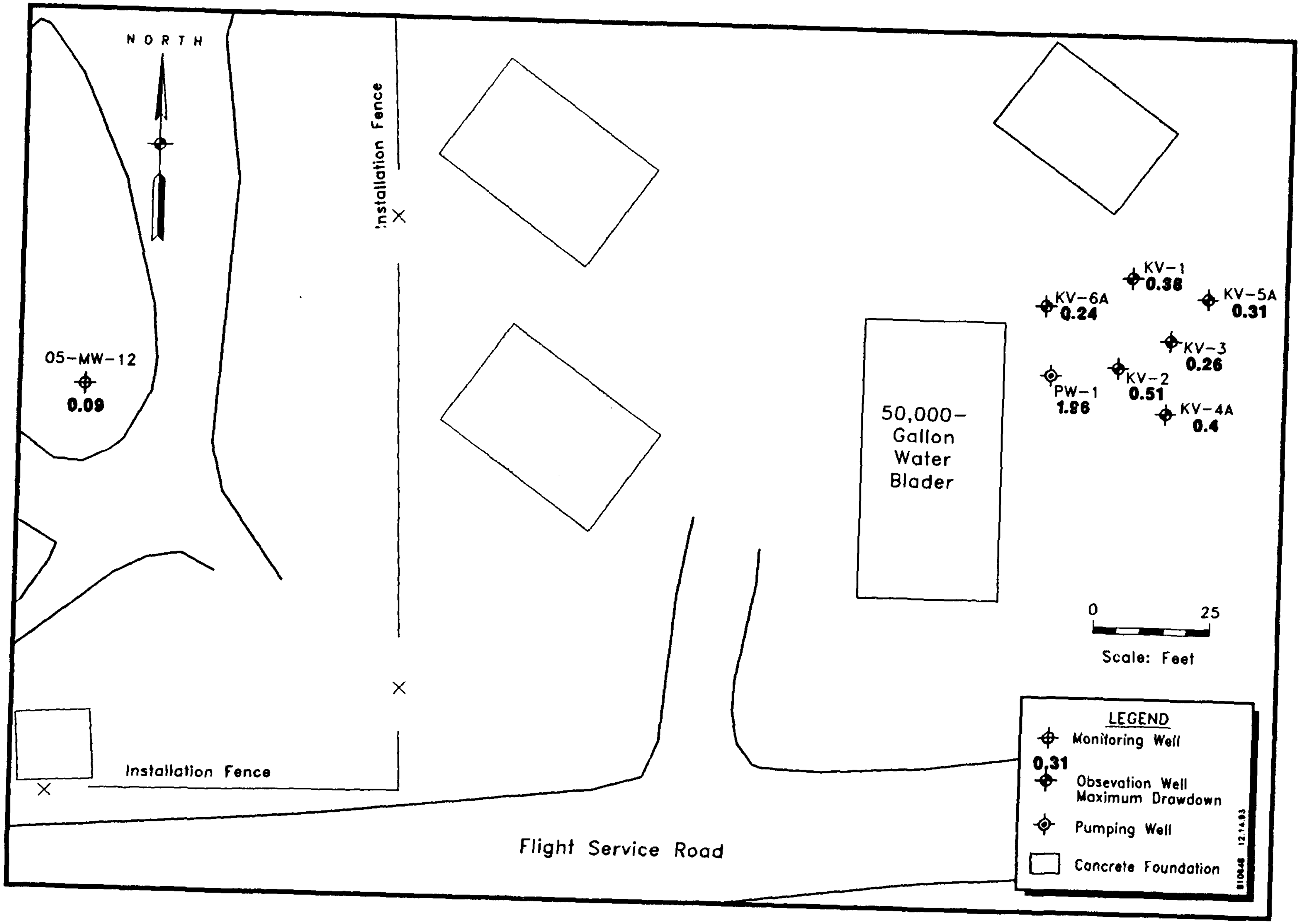

Figure 4-2. Maximum Drawdown Recorded in Test Wells at the End of the 9.5-Hour Pumping Test

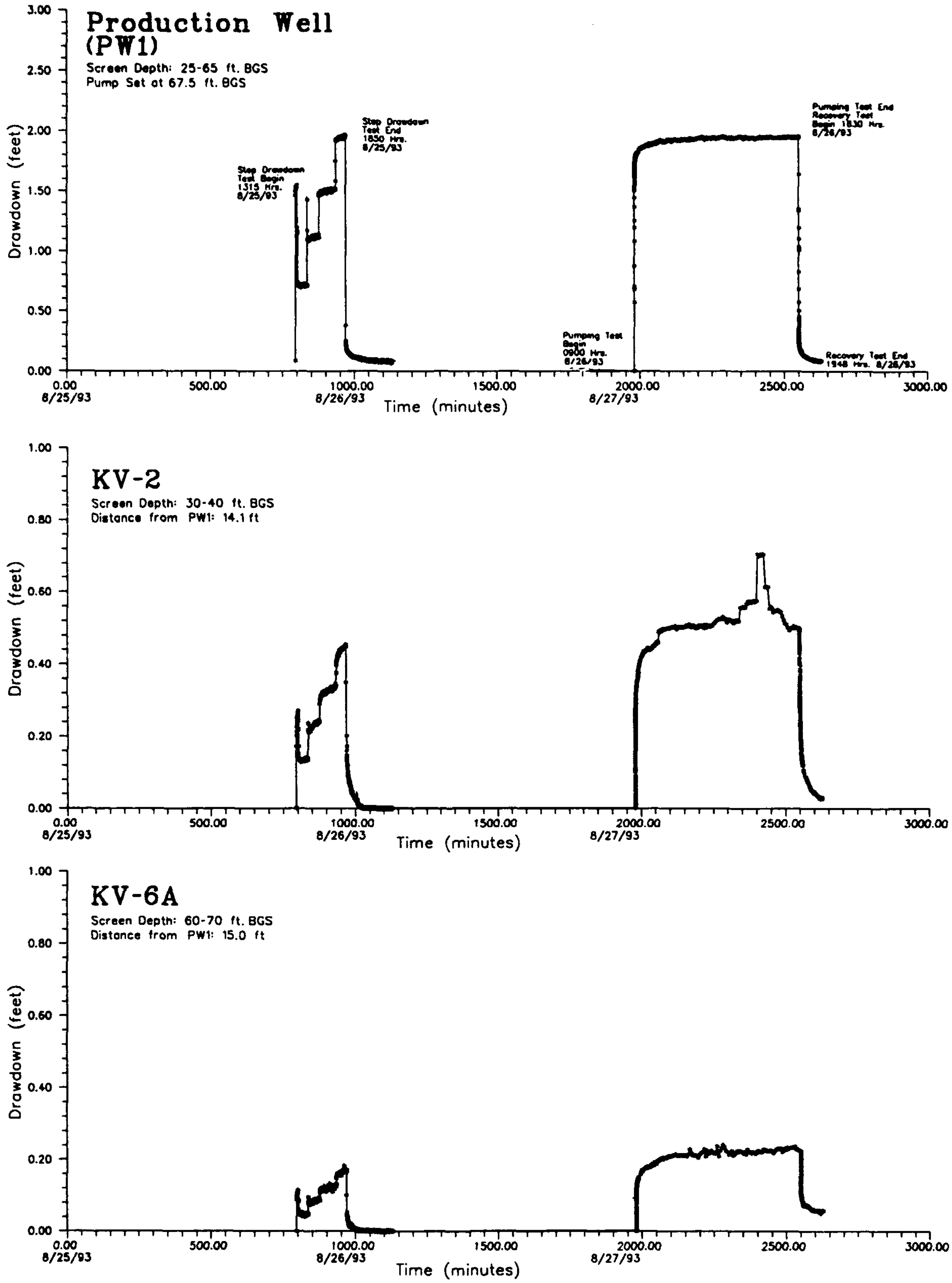

Figure 4-3. Pumping Test Hydrograph for Wells PW-1, KV-2 and KV-6A

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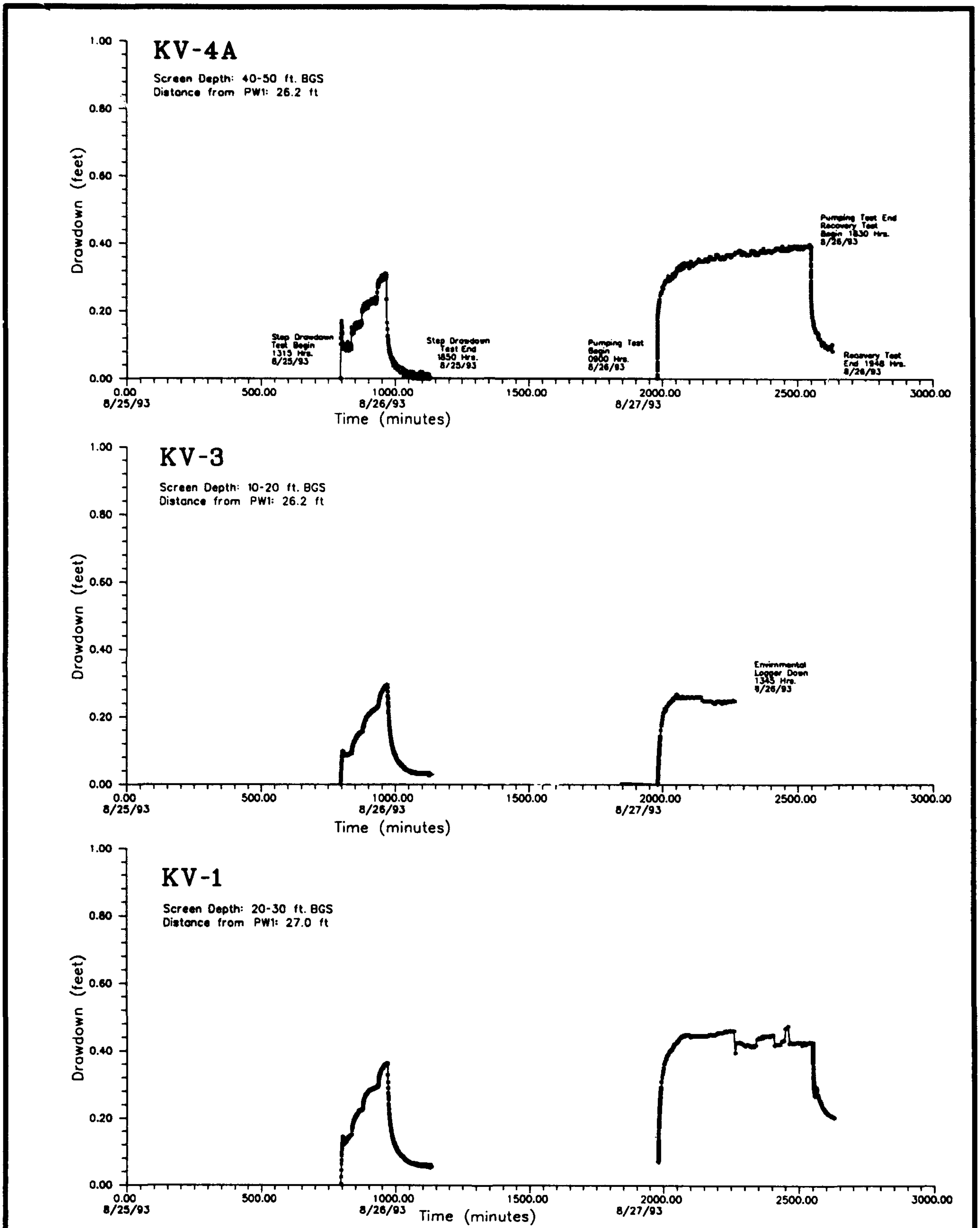

Figure 4-4. Pumping Test Hydrograph for Wells KV-4A, KV-3, and KV-1

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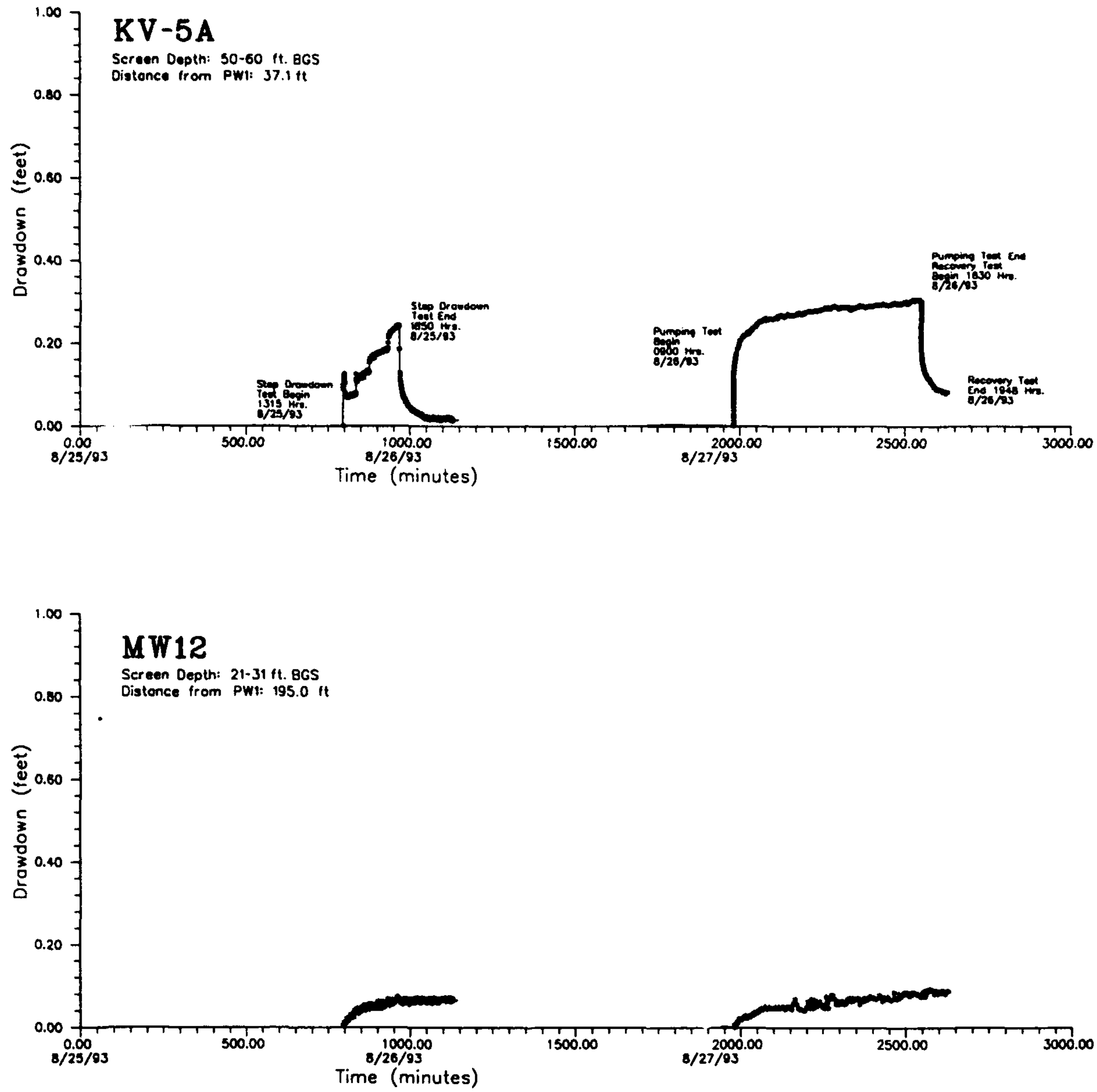

Figure 4-5. Pumping Test Hydrograph for Wells KV-5A and 05-MW-12

MISC7 HYDRO3 SAC

decrease in the rate of drawdown with time as the aquifer recharge rate approximates the pumping discharge rate. The overall shape of the drawdown curve was consistent with the Neuman (early data) Type-A curves, which suggests that gravity drainage in the unconfined aquifer did not occur during the 9.5-hour pumping test.

Some local fluctuations, or spikes, occurred in wells KV-1, KV-2, and KV-3 during the latter stages of the test. Since the pump constantly discharged at 75 gpm, these fluctuations cannot be explained by oscillations in the pumping rate. The spikes are of short duration and do not influence the overall drawdown trend in the wells and were ignored for drawdown analysis. They were likely the result of a slug effect due to the positioning of the borehole flowmeter in the tested wells. Also, some movement of the pressure transducer during flowmeter positioning may have contributed to the apparent water level spikes.

Three water samples were collected for volatile organic analysis before the end of the constant-discharge test to determine the ultimate fate of the pumped water. The analyses showed nondetect for volatile organic constituents and the stored water was released into a nearby sewer. The results of these analyses are included in Appendix A.

The recovery phase of the test is also shown on the pumping test hydrographs. Monitoring of the recovery was conducted for 78 min after the pump was shut off. During this time, the pumping well recovered 95%; recovery in the observation-wells ranged from 58% in KV-1 to 85% in KV-2. This range in recovery was attributed to transmissivity differences of the monitored aquifer zones. Recovery data for KV-3 were lost due to pressure transducer malfunction.

Data curves and pumping test data analysis can be found in the appendices: drawdown data, curves, and Neuman (1975) type curves (Appendix B); recovery data and graphs with Neuman analysis (Appendix C); and drawdown data plots analyzed by the Cooper and Jacob (1946) method (Appendix D).

For each observation well, estimates for transmissivity and hydraulic conductivity were calculated using both drawdown and recovery test data. For the pumping well, PW-1, values were calculated using recovery test data only. The calculated range of transmissivity and hydraulic conductivity values were consistent with published ranges for sand and gravelly sand aquifers (Freeze and Cherry, 1979). The transmissivity values using the three pumping test analytical methods are summarized in Table 4-1. The corresponding hydraulic conductivity values using the three methods are shown for comparison in Figure 4-6.

Neuman-drawdown transmissivity values ranged from 2,200 to 19,800 ft^2/day. Corresponding hydraulic conductivity values ranged from 22 to 198 ft/day; with the lowest values at depths of 50 to 70 ft bgl. Neuman-recovery transmissivity values, however, ranged from 24,000 to 120,000 ft^2/day, and showed an overall increase with depth. The corresponding hydraulic conductivity values ranged from 241 to 1,200 ft/day (no recovery data was obtained for the 10-20 ft depth). Cooper-Jacob transmissivity values ranged from about 15,000 to 64,000 ft^2/day, with corresponding K ranges of 149 to 644 ft/day. Both Neuman recovery and Cooper-Jacob drawdown values were similar in magnitude and showed an increasing trend downward from the 20 to 30 ft depth, consistent with the overall increasing-downward grain size of the aquifer.

Aquifer storativity was calculated using the Cooper-Jacob (1946) method. Storativity values are presented in Table 4-1 and range from 0.0006 to 0.05. In general, decreasing storage is apparent with depth. According to Freeze and Cherry (1979), storativity values from 0.005 to 0.00005 are indicative of confined aquifers. Additionally, the storativity value for unconfined aquifers normally ranges from 0.01 to 0.30, suggesting that groundwater flow deeper than 20 ft may be under confined conditions, or under pressure greater than atmospheric. More pumping test data are needed to understand the true range and spatial relationship of storativity values.

Table 4-1

Summary of Transmissivity (T), Hydraulic Conductivity (K), Storativity (S), and Average Linear Velocity (V) for Pumping Test, Site ST05, Galena Airport, Alaska

Evaluation Method		Neuman Drawdown			Neuman Recovery			Cooper and Jacob			
Aquifer Parameter*		T	K	V	T	K	V	T	K	V	S
Well ID	Screen Depth										
PW-1	25 - 65	NA	----	----	29,400	294	0.38	----	----	0.38	----
KV-3	10 - 20	8,200	82	0.11	----	----	----	14,900	149	0.19	0.05
KV-1	20 - 30	18,100	181	0.24	24,100	241	0.31	16,500	165	0.21	0.005
KV-2	30 - 40	19,800	198	0.26	25,700	257	0.33	26,400	264	0.34	0.0004
KV-4A	40 - 50	9,000	96	0.12	36,200	362	0.47	31,800	318	0.41	0.001
KV-5A	50 - 60	2,000	22	0.03	50,900	509	0.66	40,600	406	0.53	0.0008
KV-6A	60 - 70	4,800	48	0.06	120,300	1,203	1.56	64,400	644	0.83	0.0006
Average Per Method		10,450	104	0.14	47,766	478	0.62	32,433	324	0.41	NA

* Where:

T = transmissivity, in ft^2/day, calculated according to specified evaluation method (described in text).

K = hydraulic conductivity defined by T/b, in ft/day; b = 100 ft (affected thickness).

V = average linear velocity, defined by $\frac{Ki}{n}$, in ft/day, where i = 0.00039, and n = 30%.

S = storativity (dimensionless), calculated according to Cooper and Jacob (1946).

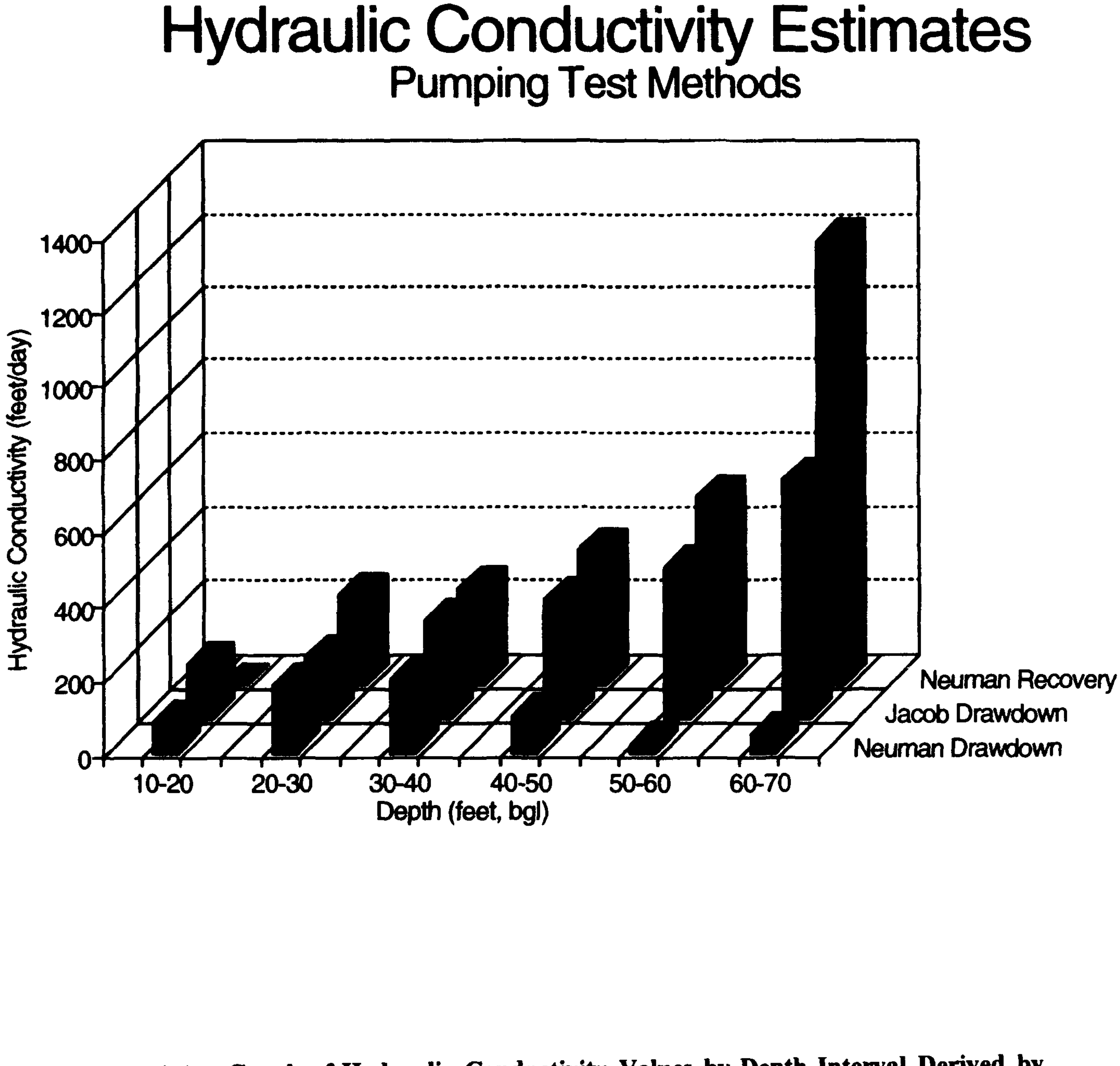

Figure 4-6. Graph of Hydraulic Conductivity Values by Depth Interval Derived by Three Pumping Test Analytical Methods

The Neuman drawdown method of analysis may not be applicable to some of the drawdown data because of abnormally low transmissivity values for the depths 40 to 70 ft bgl. This trend of values is contrary to the increasing-drawdown trend of aquifer grain size, as reflected by transmissivity trends calculated by the Neuman recovery and Cooper Jacob methods. Also, storativity values suggest confined conditions, which are not suited to the Neuman drawdown method.

4.2 Flowmeter Results

The Geoflow flowmeter was used to collect groundwater flow velocity data for three separate measurement events: the Ambient-May, the Ambient-August, and Pumping Test events. Appendix E contains all field flowmeter data.

The velocities recorded during the two ambient tests are graphed along with groundwater direction diagrams in Figure 4-7. Note the velocity scale change between the May and August graph. The direction roses show the frequency of the velocity vector measurements with respect to compass direction within 10-degree azimuth increments. Stable, repeatable data from 43 to 67 ft bgl were only collected during the August ambient period. The velocities for the Ambient-May test range from 0.8 to 5.4 ft/day. One distinct high-velocity zone is apparent at the 16 and 18 ft depths. The predominant flow direction in May is northward.

During the Ambient-August test, overall groundwater velocities are slightly greater, ranging from 1.0 to 10.8 ft/day, likely due to a higher groundwater gradient in response to lowering river levels. High-velocity zones (greater than 4.0 ft/day) were present at 16, 27, 36, 56, and 65 ft bgl. However, some of these zones do not correspond to high velocity zones during the Ambient May test, notably at 27 and 36 ft bgl. Also, at 18 ft bgl, a much lower velocity was recorded during the August test. The predominant flow direction measured by the flowmeter in August is south-southwestward, similar to the flow direction derived by the August 15 water level survey.

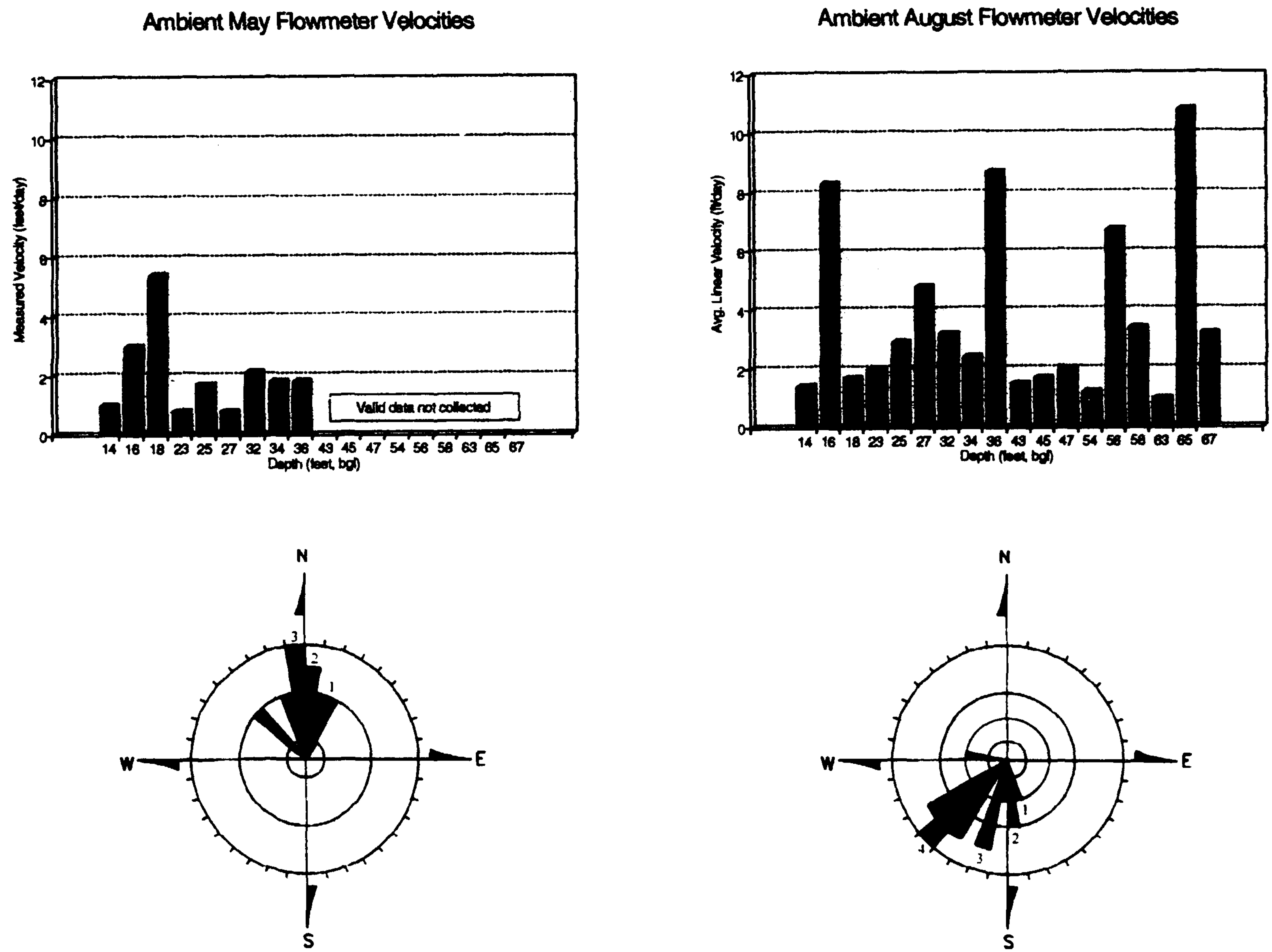

Figure 4-7. Flowmeter Velocity Plot and Direction Rose for Ambient-May and Ambient-August Flowmeter Tests

Ambient flowmeter test and the pumping test flowmeter results by depth are graphed in Figure 4-8. As in the Ambient-May test, valid flowmeter measurements were not obtained during the pumping test for the 47 to 67 ft depths. The flow measurements recorded during the pumping test show an expected increase in response to the pumping-induced gradient. On average, recorded velocities were 3.8 times greater than the Ambient-August measurements; the increases ranged from 1.5 to 7.2 times the Ambient August velocity. One zone at 16 ft bgl, however, showed an anomalous decrease in velocity during the pumping test, recording 2.3 ft/day compared with 8.3 ft/day during the Ambient-August test. During Ambient-August testing, this zone showed higher-than-average velocity. Since this zone is nine-feet above the pumping well screened interval, the low velocity likely reflects preferential flow in the deeper, more conductive aquifer zones.

4.3 Comparison of Pumping Test and Flowmeter Results

The pumping and flowmeter testing data allow an understanding of aquifer property changes with depth and a direct comparison of aquifer testing methods at the Galena test site. Table 4-2 summarizes the aquifer lithology, with the calculated hydraulic conductivities and velocities (pumping test), and the averaged velocities measured by the flowmeter. The listed lithology is the predominant aquifer material for the 10-ft section of aquifer. Similarly, both hydraulic conductivity and velocity values are averaged over 10-ft screened interval of the aquifer. The values clearly show the overall correlation between increasing aquifer grain size with depth (silt to gravelly sand) and the increasing hydraulic conductivity and average linear velocity. Also shown in the table are individual high-velocity zones recorded by the flowmeter during the Ambient-August test.

The average linear velocities shown in Table 4-2 were calculated by independent methods. A comparison of the values calculated by the pumping test and flowmeter methods is illustrated in Figure 4-9. For each 10-ft zone, the flowmeter average velocities are consistently 3.2 to 20 times greater than values calculated using the pumping test recovery data. The reasons for the differences between methods include:

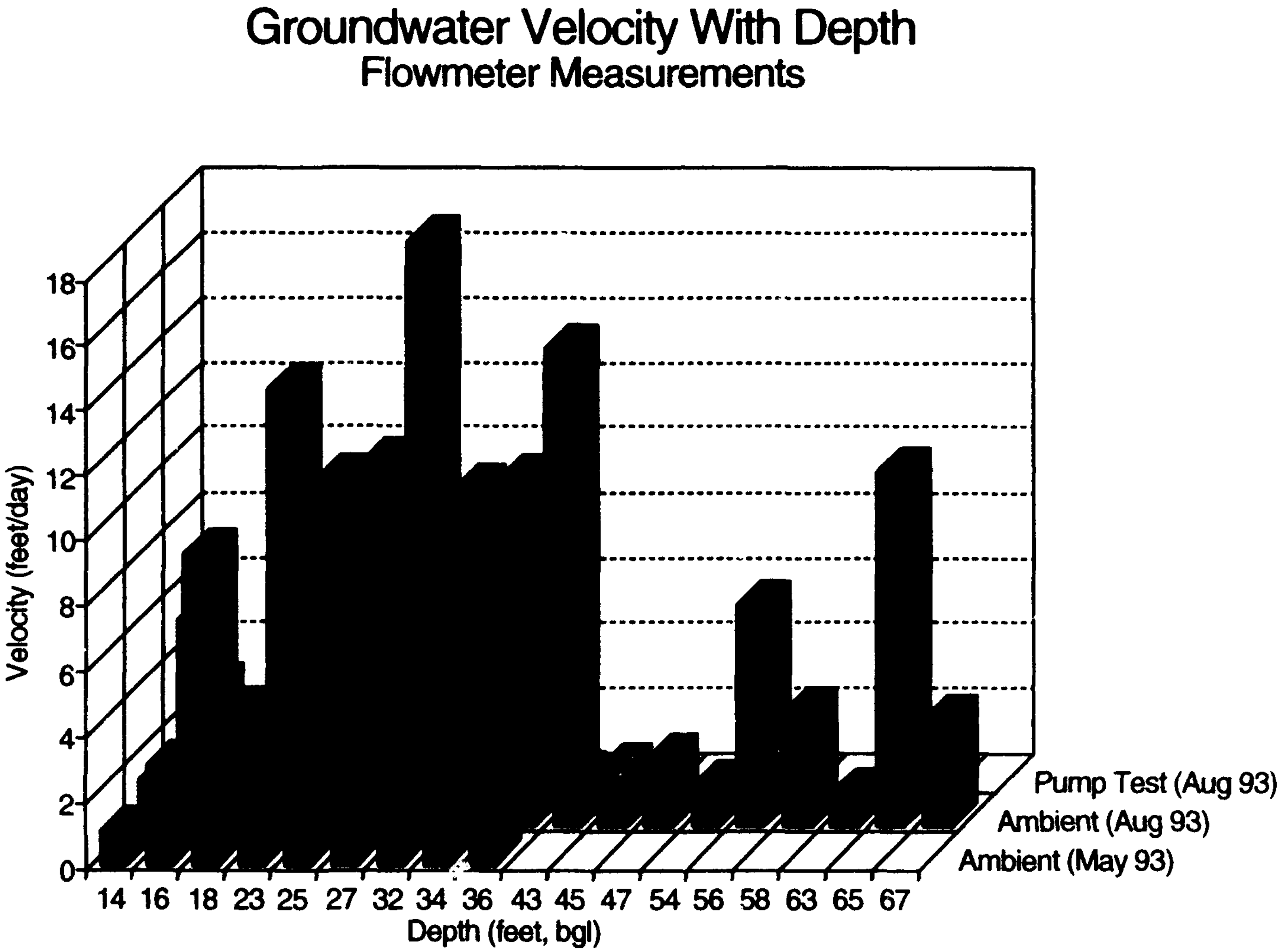

Figure 4-8. Comparison of Flowmeter Velocities by Depth for Three Test Periods--Ambient-May, Ambient-August, and Pumping Test

Table 4-2

Summary of Aquifer Properties With Depth, Galena Airport Aquifer Testing Site

Depth Range (ft)	Predominant Lithology	Hydraulic Conductivity *		Average Linear Velocity		Maximum Velocity Zones
		(ft/day)	(cm/sec)	Pump Test * (ft/day)	Flowmeter ** (ft/day)	(ft/day)
10-20	Silty Sand	149	0.052	0.19	3.8	8.3 at 16 ft
20-30	Sand	241	0.085	0.26	3.2	4.8 at 27 ft
30-40	Sand	257	0.091	0.34	4.8	8.7 at 36 ft
40-50	Gravelly Sand	362	0.13	0.44	1.7	----
50-60	Gravelly Sand	509	0.18	0.60	3.8	6.7 at 56 ft
60-70	Gravelly Sand	1,203	0.42	1.20	5.0	10.8 at 65 ft

* Pumping Test recovery (Neuman) data analysis (see Table 4-1), except for 10-20 ft interval.

** Averaged over 10 ft aquifer zones.

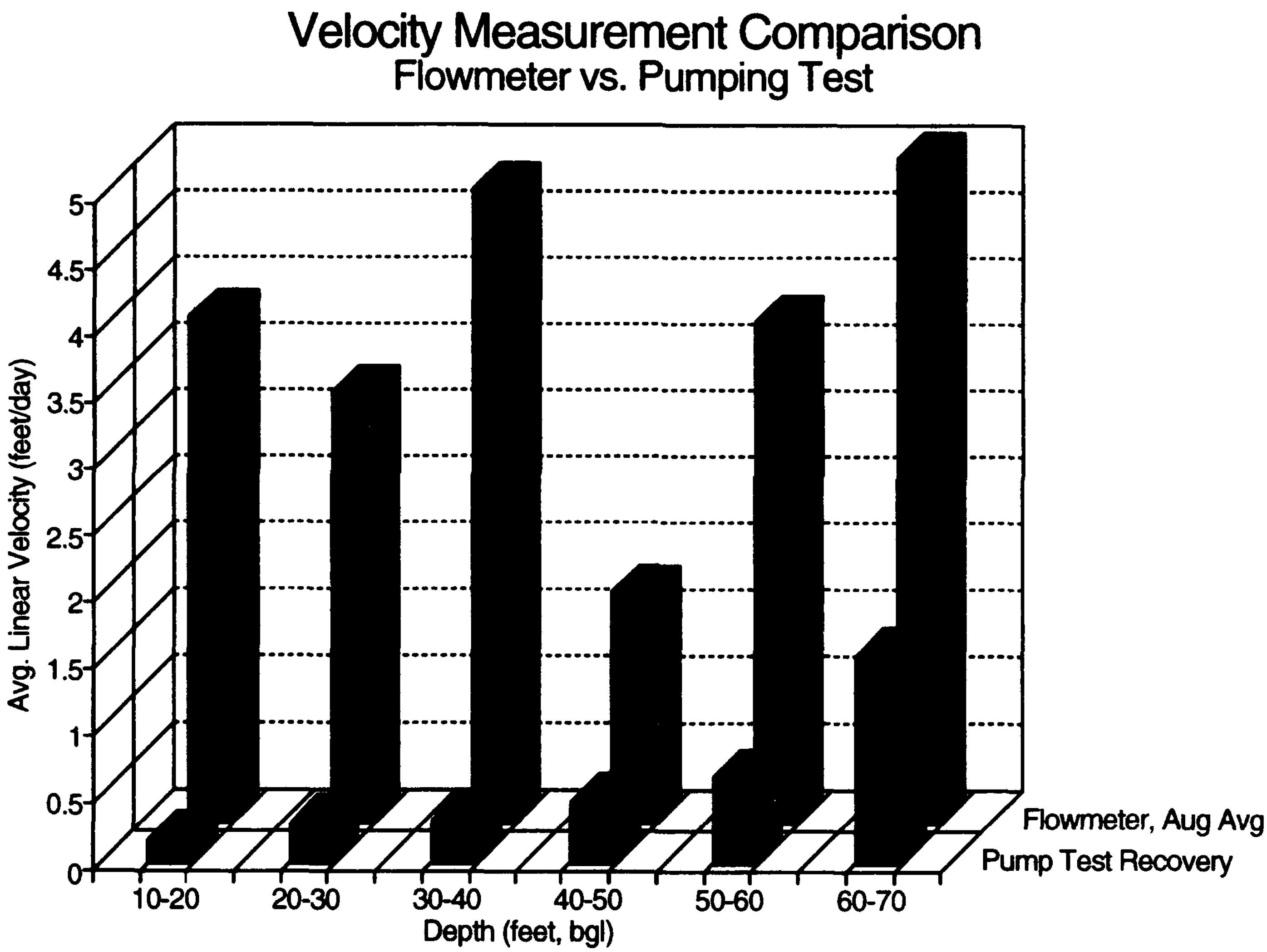

Figure 4-9. Graph of Aquifer Average Velocities by Depth Interval Showing Comparison of Pumping Test and Flowmeter Results

- Pumping test analytical methods are general estimates of the overall thickness of affected aquifer;

- Some pumping test analytical method assumptions (see Section 3.3) assume a ideal pumping test scenario--for most pumping tests they are often not realistic. For example, the assumptions concerning a homogeneous, infinite aquifer with a lower aquiclude were not appropriate for the Galena pumping test;

- Estimates of formation effective porosity (n = 30%) and depth of the effective aquifer (due to pumping, b = 100 ft) are assumed; and

- The flowmeter measurements may be biased slightly high due to the potential for a component of vertical flow and turbulence through the borehole and well screen.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The aquifer testing conducted during the 1993 field season at Galena provided valuable data about the shallow aquifer at Galena test site. This section presents conclusions about the aquifer testing methods, the aquifer properties, and recommends additional data collection in conjunction with other RI/FS activities to improve the understanding of the aquifer system.

Testing Methods

- The pumping test at the Galena test site was conducted successfully, yielding valid data to calculate transmissivity, storativity, hydraulic conductivity, and groundwater average linear velocity. The measured drawdown in the pumping and observation wells was actually greater than modeled predictions.

- Ideally, the test should have been run longer to yield gravity drainage curves (Type B curve) for Neuman analysis. In practice, the duration of testing for an unconfined aquifer is at least 72 hours, which was not attainable due to constraints on containerizing the potentially contaminated pumped water. Water samples of the pumped water, however, were nondetect for volatile organic constituents.

- The Neuman recovery and Cooper-Jacob drawdown pumping test data evaluation methods were appropriate for the aquifer conditions at Galena. The Neuman drawdown method was not appropriate for the unconfined (upper 20 ft) of the aquifer because of the short duration of the test. Therefore, aquifer properties calculated with the Neuman drawdown method are not deemed reliable, especially below the 40 ft depth, where it is possible that vertical gradients within the aquifer adversely affected the drawdown curves and the flowmeter recordings.

- The pumping and flowmeter tests yielded complementary data. The pumping test provided data for the pumping zone of influence, storativity values, and hydraulic conductivity values integrated over the observation well screened interval. The flowmeter provided velocity measurement resolution for individual high-velocity zones within the test well screened interval.

- The Geoflow flowmeter was successful in providing groundwater direction and velocity profiles for the aquifer during the ambient measurements in August 1993. However, during the May ambient test, and during the pumping test, the velocities for deeper zones from 40 to 70 ft bgl could not be established, possibly reflecting the sensitivity of the meter to vertical gradients.

Aquifer Properties

- The aquifer parameter calculations were within published ranges for the aquifer material. Hydraulic conductivity values (from recovery data) ranged from 240 to 1,200 ft/day (0.085 to 0.42 cm/sec), typical of sand to gravelly sands, respectively. The values of hydraulic conductivity and groundwater average linear velocity generally showed strong correlation with the increasing aquifer grain size with depth. Storativity values showed a decreasing trend with 0.05 from 10 to 20 ft bgl to 0.0006 from 60 to 70 ft bgl and suggest that groundwater flow in the aquifer below 20 ft is under confined conditions.

- The range of groundwater velocities calculated by the pumping and flowmeter tests is believed to be representative of the aquifer to a depth of 200 ft, based on available borehole logs to this depth. However, there are few borehole logs to this depth, and there are no data on the aquifer below 200 ft.

- The potential for off-site migration of contamination is greatest in the higher velocity zones ranging from 4 to about 10 ft/day. Ignoring the effects of dispersion and attenuation (and assuming interconnected high-velocity zones and constant gradient toward the river), the distance of off-site migration ranges from 1460 ft to 3650 ft/year, respectively. In effect, this migration rate delivers contamination of unknown concentration to the river in about one year.

Recommendations

- The flowmeter is recommended for future use at Galena--it offers logistical and cost advantages because it requires less equipment needs, fewer test man-hours, and generates no waste water. The potential contaminant migration range for relative high-velocity zones suggests the need for additional down-gradient contaminant monitoring and further groundwater velocity testing with the flowmeter.

- The aquifer properties described in this report are believed representative of the installation area. If remedial action is needed in peripheral areas to the "installation triangle", additional pumping tests would be warranted. Potential future aquifer pumping tests should use existing monitor wells where possible and employ a pumping well centrally located to the observation wells.

- The installation of nested deep wells for contaminant monitoring provides an opportunity for additional collection of useful data:

  -- The borehole should be drilled with cable rig equipment (to minimize flowing sands and wellbore skin effect) and the monitor well completed with 10-ft screen (or less) according to the ASTM 963 specifications to allow flowmeter recording of deep aquifer velocities;

  -- Continuous water level monitoring of at least two nested wells should be conducted to determine magnitude and potential fluctuation of vertical gradients;

  -- Representative formation samples for grain size analysis should be collected while drilling the deep wells; and

  -- After the deep nested wells and other step-out shallow wells are installed, geophysical logging should be conducted on all active wells to better define lithology correlations and calibrate aquifer properties to lithologies. The recommended geophysical logs-natural gamma ray, focused induction, and density/neutron can all be run inside of the well casing.

- Data collected from the continuous water level monitoring is key to understanding vertical and horizontal groundwater gradients and fluctuations in response to river trends. In addition to the above-mentioned deep monitor wells, two piezometers very near the river, and one piezometer (or existing monitor well) in the north installation area should be added to the existing network. The measuring point (top of casing) should be resurveyed to confirm accuracy.

- If obtainable, historical river level data from the Galena river gauging station should be gathered and plotted to derive a statistical basis for flood and low-river levels at Galena. These levels directly affect the groundwater flow in the aquifer at Galena.

6.0 REFERENCES

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APPENDIX A

WATER SAMPLE ANALYTICAL RESULTS

File ID Location Sample ID (Dilution)	1358 GALENA PW-1-1	1359 GALENA PW-1-2	1358 GALENA PW-1-3
units	(ug/L)	(ug/L)	(ug/L)
1,1-DCA	ND	ND	ND
Chloroform	ND	ND	ND
1,1,1-TCA	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND
1,2-DCA	ND	ND	ND
TCE	ND	ND	ND
PCE	ND	ND	ND
1,3-DCE	ND	ND	ND
1,4-DCE	ND	ND	ND
1,2-DCE	ND	ND	ND
1,1-DCE	ND	ND	ND
t-1,2-DCE	ND	ND	ND
c-1,2-DCE	ND	ND	ND
Benzene	ND	ND	ND
Toluene	ND	ND	ND
Chlorobenzene	ND	ND	ND
Ethylbenzene	ND	ND	ND
m/p-Xylene	ND	ND	ND
o-Xylene	ND	ND	ND

APPENDIX B

DRAWDOWN DATA GRAPHS AND NEUMAN TYPE CURVES

Time-Drawdown Data for Galena Pumping Test

Time	Drawdown						
Minutes	PW-1	KV-4	KV-5	KV-2	KV-3	KV-6	KV-1
0	0	-0.006	0	0	-0.006	0.003	0.072
0.0083	0.006	0	0	0	-0.006	0	0.072
0.0166	0.006	-0.006	0	0	-0.006	0	0.072
0.025	0.685	0	0	0.006	-0.006	0.003	0.069
0.0333	1.199	-0.006	0	0.009	-0.006	0.006	0.072
0.0416	0.704	-0.006	0.006	0.009	-0.006	0.009	0.072
0.05	0.571	0.006	0.009	0.015	-0.006	0.009	0.072
0.0583	0.679	0	0.012	0.018	-0.006	0.015	0.072
0.0666	0.875	0.012	0.018	0.028	-0.006	0.019	0.072
0.075	1.085	0.012	0.018	0.037	-0.006	0.025	0.072
0.0833	1.256	0.025	0.025	0.044	-0.006	0.028	0.072
0.0916	1.37	0.031	0.028	0.053	-0.006	0.031	0.072
0.1	1.447	0.031	0.034	0.063	-0.006	0.038	0.072
0.1083	1.504	0.038	0.041	0.072	-0.009	0.044	0.075
0.1166	1.535	0.044	0.047	0.082	-0.006	0.05	0.075
0.125	1.561	0.05	0.05	0.091	-0.009	0.053	0.075
0.1333	1.58	0.063	0.056	0.101	-0.006	0.063	0.075
0.1416	1.586	0.063	0.059	0.11	-0.009	0.06	0.075
0.15	1.599	0.069	0.066	0.12	-0.006	0.066	0.075
0.1583	1.599	0.076	0.069	0.129	-0.009	0.072	0.079
0.1666	1.612	0.069	0.072	0.135	-0.006	0.079	0.079
0.175	1.618	0.082	0.075	0.142	-0.009	0.079	0.079
0.1833	1.624	0.089	0.078	0.148	-0.009	0.082	0.079
0.1916	1.631	0.101	0.082	0.154	-0.009	0.085	0.079
0.2	1.631	0.101	0.082	0.161	-0.009	0.085	0.082
0.2083	1.637	0.095	0.085	0.167	-0.009	0.085	0.082
0.2166	1.637	0.101	0.088	[illegible]	-0.009	0.091	0.082
0.225	1.65	0.101	0.085	0.173	-0.009	0.088	0.082
0.2333	1.656	0.114	0.088	0.176	-0.009	0.095	0.082
0.2416	1.662	0.108	0.091	0.183	-0.009	0.091	0.085
0.25	1.656	0.108	0.091	0.186	-0.009	0.095	0.085
0.2583	1.662	0.114	0.091	0.189	-0.006	0.095	0.085
0.2666	1.662	0.114	0.091	0.192	-0.009	0.095	0.085
0.275	1.669	0.114	0.094	0.199	-0.009	0.095	0.085
0.2833	1.662	0.114	0.094	0.199	-0.009	0.098	0.085
0.2916	1.669	0.12	0.094	0.199	-0.009	0.098	0.088
0.3	1.675	0.114	0.097	0.205	-0.009	0.098	0.088
0.3083	1.669	0.127	0.097	0.208	-0.006	0.101	0.088
0.3166	1.675	0.12	0.097	0.211	-0.006	0.098	0.088
0.325	1.681	0.127	0.097	0.211	-0.009	0.101	0.088
0.3333	1.675	0.127	0.1	0.211	-0.009	0.101	0.091
0.35	1.675	0.127	0.104	0.218	-0.006	0.104	0.091
0.3666	1.681	0.133	0.104	0.224	-0.006	0.104	0.094
0.3833	1.681	0.133	0.104	0.227	-0.006	0.104	0.094
0.4	1.688	0.127	0.107	0.23	-0.006	0.107	0.097
0.4166	1.7	0.139	0.107	0.233	-0.006	0.107	0.097
0.4333	1.7	0.133	0.107	0.233	-0.006	0.107	0.097
0.45	1.694	0.139	0.11	0.24	-0.006	0.11	0.101
0.4666	1.694	0.139	0.11	0.24	-0.006	0.11	0.101
0.4833	1.694	0.139	0.11	0.243	-0.006	0.11	0.104

0.5	1.707	0.133	0.11	0.246	-0.006	0.11	0.104
0.5166	1.694	0.139	0.11	0.246	-0.006	0.11	0.107
0.5333	1.713	0.152	0.113	0.249	-0.006	0.11	0.107
0.55	1.713	0.146	0.113	0.252	-0.006	0.114	0.107
0.5666	1.713	0.146	0.113	0.252	-0.006	0.114	0.11
0.5833	1.719	0.146	0.116	0.255	-0.006	0.11	0.11
0.6	1.713	0.152	0.116	0.259	-0.003	0.114	0.113
0.6166	1.713	0.152	0.116	0.259	-0.003	0.114	0.113
0.6333	1.719	0.146	0.116	0.259	-0.003	0.114	0.116
0.65	1.713	0.146	0.116	0.262	-0.003	0.114	0.113
0.6666	1.719	0.152	0.116	0.262	-0.003	0.117	0.116
0.6833	1.726	0.146	0.116	0.262	-0.003	0.114	0.116
0.7	1.719	0.152	0.119	0.265	-0.003	0.117	0.12
0.7166	1.726	0.158	0.116	0.265	-0.003	0.114	0.12
0.7333	1.719	0.152	0.119	0.265	-0.003	0.114	0.12
0.75	1.719	0.152	0.119	0.268	0	0.117	0.123
0.7666	1.719	0.152	0.119	0.271	0	0.117	0.123
0.7833	1.732	0.152	0.119	0.268	0	0.117	0.123
0.8	1.726	0.158	0.119	0.271	0	0.117	0.126
0.8166	1.719	0.146	0.123	0.271	0	0.117	0.126
0.8333	1.726	0.158	0.123	0.274	0	0.117	0.126
0.85	1.726	0.158	0.119	0.271	0.003	0.117	0.129
0.8666	1.726	0.152	0.123	0.274	0.003	0.117	0.129
0.8833	1.726	0.158	0.123	0.278	0.003	0.117	0.129
0.9	1.726	0.158	0.123	0.274	0.003	0.117	0.132
0.9166	1.732	0.165	0.123	0.274	0.003	0.117	0.132
0.9333	1.726	0.158	0.126	0.278	0.003	0.117	0.132
0.95	1.732	0.158	0.126	0.278	0.006	0.12	0.135
0.9666	1.732	0.165	0.123	0.281	0.006	0.12	0.135
0.9833	1.738	0.171	0.123	0.278	0.006	0.117	0.135
1	1.738	0.158	0.126	0.284	0.006	0.12	0.135
1.2	1.738	0.165	0.129	0.287	0.012	0.12	0.145
1.4	1.738	0.171	0.129	0.293	0.015	0.123	0.151
1.6	1.751	0.178	0.132	0.297	0.022	0.126	0.158
1.8	1.764	0.178	0.132	0.303	0.025	0.123	0.164
2	1.757	0.178	0.132	0.306	0.028	0.126	0.173
2.2	1.751	0.178	0.138	0.312	0.034	0.126	0.176
2.4	1.77	0.184	0.135	0.312	0.038	0.129	0.183
2.6	1.777	0.178	0.141	0.319	0.044	0.133	0.186
2.8	1.77	0.19	0.141	0.322	0.047	0.133	0.192
3	1.777	0.19	0.145	0.328	0.05	0.133	0.195
3.2	1.777	0.197	0.145	0.328	0.053	0.133	0.202
3.4	1.783	0.19	0.145	0.331	0.06	0.136	0.205
3.6	1.777	0.197	0.148	0.331	0.063	0.136	0.208
3.8	1.783	0.203	0.148	0.338	0.066	0.139	0.214
4	1.777	0.203	0.151	0.328	0.069	0.133	0.218
4.2	1.789	0.203	0.151	0.334	0.072	0.139	0.221
4.4	1.783	0.197	0.154	0.338	0.076	0.139	0.224
4.6	1.796	0.197	0.154	0.341	0.079	0.139	0.227
4.8	1.789	0.209	0.154	0.341	0.082	0.139	0.23
5	1.789	0.203	0.157	0.344	0.085	0.142	0.233
5.2	1.802	0.203	0.157	0.344	0.088	0.139	0.237
5.4	1.796	0.209	0.157	0.347	0.091	0.142	0.24

5.6	1.808	0.209	0.16	0.347	0.095	0.142	0.243
5.8	1.796	0.216	0.16	0.35	0.098	0.142	0.246
6	1.802	0.216	0.16	0.353	0.098	0.142	0.249
6.2	1.796	0.216	0.164	0.353	0.101	0.139	0.249
6.4	1.796	0.222	0.164	0.353	0.104	0.145	0.252
6.6	1.796	0.222	0.164	0.357	0.107	0.142	0.255
6.8	1.802	0.209	0.164	0.357	0.11	0.142	0.259
7	1.802	0.216	0.164	0.357	0.11	0.145	0.262
7.2	1.808	0.222	0.164	0.36	0.114	0.145	0.262
7.4	1.808	0.222	0.164	0.363	0.117	0.145	0.265
7.6	1.808	0.222	0.167	0.363	0.117	0.148	0.268
7.8	1.815	0.222	0.167	0.366	0.12	0.145	0.271
8	1.815	0.222	0.167	0.366	0.123	0.148	0.271
8.2	1.821	0.228	0.17	0.369	0.126	0.148	0.274
8.4	1.815	0.228	0.17	0.369	0.126	0.148	0.278
8.6	1.821	0.228	0.17	0.369	0.129	0.148	0.278
8.8	1.821	0.228	0.173	0.372	0.133	0.152	0.281
9	1.815	0.228	0.173	0.372	0.133	0.148	0.284
9.2	1.815	0.228	0.173	0.372	0.136	0.148	0.284
9.4	1.815	0.228	0.173	0.376	0.139	0.152	0.287
9.6	1.821	0.235	0.173	0.376	0.139	0.152	0.29
9.8	1.821	0.235	0.176	0.379	0.142	0.152	0.29
10	1.821	0.235	0.176	0.382	0.142	0.152	0.293
12	1.827	0.247	0.186	0.391	0.161	0.158	0.309
14	1.827	0.254	0.189	0.398	0.174	0.158	0.322
16	1.846	0.254	0.192	0.404	0.183	0.164	0.331
18	1.846	0.26	0.198	0.41	0.193	0.167	0.341
20	1.853	0.273	0.205	0.417	0.202	0.171	0.35
22	1.859	0.273	0.208	0.42	0.212	0.167	0.36
24	1.865	0.267	0.208	0.426	0.215	0.171	0.363
26	1.865	0.279	0.214	0.426	0.224	0.174	0.369
28	1.859	0.286	0.214	0.429	0.218	0.174	0.376
30	1.872	0.286	0.217	0.432	0.221	0.174	0.379
32	1.872	0.292	0.217	0.436	0.224	0.177	0.385
34	1.878	0.292	0.22	0.432	0.231	0.177	0.388
36	1.872	0.292	0.22	0.436	0.231	0.18	0.388
38	1.878	0.292	0.22	0.436	0.234	0.18	0.391
40	1.878	0.292	0.223	0.439	0.237	0.18	0.395
42	1.884	0.305	0.223	0.439	0.24	0.177	0.398
44	1.884	0.298	0.227	0.445	0.243	0.18	0.401
46	1.891	0.292	0.223	0.445	0.243	0.183	0.401
48	1.891	0.298	0.223	0.442	0.243	0.183	0.404
50	1.878	0.298	0.227	0.439	0.247	0.18	0.404
52	1.891	0.298	0.23	0.439	0.247	0.183	0.407
54	1.897	0.298	0.23	0.442	0.25	0.183	0.41
56	1.897	0.298	0.233	0.442	0.253	0.183	0.414
58	1.891	0.311	0.236	0.445	0.25	0.19	0.417
60	1.897	0.311	0.236	0.445	0.256	0.19	0.42
62	1.891	0.311	0.239	0.448	0.256	0.186	0.42
64	1.891	0.311	0.239	0.451	0.259	0.19	0.423
66	1.897	0.305	0.239	0.451	0.256	0.186	0.423
68	1.897	0.317	0.242	0.451	0.262	0.19	0.426
70	1.897	0.311	0.242	0.455	0.266	0.193	0.429

72	1.897	0.317	0.246	0.455	0.266	0.193	0.429
74	1.91	0.324	0.249	0.458	0.256	0.196	0.432
76	1.91	0.33	0.249	0.458	0.256	0.196	0.432
78	1.897	0.324	0.252	0.461	0.259	0.199	0.436
80	1.903	0.324	0.252	0.461	0.259	0.199	0.439
82	1.91	0.33	0.252	0.489	0.259	0.202	0.439
84	1.916	0.324	0.252	0.489	0.256	0.199	0.442
86	1.916	0.337	0.255	0.489	0.256	0.202	0.442
88	1.916	0.324	0.252	0.489	0.256	0.202	0.442
90	1.923	0.337	0.255	0.493	0.259	0.205	0.445
92	1.923	0.337	0.258	0.493	0.259	0.205	0.445
94	1.916	0.33	0.255	0.496	0.259	0.205	0.445
96	1.916	0.33	0.258	0.493	0.256	0.202	0.445
98	1.916	0.343	0.261	0.496	0.259	0.205	0.448
100	1.923	0.33	0.255	0.496	0.256	0.205	0.445
105	1.91	0.343	0.258	0.496	0.256	0.205	0.448
110	1.916	0.337	0.261	0.499	0.259	0.209	0.448
115	1.929	0.343	0.261	0.499	0.259	0.209	0.448
120	1.929	0.33	0.258	0.499	0.256	0.209	0.442
125	1.929	0.349	0.261	0.502	0.259	0.212	0.445
130	1.916	0.343	0.264	0.502	0.259	0.212	0.445
135	1.929	0.337	0.261	0.502	0.256	0.215	0.445
140	1.935	0.343	0.268	0.505	0.259	0.212	0.445
145	1.929	0.343	0.268	0.496	0.259	0.212	0.445
150	1.923	0.349	0.268	0.502	0.259	0.212	0.445
155	1.929	0.356	0.264	0.502	0.259	0.212	0.445
160	1.923	0.349	0.268	0.502	0.259	0.212	0.445
165	1.935	0.349	0.271	0.502	0.25	0.212	0.445
170	1.929	0.349	0.268	0.502	0.247	0.212	0.445
175	1.935	0.349	0.268	0.505	0.247	0.209	0.445
180	1.929	0.356	0.268	0.505	0.247	0.215	0.445
185	1.935	0.356	0.268	0.508	0.247	0.228	0.448
190	1.923	0.349	0.271	0.508	0.247	0.218	0.448
195	1.942	0.362	0.271	0.502	0.247	0.212	0.451
200	1.935	0.362	0.274	0.505	0.247	0.212	0.448
205	1.929	0.356	0.271	0.505	0.243	0.212	0.448
210	1.935	0.356	0.271	0.499	0.24	0.209	0.448
215	1.935	0.356	0.274	0.499	0.24	0.205	0.451
220	1.942	0.368	0.274	0.505	0.247	0.215	0.455
225	1.942	0.368	0.277	0.505	0.247	0.218	0.455
230	1.942	0.362	0.277	0.505	0.247	0.221	0.455
235	1.954	0.356	0.277	0.505	0.243	0.228	0.455
240	1.942	0.356	0.277	0.499	0.24	0.209	0.455
245	1.929	0.362	0.277	0.508	0.247	0.224	0.458
250	1.948	0.356	0.28	0.502	0.247	0.218	0.461
255	1.942	0.362	0.277	0.505	0.243	0.218	0.458
260	1.942	0.368	0.28	0.505	0.247	0.224	0.461
265	1.935	0.368	0.28	0.505	0.247	0.218	0.461
270	1.948	0.368	0.283	0.505	0.247	0.218	0.461
275	1.942	0.362	0.283	10.226	0.247	0.218	0.461
280	1.948	0.368	0.287	10.252	0.25	0.237	5.423
285	1.935	0.368	0.283	10.233	0.247	0.209	0.395
290	1.942	0.375	0.287	10.229	-4.102	0.224	0.426

295	1.948	0.375	0.283	0.369	-4.086	0.231	0.426
300	1.948	0.375	0.287	0.524	-4.09	0.24	0.426
305	1.954	0.381	0.29	0.53	-6.139	0.234	0.426
310	1.954	0.381	0.29	0.524	-6.139	0.224	0.423
315	1.942	0.368	0.287	0.524	-6.139	0.221	0.42
320	1.948	0.375	0.283	0.515	-6.143	0.215	0.417
325	1.935	0.375	0.287	0.521	-6.139	0.221	0.417
330	1.948	0.368	0.287	0.521	-6.139	0.224	0.42
335	1.935	0.368	0.287	0.521	-6.136	0.212	0.417
340	1.948	0.368	0.287	0.515	-6.136	0.215	0.417
345	1.942	0.368	0.287	0.515	-6.136	0.218	0.414
350	1.942	0.381	0.287	0.521	-6.133	0.224	0.417
355	1.948	0.375	0.28	0.521	-6.136	0.221	0.414
360	1.948	0.381	0.287	0.518	-6.133	0.224	0.417
365	1.961	0.368	0.283	0.556	-6.136	0.221	0.436
370	1.954	0.375	0.287	0.556	-6.133	0.218	0.439
375	1.948	0.368	0.287	0.559	-6.133	0.221	0.439
380	1.935	0.375	0.287	0.556	-6.13	0.215	0.439
385	1.954	0.381	0.293	0.565	-6.13	0.228	0.445
390	1.948	0.375	0.29	0.572	-6.127	0.221	0.442
395	1.948	0.387	0.29	0.572	-6.127	0.221	0.445
400	1.942	0.375	0.287	0.572	-6.127	0.218	0.445
405	1.942	0.375	0.287	0.572	-6.13	0.221	0.445
410	1.948	0.381	0.29	0.575	-6.127	0.218	0.445
415	1.948	0.381	0.29	0.572	-6.127	0.218	0.445
420	1.935	0.381	0.29	0.575	-6.124	0.224	0.448
425	1.942	0.375	0.29	0.704	-6.124	0.224	0.448
430	1.948	0.381	0.293	0.701	-6.124	0.221	0.417
435	1.954	0.381	0.293	0.704	-6.124	0.221	0.42
440	1.942	0.387	0.293	0.704	-6.12	0.228	0.42
445	1.948	0.387	0.293	0.704	-6.12	0.228	0.42
450	1.954	0.387	0.293	0.613	-6.12	0.224	0.42
455	1.948	0.387	0.296	0.613	-6.12	0.224	0.429
460	1.954	0.381	0.293	0.613	-6.12	0.224	0.432
465	1.948	0.394	0.293	0.553	-6.117	0.224	0.432
470	1.954	0.381	0.293	0.559	-6.117	0.224	0.467
475	1.954	0.387	0.293	0.553	-6.117	0.218	0.47
480	1.948	0.387	0.296	0.543	-6.114	0.224	0.474
485	1.942	0.381	0.296	0.546	-6.114	0.228	0.423
490	1.948	0.394	0.299	0.549	-6.114	0.231	0.426
495	1.948	0.387	0.296	0.549	-6.114	0.231	0.423
500	1.948	0.387	0.296	0.546	-6.114	0.231	0.423
505	1.948	0.394	0.296	0.543	-6.111	0.221	0.423
510	1.948	0.394	0.296	10.286	-6.111	0.224	0.426
515	1.954	0.394	0.299	10.267	-6.111	0.231	0.423
520	1.948	0.387	0.299	10.252	-6.111	0.228	0.42
525	1.954	0.394	0.302	10.245	-6.108	0.234	0.385
530	1.948	0.387	0.296	0.268	-6.111	0.231	0.417
535	1.961	0.394	0.302	0.493	-6.108	0.234	0.426
540	1.954	0.387	0.302	0.499	-6.105	0.234	0.426
545	1.948	0.394	0.306	0.502	-6.105	0.234	0.42
550	1.948	0.394	0.302	0.505	-6.105	0.237	0.423
555	1.961	0.394	0.306	0.499	-6.101	0.228	0.426

560	1.942	0.394	0.306	0.502	-6.101	0.228	0.426
565	1.954	0.4	0.306	0.499	-6.101	0.224	0.426
570	1.954	0.381	0.302	0.499	-6.101	0.224	0.426

CALCULATION SET		
Prelim.		
Final		
Sheet Of		
Charge #		
Rev.	Comp. By	Chk'd By
	[signature] Date 9/1/8	Date
	Date	Date

GENERAL COMPUTATION SHEET

CLIENT NAME

PROJECT NAME KUI Drawdown Data

$\beta = 0.0561$
$S = 0.19$
$S_D = 3.0$
$r = 27.3$ ft

$C_1 = 0.0796$

$Q = 75$ gpm $= 14437.5$ ft^3/day

$K_D = \beta (b^2) / r^2$

$= 0.0561 (100)^2 / (27.3)^2$

$= 0.753$

$T = C_1 (Q S_D / s)$

$= 0.0796 [(14437.5 \text{ ft}^3/\text{day})(3.0) / (0.19 \text{ ft})]$

$= 18,145$ ft^2/day ✓

1-85-18743

GENERAL COMPUTATION SHEET

CLIENT NAME ____________________

PROJECT NAME KU2

CALCULATION SET		
Prelim.		
Final		
Sheet Of		
Charge #		
Rev.	Comp. By: RR	Chk'd By
	Date 9/11	Date
	Date	Date

$B = 0.0088$

$r = 14.8$ ft

$S = 0.29$

$S_D = 5.0$

$c_1 = 0.0796$

$Q = 75$ gpm $= 14437.5$ ft³/d

$K_D = B(b^2)/r^2$

$= 0.0088(100)^2/(14.8)^2$

$= 0.402$

$T = c_1(Q S_D/s)$

$= 0.0796 [(14437.5 (5.0)) / (0.29)]$

$= 19{,}814$ ft²/day ✓

1-85-18743

CALCULATION SET		
Prelim.		
Final		
Sheet Of		
Charge #		
Rev.	Comp. By	Chk'd By
	RR	
	Date 9/18	Date
	Date	Date

GENERAL COMPUTATION SHEET

CLIENT NAME ______

PROJECT NAME KU3

$\beta = 0.0573$ $r = 26.7$

$S = 0.14$ $c_1 = 0.0796$

$S_D = 1.0$ $Q = 75$ gpm $= 14437.5$ ft^3/day

$K_D = \beta (D^2) / r^2$

$= 0.0573 (100)^2 / (26.7)^2$

$= 0.804$

$T = c_1 (Q S_D / S)$

$= 0.0796 [(14437.5)(1.0) / (0.14)]$

$= 8208.75$ ft^2/day ✓

1-85-18743

GENERAL COMPUTATION SHEET

CLIENT NAME

PROJECT NAME KU4

CALCULATION SET		
Prelim.		
Final		
Sheet Of		
Charge #		
Rev.	Comp. By	Chk'd By
	RR Date 9/11	Date
	Date	Date

$\beta = 0.0142$ $r = 26.2$

$S = 0.12$ $c_1 = 0.0799$

$S_p = 1.0$ $Q = 75\ gpm = 14437.5\ ft^3/day$

$K_D = \beta(b^2)/r^2$

$= 0.0142(100^2)/(26.2)^2$

$= 0.207$

$T = c_1(QS_p/s)$

$= 0.0796\ [(14437.5)(1.0)/(0.12)]$

$= 9576\ ft^2/day$ ✓

1-85-18743

GENERAL COMPUTATION SHEET

CLIENT NAME ______________________

PROJECT NAME KWS

CALCULATION SET		
Prelim.		
Final		
Sheet Of		
Charge #		
Rev.	Comp. By	Chk'd By
	RR	
	Date 9/11	Date
	Date	Date

$\beta = 0.0298$

$S = 0.08$

$S_D = 0.15$

$c_1 = .0796$

$Q = 75\ gpm - 14437.5\ ft^3/day$

$r = 37.8\ ft$

$t_D = \beta (b^2)/r^2$

$= 0.0298 (100^2)/(37.8)^2$

$= 0.208$

$T = c_1 (Q s_D / s)$

$= 0.0796 (14437.5 (0.15)/0.08)$

$= 2155\ ft^2/day$ ✓

1-85-18743

GENERAL COMPUTATION SHEET

CLIENT NAME

PROJECT NAME KV6

CALCULATION SET		
Prelim.		
Final		
Sheet Of		
Charge #		
Rev.	Comp. By	Chk'd By
	RR	
	Date 9/18	Date
	Date	Date

β : .0096

r = 15.4 ft

S = 0.095

S_D = 0.4

C_1 = 0.0796

Q = 75 gpm = 14437.5 ft³/day

$K_D = \beta (b^2)/r^2$

$= 0.0096(100^2)/(15.4)^2$

$= 0.405$

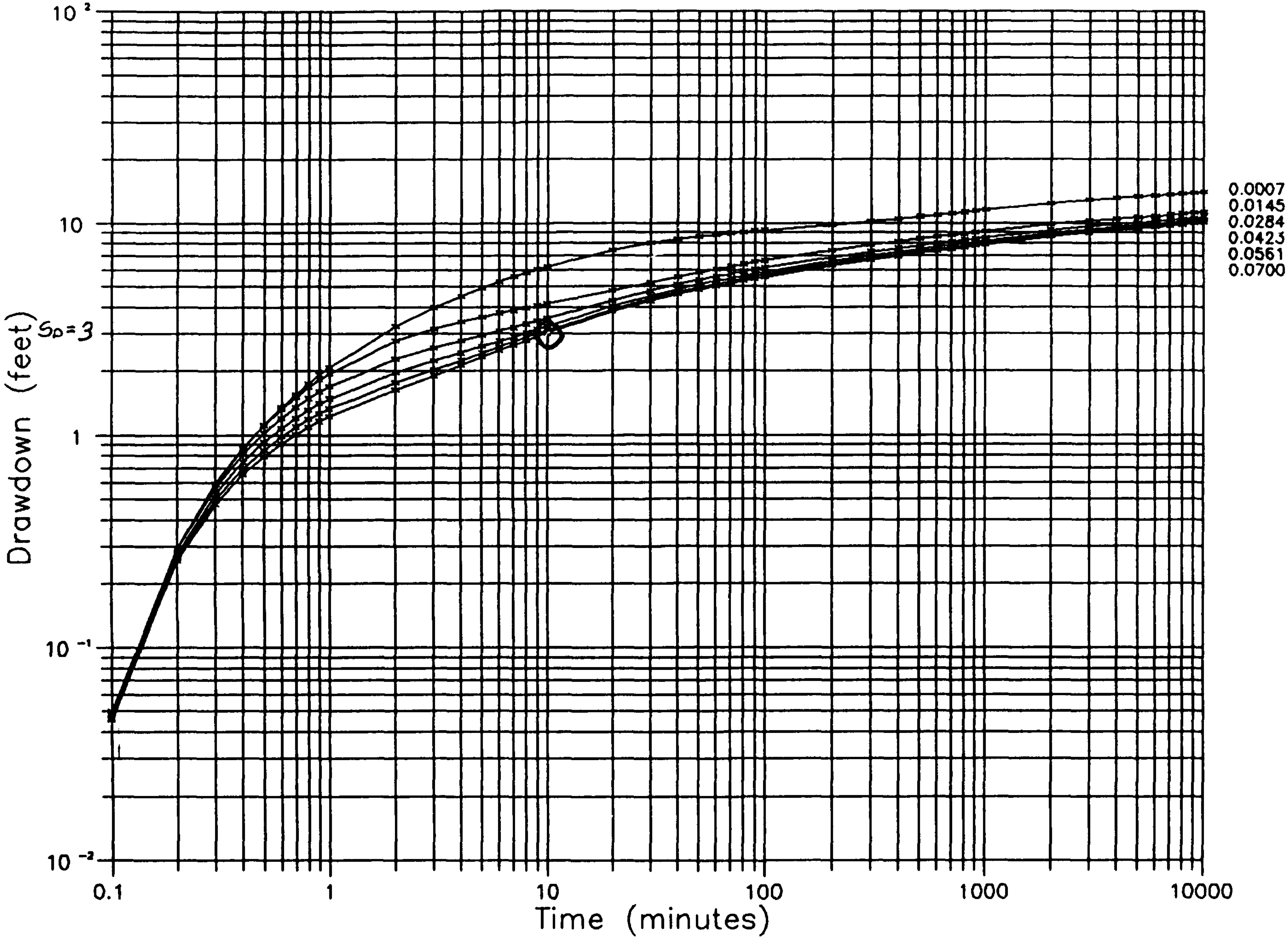
$T = C_1 (Q S_D / S)$

$0.0796[(14437.5(0.4)/(0.095)]$

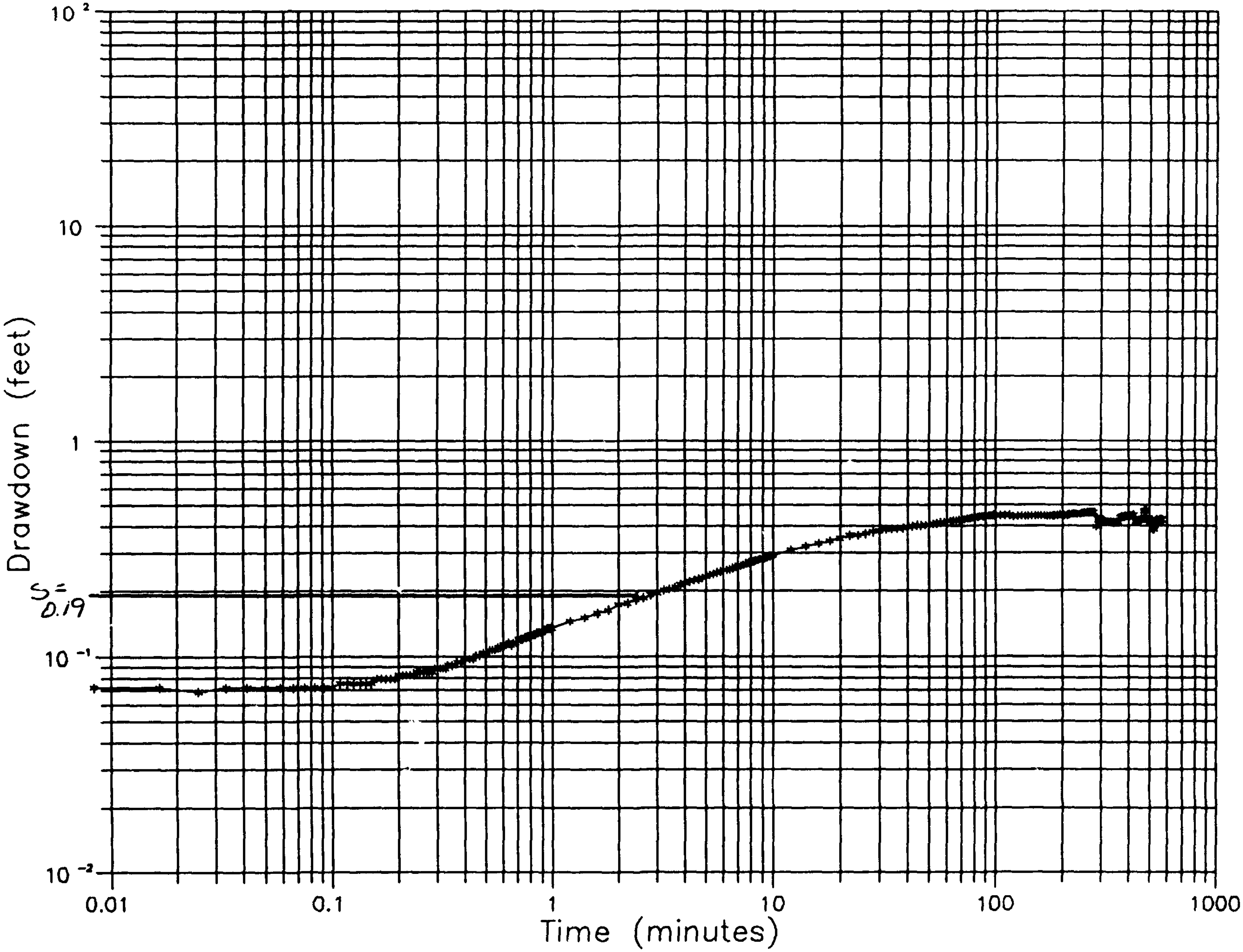
$= 4{,}838$ ft²/day ✓

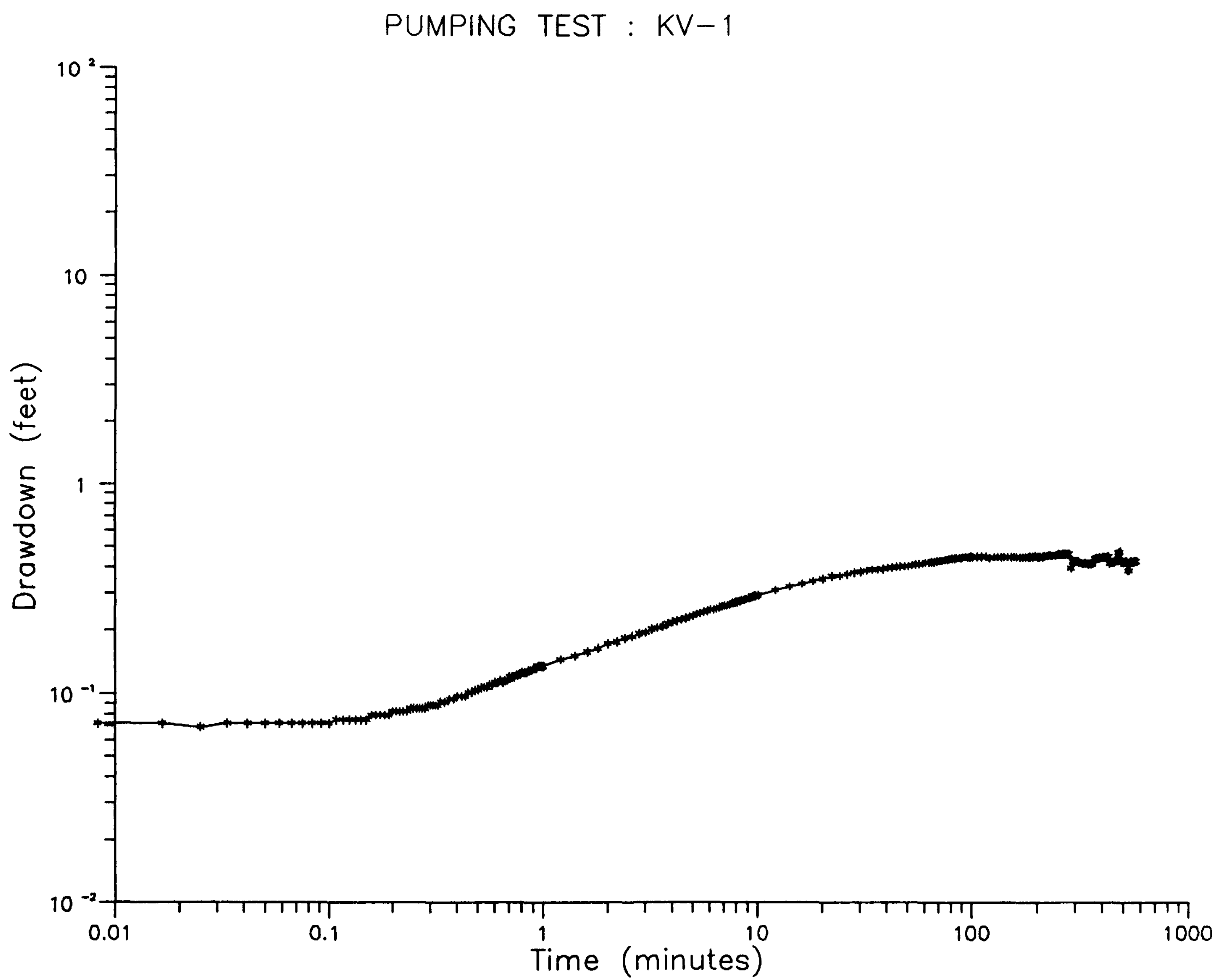
1-85-18743

TYPE A CURVES (Neuman) : KV-1

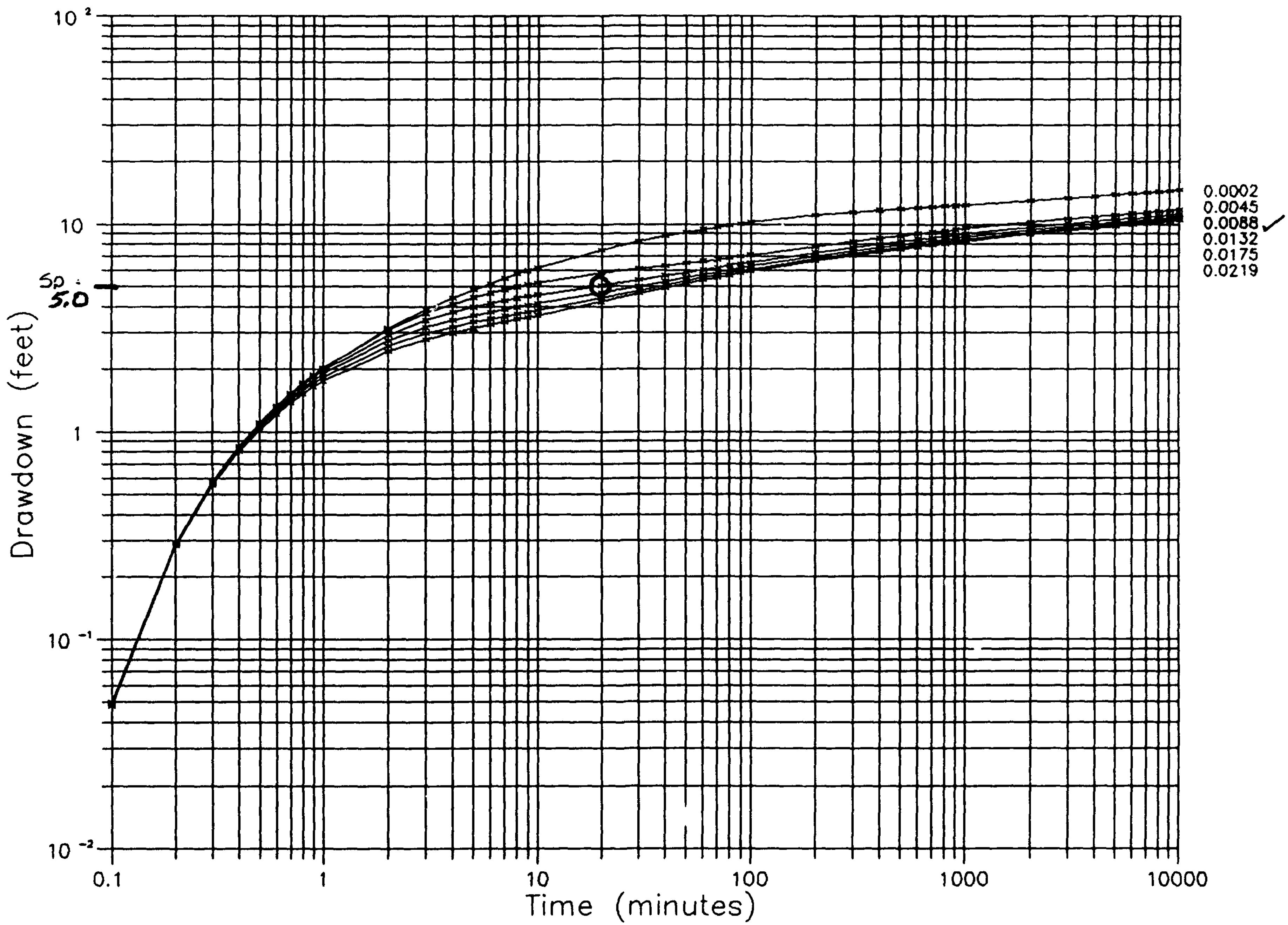


PUMPING TEST : KV-1

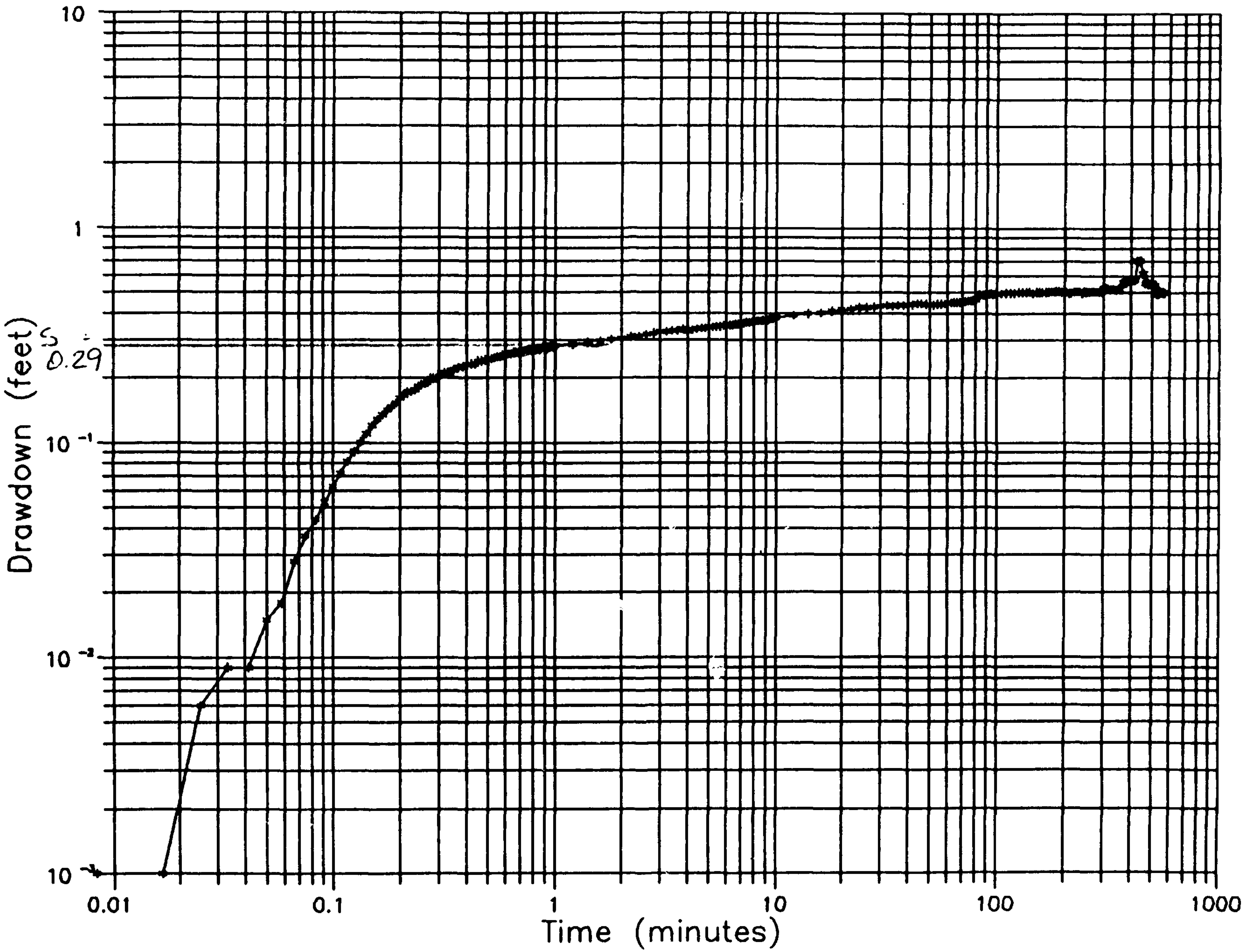



PUMPING TEST : KV-1
Drawdown (feet)
10 ²
10
1
10 ⁻¹
10 ⁻²
0.01
0.1
1
10
100
1000
Time (minutes)

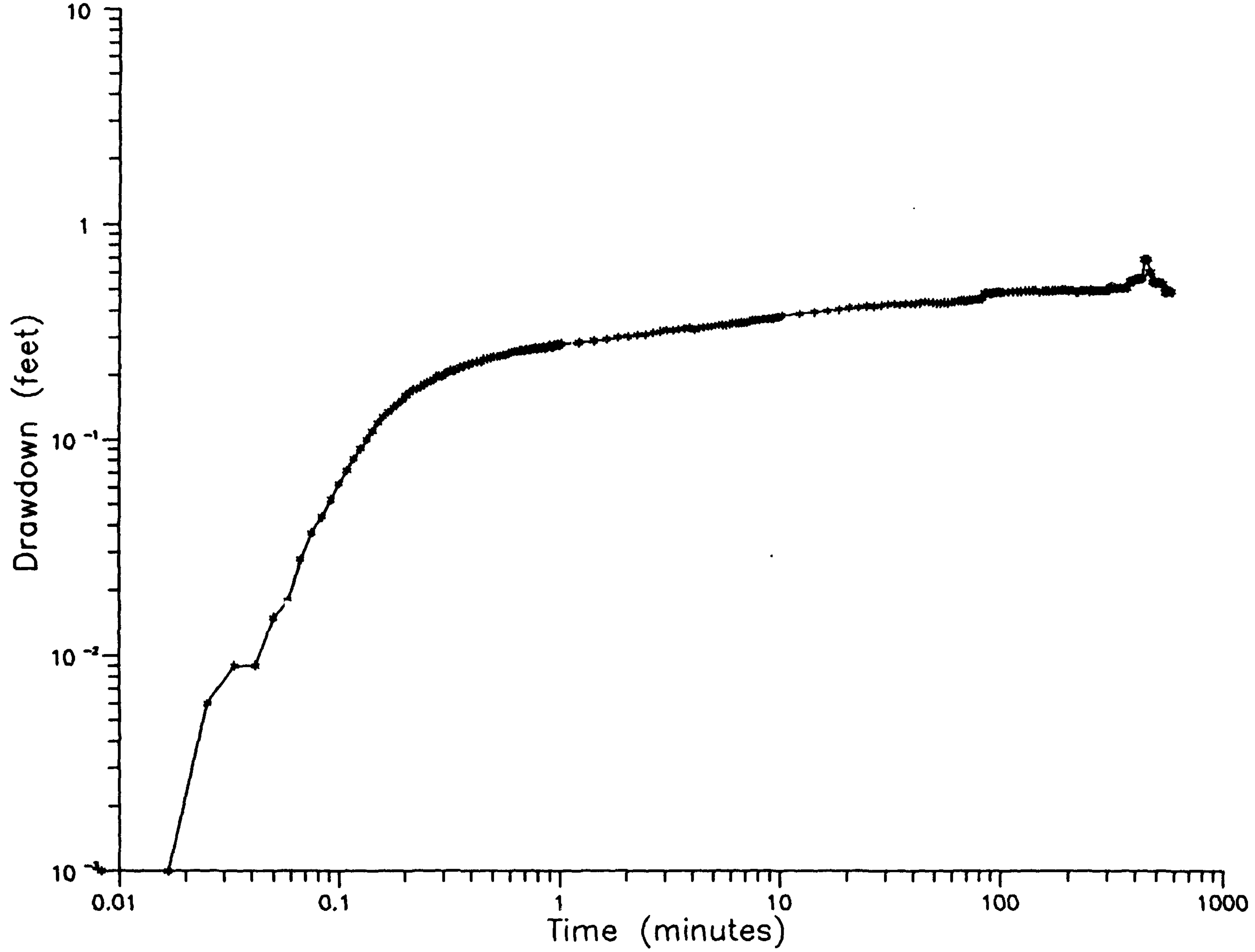
TYPE A CURVES (Neuman) : KV-2



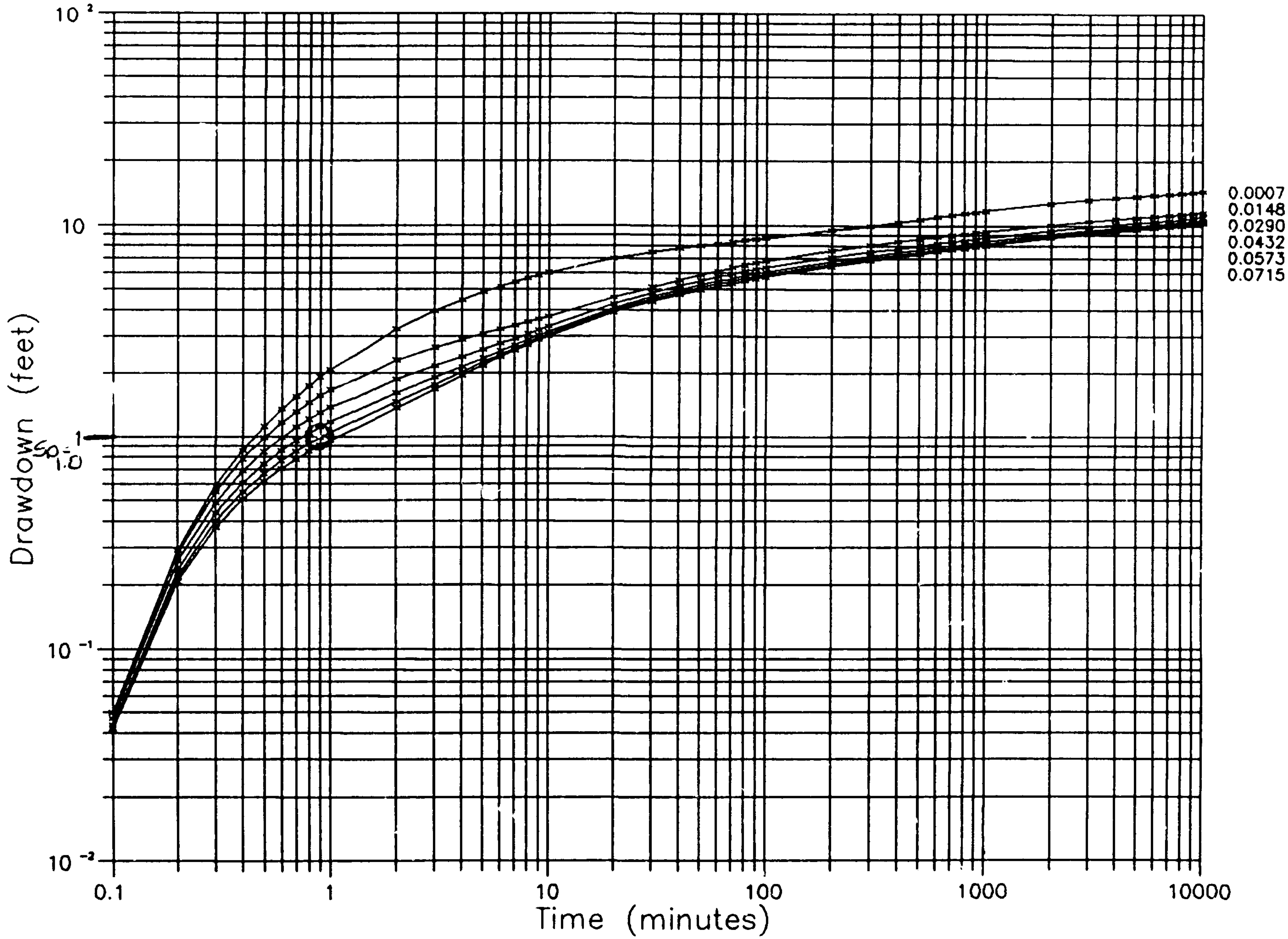
PUMPING TEST : KV-2



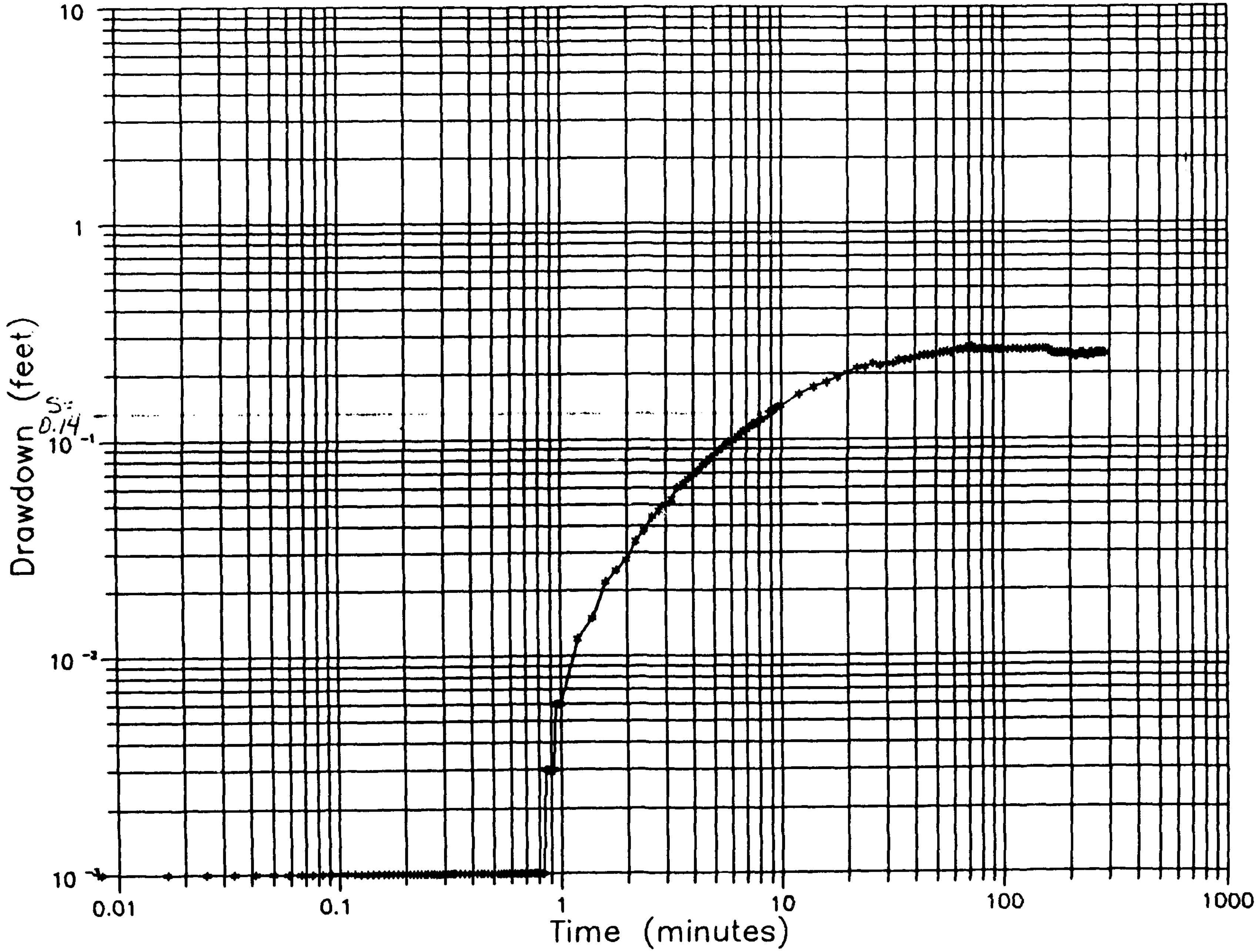
PUMPING TEST : KV-2



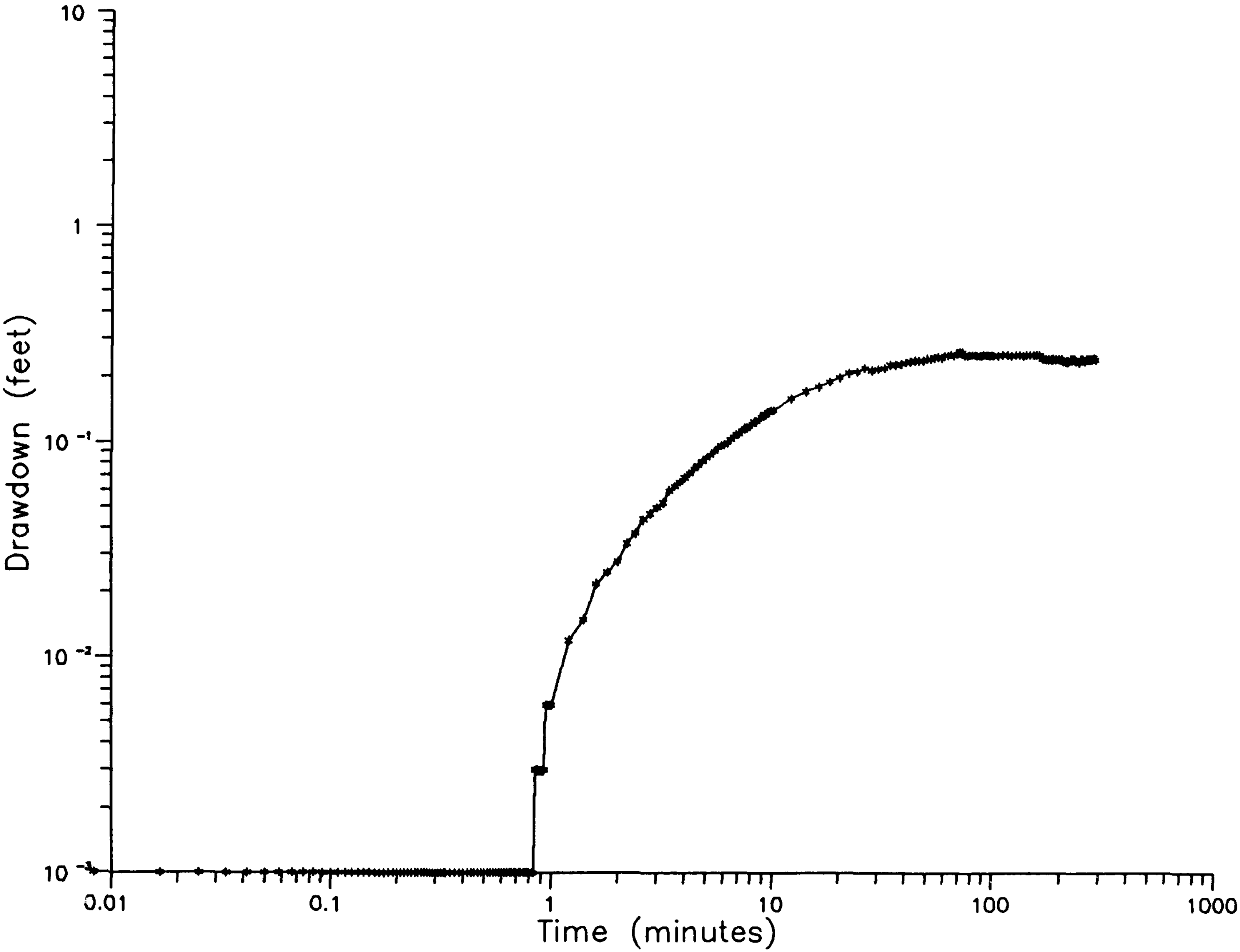
TYPE A CURVES (Neuman) : KV–3



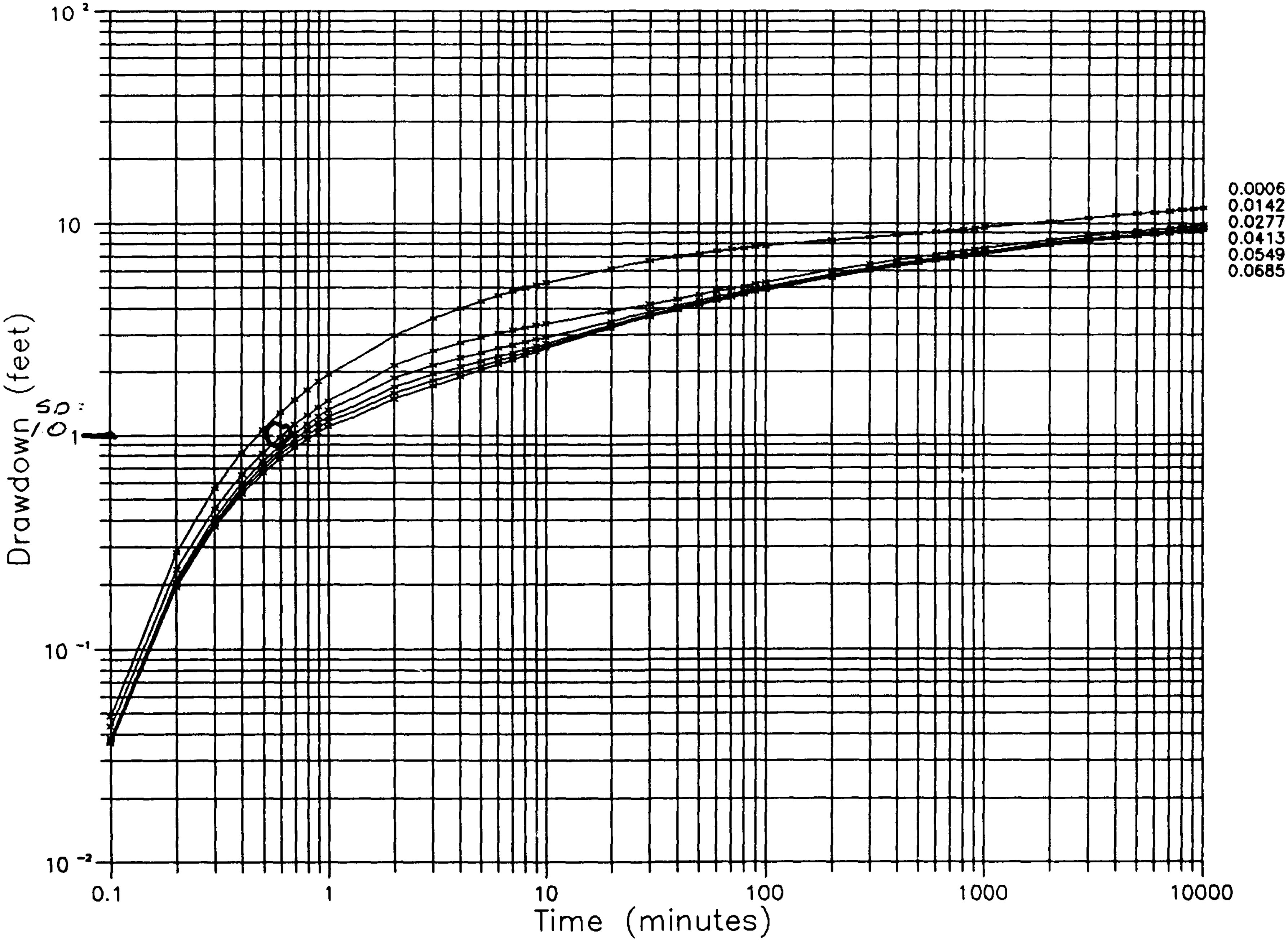
PUMPING TEST : KV-3



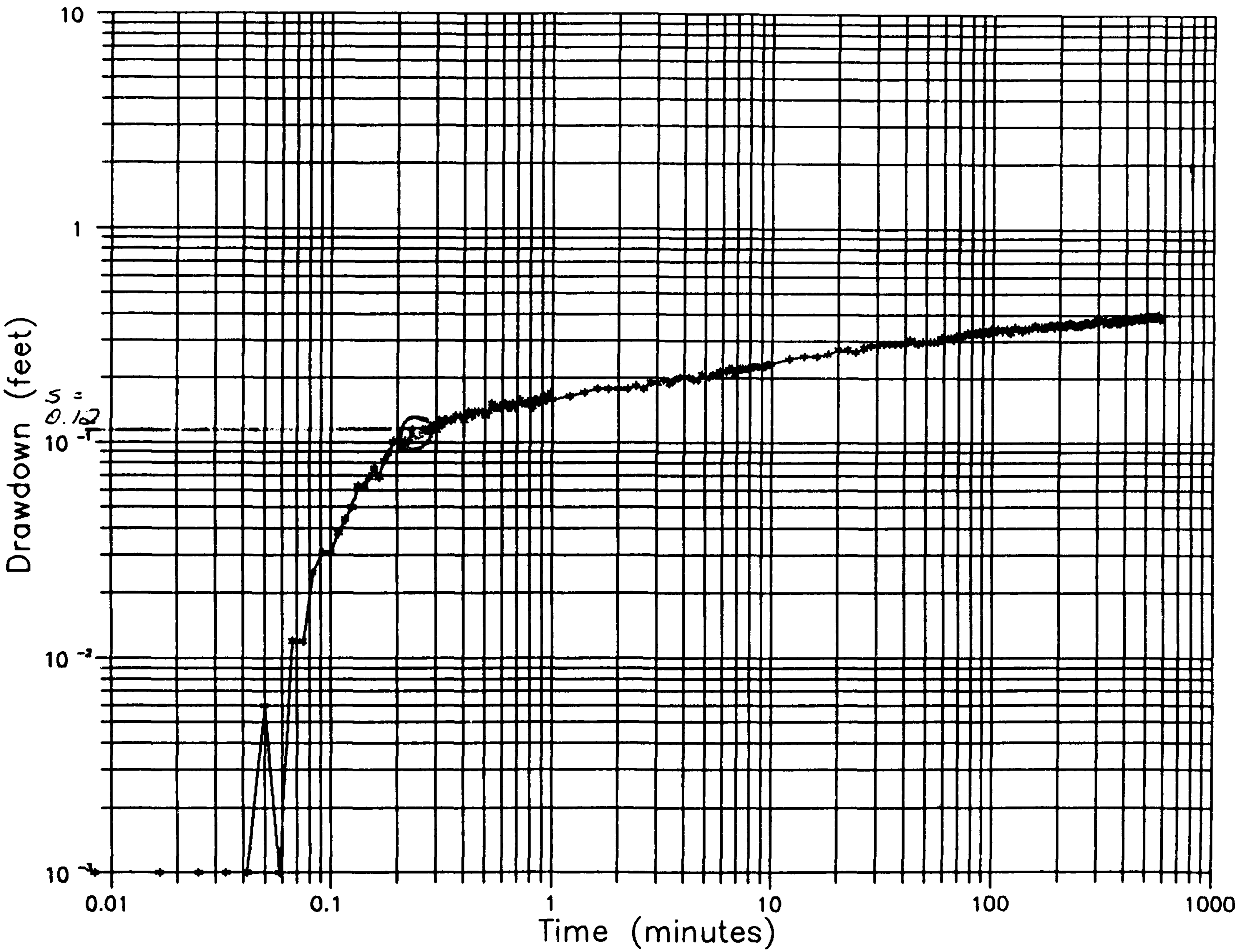
PUMPING TEST : KV-3



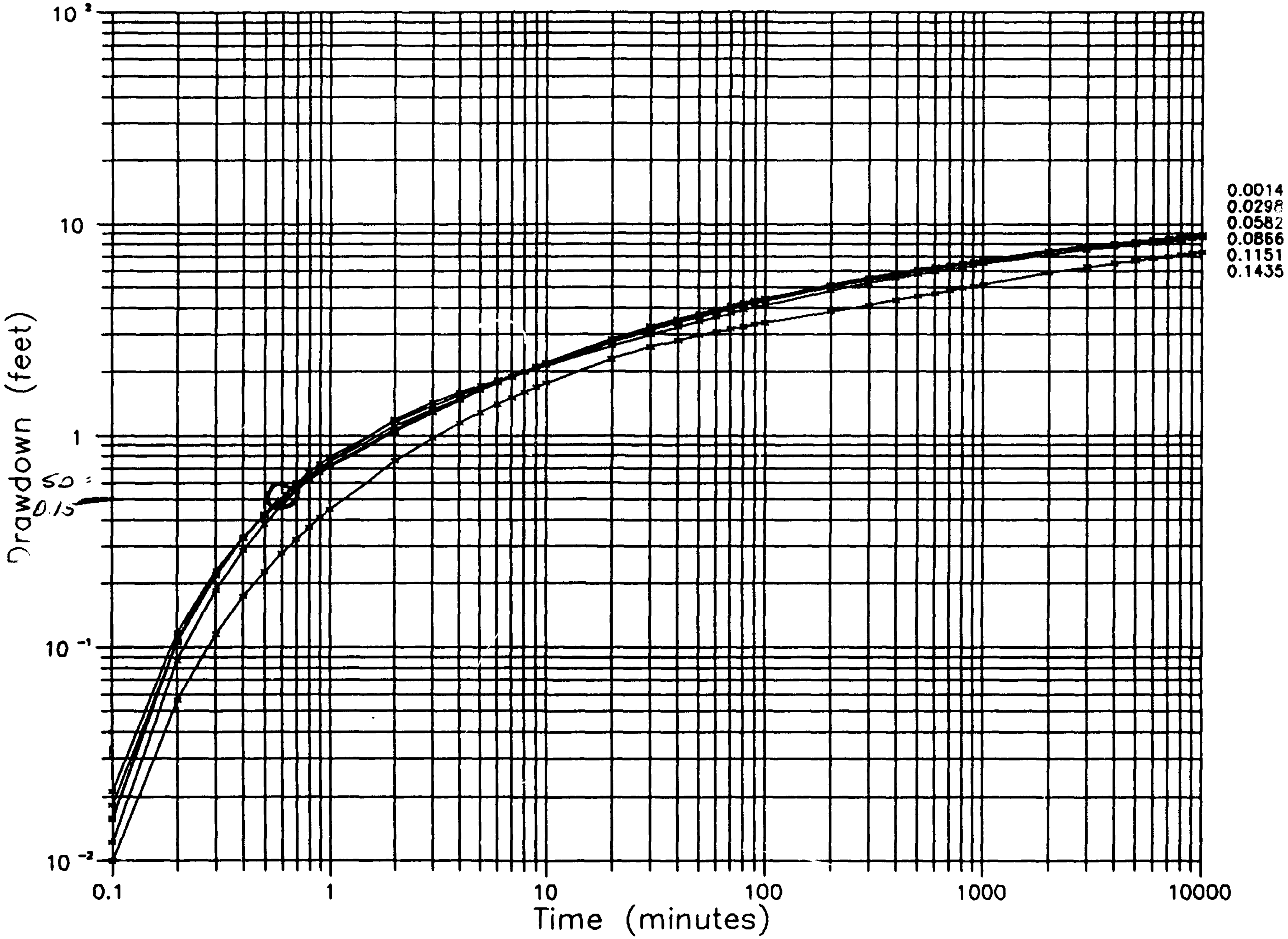
TYPE A CURVES (Neuman) : KV-4



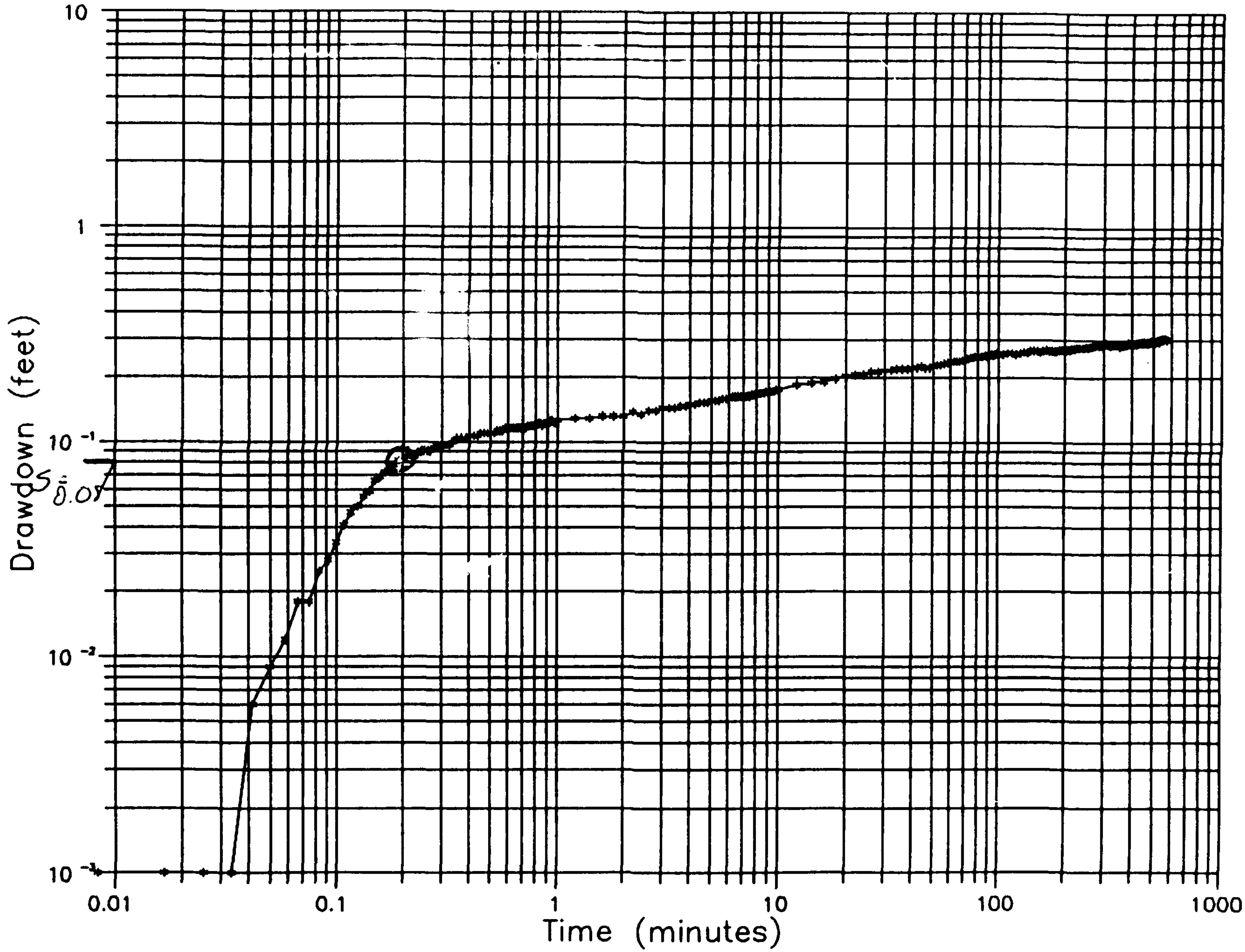
PUMPING TEST : KV-4



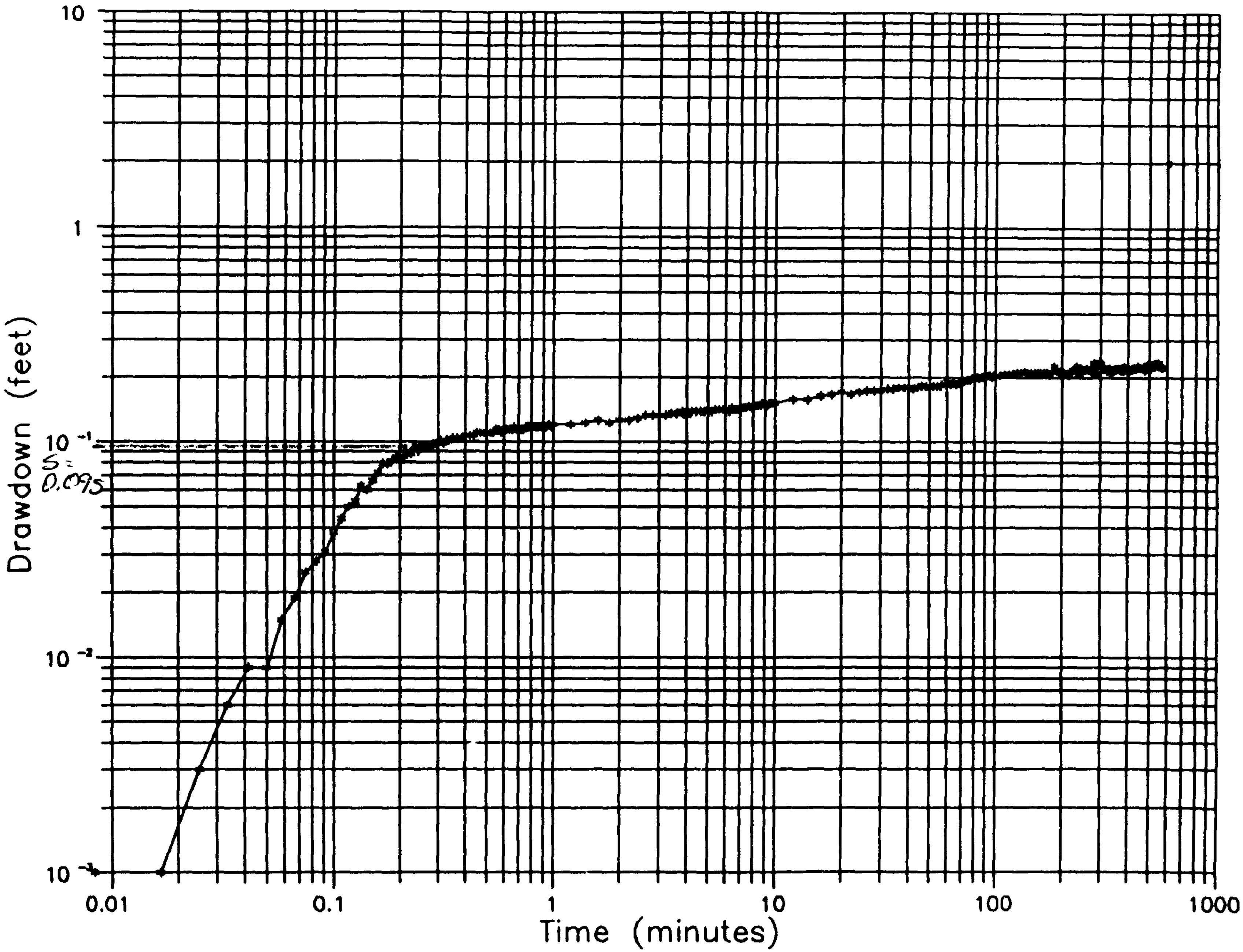
TYPE A CURVES (Neuman) : KV-5



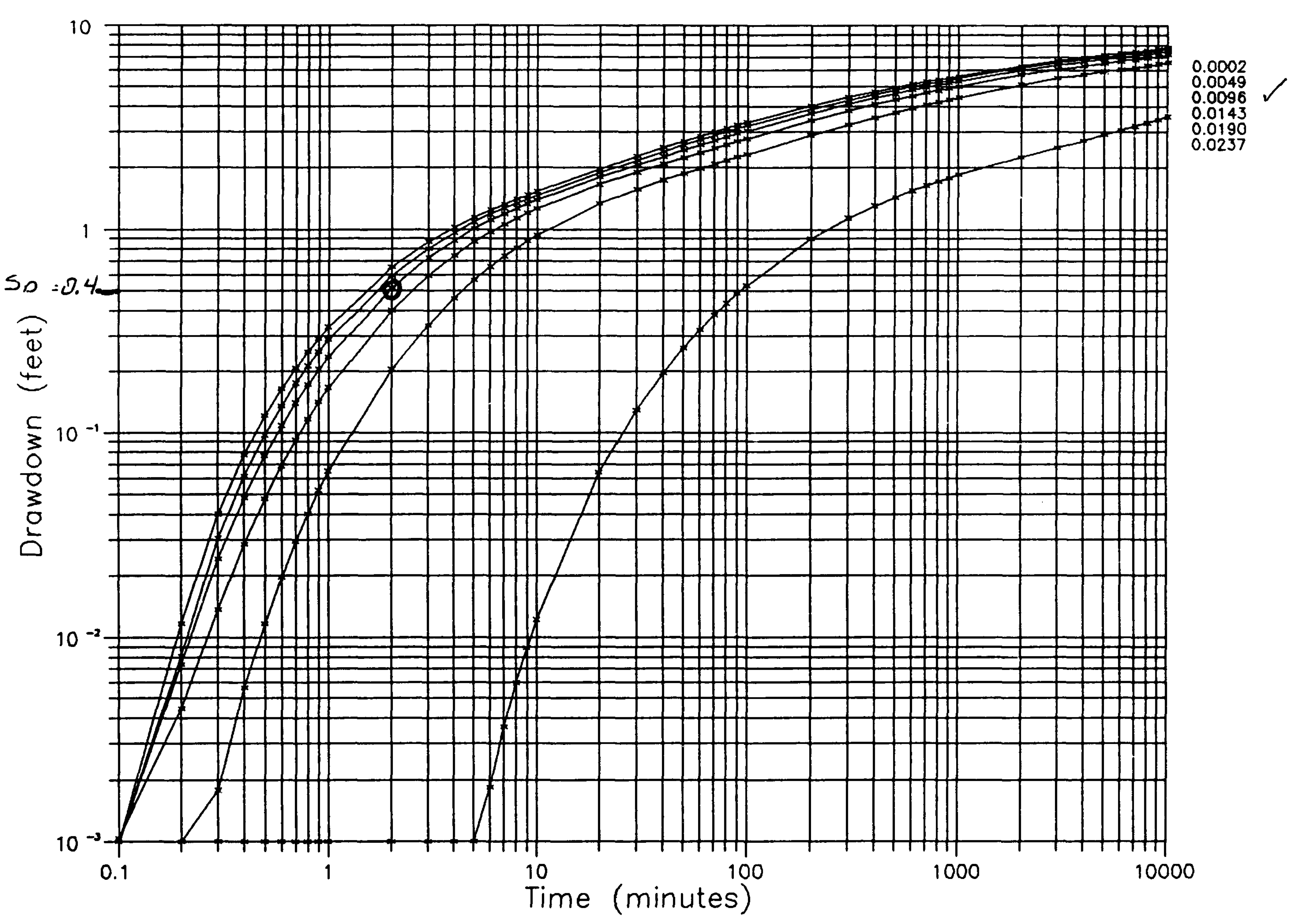
PUMPING TEST : KV-5



PUMPING TEST : KV-6



TYPE A CURVES (Neuman) : KV-6



APPENDIX C

RECOVERY DATA, GRAPHS AND ANALYSIS

Recovery Test Data for Galena Pumping Test, Aug 26, 1993

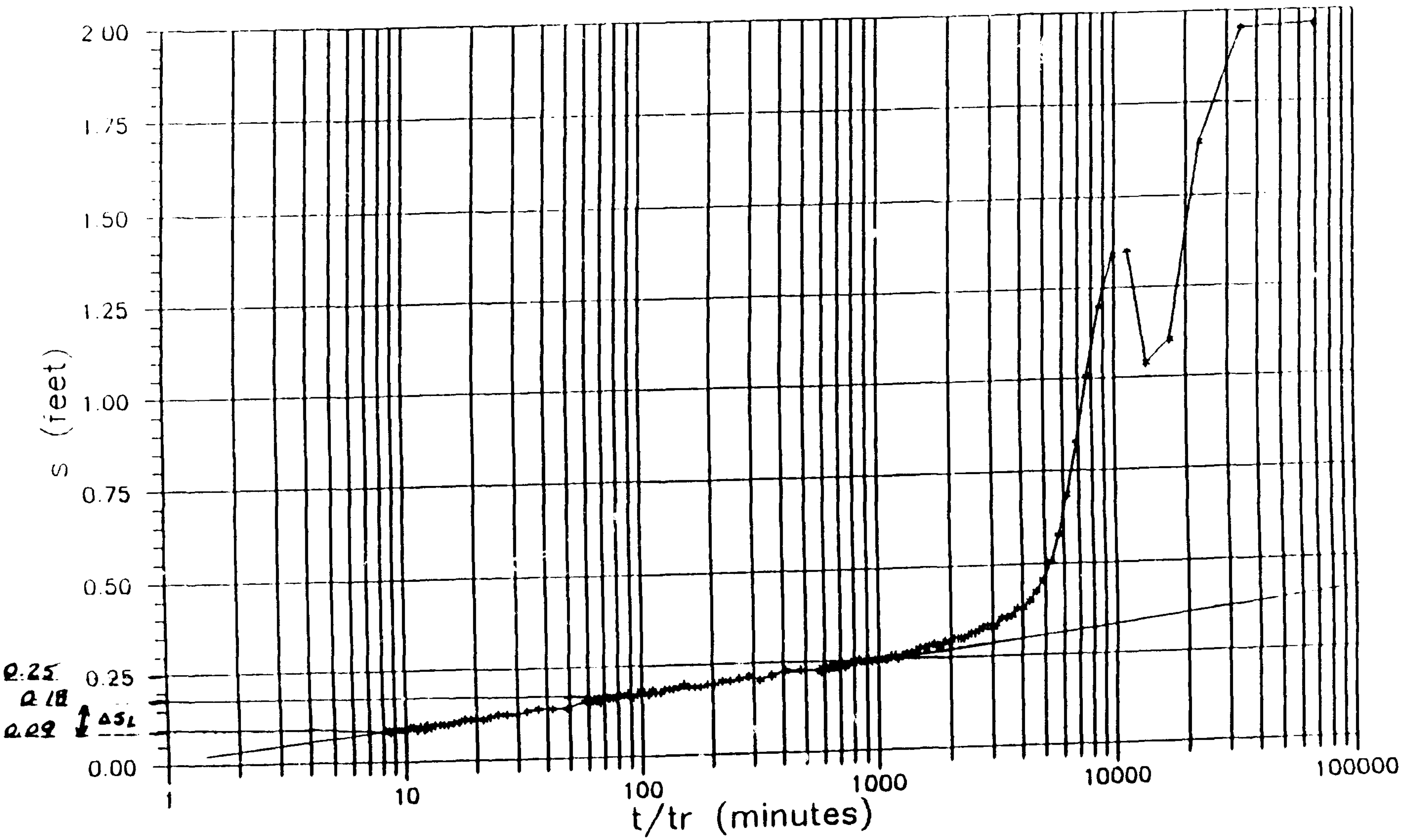
Time minutes	Drawdown (feet)							
	PW-1	KV-4	KV-5	KV-2	KV-3	KV-6	KV-1	05-MW-12
0	1.948	0.394	0.302	0.496	-6.101	0.224	0.426	0.078
0.0083	1.961	0.387	0.302	0.499	-6.105	0.221	0.426	0.078
0.0166	1.954	0.387	0.302	0.499	-6.105	0.221	0.426	0.078
0.025	1.643	0.387	0.302	0.499	-6.105	0.221	0.426	0.078
0.0333	1.104	0.387	0.302	0.493	-6.105	0.218	0.426	0.078
0.0416	1.04	0.381	0.299	0.486	-6.105	0.215	0.426	0.078
0.05	1.351	0.387	0.296	0.486	-6.105	0.212	0.426	0.078
0.0583	1.339	0.381	0.293	0.48	-6.105	0.205	0.426	0.078
0.0666	1.199	0.381	0.29	0.474	-6.105	0.202	0.426	0.078
0.075	1.009	0.375	0.287	0.464	-6.105	0.199	0.423	0.078
0.0833	0.831	0.368	0.28	0.455	-6.105	0.193	0.423	0.078
0.0916	0.685	0.362	0.277	0.448	-6.105	0.19	0.423	0.078
0.1	0.577	0.356	0.274	0.439	-6.105	0.183	0.423	0.078
0.1083	0.507	0.356	0.268	0.429	-6.105	0.18	0.423	0.078
0.1166	0.456	0.343	0.261	0.417	-6.105	0.174	0.423	0.078
0.125	0.425	0.337	0.258	0.407	-6.105	0.171	0.423	0.078
0.1333	0.399	0.337	0.252	0.398	-6.105	0.164	0.423	0.078
0.1416	0.38	0.324	0.246	0.385	-6.105	0.158	0.423	0.078
0.15	0.38	0.317	0.242	0.379	-6.105	0.155	0.42	0.078
0.1583	0.361	0.311	0.239	0.369	-6.105	0.148	0.42	0.078
0.1666	0.355	0.311	0.236	0.36	-6.105	0.145	0.42	0.078
0.175	0.355	0.305	0.23	0.357	-6.105	0.142	0.42	0.078
0.1833	0.336	0.292	0.23	0.347	-6.105	0.139	0.42	0.078
0.1916	0.33	0.286	0.223	0.341	-6.105	0.136	0.417	0.078
0.2	0.336	0.286	0.223	0.334	-6.105	0.136	0.417	0.078
0.2083	0.33	0.286	0.223	0.328	-6.105	0.129	0.417	0.078
0.2166	0.323	0.286	0.22	0.325	-6.105	0.129	0.417	0.078
0.225	0.317	0.286	0.22	0.322	-6.105	0.129	0.417	0.078
0.2333	0.317	0.279	0.217	0.316	-6.105	0.126	0.417	0.078
0.2416	0.31	0.279	0.217	0.309	-6.105	0.129	0.414	0.078
0.25	0.304	0.279	0.214	0.309	-6.105	0.126	0.414	0.078
0.2583	0.304	0.267	0.214	0.306	-6.105	0.126	0.414	0.078
0.2666	0.304	0.273	0.214	0.303	-6.105	0.126	0.414	0.078
0.275	0.304	0.273	0.211	0.3	-6.105	0.123	0.414	0.078
0.2833	0.298	0.273	0.211	0.297	-6.105	0.123	0.41	0.078
0.2916	0.291	0.267	0.211	0.293	-6.105	0.123	0.41	0.078
0.3	0.298	0.267	0.211	0.29	-6.105	0.123	0.41	0.078
0.3083	0.291	0.267	0.208	0.287	-6.105	0.123	0.41	0.078
0.3166	0.285	0.267	0.208	0.287	-6.105	0.12	0.41	0.078
0.325	0.285	0.267	0.208	0.287	-6.105	0.12	0.41	0.078
0.3333	0.291	0.26	0.208	0.284	-6.105	0.12	0.41	0.078
0.35	0.285	0.273	0.205	0.281	-6.105	0.12	0.407	0.078
0.3666	0.279	0.26	0.205	0.274	-6.105	0.117	0.404	0.078
0.3833	0.279	0.254	0.201	0.271	-6.105	0.114	0.404	0.078
0.4	0.272	0.254	0.201	0.268	-6.105	0.114	0.404	0.078
0.4166	0.266	0.254	0.198	0.265	-6.105	0.114	0.401	0.082
0.4333	0.266	0.254	0.198	0.262	-6.108	0.11	0.401	0.078
0.45	0.26	0.254	0.198	0.259	-6.105	0.11	0.398	0.082
0.4666	0.253	0.254	0.195	0.255	-6.108	0.11	0.398	0.082

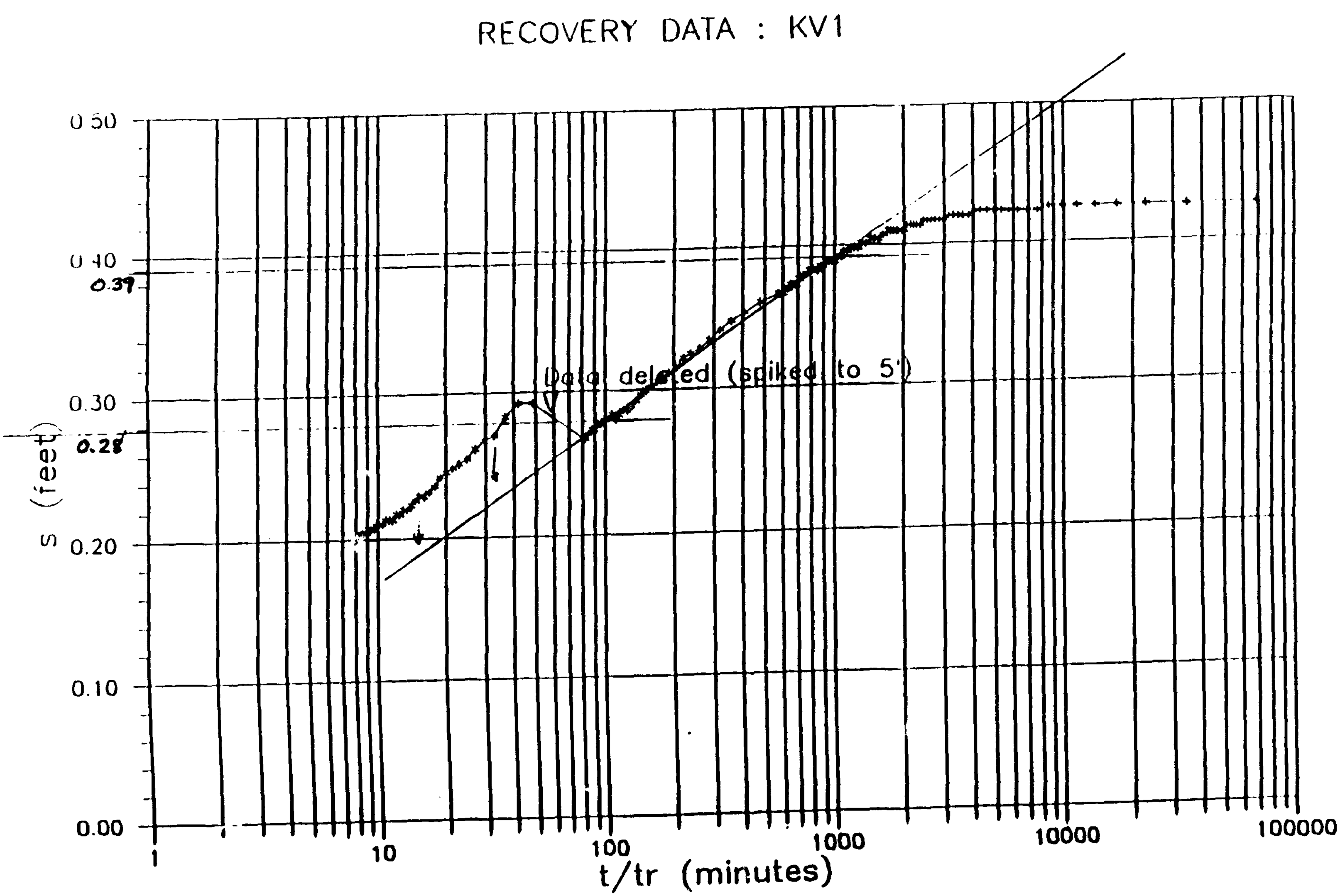
0.4833	0.26	0.254	0.195	0.255	-6.108	0.11	0.398	0.082
0.5	0.26	0.247	0.195	0.252	-6.108	0.107	0.395	0.082
0.5166	0.253	0.247	0.192	0.249	-6.108	0.107	0.395	0.082
0.5333	0.253	0.247	0.192	0.249	-6.108	0.107	0.391	0.082
0.55	0.253	0.247	0.192	0.246	-6.108	0.107	0.391	0.082
0.5666	0.253	0.241	0.192	0.246	-6.108	0.107	0.388	0.082
0.5833	0.253	0.235	0.192	0.243	-6.108	0.107	0.388	0.082
0.6	0.247	0.241	0.192	0.243	-6.108	0.107	0.388	0.082
0.6166	0.253	0.241	0.192	0.24	-6.108	0.107	0.388	0.082
0.6333	0.247	0.241	0.192	0.24	-6.111	0.104	0.385	0.078
0.65	0.247	0.241	0.189	0.24	-6.111	0.107	0.385	0.078
0.6666	0.247	0.241	0.189	0.237	-6.111	0.104	0.382	0.078
0.6833	0.253	0.235	0.189	0.237	-6.111	0.104	0.382	0.078
0.7	0.247	0.241	0.189	0.237	-6.111	0.104	0.382	0.078
0.7166	0.241	0.235	0.189	0.233	-6.111	0.104	0.382	0.078
0.7333	0.247	0.241	0.189	0.233	-6.111	0.104	0.382	0.078
0.75	0.241	0.235	0.189	0.233	-6.111	0.104	0.379	0.078
0.7666	0.241	0.228	0.189	0.23	-6.114	0.104	0.379	0.078
0.7833	0.234	0.235	0.186	0.23	-6.114	0.104	0.379	0.078
0.8	0.247	0.228	0.186	0.227	-6.114	0.104	0.376	0.078
0.8166	0.234	0.235	0.186	0.227	-6.114	0.101	0.376	0.078
0.8333	0.234	0.235	0.186	0.227	-6.114	0.104	0.372	0.078
0.85	0.234	0.228	0.186	0.227	-6.114	0.101	0.372	0.078
0.8666	0.234	0.228	0.186	0.227	-6.117	0.104	0.372	0.078
0.8833	0.234	0.228	0.182	0.224	-6.117	0.101	0.372	0.078
0.9	0.234	0.228	0.182	0.224	-6.117	0.101	0.369	0.078
0.9166	0.228	0.228	0.182	0.224	-6.117	0.101	0.369	0.078
0.9333	0.234	0.235	0.182	0.221	-6.117	0.101	0.369	0.078
0.95	0.228	0.235	0.182	0.221	-6.117	0.101	0.366	0.078
0.9666	0.234	0.228	0.182	0.221	-6.117	0.101	0.366	0.078
0.9833	0.222	0.235	0.182	0.221	-6.12	0.101	0.366	0.078
1	0.228	0.228	0.182	0.221	-6.12	0.101	0.366	0.078
1.2	0.228	0.222	0.176	0.211	-6.124	0.101	0.36	0.082
1.4	0.228	0.216	0.176	0.208	-6.13	0.101	0.353	0.082
1.6	0.215	0.216	0.173	0.202	-6.133	0.098	0.347	0.082
1.8	0.203	0.216	0.173	0.199	-6.139	0.098	0.341	0.082
2	0.215	0.203	0.17	0.192	-6.143	0.098	0.334	0.082
2.2	0.209	0.209	0.167	0.189	-6.149	0.098	0.328	0.085
2.4	0.203	0.209	0.167	0.186	-6.152	0.095	0.325	0.085
2.6	0.203	0.197	0.164	0.183	-6.158	0.095	0.322	0.085
2.8	0.196	0.203	0.164	0.18	-6.162	0.095	0.316	0.085
3	0.196	0.203	0.164	0.176	-6.165	0.095	0.312	0.085
3.2	0.19	0.197	0.16	0.173	-6.168	0.095	0.309	0.082
3.4	0.19	0.197	0.16	0.17	-6.174	0.091	0.306	0.078
3.6	0.19	0.19	0.157	0.167	-6.177	0.091	0.303	0.078
3.8	0.196	0.19	0.157	0.167	-6.181	0.091	0.3	0.082
4	0.19	0.19	0.157	0.164	-6.184	0.088	0.297	0.082
4.2	0.184	0.184	0.154	0.158	-6.187	0.088	0.293	0.085
4.4	0.184	0.184	0.151	0.154	-6.19	0.085	0.29	0.085
4.6	0.184	0.184	0.151	0.151	-6.193	0.085	0.287	0.088
4.8	0.177	0.184	0.151	0.151	-6.196	0.082	0.287	0.088
5	0.177	0.178	0.151	0.148	-6.2	0.082	0.284	0.085
5.2	0.184	0.178	0.151	0.148	-6.203	0.082	0.281	0.085

5.4	0.171	0.171	0.148	0.148	-6.206	0.082	0.284	0.085
5.6	0.177	0.178	0.148	0.148	-6.209	0.082	0.281	0.085
5.8	0.184	0.171	0.148	0.145	-6.212	0.082	0.281	0.085
6	0.171	0.171	0.148	0.145	-6.212	0.082	0.278	0.085
6.2	0.165	0.171	0.145	0.145	-6.215	0.082	0.278	0.085
6.4	0.165	0.171	0.145	0.142	-6.219	0.082	0.274	0.085
6.6	0.177	0.165	0.145	0.142	-6.219	0.082	0.274	0.082
6.8	0.171	0.165	0.145	0.139	-6.222	0.079	0.271	0.082
7	0.171	0.165	0.141	0.135	-6.225	0.079	0.268	0.082
7.2	0.171	0.165	0.141	0.135	-6.228	0.079	0.268	0.078
7.4	0.165	0.165	0.141	0.132	-6.228	0.076	5.353	0.078
7.6	0.165	0.165	0.141	0.132	-6.231	0.076	5.391	0.075
7.8	0.165	0.158	0.141	0.132	-6.231	0.076	5.369	0.075
8	0.165	0.165	0.141	0.139	-6.234	0.076	5.369	0.078
8.2	0.165	0.165	0.138	0.132	-6.238	0.076	5.363	0.078
8.4	0.171	0.158	0.138	0.129	-6.238	0.072	5.363	0.082
8.6	0.152	0.158	0.138	0.126	-6.241	0.072	5.382	0.082
8.8	0.165	0.158	0.135	0.126	-6.241	0.076	5.378	0.085
9	0.158	0.158	0.135	0.126	-6.244	0.076	5.378	0.085
9.2	0.165	0.165	0.135	0.123	-6.244	0.076	5.378	0.085
9.4	0.158	0.158	0.135	0.123	-6.247	0.076	5.378	0.085
9.6	0.152	0.158	0.135	0.123	-6.247	0.076	5.375	0.085
9.8	0.158	0.152	0.132	0.12	-6.25	0.076	5.375	0.085
10	0.158	0.152	0.132	0.12	-6.253	0.076	5.375	0.085
12	0.139	0.152	0.129	0.107	-6.266	0.076	0.293	0.085
14	0.139	0.146	0.126	0.101	-6.276	0.072	0.293	0.091
16	0.139	0.139	0.123	0.094	-6.285	0.072	0.284	0.088
18	0.133	0.139	0.119	0.088	-6.295	0.072	0.271	0.088
20	0.126	0.139	0.116	0.088	-6.301	0.072	0.268	0.091
22	0.126	0.139	0.116	0.082	-6.307	0.072	0.262	0.094
24	0.126	0.127	0.113	0.079	-6.317	0.069	0.255	0.091
26	0.12	0.133	0.11	0.075	-6.32	0.069	0.252	0.091
28	0.114	0.12	0.107	0.072	-6.326	0.069	0.249	0.091
30	0.114	0.12	0.107	0.069	-6.333	0.066	0.246	0.091
32	0.114	0.12	0.104	0.063	-6.336	0.066	0.243	0.088
34	0.114	0.114	0.1	0.06	-6.342	0.063	0.237	0.088
36	0.107	0.108	0.1	0.056	-6.345	0.06	0.233	0.082
38	0.107	0.101	0.094	0.053	-6.352	0.06	0.23	0.082
40	0.101	0.108	0.094	0.05	-6.352	0.06	0.23	0.088
42	0.101	0.108	0.094	0.05	-6.355	0.06	0.227	0.088
44	0.101	0.108	0.091	0.047	-6.361	0.06	0.224	0.085
46	0.101	0.108	0.088	0.044	-6.361	0.057	0.221	0.082
48	0.095	0.101	0.091	0.047	-6.364	0.057	0.221	0.085
50	0.101	0.095	0.088	0.044	-6.367	0.057	0.218	0.088
52	0.088	0.101	0.088	0.041	-6.371	0.057	0.218	0.085
54	0.095	0.095	0.088	0.041	-6.371	0.057	0.214	0.085
56	0.088	0.095	0.088	0.041	-6.374	0.057	0.214	0.088
58	0.095	0.095	0.088	0.037	-6.374	0.057	0.214	0.088
60	0.095	0.095	0.085	0.037	-6.377	0.057	0.211	0.085
62	0.088	0.089	0.085	0.034	-6.377	0.057	0.211	0.088
64	0.088	0.095	0.085	0.034	-6.38	0.053	0.211	0.088
66	0.088	0.095	0.085	0.034	-6.38	0.057	0.208	0.088
68	0.088	0.095	0.082	0.028	-6.383	0.05	0.208	0.082

70	0.088	0.089	0.082	0.028	-6.383	0.053	0.208	0.085
72	0.088	0.095	0.082	0.028	-6.383	0.053	0.205	0.085
74	0.082	0.095	0.082	0.028	-6.386	0.057	0.205	0.088
76	0.088	0.101	0.082	0.031	-6.386	0.057	0.205	0.088
78	0.088	0.082	0.082	0.028	-6.39	0.057	0.202	0.088

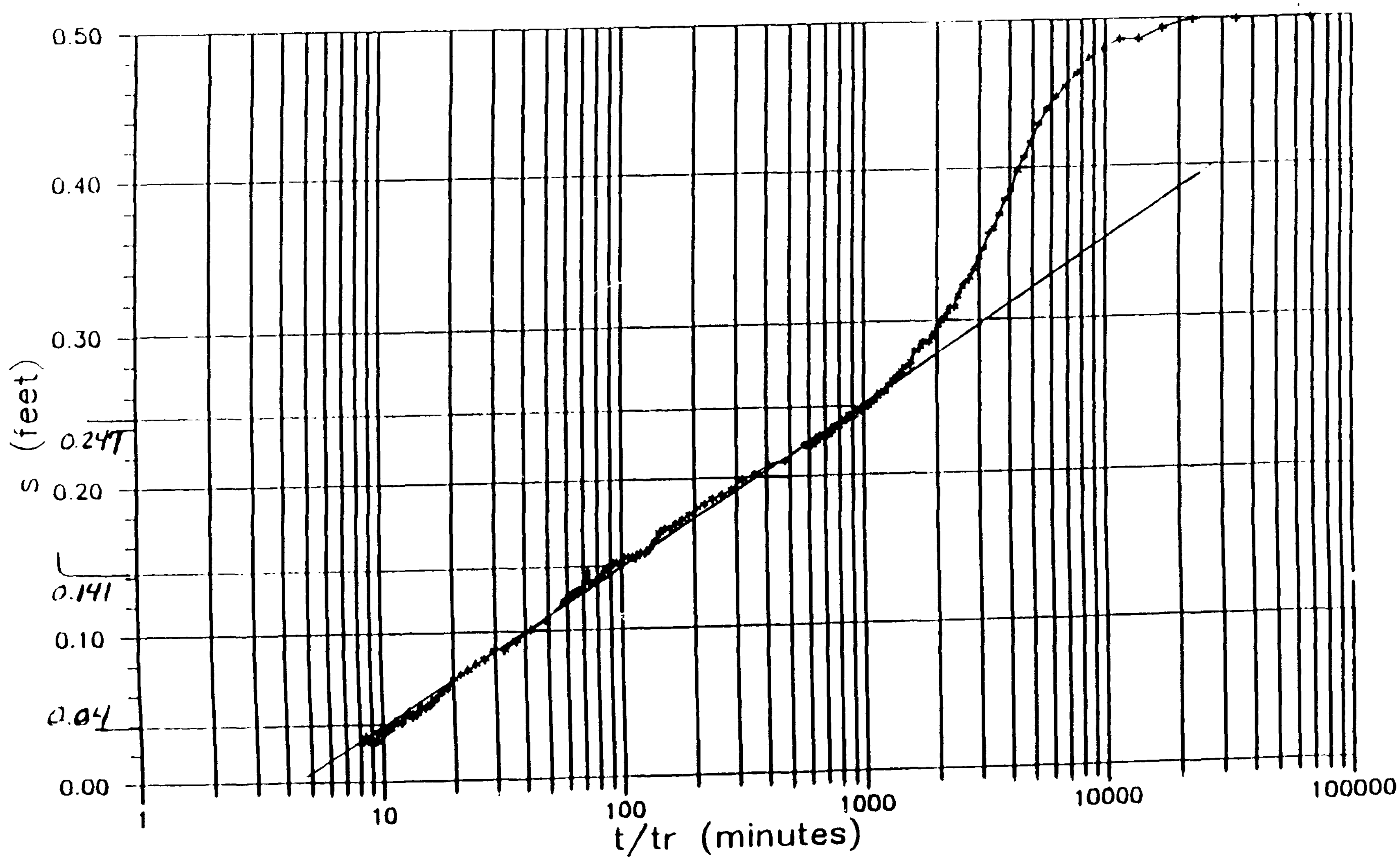
RECOVERY DATA : Pumping Well



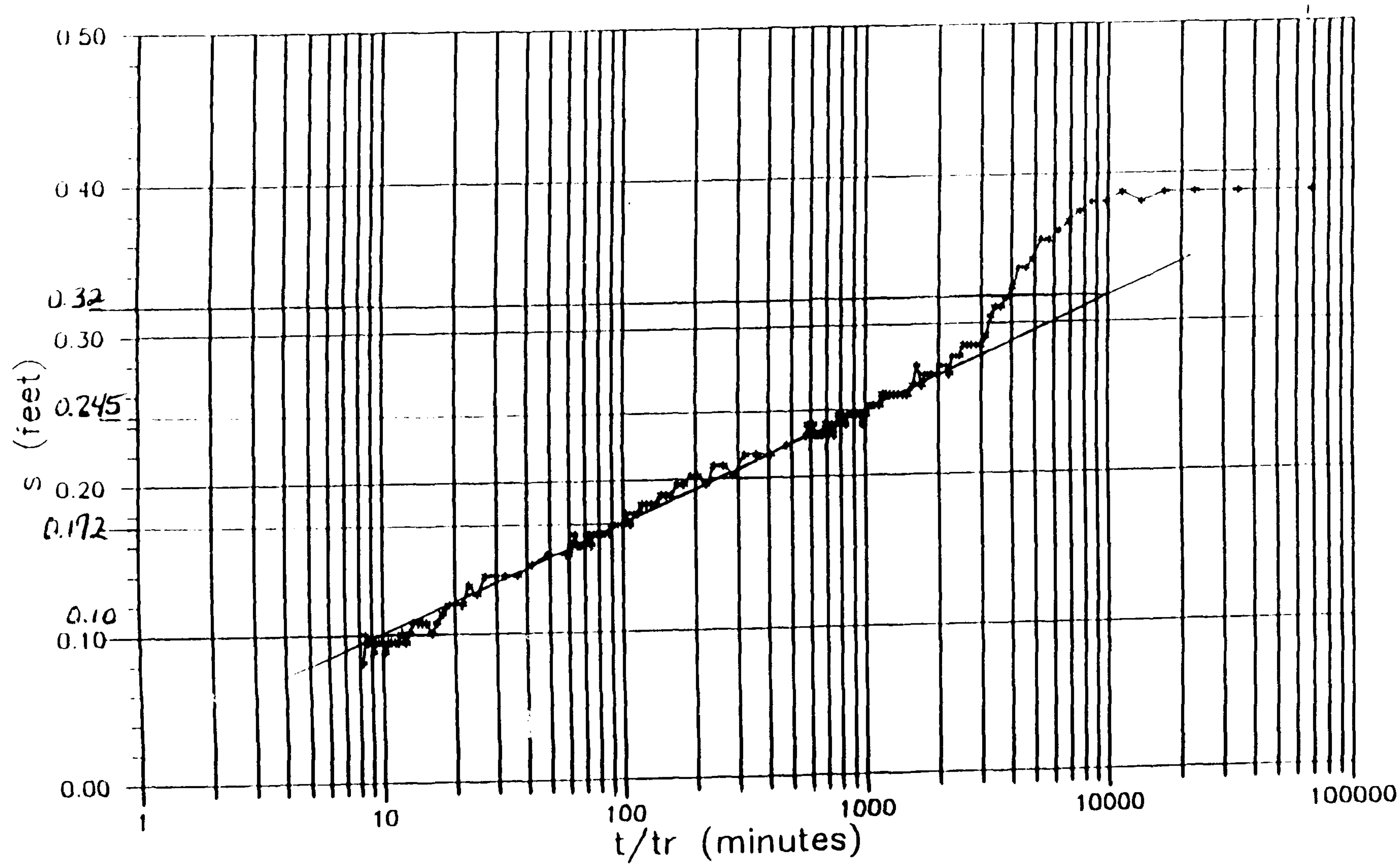


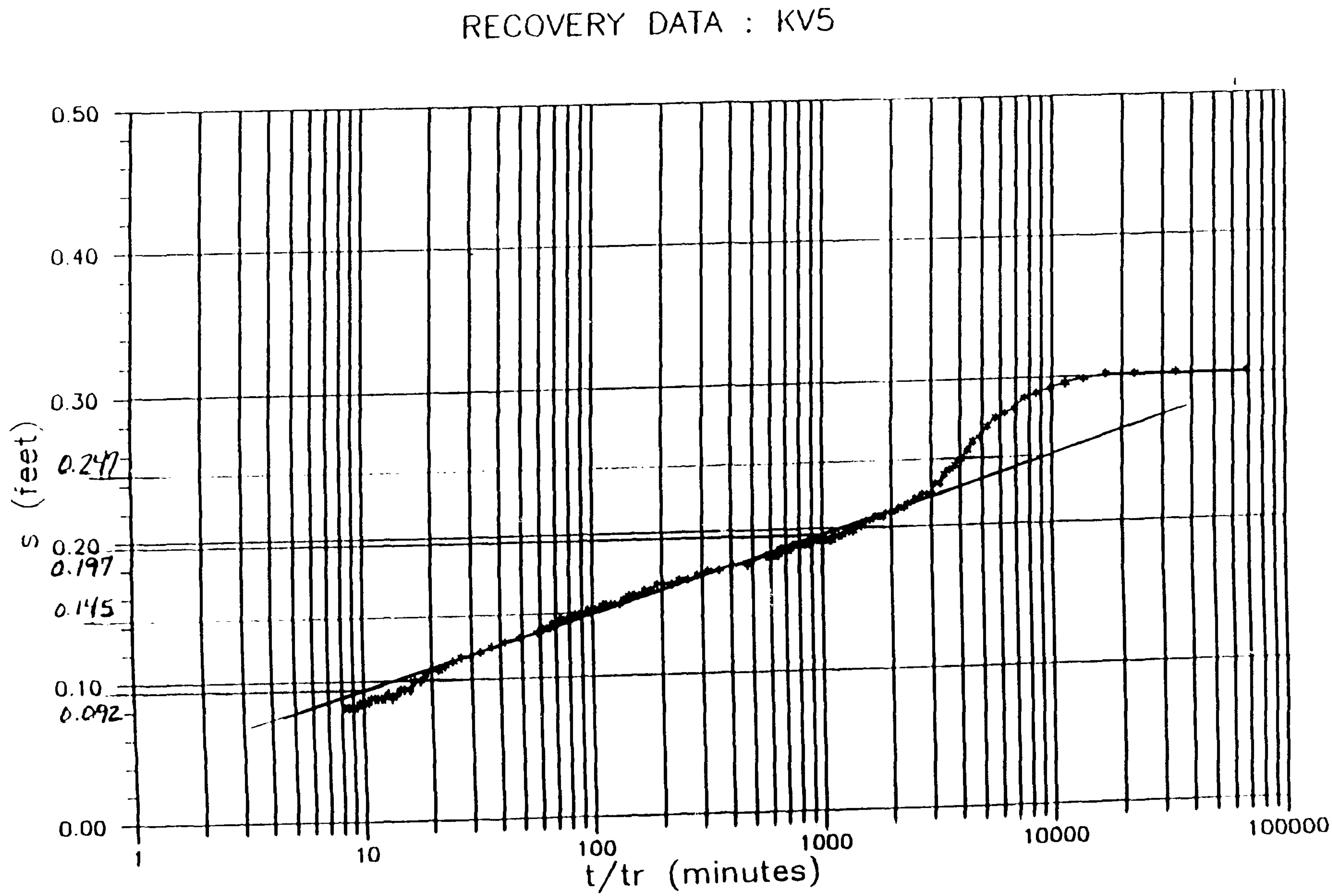
RECOVERY DATA : KV1
Data deleted (spiked to 5')
s (feet)
0.50
0.40
0.39
0.30
0.28
0.20
0.10
0.00
1
10
100
1000
10000
100000
t/tr (minutes)

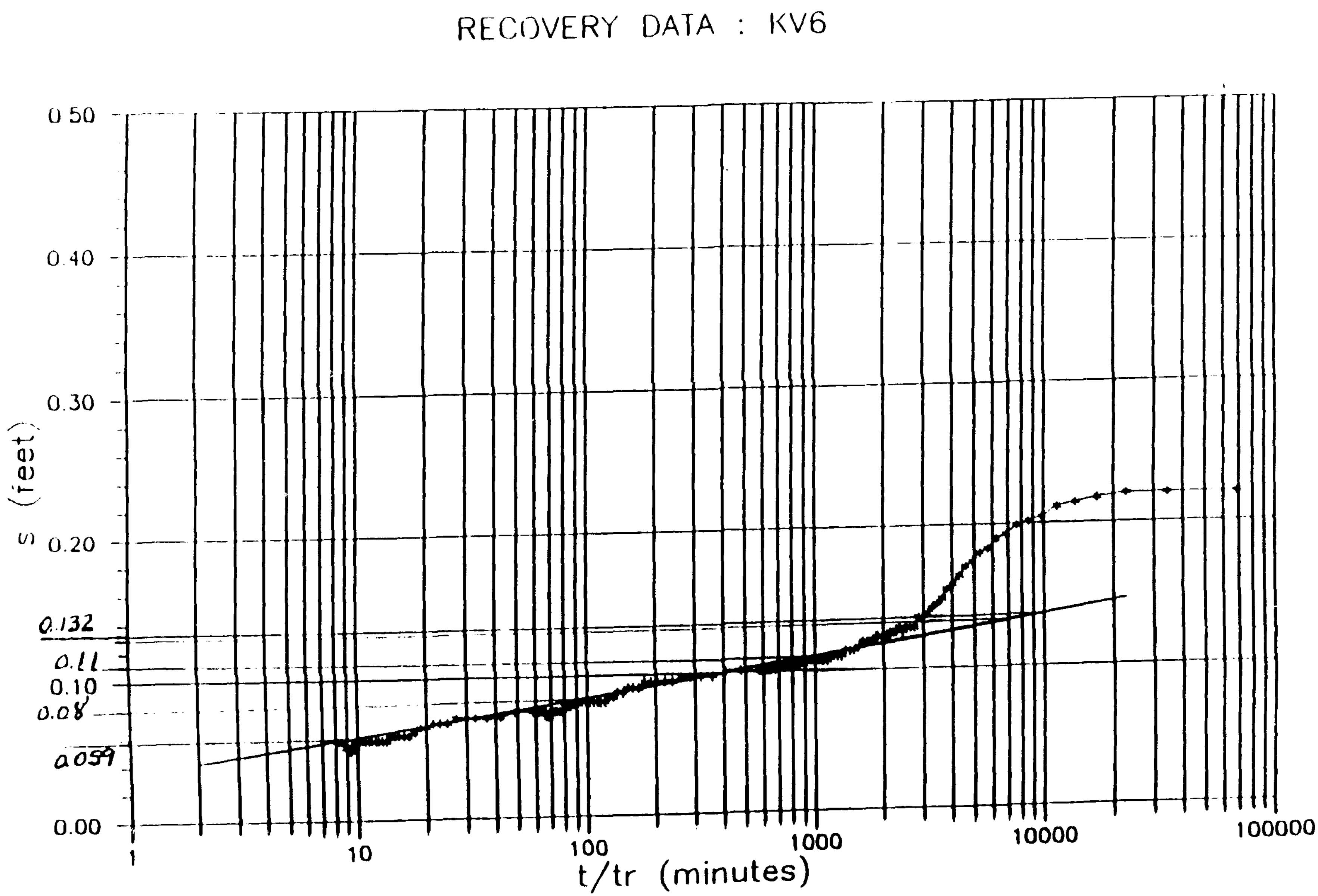
RECOVERY DATA : KV2



RECOVERY DATA : KV4



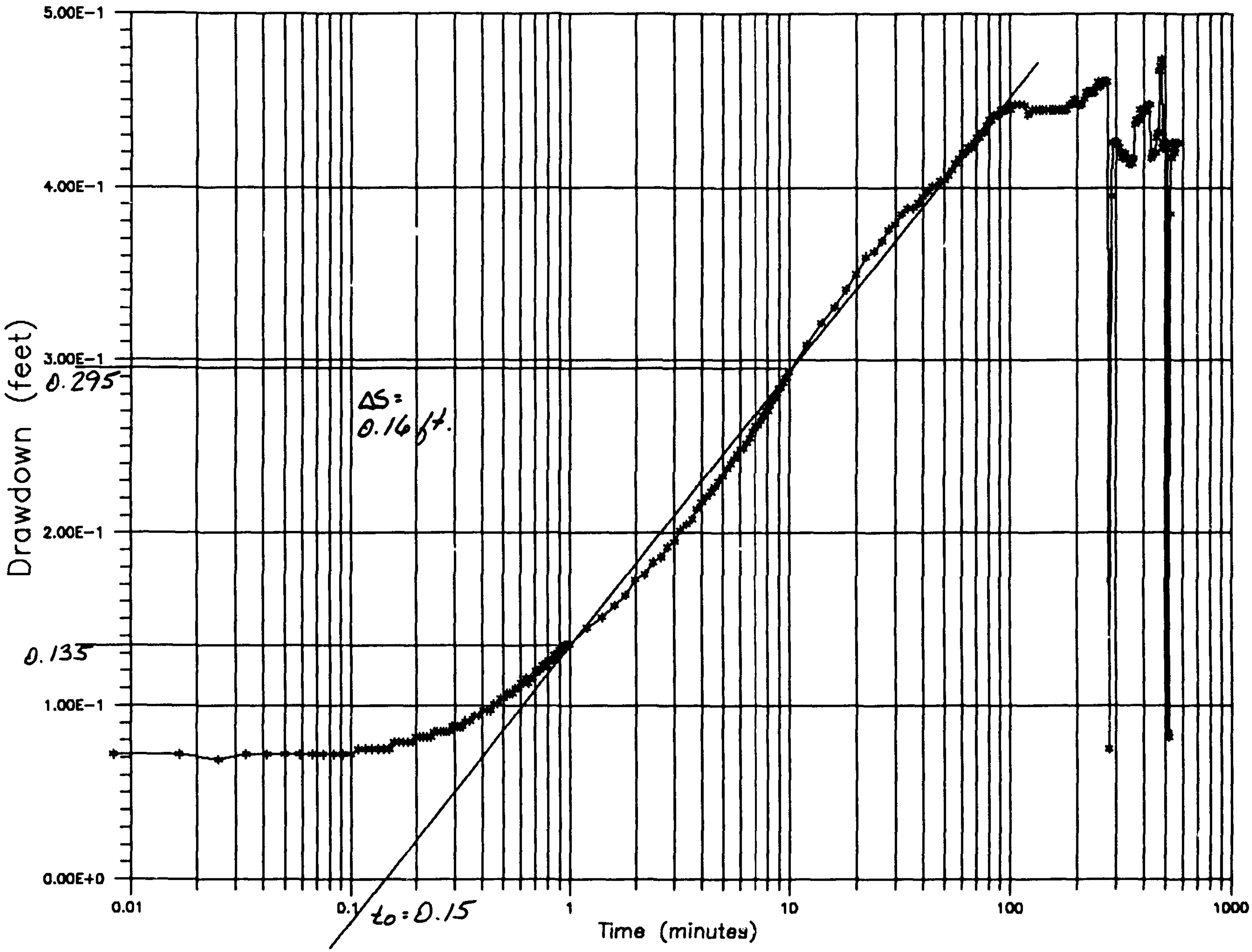

RECOVERY DATA : KV5
0.50
0.40
0.30
0.247
0.20
0.197
0.145
0.10
0.092
0.00
s (feet)
1
10
100
1000
10000
100000
t/tr (minutes)


RECOVERY DATA : KV6
s (feet)
0.50
0.40
0.30
0.20
0.132
0.11
0.10
0.08
0.059
0.00
1
10
100
1000
10000
100000
t/tr (minutes)

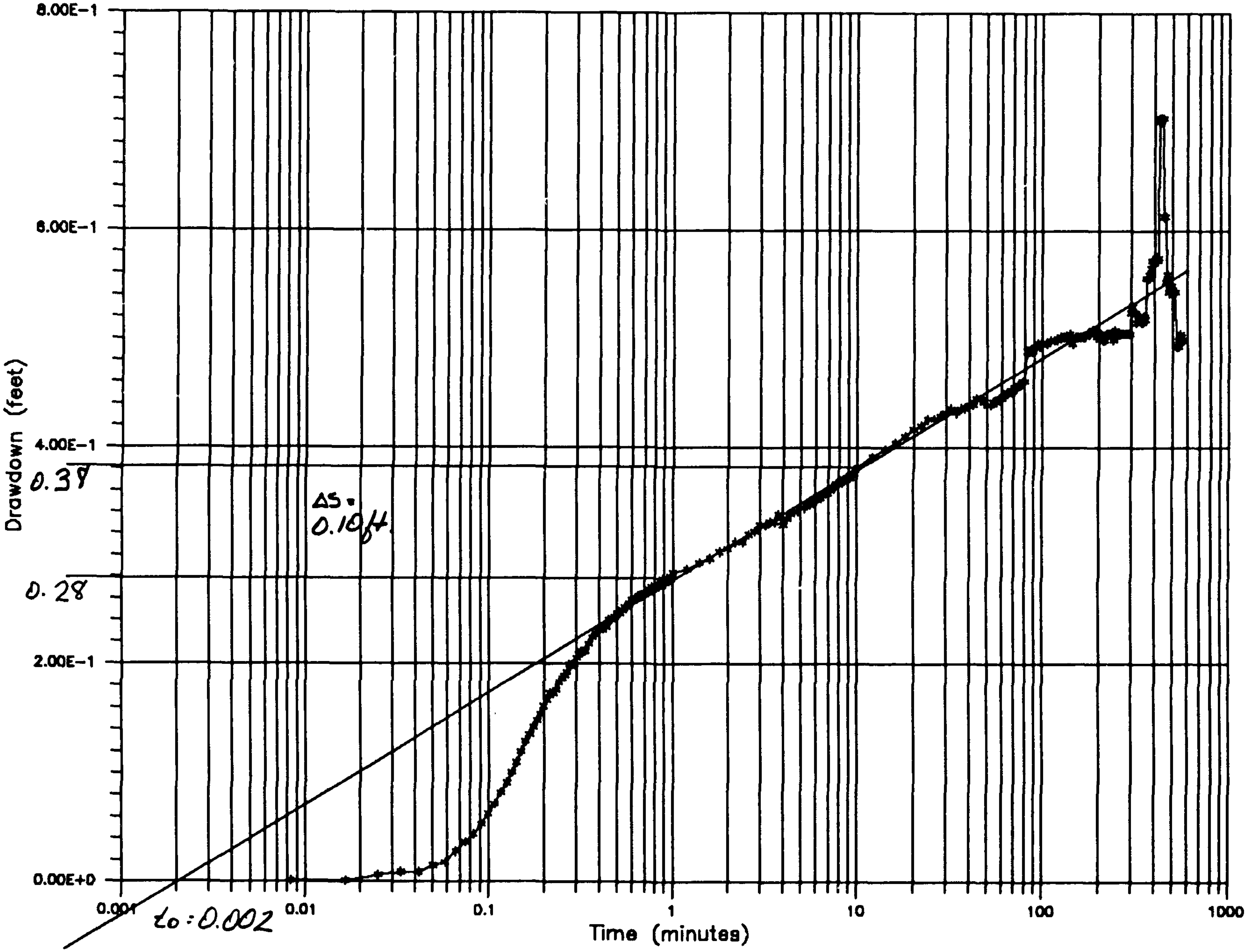
APPENDIX D

DRAWDOWN DATA GRAPHS ANALYZED BY THE COOPER AND JACOB METHOD

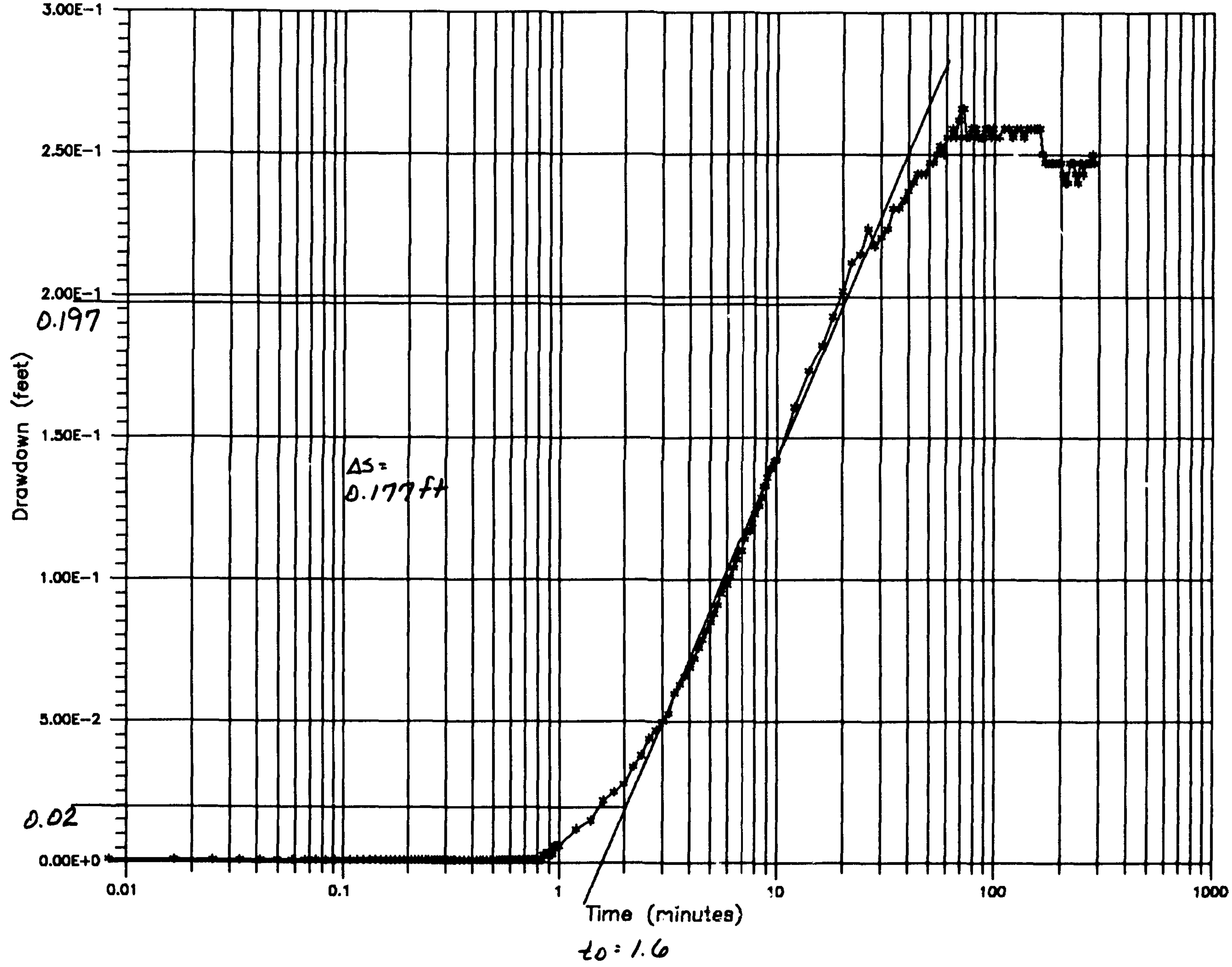
PUMPING TEST : KV-1



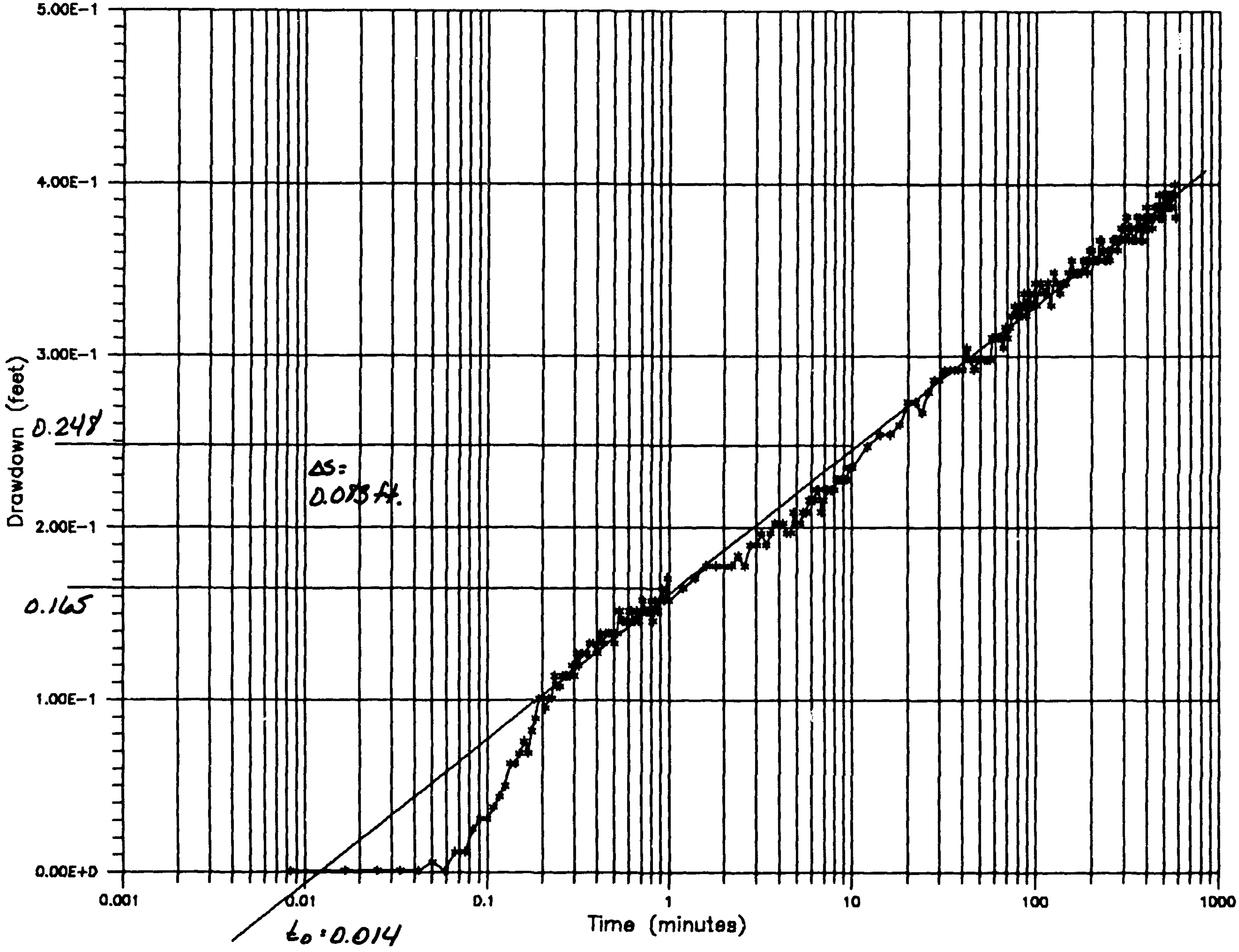
PUMPING TEST : KV-2

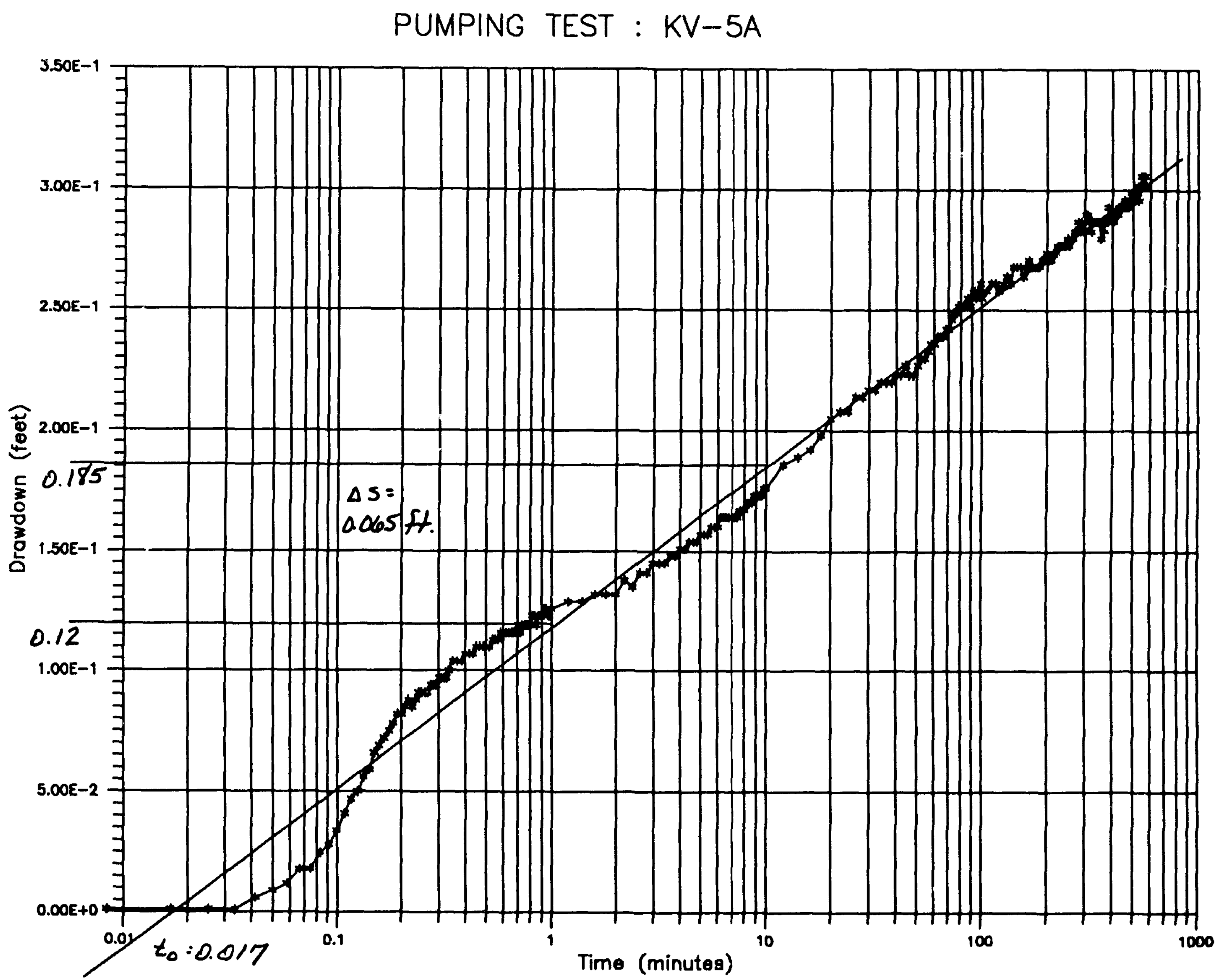


PUMPING TEST : KV-3



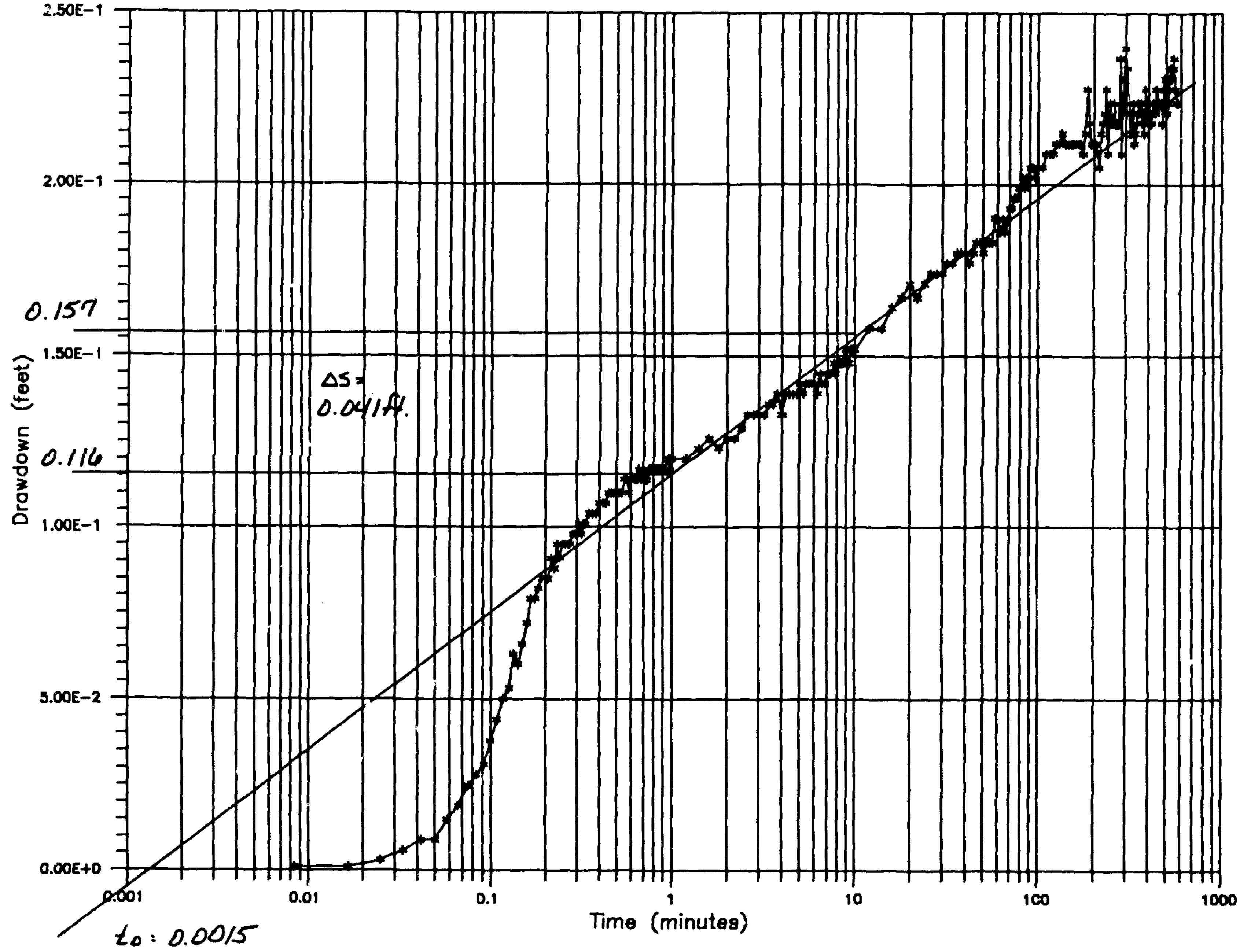
PUMPING TEST : KV-4A





PUMPING TEST : KV-5A
3.50E-1
3.00E-1
2.50E-1
2.00E-1
1.50E-1
1.00E-1
5.00E-2
0.00E+0
Drawdown (feet)
0.185
0.12
Δs =
0.065 ft.
0.01
0.1
1
10
100
1000
Time (minutes)
t_0 : 0.017

PUMPING TEST : KV-6A



APPENDIX E

AIR FORCE MEMO ON FLOWMETER TESTING AND DATA ANALYSIS

InterOffice Memo

To: WES LANNEN

From: JOE MILLHOUSE

Date: October 15, 1993

Subject: Preliminary Report on the KVA Ground Water Flow Study at Galena AFS AK

As you know, a ground water flow study is currently in progress at Galena AFS AK. Two sets of ground water data have been collected so far: one set in May during break-up of the Yukon River, and a second in conjunction with a hybrid pumping test conducted during late August. A third set of data will be collected near the end of October, hopefully before Yukon River freeze-up. In mid-November I'll send you a final report on our findings.

Objectives

In March 1993, 11CEOS agreed to conduct the study to support the RI/FS data collection effort performed by Radian Corporation. The objectives of the study were as follows:

1. Determine the direction and rate of ground water flow at the POL site, using a KVA Model 40 Ground Water Flow meter

2. Install six specially constructed monitoring wells to determine the vertical profile of flow, if possible

3. Collect flow data in conjunction with a hybrid pumping test conducted by Radian Corporation

4. Determine any temporal changes in flow, particularly during periods of high ground water associated with the break-up of the Yukon River

The data collected in this study will be used to develop a model of the Yukon River alluvial system. A complete characterization of the ground water aquifer is necessary to determine the extent of the suspected POL contamination of the ground water at Galena.

Methodology

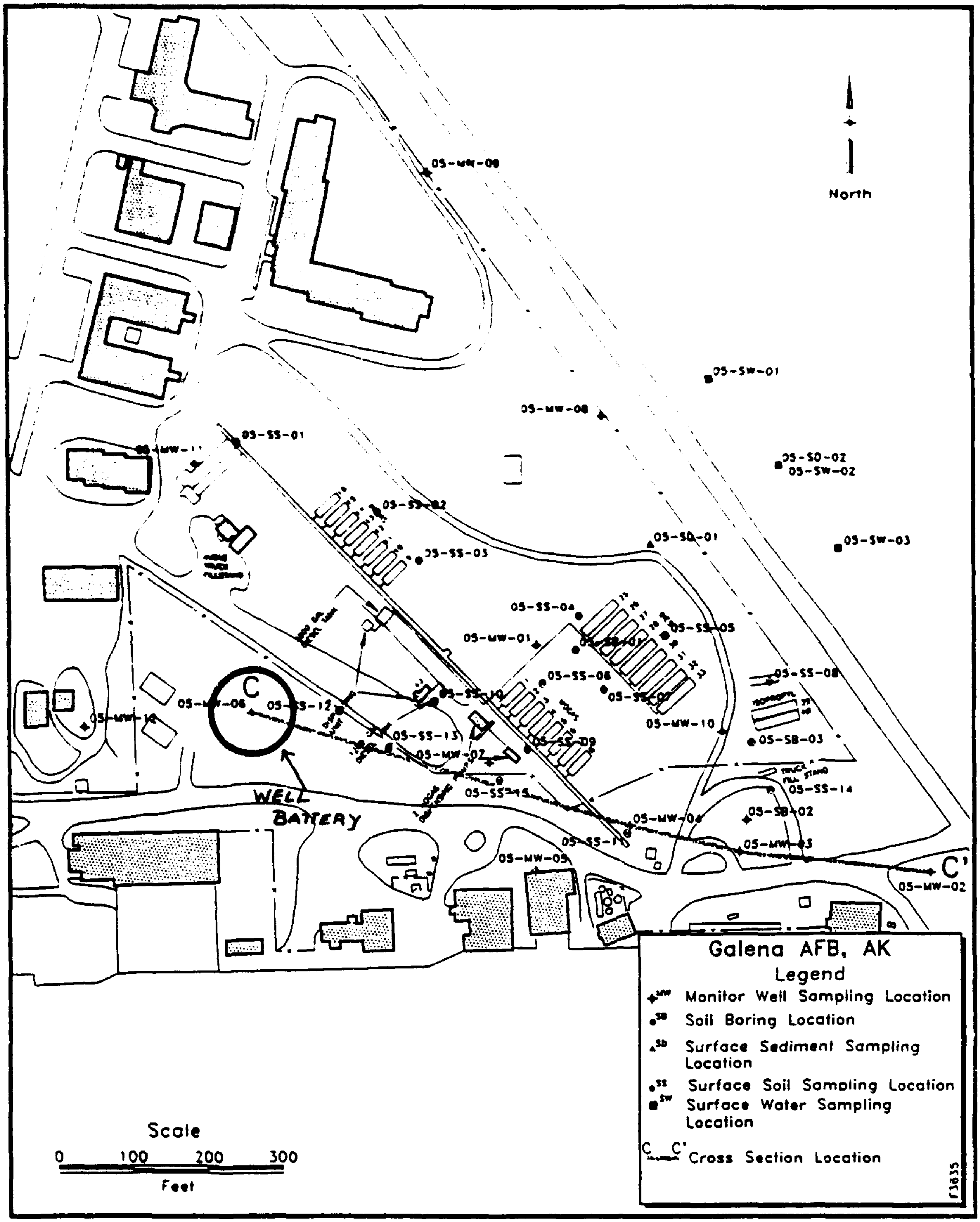
The GEOFLO ground water flow meter employs a heat pulsing technique to determine the direction and magnitude of ground water flow. Rapid and direct ground water flow measurement uses the characteristics of heat transfer across a porous material. A submersible probe is lowered down a well and secured at a known depth. The probe is left in the well for several minutes to allow it to come to thermal equilibrium and to eliminate the slug effect caused by displacing the water in the well during insertion. The probe emits a transient short duration heat pulse which propagates in the direction of flow. The probe heater is surrounded by a circular array of matched thermal sensors which detect any temperature rise. Because the heat source in located in the center of the matched sensors, one pair of sensors will lie along the axis of flow. In a no flow condition, the center of the heat pulse remains stationary and all sensors see the same temperature rise. In a flow condition , the center of the heat pulse is displaced in the direction of flow, and at the rate of ground water flow. By scanning all pairs of matched sensors, the operator gains information about the polar component of flow. The probe is then rotated 180° in the well and allowed to re-equilibrate. A second set of readings is then collected at the same depth. Subtracting the two values corrects for any thermal bias. The machine reading results in an array of four sets of values proportional to the annular component of flow in each direction. If the flow across the well screen is uniform, a circular array will occur. With steady horizontal flow, the net change in each vector readout represents a fraction of the magnitude of flow in the principal direction, proportional to the cosine of the sensors' angular displacement from the in-line flow direction. Since the sensors are placed around the heat source in 45 degree increments, the magnitude of the vector at 45 degrees to the principal flow direction would be equal to the cosine of the angle. Any deviation from this cosine test indicates a non-uniform flow condition.

Practical calibration of the flow meter to translate the meter readouts into transport velocity involves the use of a flow chamber, (porous plate permeameter). To simplify corrections for well-screen resistance and hydraulic-conductivity difference between the formation, annular packing, and the internal packing, a duplicate crossection of the well emplacement is constructed in the flow chamber. Aquifer material is compacted into the flow chamber. A short section of well screen is placed in the chamber surrounded by an annular sand pack. Water is circulated through the chamber at a known flow rate and the machine readings are recorded. Three sets of machine readings are collected at different flow rates and plotted on arithmetic graph paper. The result is a linear plot of velocity-vs-machine units. Measurements collected in the field (down the well) are converted to velocity using the calibration curve.

Well Installation

The accuracy of determination of the flow, in water bearing strata, depends greatly on the method of emplacement of the well into the water-bearing strata. It is essential to maintain capillary flow across the entire screened crossection to allow measurement of transport velocities. The choice of well screen, screen length, type of packing material between the well screen and the formation, method of drilling, development, and centralizing of the screen in the borehole all have a important role in obtaining accurate flow data.

One 6-inch diameter PVC pumping well and six 4-inch PVC monitoring wells were constructed in a circular array around 05-MW-06. The wells were placed between 10 and 30 foot radiuses from 05-MW-06. The pumping well was screened between 25 and 65 feet below the land surface using 6-inch stainless steel Johnson V-wire screen. Twenty seven feet of blank PVC casing was installed above the screen and 5 feet of blank casing was installed below the screen. The monitoring wells were constructed with a 10 foot



WELL LOCATIONS
POL AREA, Galena AFS, Alaska

screened section from 60-70 feet, 50-60 feet, 40-50 feet, 30-40 feet, 20-30 feet, and 10-20 feet, respectively. The wells were constructed using Johnson V-wire PVC continuous wrapped screen in accordance w ASTM Special Method 963 "Monitoring Well Construction, and Recommende cedures for Direct Ground-Water Flow Measurements Using a Heat-Pulsing Flow Meter." The wells were staked prior to drilling, using a cloth tape and a right angle prism, using monitoring well 05-MW-06 as reference. The monitoring well locations are shown on the attached map.

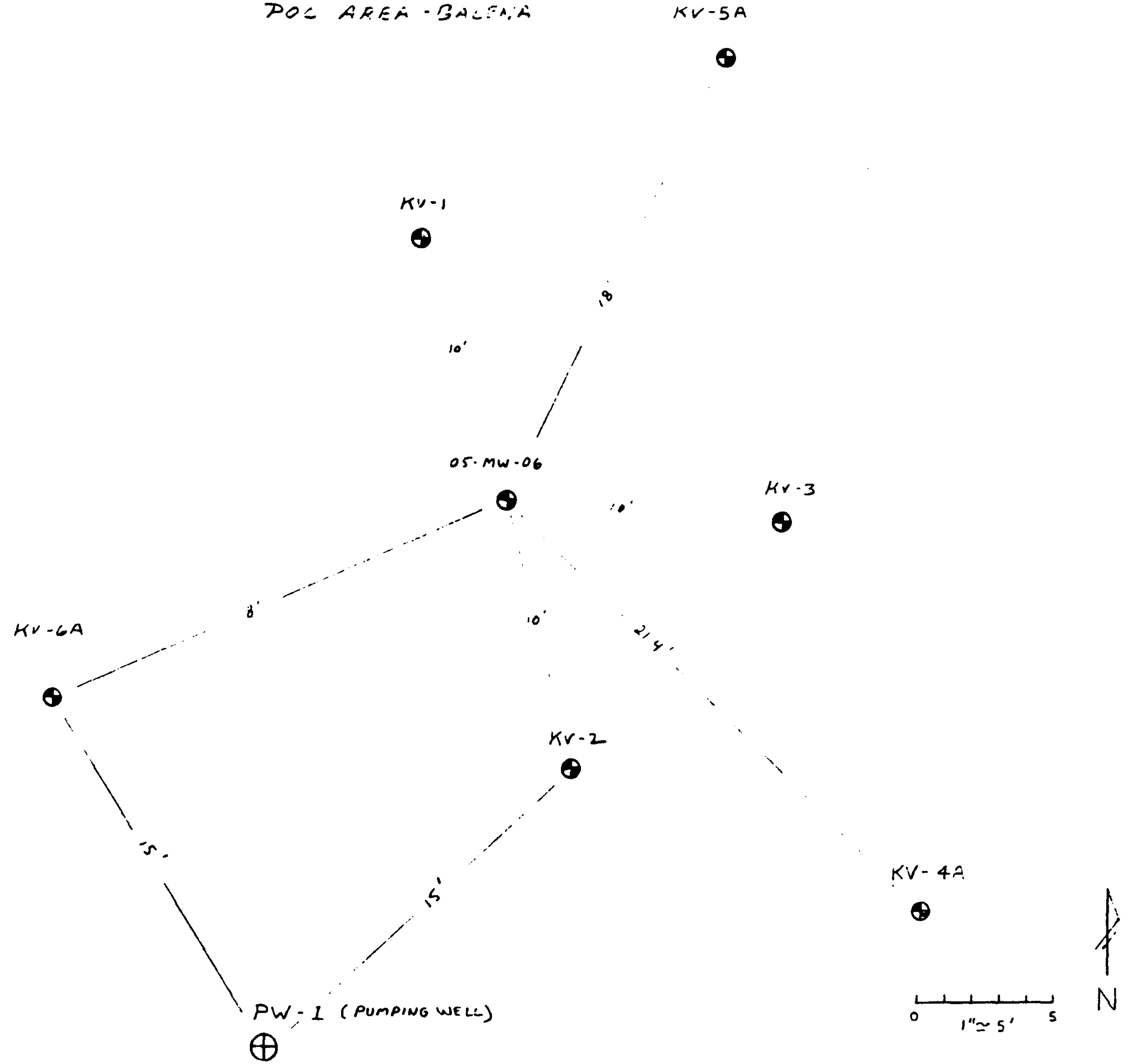
The wells were drilled with a CME-850 drill, fitted with a 12 inc O.D. hollow-stem auger. The drill is owned and operated by the 11 CEOS/CEOR, Elmendorf AFB AK. Samples were collected in each boring at 2.5 to 5.0 foot intervals. Samples were collected by driving a 3.0 inch diameter sampler 24 inches ahead of the auger, using a 300 pound hammer free falling a distance of 30 inches. The penetration-resistance value shown on the well boring logs is the number of blows required drive the sampler the last 12 inches. As the samples were recovered they were classified and retained for calibrating the flow meter. The information obtained d g the field exploration is presented graphically on the attached well logs. It should be noted that the descriptions shown on the attached well logs are based on visual classifications only, they have not been verified by laboratory testing

Data Collection

The procedure for determining flow rate and direction consists of lowering a probe down the well using hollow aluminum rods with snap connectors. The orientation of the probe is controlled by a magnetic compass attached to the top of the rods. The probe is left to stabilize for a short time and a set of four readings are recorded. The axis of flow is found by plotting the individual vectors (head to tail) on polar graph paper. The principal flow direction is determined by connecting a line from the origin to the point of the last vector. Rate is determined from the calibration curve, using the machine reading which corresponds to the strongest vector (i.e. along the axis of flow). Three sets of data were collected at equally spaced intervals within each of the 10-foot well screens. The mean flow and direction across a screen is the average of the three readings.

The wells were first profiled between 25-27 May 1993. The three shallow wells, KV-1, KV-2, and KV-3 produced relatively consistent data. The data from wells KV-4, KV-5, KV-6 (40-70 feet) produced unusable data. The vector plots from these wells failed to show any uniformity of flow. Construction of these wells was complicated by the presence of heaving, or fluidized sand intruding into the open auger during well construction. We believe that this prevented the placement of a uniform sand pack around the annulus of the screen, which distorted the flow field through the screen. The three wells were re-drilled in August using wooden plugs wedged into the bottom of the auger to prevent sand and gravel from rising into the borehole under hydrostatic pressure. A second set of data, collected in August, produced much better results. The re-drilled wells are numbered KV-4A, KV-5A, and KV-6A on the well logs.

WELL LOCATIONS
POL AREA - BALENA



A second set of ambient data was collected between 21-30 August 1993. Five of the six wells produced relatively consistent data. Re-drilled well KV-6A continues to give inconsistent results.

Radian Corporation conducted an aquifer pumping test in July as part of the IRP field activities. Pumping tests are used to evaluate the hydraulic characteristics of the upper part of the aquifer, including transmissivity, storage coefficient, and hydraulic conductivity. The data are necessary to understand ground water and hydrocarbon migration through the subsurface, and for developing an effective and efficient remediation/treatment system.

Direct velocity measurements can be used in conjunction with pumping to determine the hydraulic conductivity of a strata. Calculating hydraulic conductivity using the GEOFLO flow meter is based upon velocity changes observed during pumpage from a well located down gradient of an observation well. The six inch well was pumped for 11 hours at a rate of 75 gallons per minute and the decline in water levels in the observation well were recorded. The wells were profiled using the GEOFLO. The hydraulic conductivity is directly proportional to the observed change in velocity and inversely proportional to drawdown, as a result of pumping.

Results

The first set of flow data was collected in May 1993, during the break-up of the Yukon River. Only the data from the three shallow wells are presented. The data from the deeper wells was unusable for the reasons mentioned above.

Ground water levels respond to changes in water levels at the river. The response of the water table to recharge is very rapid. During periods of high water, water from the Yukon River recharges to local unconfined aquifers. During the period 05-21 May, ground water levels rose 10 feet, or 1.6 feet per day. The ground water gradient, measured on May 17 1993, was 1.6×10^{-3} in a north-northwest direction (337^{o}) away from the river. Ground water flow directions, measured with the flow meter, varied from 353^{o} to 3^{o} with a mean direction of 340^{o}. This result is very close to the direction calculated using the gradient solution. These flow directions reflect localized flow changes due to recharge events associated with the spring flood.

The velocity data showed much greater variability. Velocities ranged from 0.8 to 5.4 feet per day. Averaged over the screened portioned of the aquifer the mean flow is 1.8 feet per day. Ground water flow directions and rates are shown in tabulated on the following page.

A second set of ambient data was collected in August 1993. The data from all six wells is presented, however data from well KV-6A is not included in the analysis. Ground water flow direction ranged from 154° to 218° with an average value of 183°. Ground water flow direction has reversed from the direction in May, and now flow south-southwest toward the river. Velocities ranged between 1.2 to 8.7 feet per day with an average value of 3.4 feet per day. The individual velocities show the same variability as the May data, however when averaged over the entire screened interval velocities are reasonably consistent.

The GEOFLO data can be used to calculate hydraulic conductivity. Assuming a field porosity of 28 percent, and using the average water table gradient of 1.5 x 10^{-3} (Radian, 1993), the mean hydraulic conductivity (K) can be calculated from Darcy's transport equation for flow :

$$K = \frac{\overline{V}n}{dh/dl}$$

Where:

$\overline{V}$ = mean transport velocity

n = porosity

dh = change in static head slope

dl = change in distance slope

The hydraulic conductivity values for the May 1993 data ranges from 170 to 520 feet per day with an average of 340 feet per day. The conductivity values for August range from 340 to 880 feet per day, with an average of 630 feet per day.

The wells were profiled again during the aquifer pumping test. The well was pumped for 11 hours at a rate of 75 gallons per minute. Three wells were profiled while pumping, and the drawdown recorded. Nine observations were made, of which only four produced usable data. Hydraulic conductivity can be determined from the following expression:

$$K = \frac{(\overline{V}o - \overline{V}_i)\, n}{Ho + H_i}$$

Where:

H_o = Static ground water gradient

H_i = Gradient induced by pumping

Hydraulic conductivity calculated by this method range from 590 to 1070 feet per day. As a backcheck on velocity from pumping, the transport velocity change in a uniform strata at a known distance from the pumping well can be computed as:

$$\Delta\bar{V} = \frac{Q}{2\pi Dnm}$$

Where:

$\Delta\bar{V}$ = transport velocity (feet/day)

Q = pumping rate (cu. ft/day

π = 3.14

D = Diameter (2l from pumping well to observation well)

n = field porosity

m = depth of screen

The calculated velocity change and the observed velocity agree for wells KV-2 and KV-3. Well KV-1 had a much higher pumping velocity than expected. The hydraulic conductivity value for KV-1, measured during the pumping test, is believed to be high when compared to the ambient data.

Conclusions

The conclusion from the data collected thus far are summarized below.

- The GEOFLO flow meter was very successful in determining ground water flow directions. In many cases where ground water velocities could not be determined, the principal flow directions could easily be established.

- Velocity measurements collected during the pumping test provided mixed results. When the method worked, it seemed to work well. When a uniform flow field is present, consistent data was obtained. This occurred however, in only three of the nine observations made.

- The velocity profiles show considerable variability in flow rate within each screened section. All aquifers, regardless of how uniform, will display some degree of heterogeneity. The variability in flow rates exhibited by the data is not believed to be the result of heterogeneity in the aquifer, but rather to distortion of the flow field through the well screen. Dr. William Kerfoot, of KV-Associates agreed that a 10-fold increase in velocity in a uniform strata is too large. He recommended using shorter sections of well screen, to minimize this effect of cross-channeling, and to isolate the zone of interest. If that were not possible, Dr. Kerfoot suggested calculating the mean flow rate and direction across the intercepted cross section of the screen.

- Hydraulic conductivity values calculated using the flow meter are consistent with those anticipated in clean sands and gravels (Freeze & Cherry, 1979) such as those found at the site. Averaging the flow rate within each screen section provides reasonably consistent data, however, a continuous profile of velocity with depth is not possible.

AMBIENT GROUND WATER FLOW DATA

MAY 1993

WELL NO.	DEPTH (ft)	FLOW DIRECTION (deg)	AMBIENT VELOCITY (ft/day)		MEAN DIRECTION (deg)	MEAN STATIC VELOCITY (ft/day)	MEAN AMBIENT (K) (ft/day)
	14	3	1.0				
KV-3	16	326	3.0		332	2.8	520
	18	293	5.4				
	22	336	0.8				
KV-1	24	337	1.7		334	0.9	170
	26	32	0.8				
	32	348	2.1				
KV-2	34	353	1.8		347	1.9	360
	36	340	1.8				
			$\bar{X}$ = 1.8				

AMBIENT GROUND WATER FLOW DATA

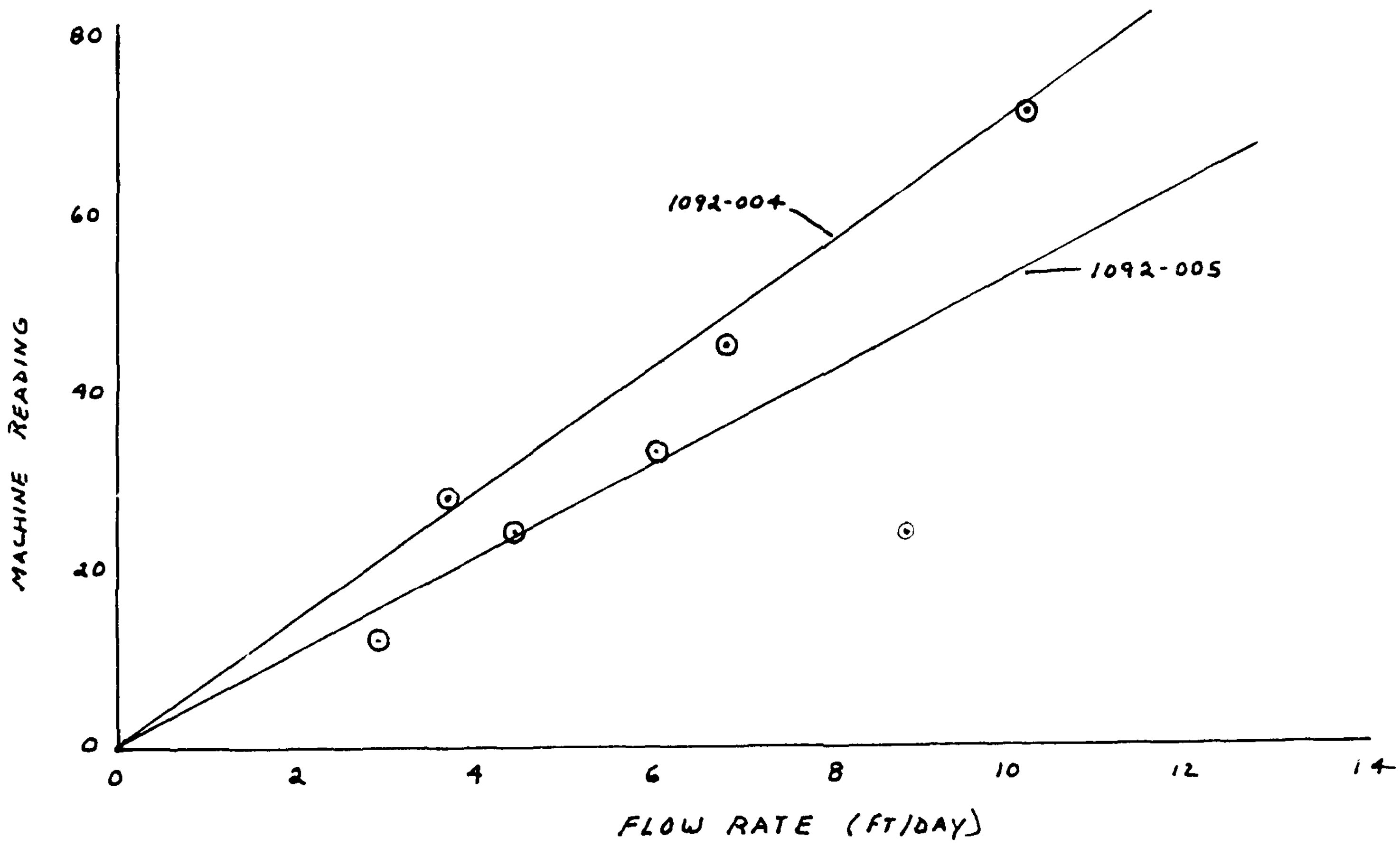
AUGUST 1993

WELL NO.	DEPTH (ft)	FLOW DIRECTION (deg)	AMBIENT VELOCITY (ft/day)		MEAN DIRECTION (deg)	MEAN STATIC VELOCITY (ft/day)	MEAN AMBIENT (K) (ft/day)
	14	195	1.4				
KV-3	16	154	8.3		160	3.7	690
	18	169	1.7				
	23	178	2.0				
KV-1	25	174	2.9		168	3.2	600
	27	158	4.8				
	32	194	3.2				
KV-2	34	204	2.4		203	4.7	880
	36	213	8.7				
	43	199	1.5				
KV-4A	45	203	1.7		186	1.8	340
	47	159	2.0				
	54	197	1.2				
KV-5A	56	218	6.7		194	4.3	800
	58	209	3.4				
	63	140	1.0				
KV-6A	65	204	10.8		-	-	-
	67	251	3.2				
			$\bar{X}$ = 3.4				

PUMPING GROUND WATER FLOW DATA
AUGUST 1993

WELL NO.	DEPTH (ft)	FLOW DIRECTION (deg)	AMBIENT VELOCITY (ft/day)	PUMPING VELOCITY (ft/day)	MEAN PUMPING VELOCITY (ft/day)	PUMPING GRADIENT	OBSERVED VELOCITY CHANGE (ft/day)	PUMPING (K) (ft/day)		CALC. VELOCITY CHANGE (ft/day)
	14	-	1.4	5.1	5.1	0.00175	3.7	590		3.8
KV-3	16	-	8.3							
	18	-	1.7							
	23	-	2.0	9.4	9.4	0.00193	7.4	1070		3.4
KV-1	25	-	2.9							
	27	-	4.8							
	32	-	3.2	9.1		0.00201				
KV-2	34	-	2.4		11.3		5.3	750		6.8
	36	-	8.7	13.4		0.00195				

POL AREA - GALENA AFS AK



MODEL 40 GEOFLO
S/N. 1092-004, 1092-005
SCREEN TYPE: JOHNSON V-WIRE, 4 INCH
SLOT SIZE: 0.020" (20 SLOT)
SOIL: MEDIUM SAND WITH GRAVEL
POROSITY: 28 %

1092-004		1092-005	
FLOW RATE	READING	FLOW RATE	READING
3.65	28	2.9	12
6.78	45	4.4 8.9	24
10.17	71	6.0	33

FLOW METER CALIBRATION CURVES

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: Mill House   Date: 8-23-93

Station: Calibration   Time: ____

Location: Pol Area - Galena

Soil Conditions: Medium Sand with Gravel

Depth to Measurement: 1' (8" Permeameter)

Table of LCD Readout

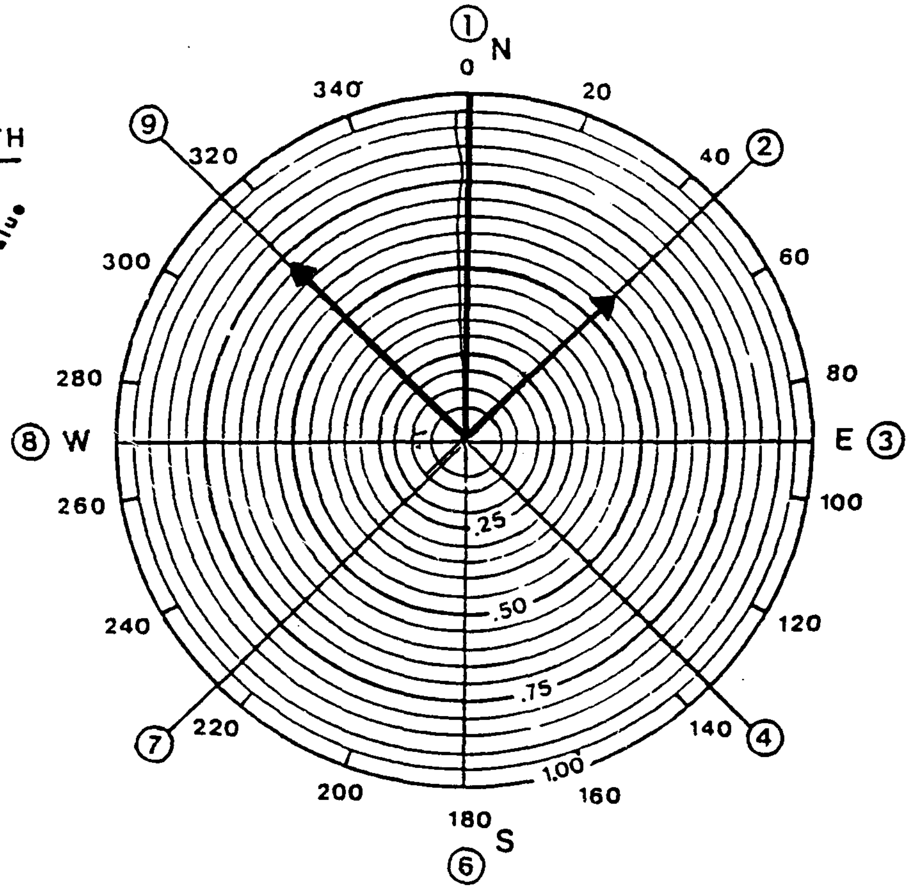
1→N

Probe pair	A start	B end	C B-A
+1/-6	9	60	51
+2/-7	7	59	52
+3/-8	0	-5	-5
+4/-9	-4	-64	-60

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{max. value}$
+1/-6	-18	-108	-90	71	1
+2/-7	-4	-33	-29	41	.58
+3/-8	9	23	14	-3	-.04
+4/-9	29	72	43	-52	-.73

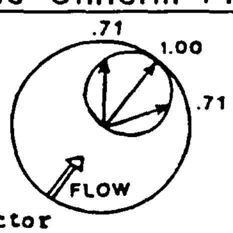


Use of Table

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-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: ____   Velocity: 10.2 ft/day

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

1092-004

Operator: Millhouse Date: 8-23-93

Station: Calibration Time: ______

Location: Dock Area - Galena

Soil Conditions: Medium Sand w/ Gravel

Depth to Measurement: 1' (8" Permeameter)

1.3 ml/min = 6.78 ft/day

Table of LCD Readout

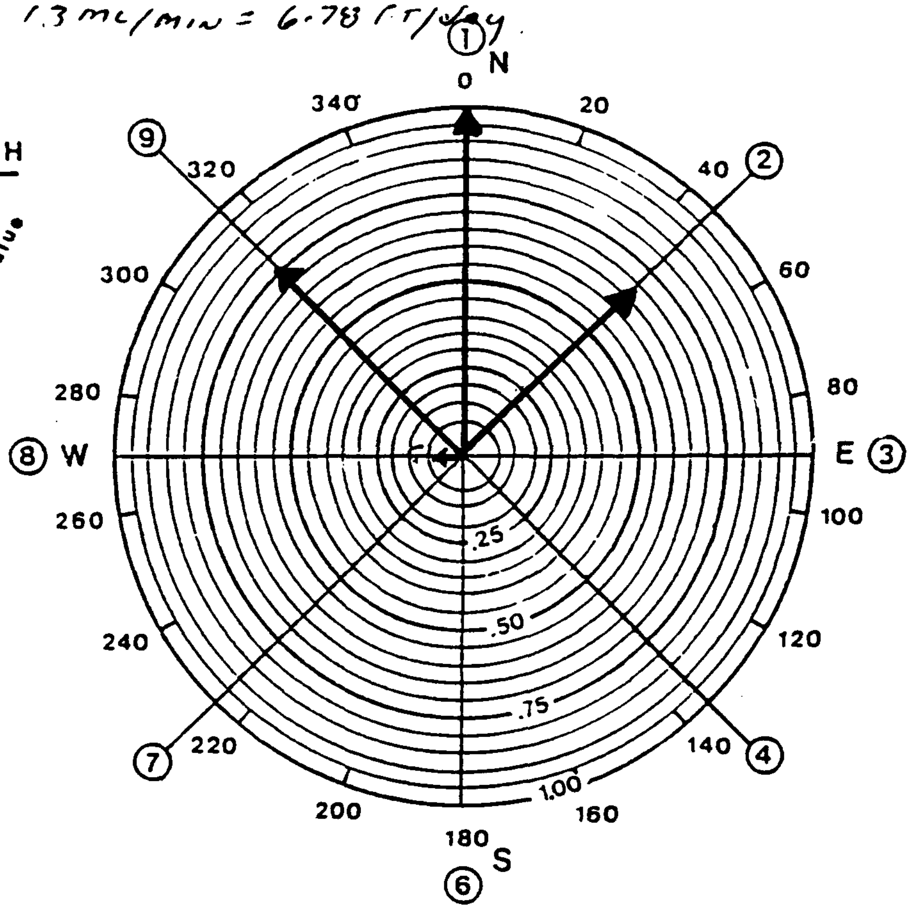
1→N

Probe pair	A start	B end	C B-A
+1/-6	+29	+58	+29
+2/-7	+32	+70	+38
+3/-8	+13	+10	-3
+4/-9	-4	-52	-48

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	+18	-43	-61	+45	+1
+2/-7	+24	0	+24	+31	+.69
+3/-8	+14	+16	+2	-3	-.07
+4/-9	+7	+27	+20	-34	-.76

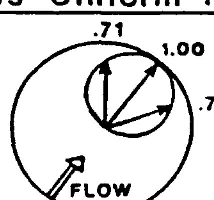


Use of Table

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-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: ______ Velocity: 6.78 ft/day

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-000

Operator: [illegible]	Date: 8/23/93
Station: Calibration	Time:
Location: [illegible]	
Soil Conditions: Medium Sand w/ Gravel	
Depth to Measurement: 1' (8" Piezometer)	

7 mL/min = 3.65 ft/day

Table of LCD Readout

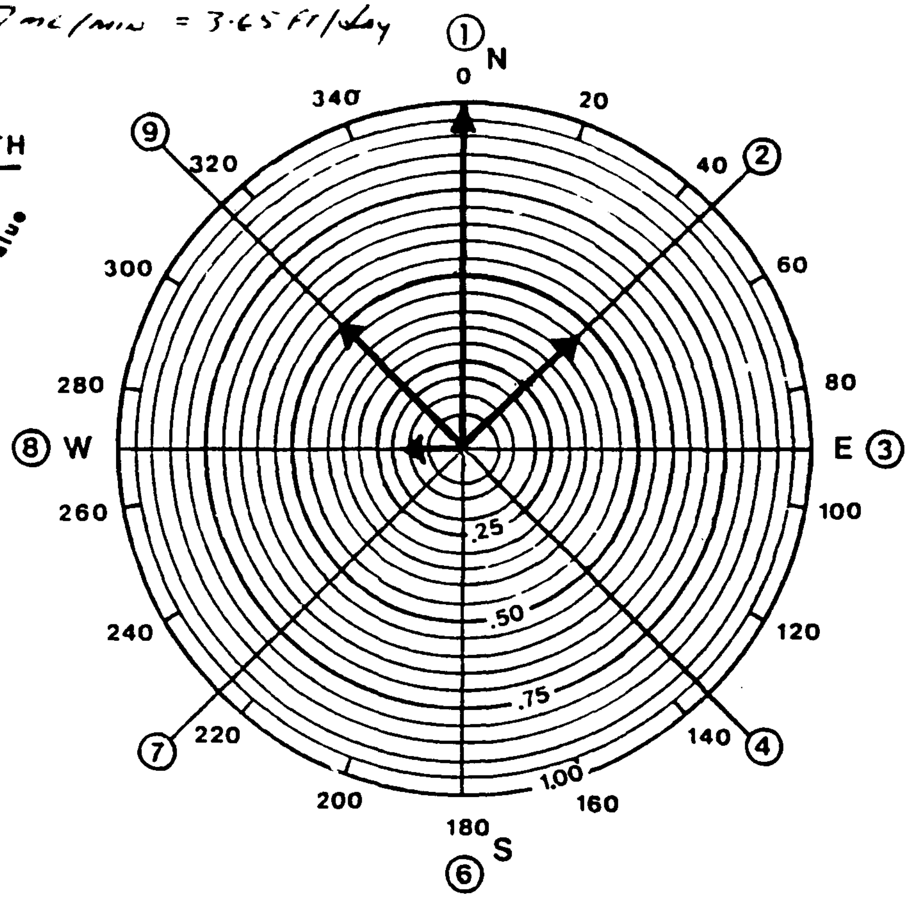
1→N

Probe pair	A start	B end	C B-A
+1/-6	-25	-24	1
+2/-7	-6	+11	+17
+3/-8	+12	+10	-2
+4/-9	+37	+1	.30

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F / max. value
+1/-6	-70	-15	-55	-28	1
+2/-7	+4	-4	8	13	.46
+3/-8	+13	+10	-3	1	.11
+4/-9	+26	+23	-3	-14	.5

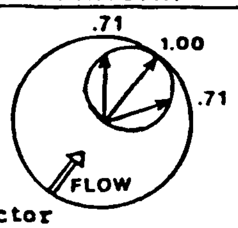


Use of Table

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 shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59-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:	Velocity: 3.65 ft/day

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

10–-005

Operator: M.illHouse	Date: 8-27-93
Station: POC AREA - GALENA	Time: 0938
Location: E PERMEAMETER (CALIBRATION)	
Soil Conditions: MEDIUM SAND WITH GRAVEL	
Depth to Measurement: INSTRUMENT S/N 1092-005	

Table of LCD Readout

1 → N

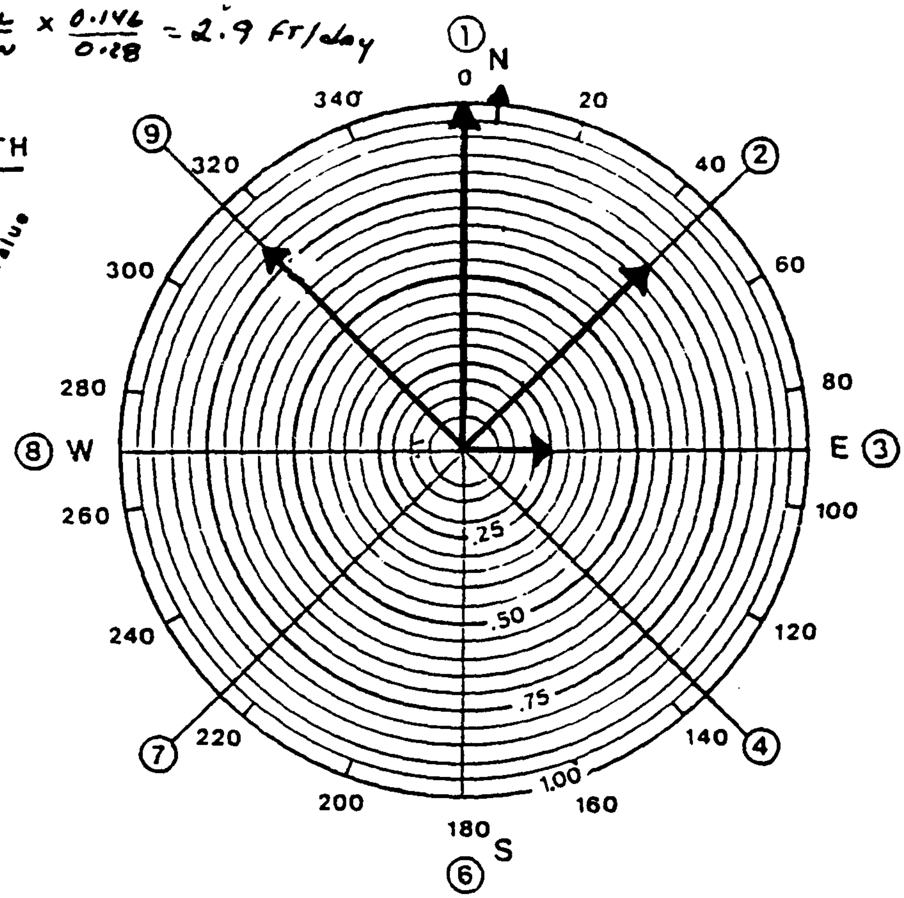
Probe pair	A start	B end	C B-A
+1/-6	-43	-28	15
+2/-7	-6	-50	-44
+3/-8	4	-5	-9
+4/-9	38	0	-38

$5.5 \frac{mL}{min} \times \frac{0.146}{0.28} = 2.9$ FT/day

ROTATE PROBE 180° AT SAME DEPTH

1 → S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{max. value}$
+1/-6	16	8	-8	12	1
+2/-7	38	-23	-61	9	.75
+3/-8	11	7	-4	-3	.3
+4/-9	0	-18	-18	-10	-.83

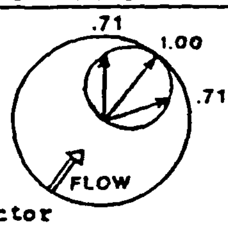


Use of Table

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-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: 6°	Velocity: 2.9 FT/day

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

1092-005

Operator: Millhouse		Date: 8-27-93	
Station: Poc Area - Galena		Time: 0800	
Location: 8" Permeameter (Calibration)			
Soil Conditions: Medium Sand with Gravel			
Depth to Measurement: Instrument S/N 1092-005			

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	-61	-35	26
+2/-7	-17	-55	-38
+3/-8	2	-3	-5
+4/-9	50	6	-44

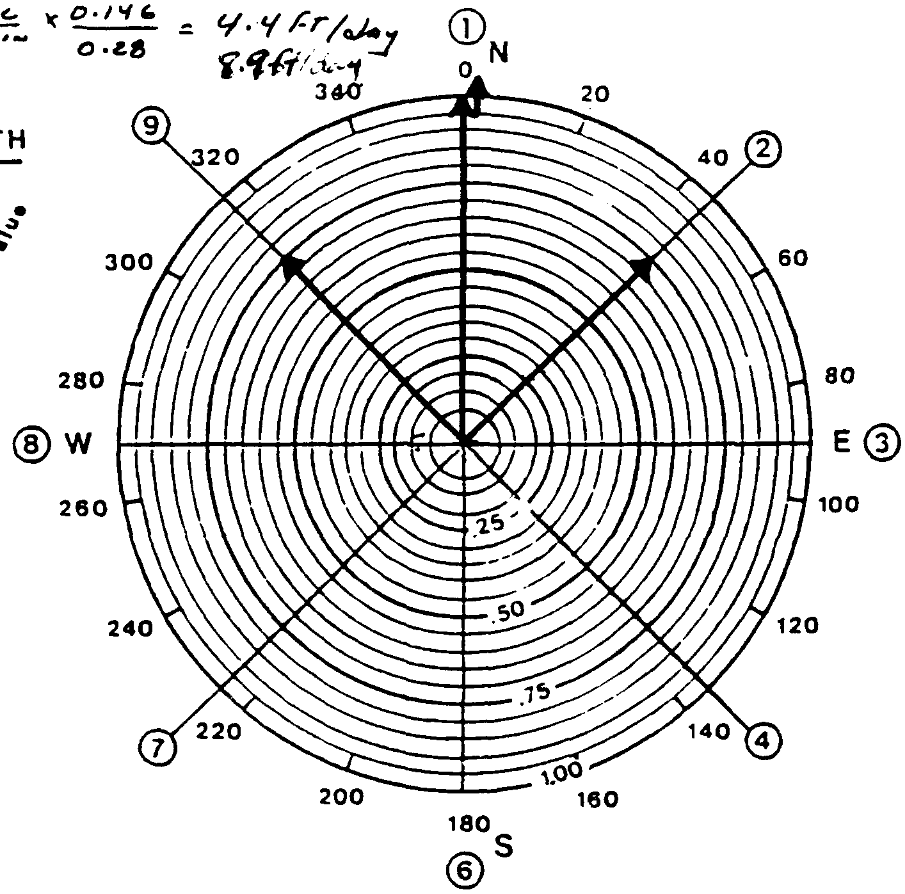
$\frac{17 \text{ mc}}{\text{min}} \times \frac{0.146}{0.28} = 4.4$ Ft/day

8.9 ft/day

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	E-D	F $\frac{N-S}{2}$	G $\frac{F}{max. value}$
+1/-6	52	31	-21	24	1
+2/-7	74	1	-73	18	.75
+3/-8	6	0	-6	1	.04
+4/-9	-28	-36	-8	-18	-.75

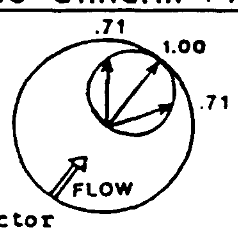


Use of Table

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-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: 3°	Velocity: 4.4 Ft/day

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

1092-005

Operator: M. Millhouse Date: 8-27-93

Station: POL Area - Galena Time: 0930

Location: 8" Permeameter (Calibration)

Soil Conditions: Medium Sand with Gravel

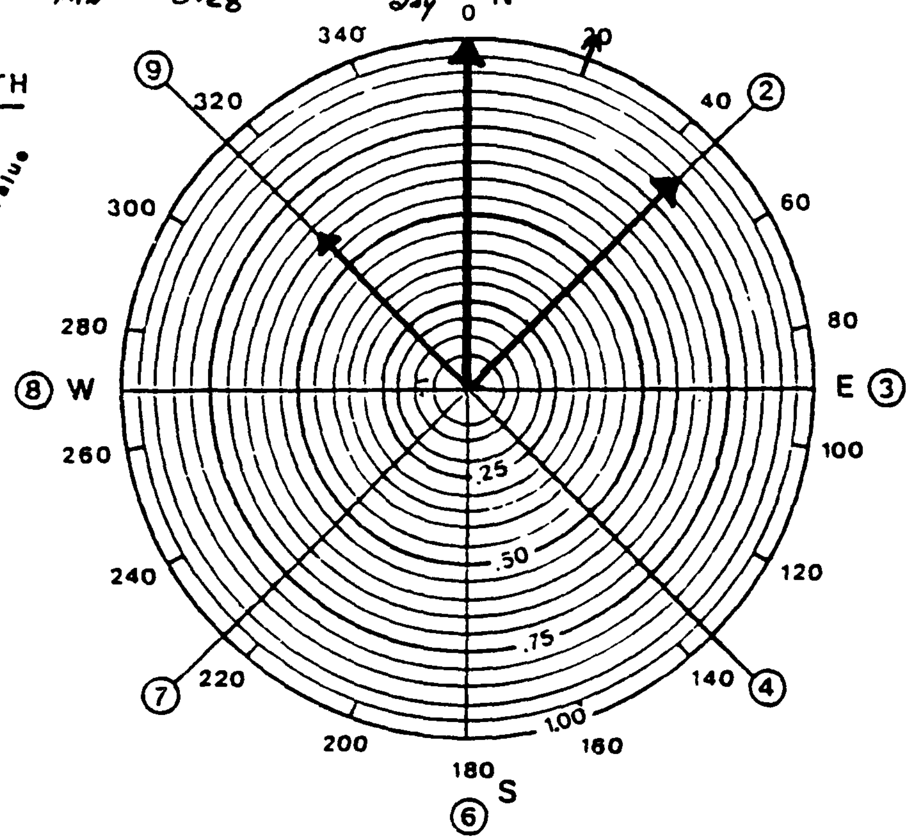
Depth to Measurement: Instrument S/N 1092-005

Table of LCD Readout

1→N

Probe pair	A start	B end	C B-A
+1/-6	-23	+18	41
+2/-7	-8	-31	-23
+3/-8	12	+11	-1
+4/-9	14	-37	-51

$11.5 \frac{mL}{min} \times \frac{0.146}{0.28} = 6.0 \frac{ft}{day}$



ROTATE PROBE 180° AT SAME DEPTH

1→S

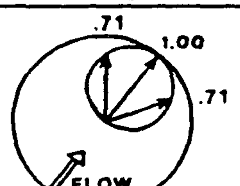
Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{max.\ value}$
+1/-6	13	-12	-25	33	1
+2/-7	27	-50	-77	27	.82
+3/-8	10	7	-3	1	.03
+4/-9	0	-9	-9	-21	-.63

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-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: 20° Velocity: 6.0 Ft/day

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

MAY 1993
AMBIENT FLOW DATA

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: Millhouse Date: 5-28-93

Station: [illegible] Time: 0930

Location: KV-3 14' BLS

Soil Conditions: [illegible] Sand w/ Gravel

Depth to Measurement: 17' BTOC; 14' BLS

Table of LCD Readout

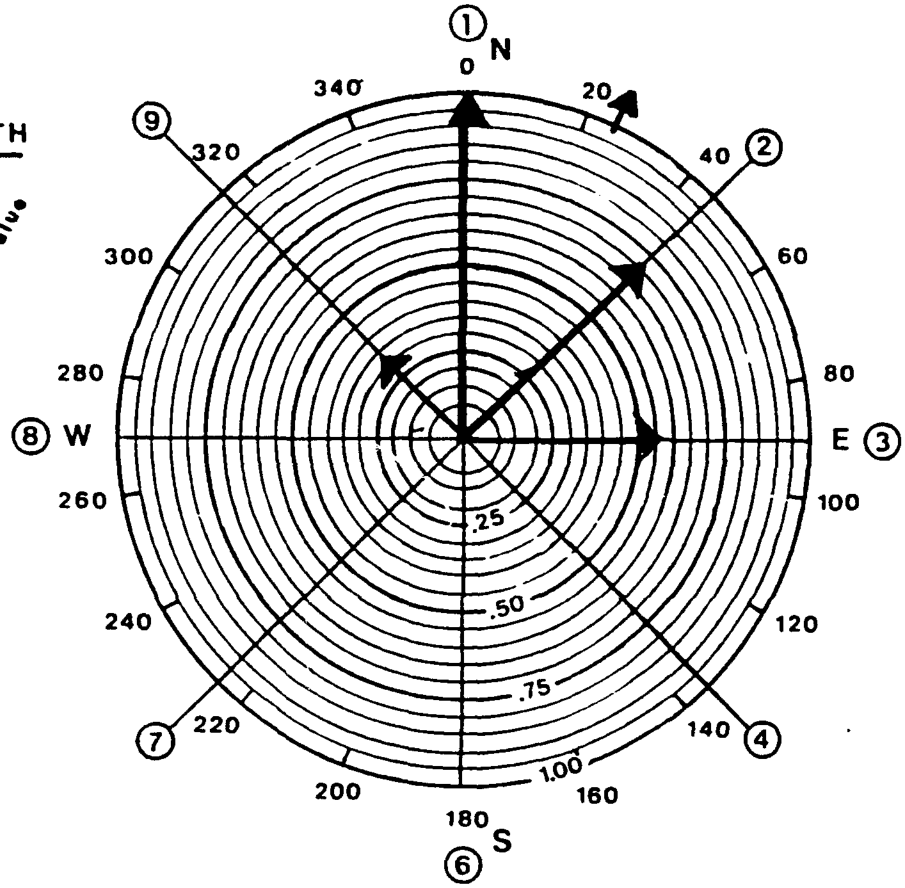
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	64	64
+2/-7	17	57	40
+3/-8	11	16	5
+4/-9	11	-65	-76

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F / max. value
+1/-6	0	46	46	9	1
+2/-7	17	43	26	7	.78
+3/-8	6	1	-5	5	.56
+4/-9	4	-66	-70	-3	.33

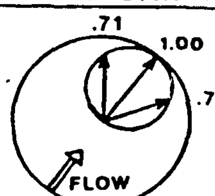


Use of Table

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-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).

1.0

Magnetic Direction: 25° Velocity: 1.0 FT/day

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

1092-004

Operator: Millhouse   Date: 5-28-93

Station: Pol Area Galena   Time: 0800

Location: KV-3 16' BLS

Soil Conditions: Medium Sand w/ Gravel

Depth to Measurement: 19' BTOC, 16' BLS

Table of LCD Readout

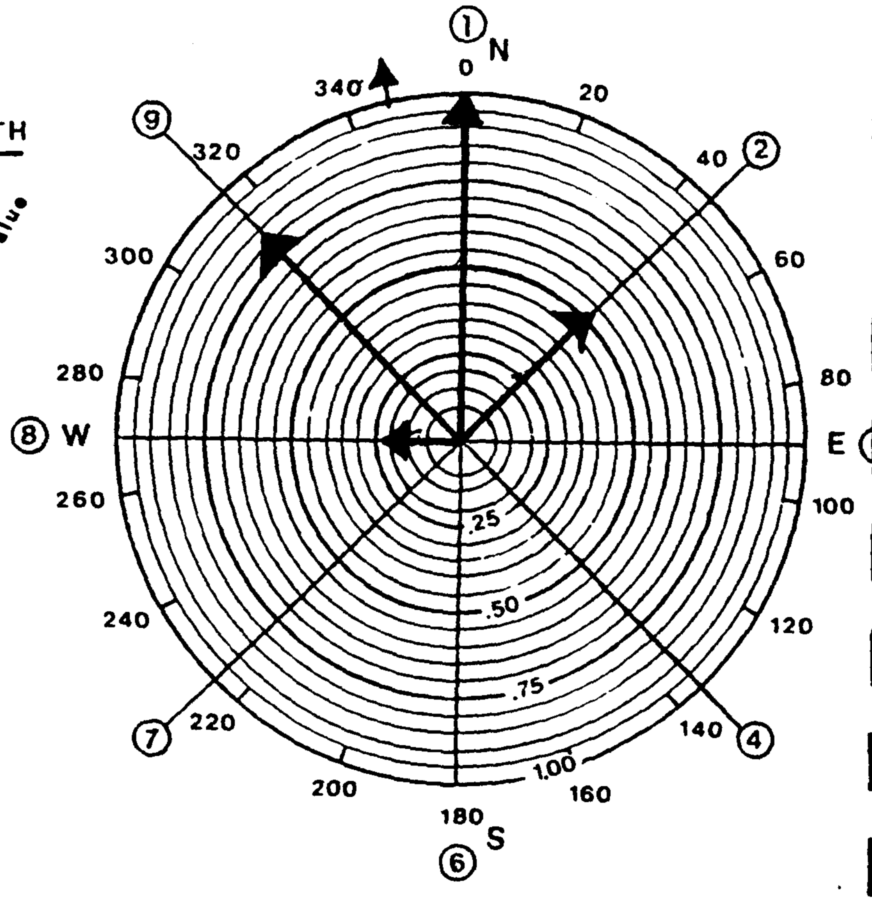
1→N

Probe pair	A start	B end	C B-A
+1/-6	-4	41	45
+2/-7	17	32	15
/-8	11	-4	-15
/-9	12	-65	-77

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{max.\ value}$
+1/-6	-8	-17	-9	27	1
+2/-7	15	2	-13	14	.52
+3/-8	7	5	-4	-6	.22
+4/-9	10	-23	-33	-22	.82

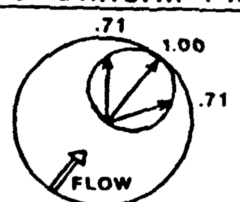


Use of Table

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-HP41C) calculator

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).

3.0

Magnetic N: Direction: 348°   Velocity: 3.0 FT/day

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

9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: M.LLHOUSE	Date: 5-28-93
Station: POL ART [illegible] -GALENA	Time: 0700
Location: KV-3 18' BLS	
Soil Conditions: MEDIUM SAND & GRAVEL	
Depth to Measurement: 21' BTOC 18' BLS	

Table of LCD Readout

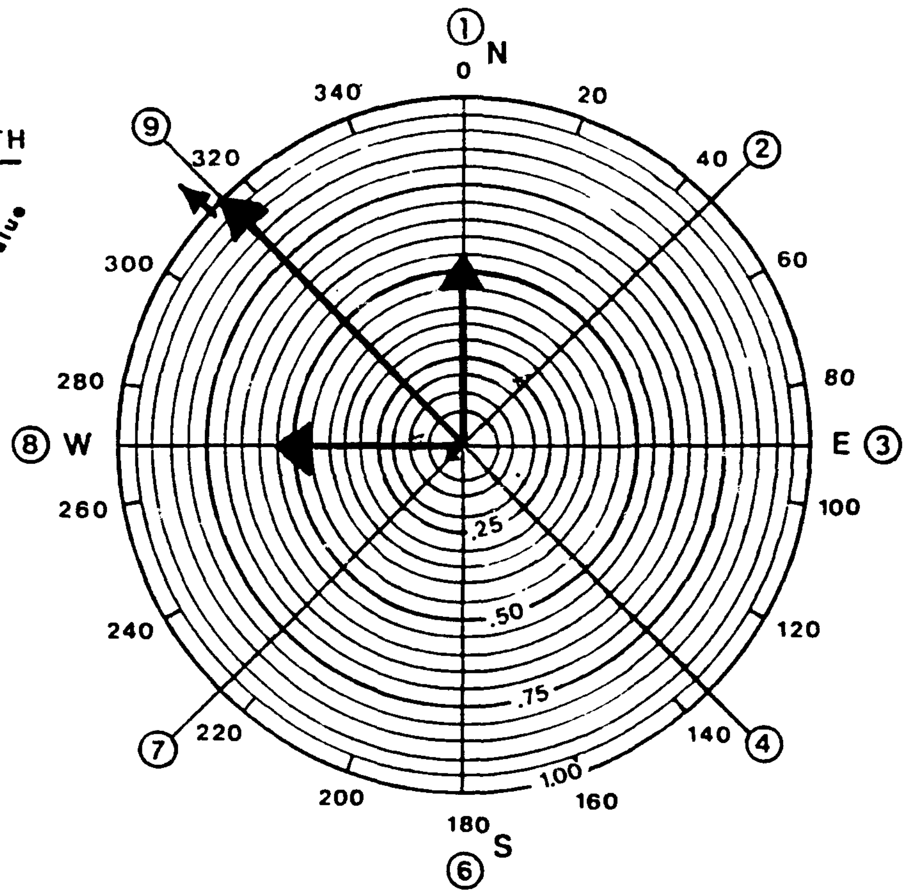
1→N

Probe pair	A start	B end	C B-A
+1/-6	-8	-26	-18
+2/-7	14	-28	-42
+3/-8	13	-90	-103
+4/-9	14	-71	-105

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{max. value}$
+1/-6	0	-70	[illegible]	26	.53
+2/-7	19	-13	-32	-5	.10
+3/-8	12	[illegible]	-49	-27	.55
+4/-9	10	2	-8	-49	1

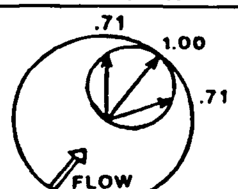


Use of Table

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-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). 5.4

MAGNETIC Direction: 315°	Velocity: 5.4 FT/Day

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

1092-004

Operator: [illegible]	Date: 5-25-93
Station: [illegible]	Time: 1615
Location: KV-1 [illegible]	
Soil Conditions: [illegible]	
Depth to Measurement: 25' BTOC; 22' BGS	

Table of LCD Readout

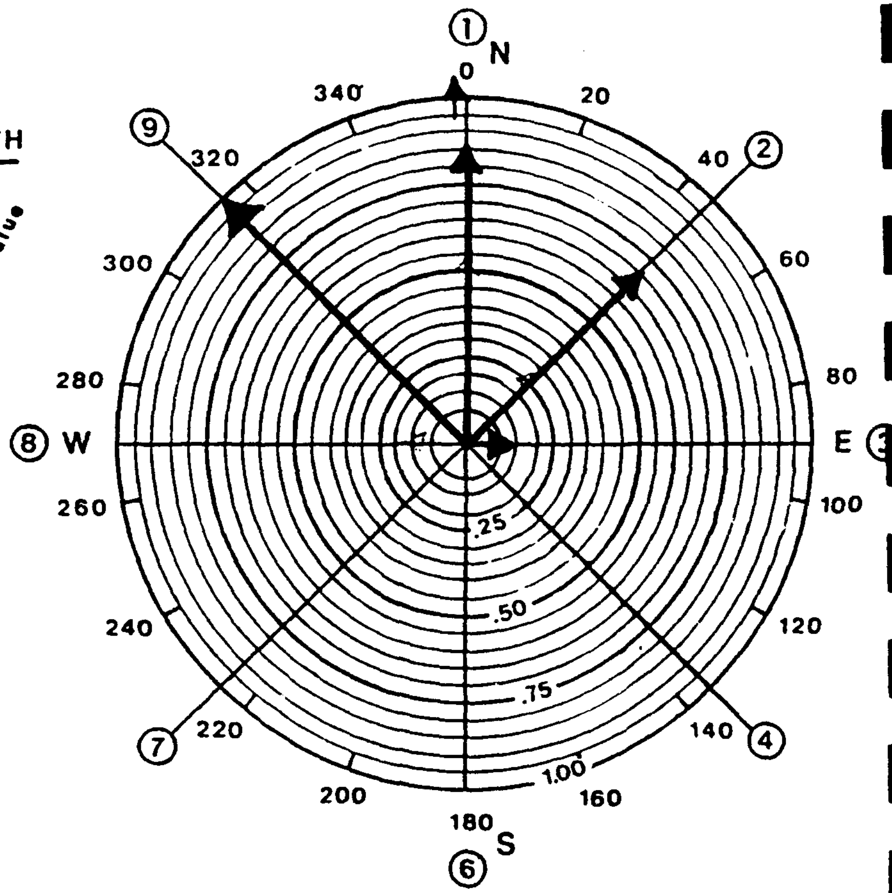
1→N

Probe pair	A start	B end	C B-A
+1/-6	4	15	11
+2/-7	3	46	43
+3/-8	0	53	53
+4/-9	2	15	13

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	6	.86
+2/-7	11	44	33	5	.71
+3/-8	9	60	51	1	.14
+4/-9	2	29	27	-7	1

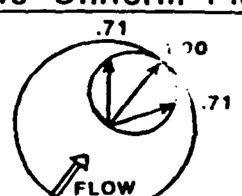


Use of Table

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-HP41C) calculator

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: 358°	Velocity: 0.8 Ft/day

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: Millhouse		Date: 5-25-93	
Station: [illegible]		Time: 1350	
Location: KV-1 [illegible]			
Soil Conditions: [illegible]			
Depth to Measurement: 27' BTOC, 30' BLS			

Table of LCD Readout

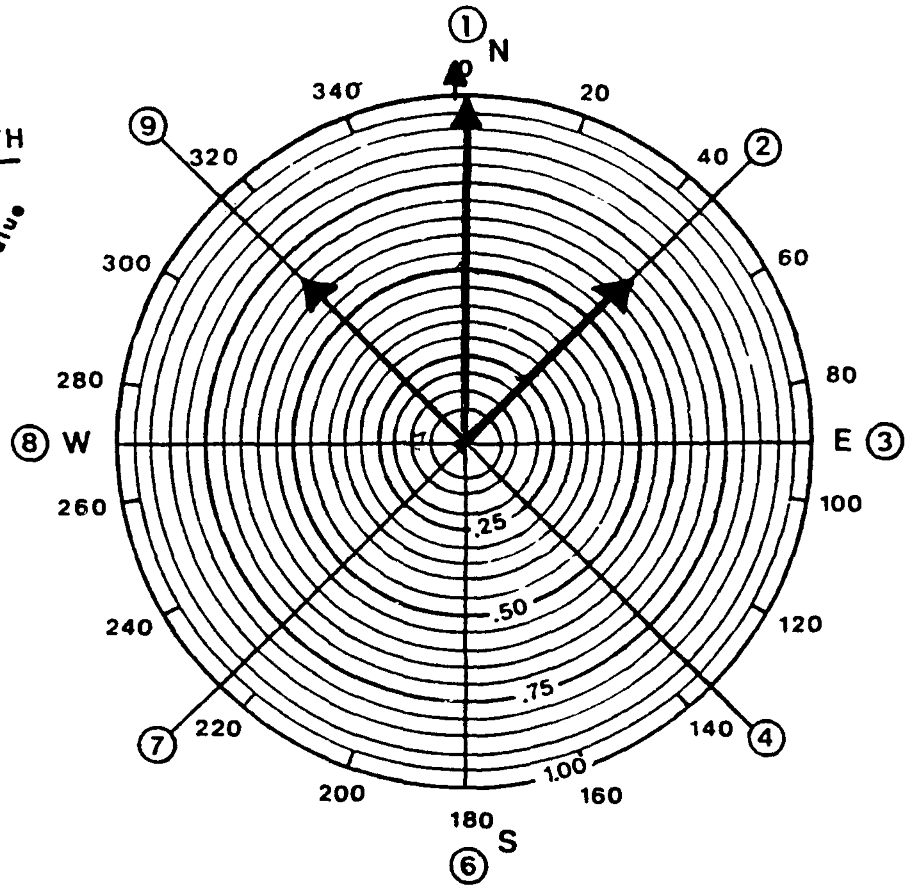
1→N

Probe pair	A start	B end	C B-A
+1/-6	5	35	30
+2/-7	12	56	44
+3/-8	-3	37	40
+4/-9	-13	-15	-2

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	1	0	15	1
+2/-7	9	33	24	10	.67
+3/-8	-5	37	42	-1	.07
+4/-9	-10	7	17	-10	.67

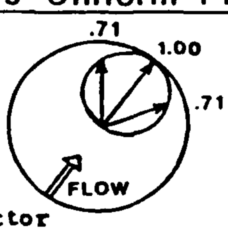


Use of Table

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-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).

1.67

Direction: 359°	Velocity:

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: Millhouse	Date: [illegible]
Station: Pac Gate - [illegible]	Time: 1100
Location: KV-1 21' BLS	
Soil Conditions: [illegible]	
Depth to Measurement: 29' [illegible] BLS	

Table of LCD Readout

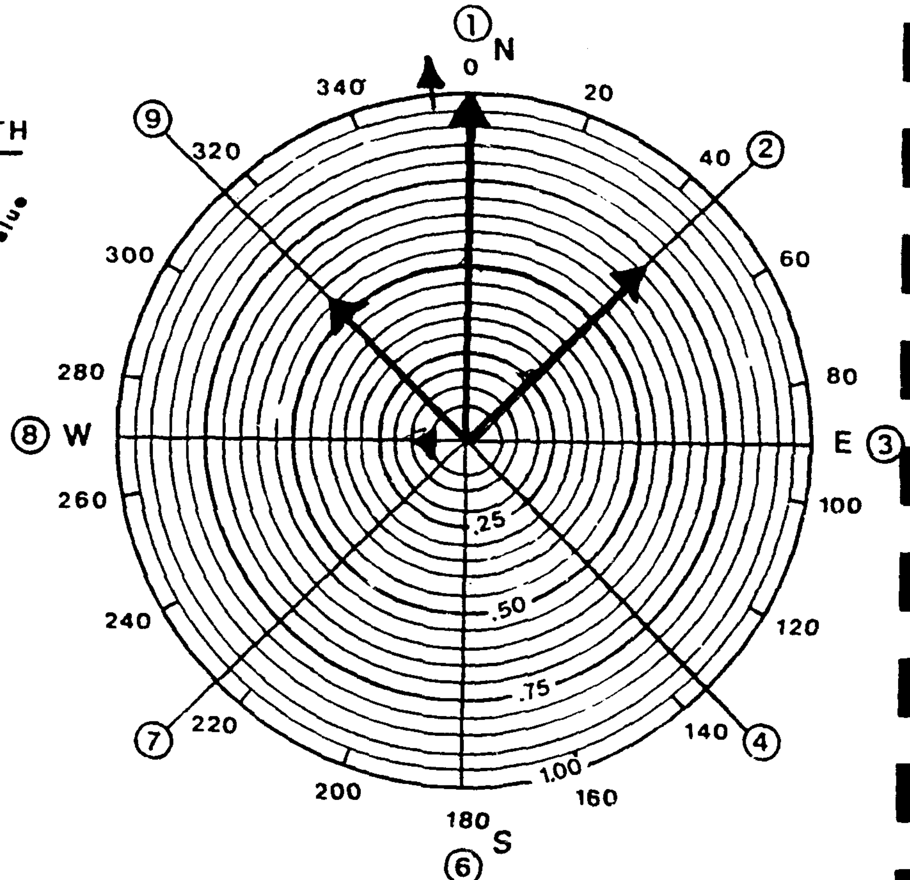
1→N

Probe pair	A start	B end	C B-A
+1/-6	5	22	17
+2/-7	7	21	14
+3/-8	3	7	4
+4/-9	0	-7	-7

ROTATE PROBE 180° AT SAME DEPTH

→S

Probe pair	D start	E end	S E-D	F (N-S)/2	G F/max. value
+1/-6	-2	1	3	7	1
+2/-7	5	9	4	5	.71
+3/-8	5	11	6	-1	.14
+4/-9	5	6	1	-4	.57

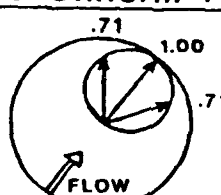


Use of Table

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 strongest 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-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).

.78

Magnetic Direction: 354°	Velocity: 0.8 FT/day

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-CC4

Operator: Millhouse Date: 5-27-93

Station: [illegible] Time: 1530

Location: KV-2 32.3 BGS

Soil Conditions: [illegible]

Depth to Measurement: 35' BTOC; 32.3 BGS

Table of LCD Readout

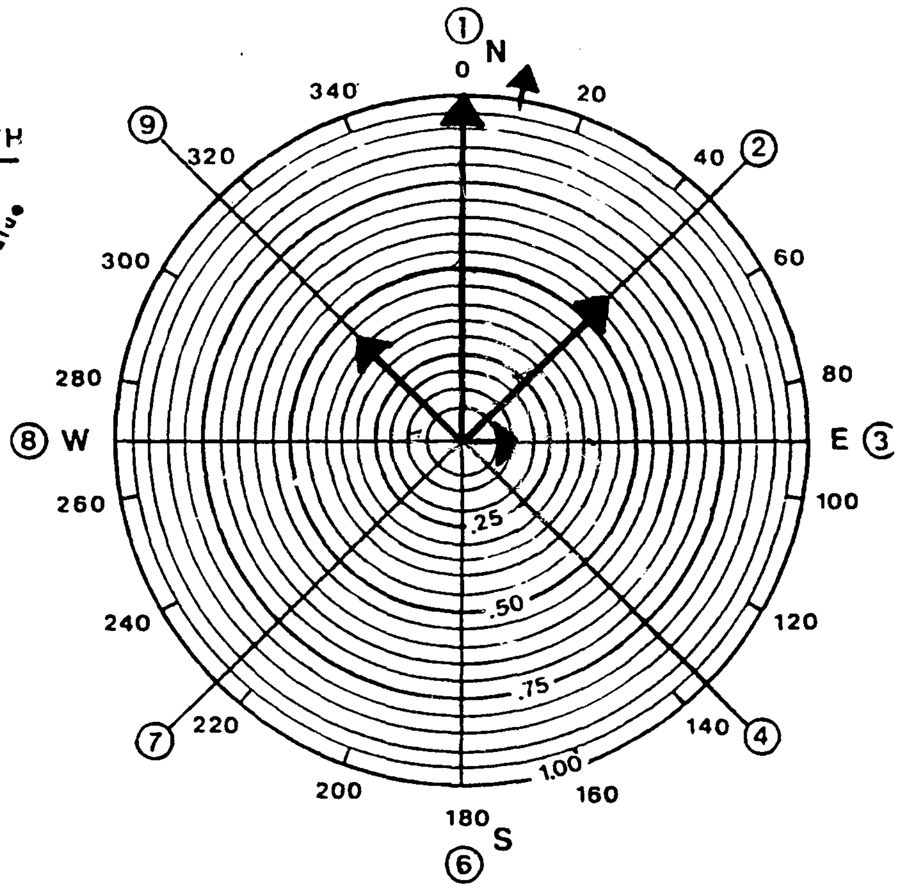
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-5	-5
+2/-7	21	52	31
+3/-8	16	11	-5
+4/-9	15	-22	-37

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F / max. value
+1/-6	0	-43	-43	19	1
+2/-7	22	32	10	11	.58
+3/-8	15	5	-10	3	.16
+4/-9	15	-6	-21	-8	.42

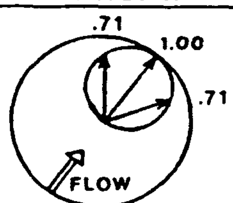


Use of Table

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-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).

Magnetic Direction: 10° Velocity: 2.11 Ft/day

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**

1092-004

Operator: [illegible] Date: 5-27-93

Station: [illegible] Time: 1515

Location: [illegible] 34.3 BLS

Soil Conditions: [illegible]

Depth to Measurement: 37' BTOC; 34.3 BLS

Table of LCD Readout

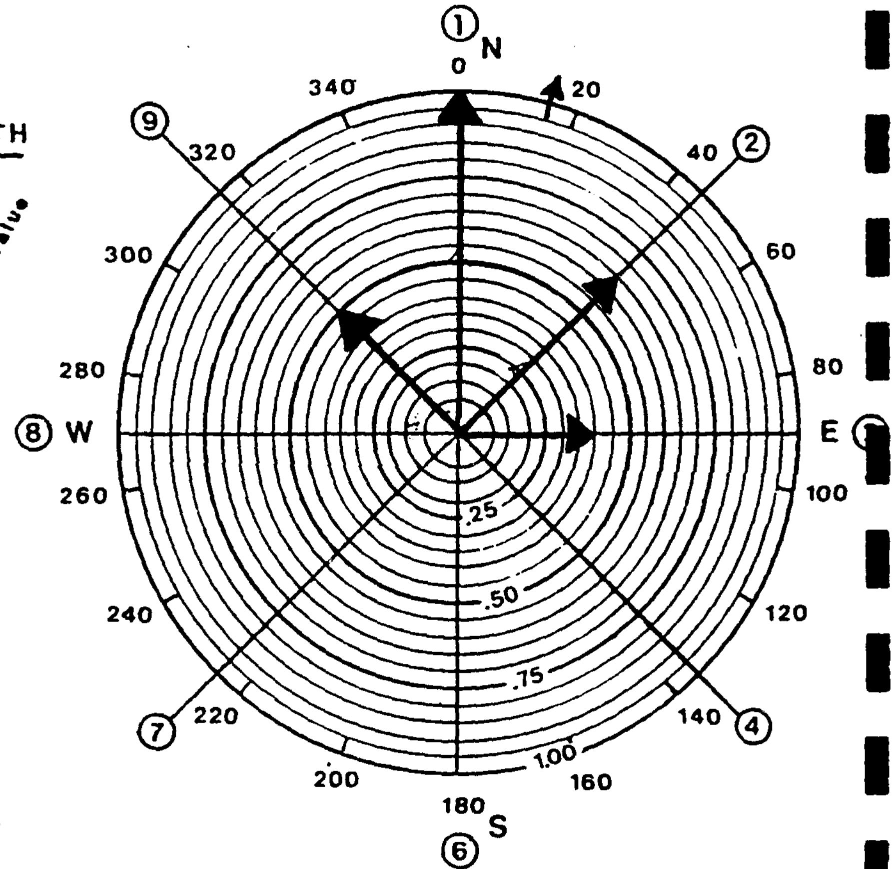
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-9	-9
+2/-7	19	43	24
+3/-8	15	14	-1
+4/-9	14	75	29

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	-40	-40	16	1
+2/-7	19	24	5	10	.63
+3/-8	15	3	-12	6	.38
+4/-9	14	0	-14	-8	.5

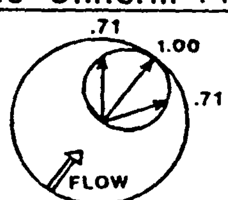


Use of Table

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 shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59-HP41C) calculator

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).

Magnetic
Direction: 15° Velocity: 1.8 FT/day

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

 9/82

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

1092-004

Operator: Millhouse Date: 5-27-93

Station: [illegible] Time: 1020

Location: MW-2 36.3 BLS

Soil Conditions: Medium Sand w/ Gravel

Depth to Measurement: 39' BTOC; 36.3 BLS

Table of LCD Readout

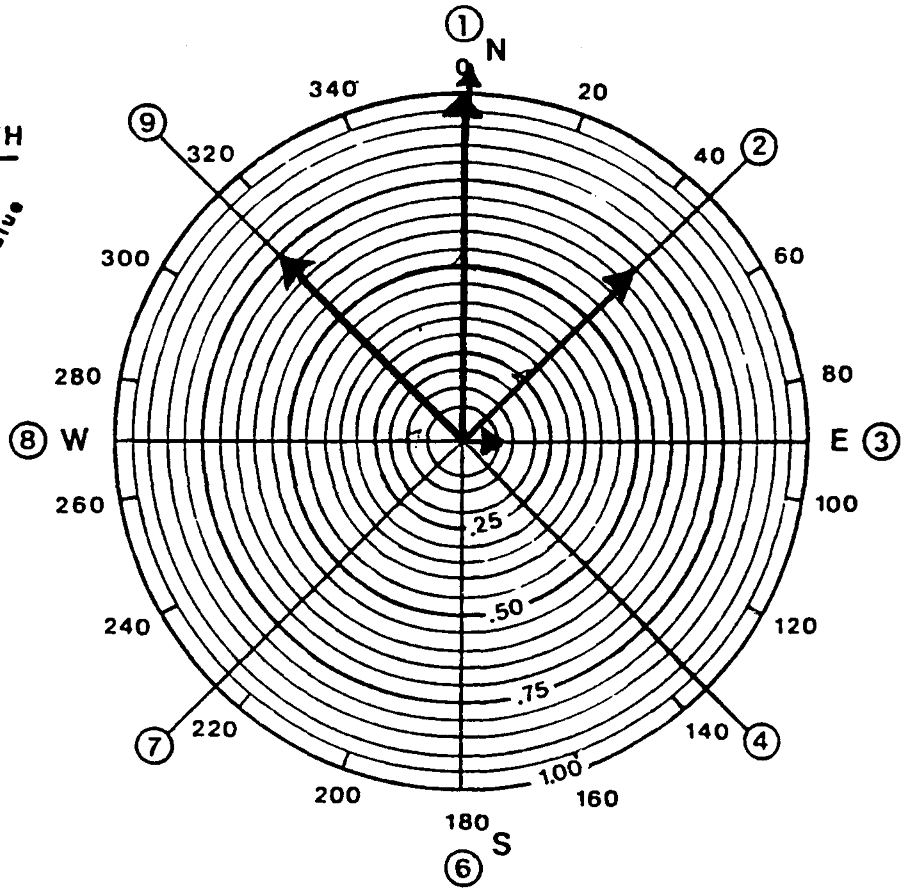
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-11	-11
+2/-7	20	45	25
+3/-8	14	7	-5
+4/-9	15	-16	-31

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	[illegible]	-42	-42	16	1
+2/-7	21	25	4	11	.69
+3/-8	15	5	-10	3	.12
+4/-9	15	[illegible]	-8	-12	.75

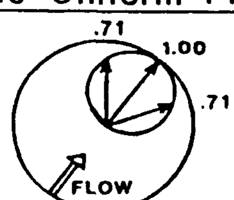


Use of Table

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-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).

Magnetic Direction: 20° Velocity: 1.8 ft/day (1.78)

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

AUGUST 1993
AMBIENT FLOW DATA

GROUNDWATER FLOW WORKSHEET

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

1092-005

Operator: MillHouse	Date: 8-20-93
Station: KV-3	Time:
Location: POC Area - Galena	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 19' BTOC; 16' BLS	

Table of LCD Readout

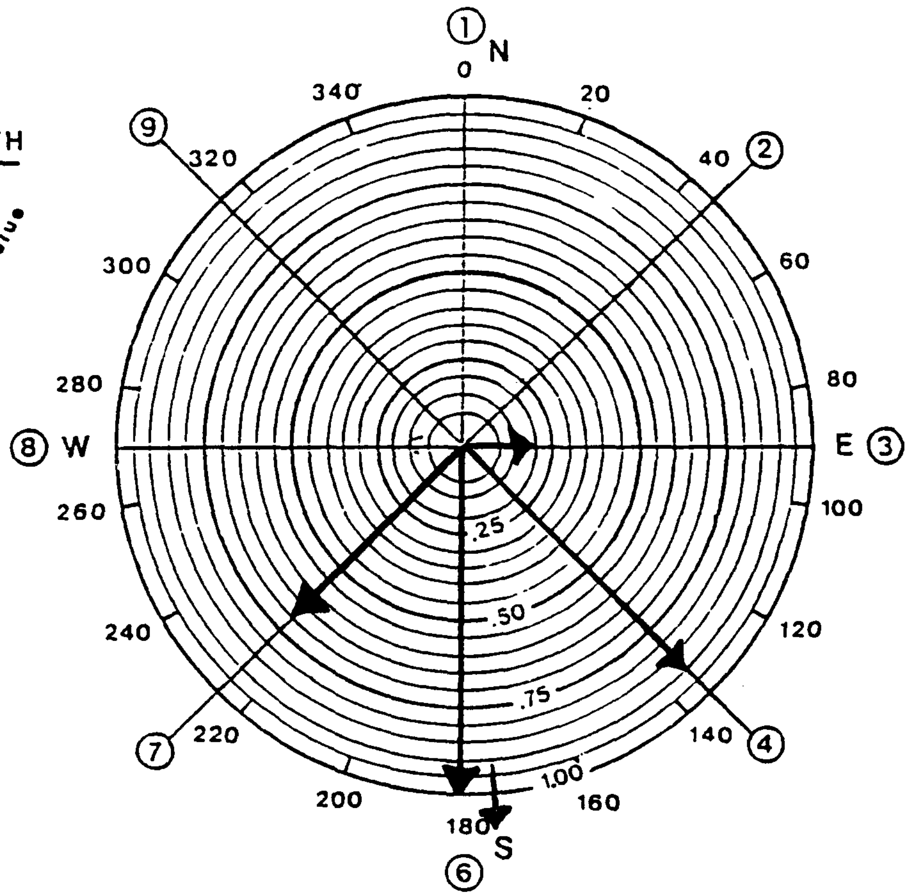
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-80	-80
+2/-7	0	-279	-279
+3/-8	14	-235	-221
+4/-9	-5	-55	-50

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F / max. value
+1/-6	-5	24	29	-55	-1
+2/-7	-6	-209	-203	-38	-.69
+3/-8	-11	-252	-241	10	.18
+4/-9	5	-143	-148	49	.89

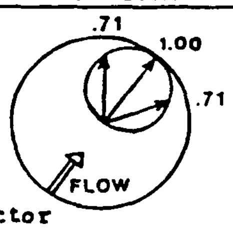


Use of Table

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-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: 176°	Velocity: 3.3

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

00992-004

Operator: Millhouse Date: 8-21-93

Station: KV-3 Time:

Location: POC Area - Galena

Soil Conditions: Medium Sand w/ Gravel

Depth to Measurement: 17' BTOC ; 14' BLS

Table of LCD Readout

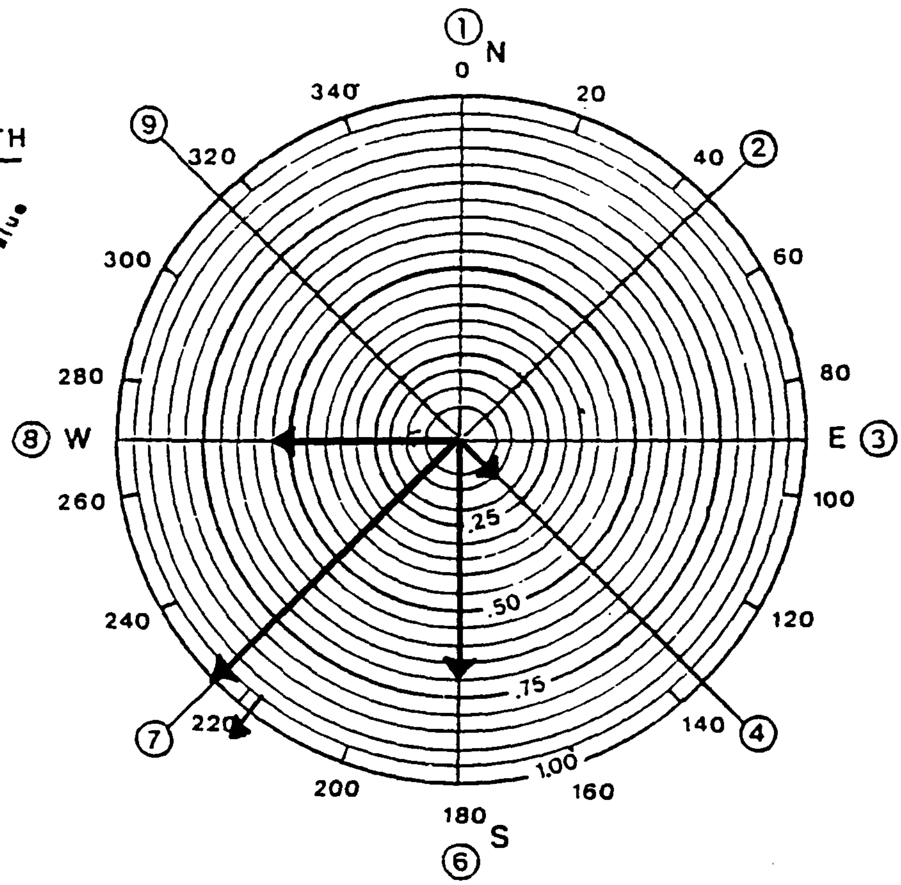
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	+10	10
+2/-7	20	-53	-73
+3/-8	17	-39	-56
+4/-9	17	-71	-28

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	28	28	-9	-.69
+2/-7	3	-44	-47	-13	-1
+3/-8	0	-42	-42	-7	-.54
+4/-9	5	-27	-32	2	.15

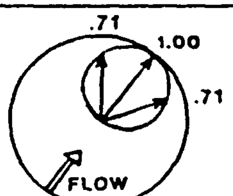


Use of Table

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-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: 217° Velocity: 1.4

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

1072-004

Operator: Millhouse	Date: 8-30-93
Station: KV-3	Time:
Location: POC Area · Galena	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 21' BTOC; 18' BLS	

Table of LCD Readout

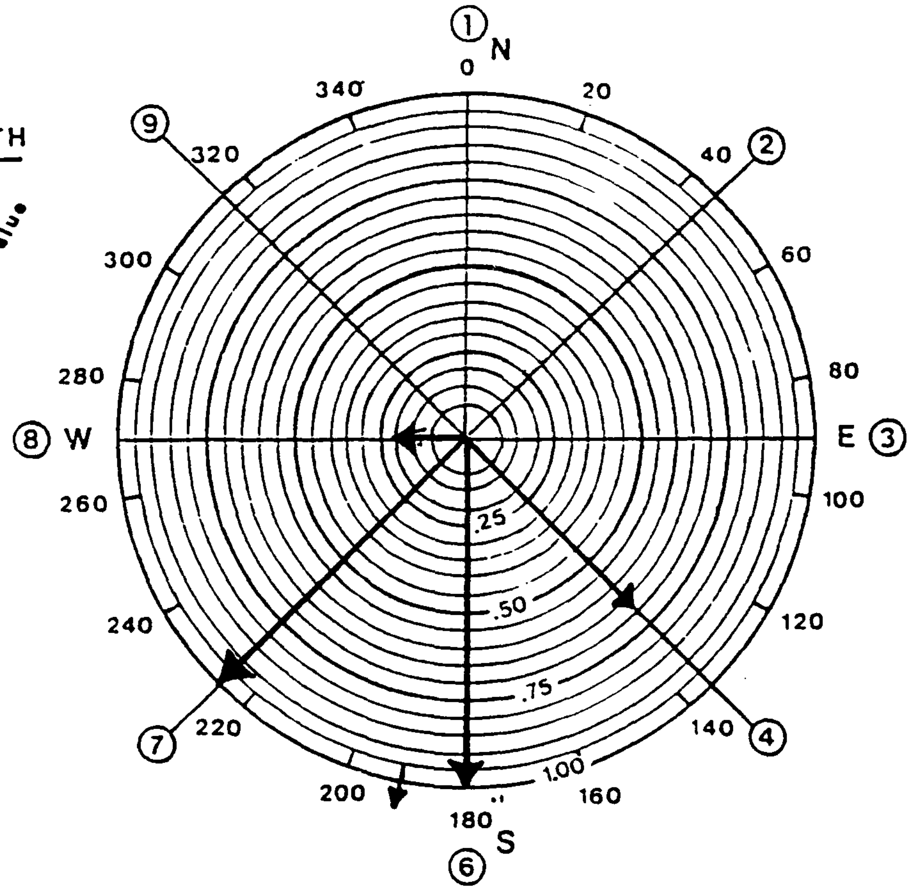
1→N

Probe pair	A start	B end	C B-A
+1/-6	-33	-57	-24
+2/-7	-31	-131	-100
+3/-8	-32	-122	-90
+4/-9	0	-42	-42

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{max.\ value}$
+1/-6	-24	-19	5	-15	-.1
+2/-7	-38	-109	-71	-15	-.1
+3/-8	-38	-122	-84	-3	-.2
+4/-9	-5	-26	-21	10	-.67

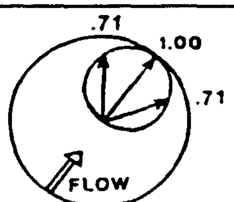


Use of Table

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-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: 191° Velocity: 1.7

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

1092-004

Operator: MillHouse		Date: 8-30-93	
Station: KV-1		Time:	
Location: POL Area - Galena			
Soil Conditions: Medium Sand with Gravel			
Depth to Measurement: 26' BTOC; 23' BLS			

Table of LCD Readout

1→N

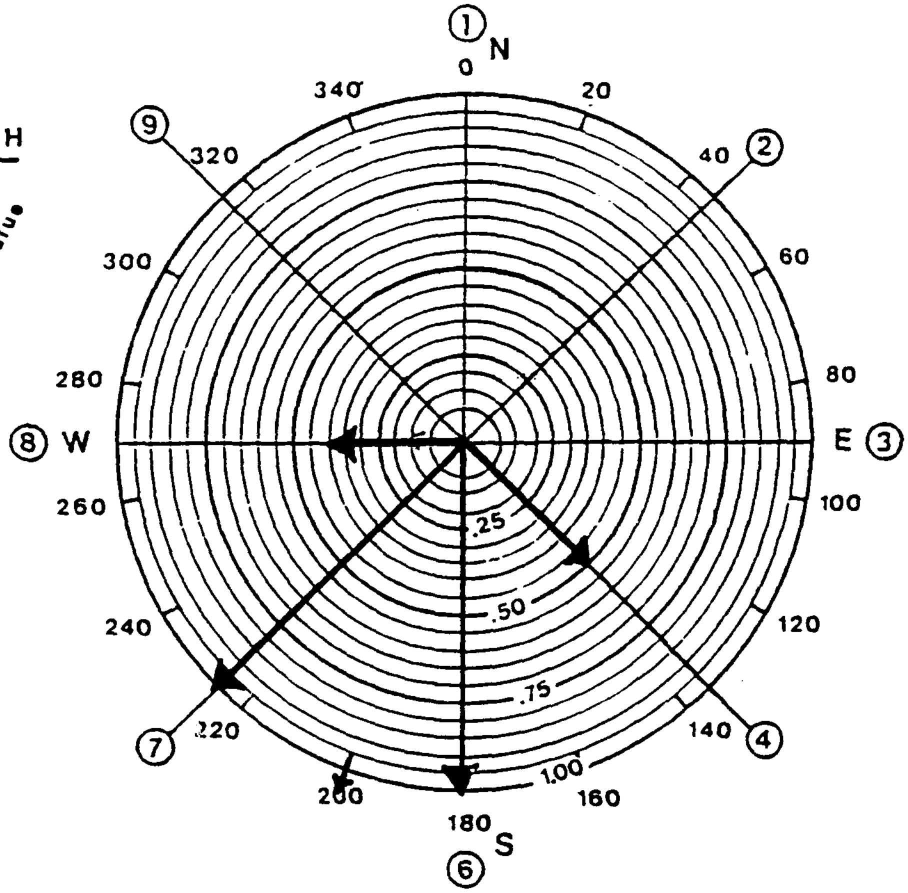
Probe pair	A start	B end	C B-A
+1/-6	0	-21	-21
+2/-7	18	-119	-137
+3/-8	15	-109	-124
+4/-9	15	-41	-56

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D
+1/-6	0	15	15
+2/-7	-5	-106	-101
+3/-8	-11	-122	-111
+4/-9	5	-28	-73

F $\frac{N-S}{2}$	G F/max. value
-18	-1
-18	-1
-7	-.39
9	.50

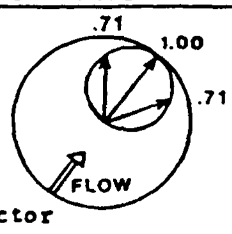


Use of Table

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-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: 200°	Velocity: 2.0

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: MillHouse Date: 8-22-93

Station: KV-1 Time: ______

Location: POC AREA - GALENA

Soil Conditions: MEDIUM SAND WITH GRAVEL

Depth to Measurement: 28' BTOC; 25' BLS

Table of LCD Readout

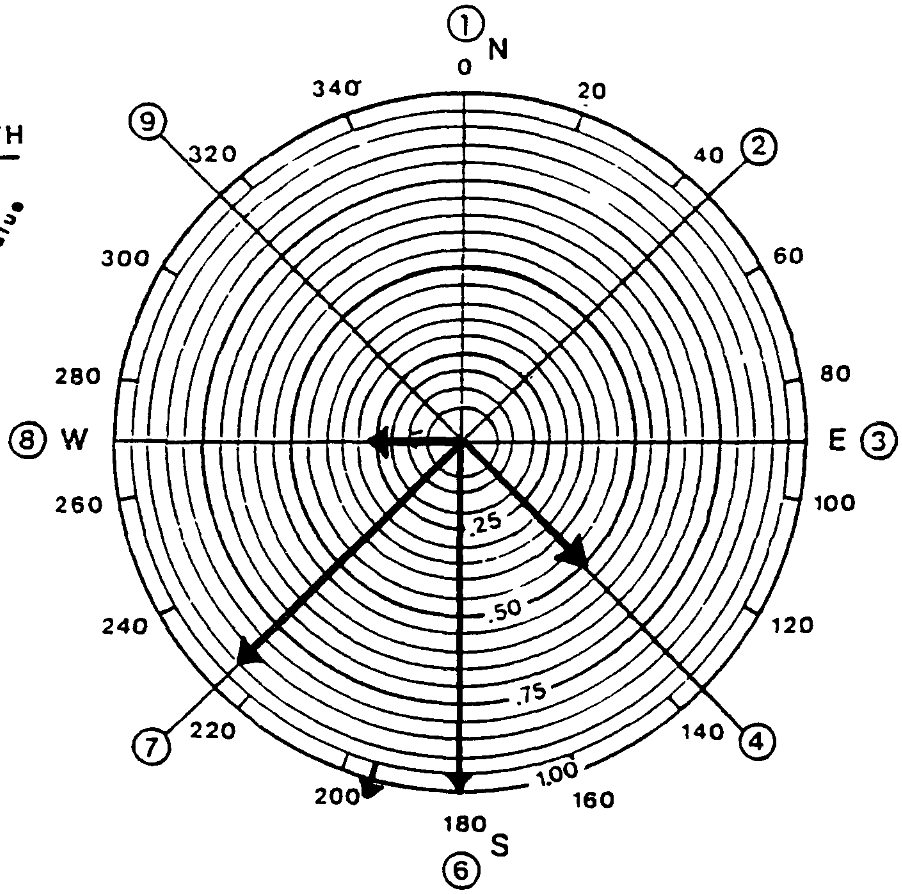
1→N

Probe pair	A start	B end	C B-A
+1/-6	3	18	15
+2/-7	25	-40	-65
+3/-8	20	-27	-47
+4/-9	17	-15	-32

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	8	75	67	-26	-1
+2/-7	15	-5	-20	-23	-.89
+3/-8	3	-30	-33	-7	-.27
+4/-9	3	-55	-58	13	.5

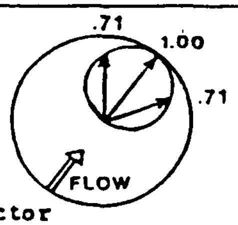


Use of Table

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 shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59-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: 196° Velocity: 2.9

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

9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: MillHouse		Date: 8-22-93	
Station: KV-1		Time:	
Location: POC AREA - GALENA			
Soil Conditions: MEDIUM SAND with GRAVEL			
Depth to Measurement: 30' BTOC; 27' BLS			

Table of LCD Readout

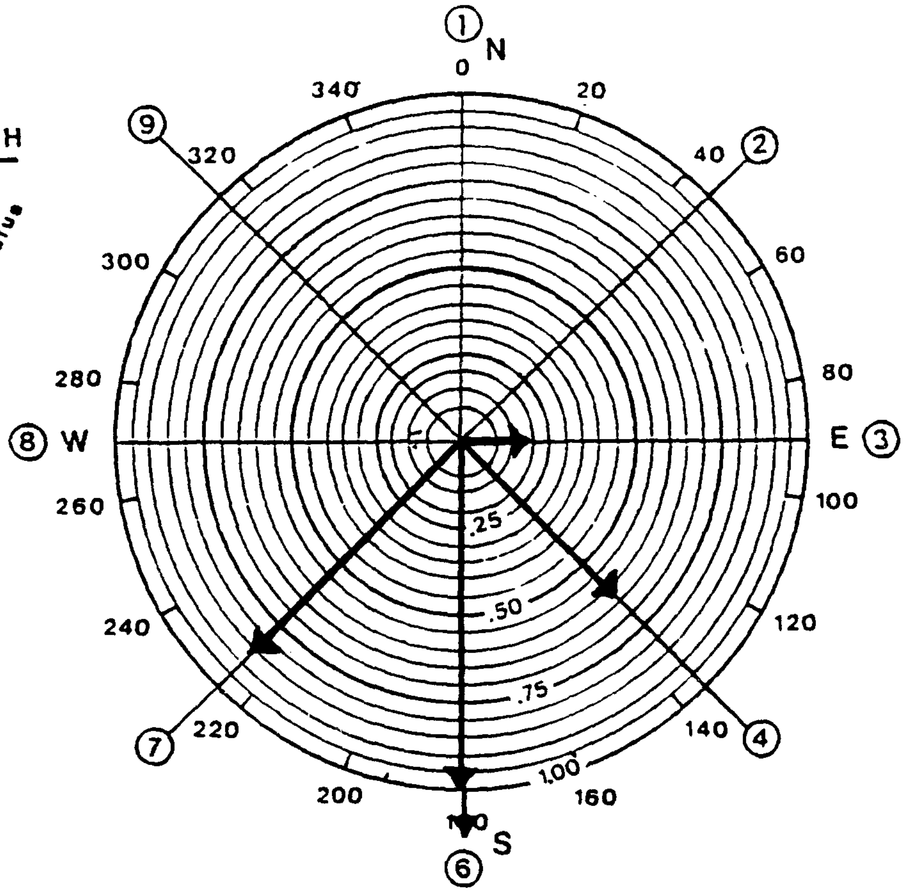
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-45	-45
+2/-7	5	-146	-151
+3/-8	0	-94	-94
+4/-9	8	-13	-21

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	40	40	-43	-1
+2/-7	0	-78	-78	-37	-.86
+3/-8	-13	-91	-78	-8	-.19
+4/-9	0	-74	-74	27	.63

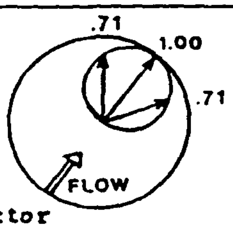


Use of Table

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-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: 180°	Velocity: 4.8

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

1092-004

Operator: MillHouse	Date: 8-20-93
Station: KV-2	Time:
Location: POC AREA	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 35 BToC; 32' BLS	

Table of LCD Readout

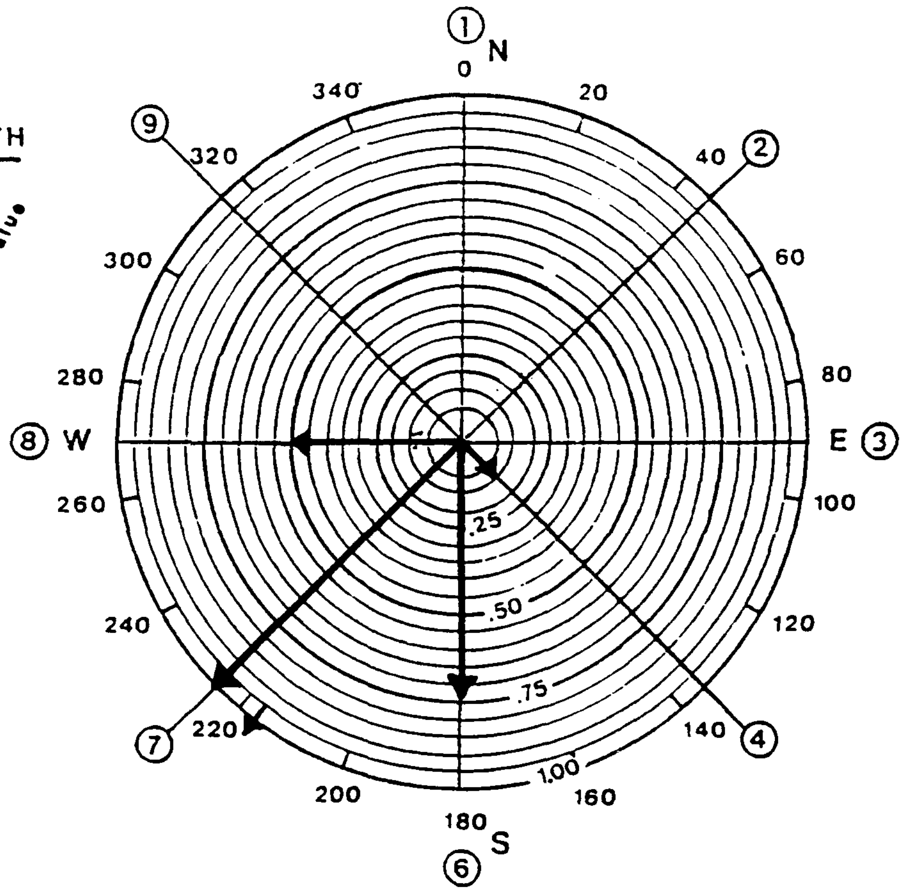
1 → N

Probe pair	A start	B end	C B-A
+1/-6	0	15	15
+2/-7	17	-120	-137
+3/-8	12	-119	-131
+4/-9	13	-79	-92

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	56	56	-21	-.72
+2/-7	18	-62	-80	-29	-1
+3/-8	12	-85	-97	-17	-.59
+4/-9	12	-87	-99	4	.14

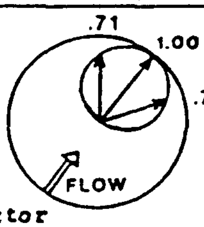


Use of Table

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 lengths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59-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: 216°	Velocity: 3.2

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

/092-004

Operator: MILLHOUSE	Date: 8-20-93
Station: KV-2	Time:
Location: POL AREA - GALENA	
Soil Conditions: MEDIUM SAND WITH GRAVEL	
Depth to Measurement: 37' BTOC; 34' BLS	

Table of LCD Readout

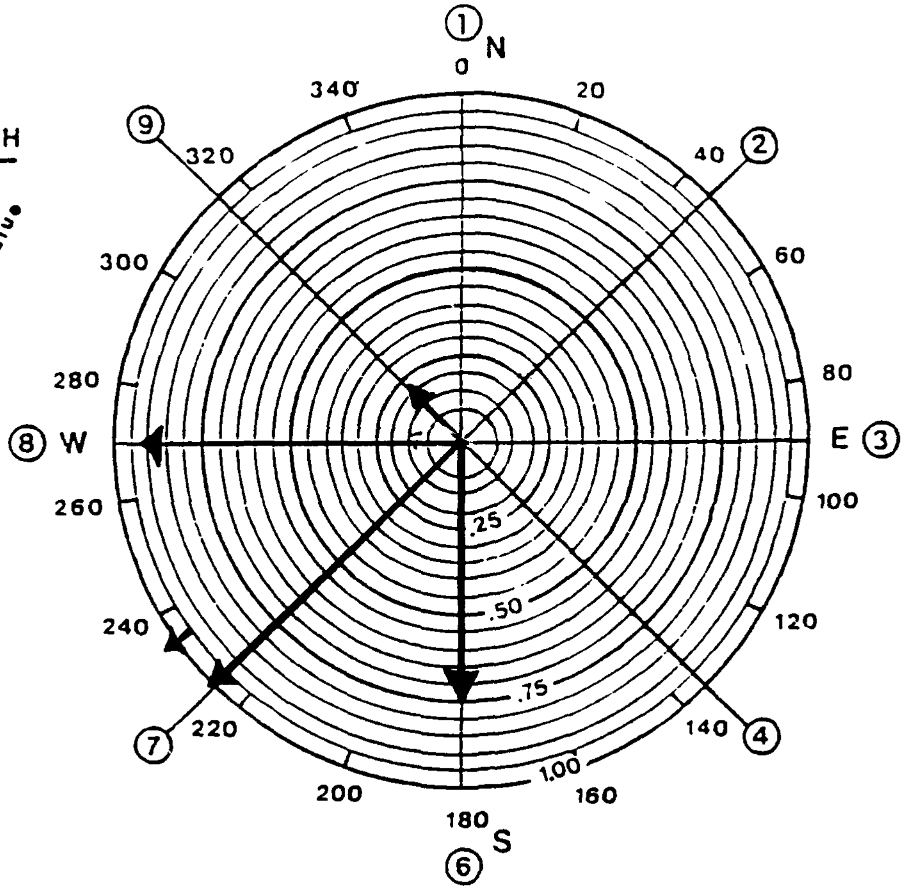
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	6	6
+2/-7	16	$\overline{152}$	$\overline{168}$
+3/-8	16	$\overline{150}$	$\overline{166}$
+4/-9	12	$\overline{90}$	$\overline{102}$

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{\text{max. value}}$
+1/-6	0	38	38	-16	.73
+2/-7	8	$\overline{117}$	$\overline{125}$	$\overline{22}$	-1
+3/-8	0	$\overline{126}$	$\overline{126}$	$\overline{20}$	$\overline{.91}$
+4/-9	5	$\overline{87}$	$\overline{92}$	-5	.23

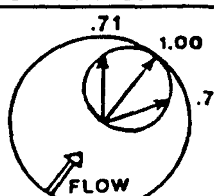


Use of Table

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-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: 226°	Velocity: 2.4

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

1092-004

Operator: Millhouse	Date: 8-20-93
Station: KV-2	Time:
Location: POL AREA - Galena	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 39' BTOC; 36' BLS	

Table of LCD Readout

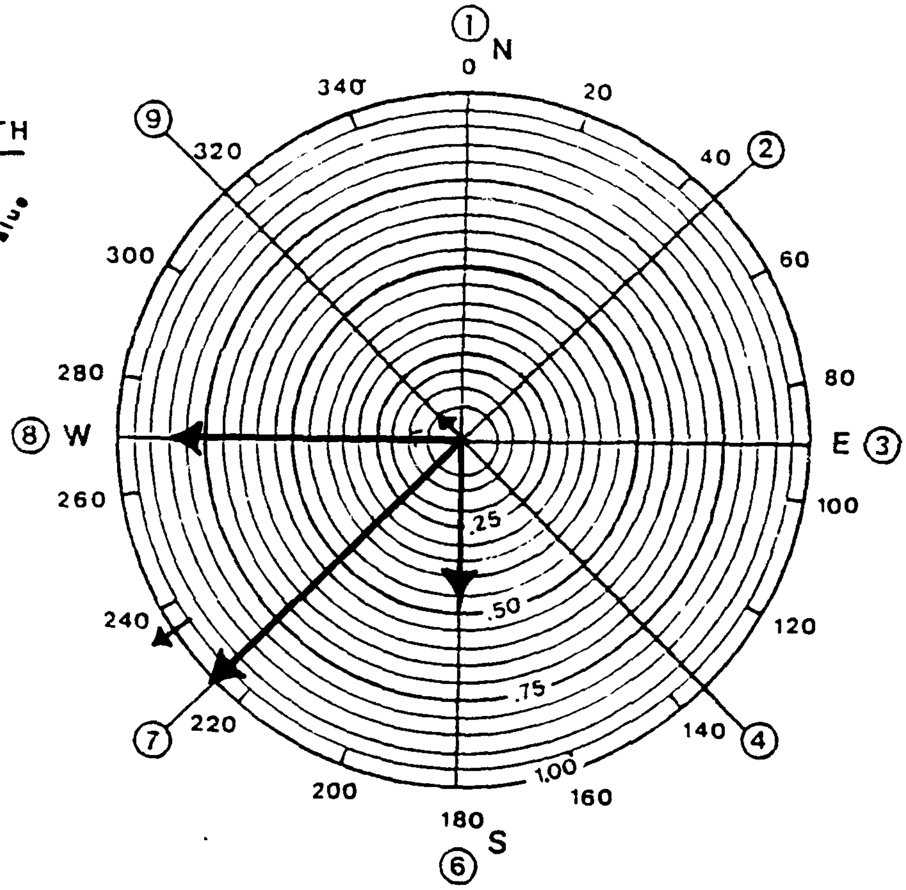
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-48	-48
+2/-7	14	-350	-364
+3/-8	8	-323	-331
+4/-9	9	-135	-144

[ROT]ATE PROBE 180° AT SAME DEPTH

[1]→S

[P]robe [pa]ir	D start	E end	S E-D	F N-S/2	G F/max. value
[+]1/-6	0	19	19	-34	-.44
[+]2/-7	0	-199	-199	-78	-1
[+]3/-8	-7	-206	-199	-66	-.84
[+]4/-9	3	-125	-128	-8	-.1

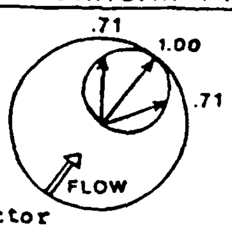


[Us]e of Table

COLUMN G - Divide each reading in [co]lumn F by the largest absolute value. [Dr]aw these 4 vectors on the circle [ch]art according to the scale provided [(i].e. strongest vector = 1.00).

[Co]sine Test Shows Uniform Flow

Vector end [poi]nts will closely [fi]t a circle in-[scr]ibed about the [lar]gest vector. [Val]ues in column G [wi]ll approximate vector [len]gths shown at right.



Vector Resolution to Determine Direction

1. Use KVA Vector Addition Program (TI-58/59-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: 235°	Velocity: 8.7

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

1092-005

Operator: OLSON Date: 8-22-93

Station: KV-4A Time:

Location: POC AREA - GALENA

Soil Conditions: MEDIUM SAND with GRAVEL

Depth to Measurement: 46' BTOC; 43' BGS

Table of LCD Readout

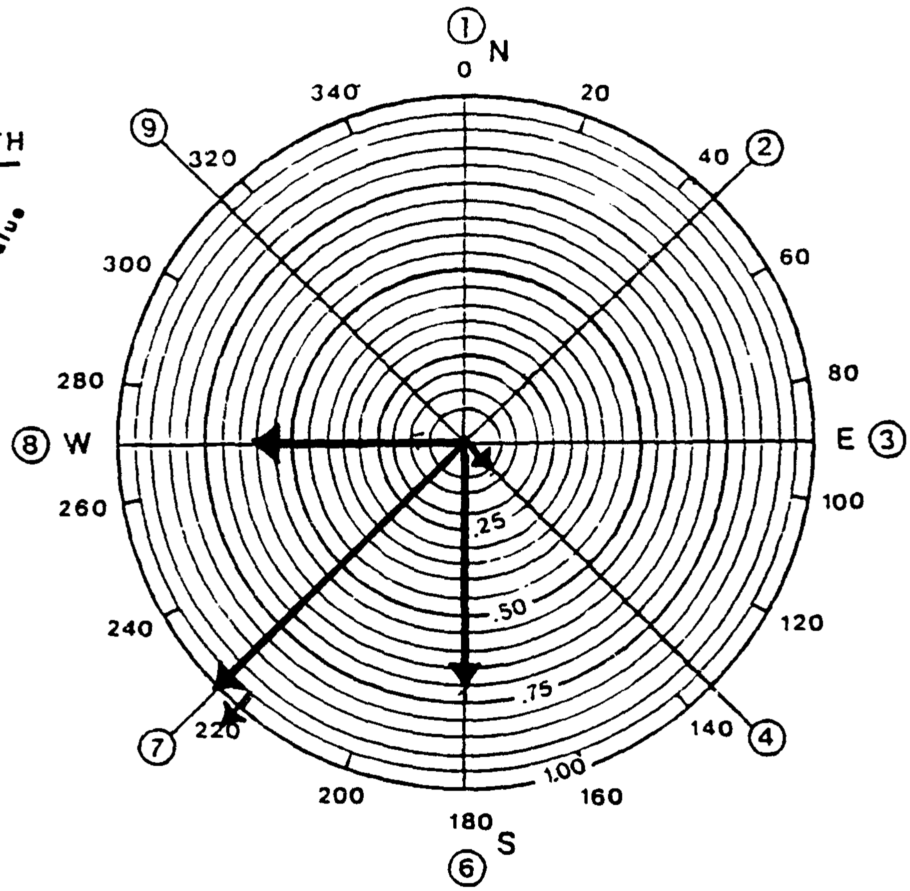
1→N

Probe pair	A start	B end	C B-A
+1/-6	-25	13	38
+2/-7	-5	-112	-107
+3/-8	6	-36	-42
+4/-9	-9	-76	-67

ROTATE PROBE 180° AT SAME DEPTH

-S

Probe pair	D start	E end	S E-D	F N-S/2	G F/max. value
+1/-6	-35	17	52	-7	-.70
+2/-7	0	-87	-87	-10	-1
+3/-8	7	-23	-30	-6	-.6
+4/-9	-9	-77	-68	1	.1

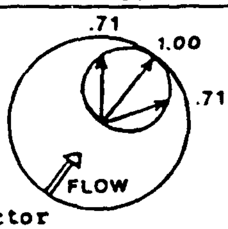


Use of Table

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-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: 221° Velocity: 1.5

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

1092-005

Operator: Olson	Date: 8-21-93
Station: KV-4A	Time:
Location: POC AREA - GALENA	
Soil Conditions: MED SAND with GRAVEL	
Depth to Measurement: 48' BTOC; 45' BLS	

Table of LCD Readout

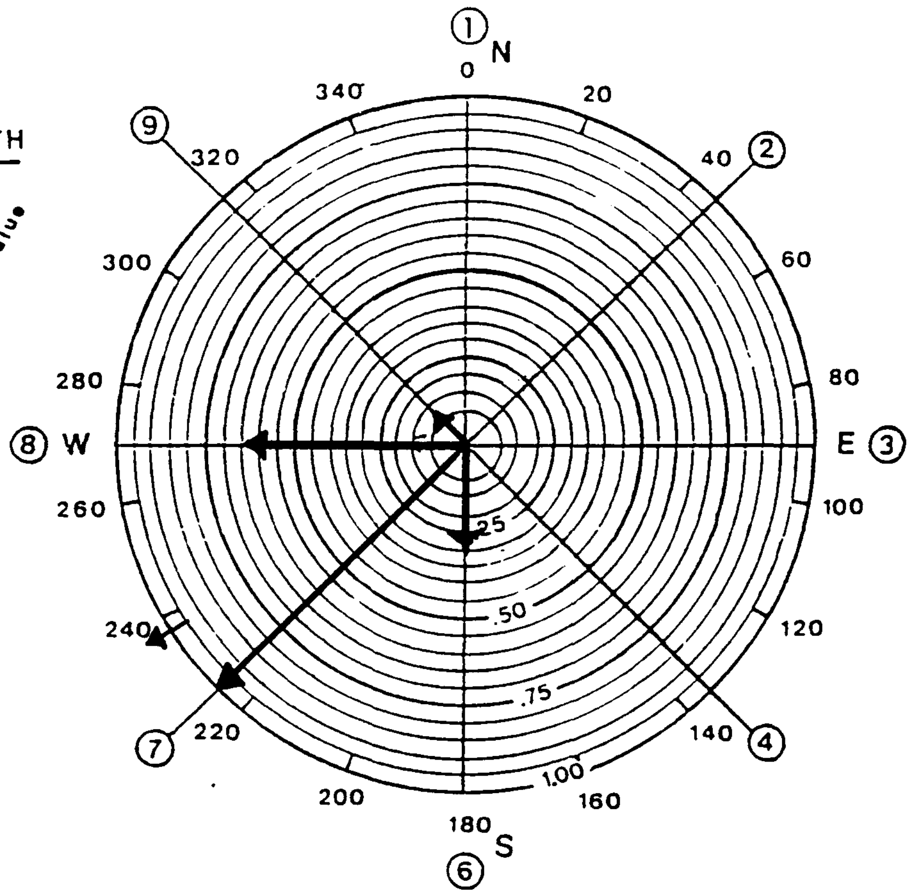
1 → N

Probe pair	A start	B end	C B-A
+1/-6	-18	0	18
+2/-7	0	-92	-92
+3/-8	10	-12	-22
+4/-9	-8	-58	-50

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	76	8	+24	-3	-.27
+2/-7	0	-70	-70	-11	-1
+3/-8	9	0	-9	-7	-.64
+4/-9	-7	-54	-47	-2	-.18

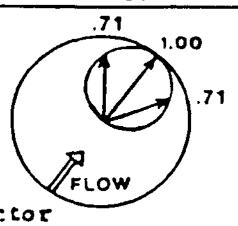


Use of Table

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 strongest 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-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: 225°	Velocity: 1.7

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

1092-005

Operator: Olson	Date: 8-21-93
Station: KV-4A	Time:
Location: POC Area – Galena	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 50' BTOC; 47' BLS	

Table of LCD Readout

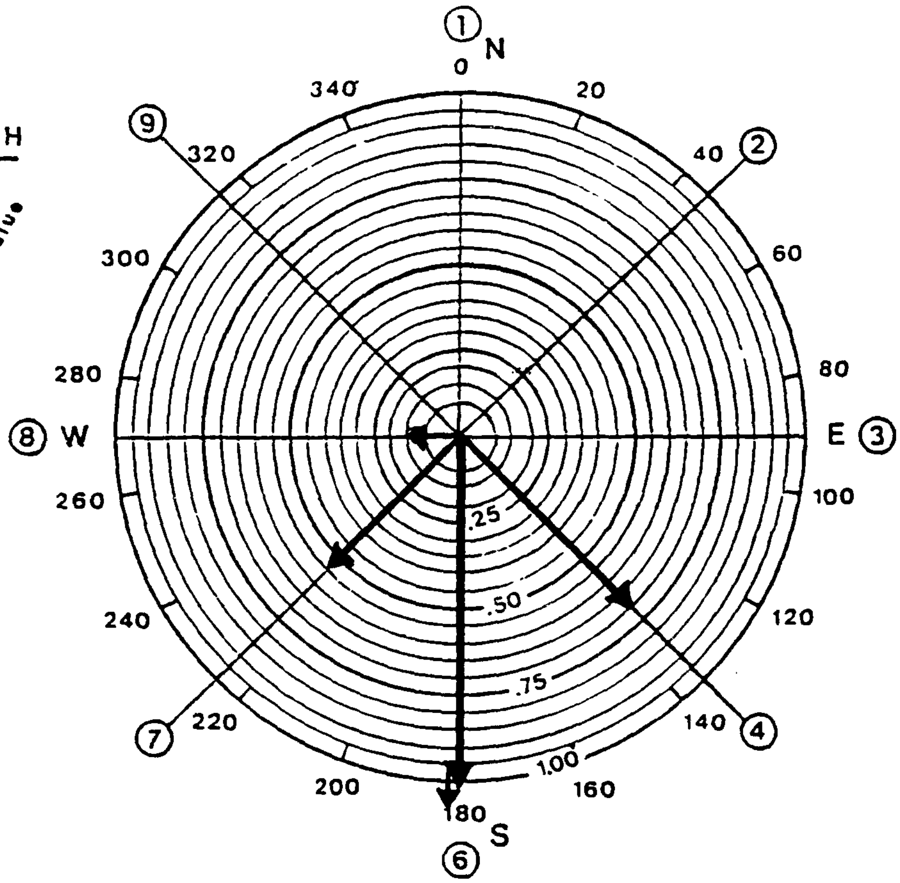
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-77	-77
+2/-7	3	-93	-90
+3/-8	14	0	-14
+4/-9	0	-23	-23

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F/max. value
+1/-6	0	8	8	-13	-1
+2/-7	0	-76	-76	-7	-.54
+3/-8	15	4	-11	-2	-.15
+4/-9	0	-40	-40	9	.69

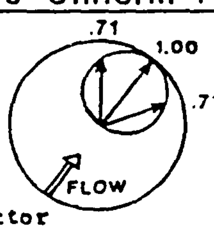


Use of Table

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-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: 181°	Velocity: 2.0

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

1092-004

Operator: Millhouse Date: 8-24-93

Station: KV-5A Time:

Location: POC AREA - GALENA

Soil Conditions: MEDIUM SAND WITH GRAVEL

Depth to Measurement: 57' BTOC; 54' BLS

Table of LCD Readout

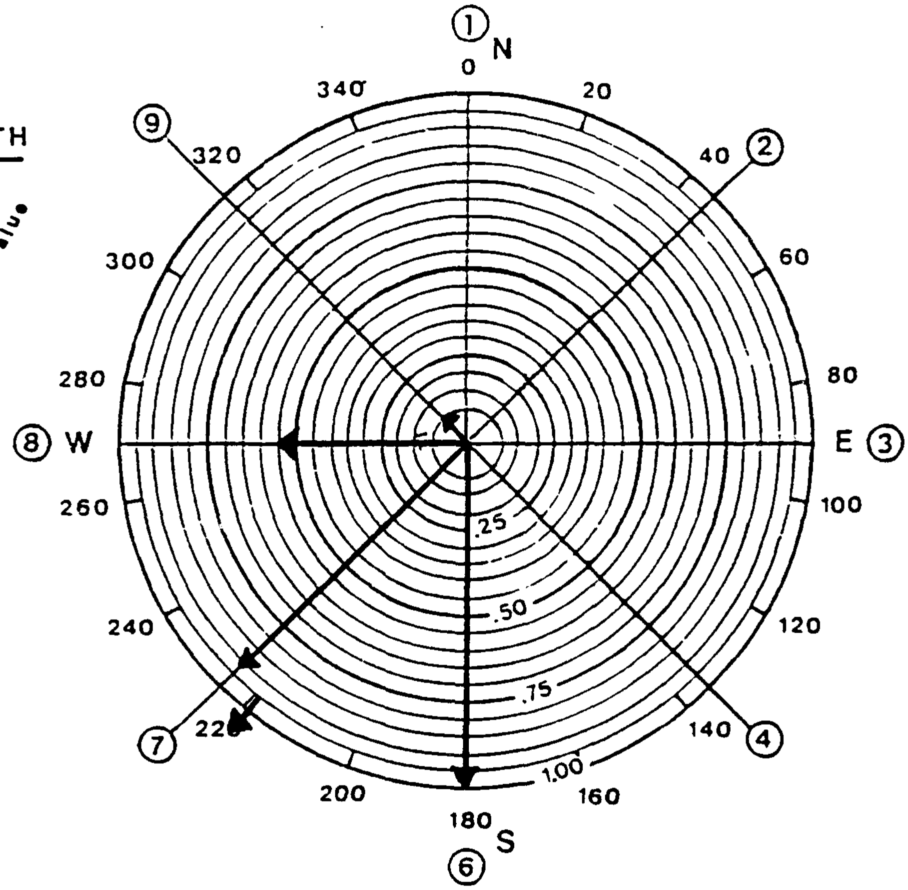
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-128	-128
+2/-7	18	-572	-590
+3/-8	13	-575	-588
+4/-9	13	-234	-247

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	-107	-107	-11	-1
+2/-7	18	-552	-570	-10	-.91
+3/-8	13	-563	-576	-6	-.55
+4/-9	14	-232	-246	-1	-.09

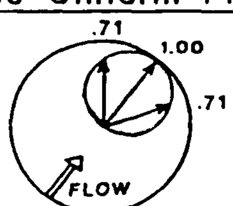


Use of Table

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 strongest 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-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: 219° Velocity: 1.2

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

1092-004

Operator: MillHouse   Date: 8-21-93

Station: KV-5A   Time: ______

Location: POC AREA - GALENA

Soil Conditions: MEDIUM SAND W/ GRAVEL

Depth to Measurement: 59' BTOC; 56 BLS

Table of LCD Readout

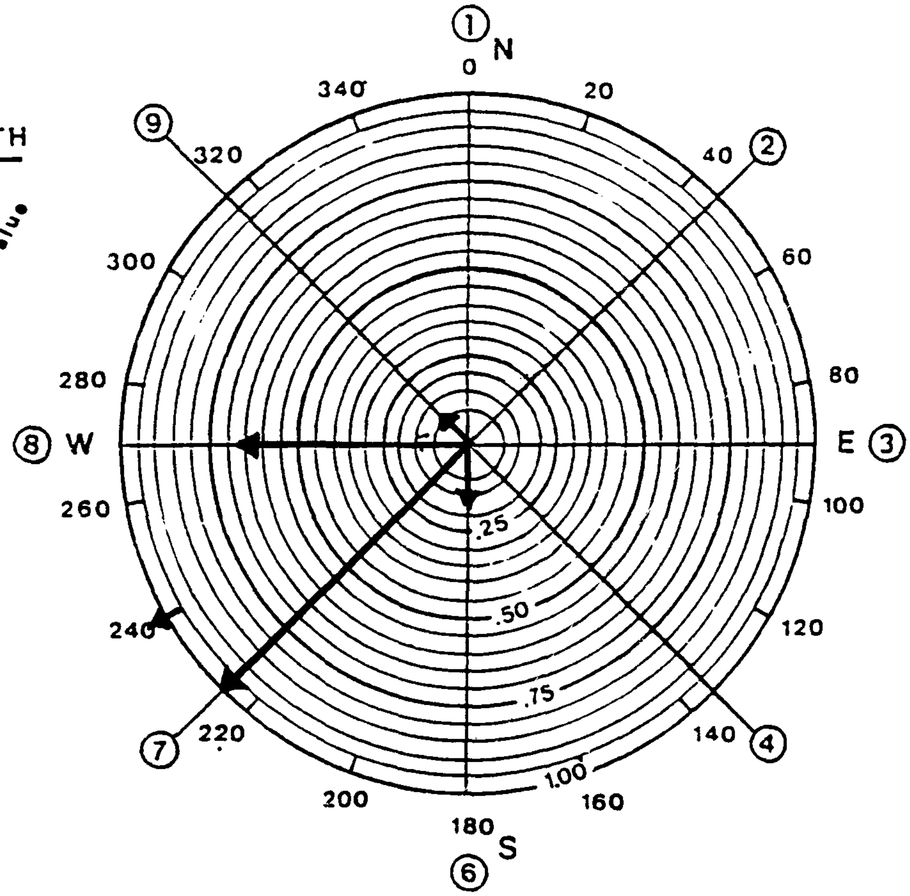
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-19	-19
+2/-7	16	-156	-172
+3/-8	12	-107	-119
+4/-9	13	-29	-42

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F / max. value
+1/-6	0	1	1	-10	-.17
+2/-7	0	-53	-53	-60	-1
+3/-8	0	-39	-39	-40	-.67
+4/-9	7	-20	-27	-8	-.13

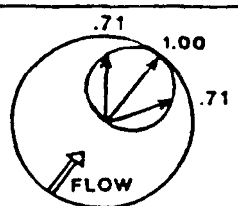


Use of Table

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-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: 240°   Velocity: 6.7

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

1092-004

Operator: MillHouse	Date: 8/21/93
Station: KV-5A	Time:
Location: POC AREA - GALENA	
Soil Conditions: MEDIUM SAND w/ GRAVEL	
Depth to Measurement: 61' BTOC; 58' BLS	

Table of LCD Readout

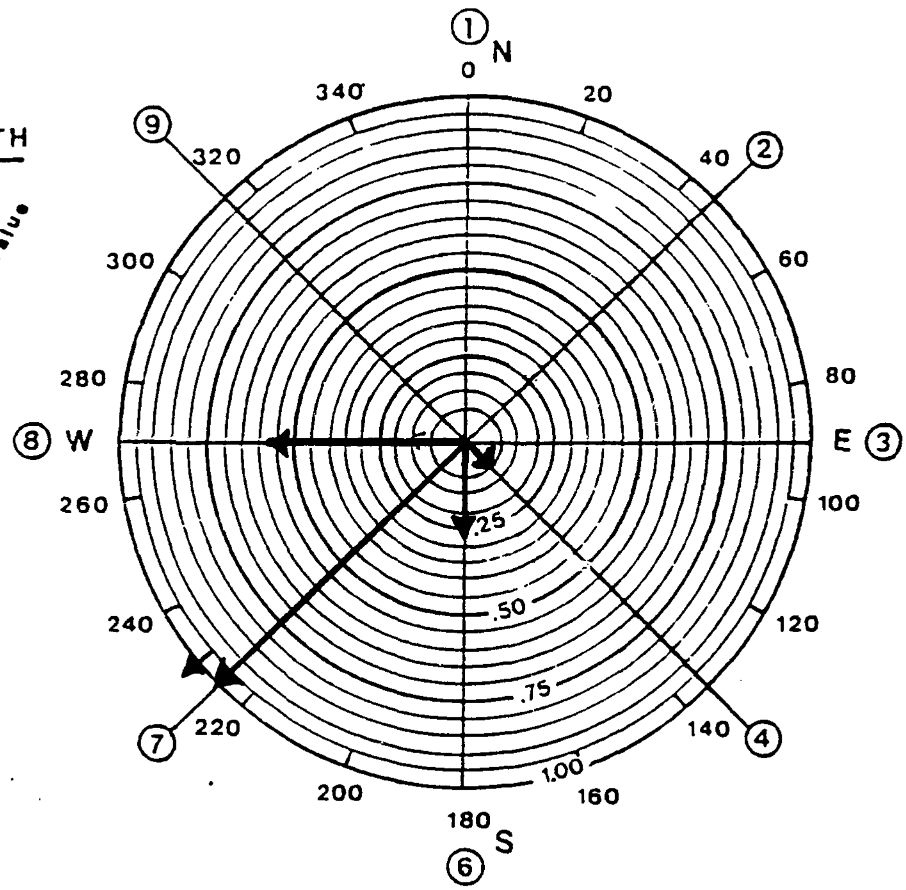
1 → N

Probe pair	A start	B end	C B-A
+1/-6	0	-25	-25
+2/-7	14	-232	-246
+3/-8	11	-182	[illegible]
+4/-9	14	-68	82

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	-9	-9	-8	-.26
+2/-7	16	-169	-185	-31	-1
+3/-8	12	-146	-158	-18	-.58
+4/-9	15	-72	-87	-3	.1

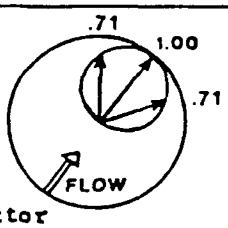


Use of Table

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-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: 231°	Velocity: 3.4

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: MillHouse　Date: 8/24/93

Station: KV-6A　Time:

Location: POC AREA - GALENA

Soil Conditions: MEDIUM SAND WITH GRAVEL

Depth to Measurement: 66' BTOC; 63' BLS

Table of LCD Readout

1→N

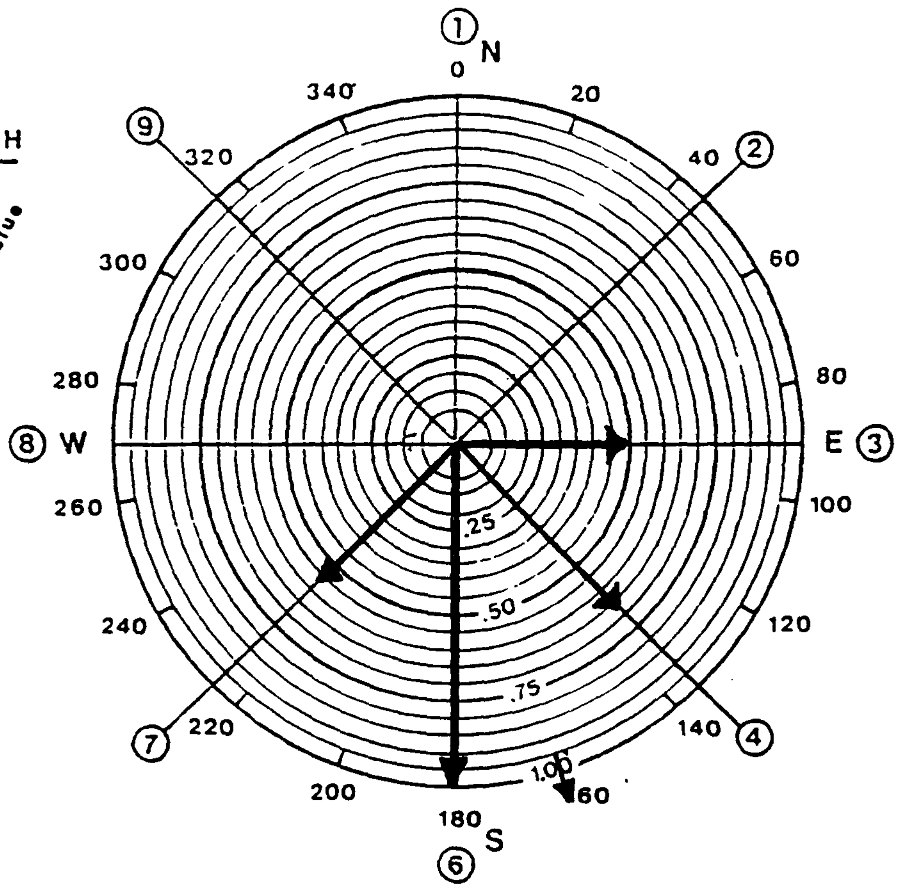
Probe pair	A start	B end	C B-A
+1/-6	0	-41	-41
+2/-7	16	-66	-82
+3/-8	11	-47	-58
+4/-9	12	1	-11

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D
+1/-6	0	-24	-24
+2/-7	16	-56	-72
+3/-8	11	-55	-66
+4/-9	12	-10	-22

F N-S/2	G F/max. value
-9	-1
-5	-.56
4	.44
6	.67

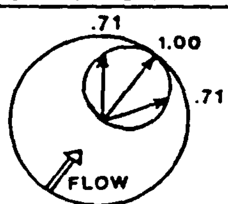


Use of Table

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-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: 162°　Velocity: 1.0

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

1092-004

Operator: MillHouse Date: 8-24

Station: KV-6A Time: ______

Location: POC AREA - GALENA

Soil Conditions: Medium Sand with Gravel

Depth to Measurement: 68' BTOC; 65 BLS

Table of LCD Readout

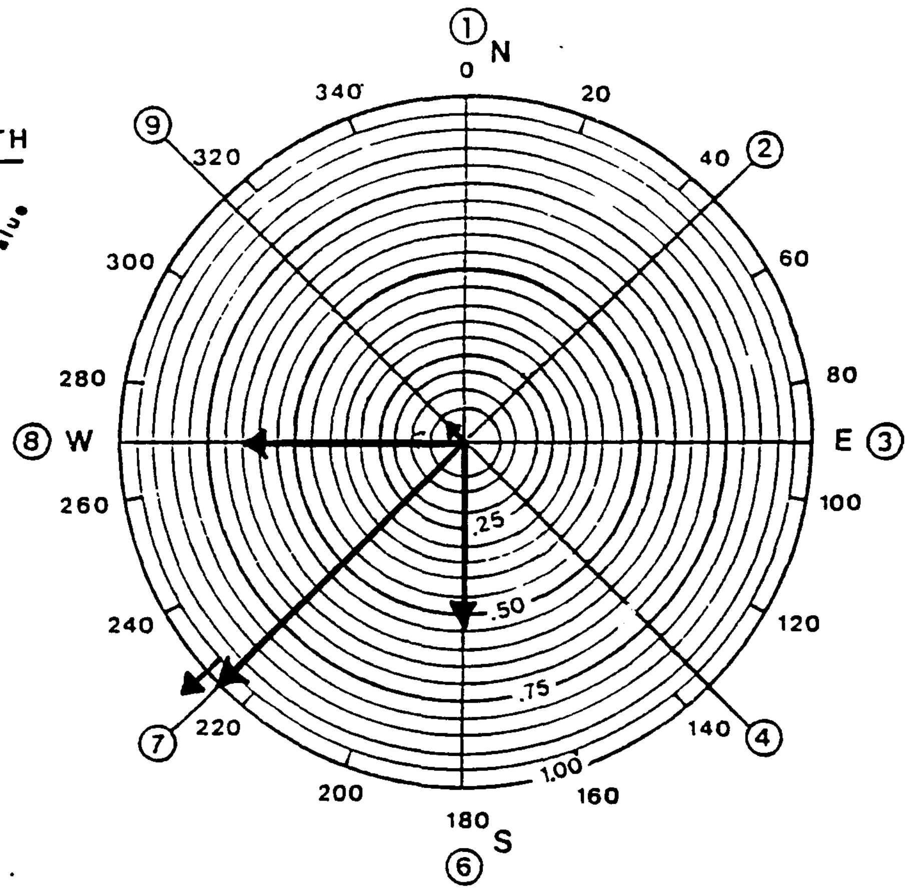
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	$\overline{206}$	$\overline{206}$
+2/-7	16	$\overline{513}$	$\overline{529}$
+3/-8	11	$\overline{414}$	$\overline{425}$
+4/-9	13	$\overline{112}$	$\overline{125}$

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F / max. value
+1/-6	0	$\overline{103}$	$\overline{103}$	$\overline{52}$	$\overline{.53}$
+2/-7	16	$\overline{320}$	$\overline{336}$	$\overline{97}$	$\overline{1}$
+3/-8	12	$\overline{292}$	$\overline{304}$	$\overline{61}$	$\overline{.63}$
+4/-9	13	$\overline{103}$	$\overline{116}$	-5	.05

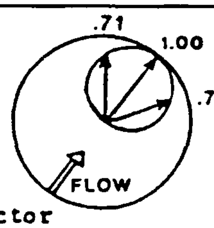


Use of Table

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 strongest 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-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: 226° Velocity: 10.8

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004

Operator: MillHouse Date: 8-24-93

Station: KV-6A Time: ______

Location: POC AREA - GALENA

Soil Conditions: MEDIUM SAND with GRAVEL

Depth to Measurement: 70' BTOC; 67' BLS

Table of LCD Readout

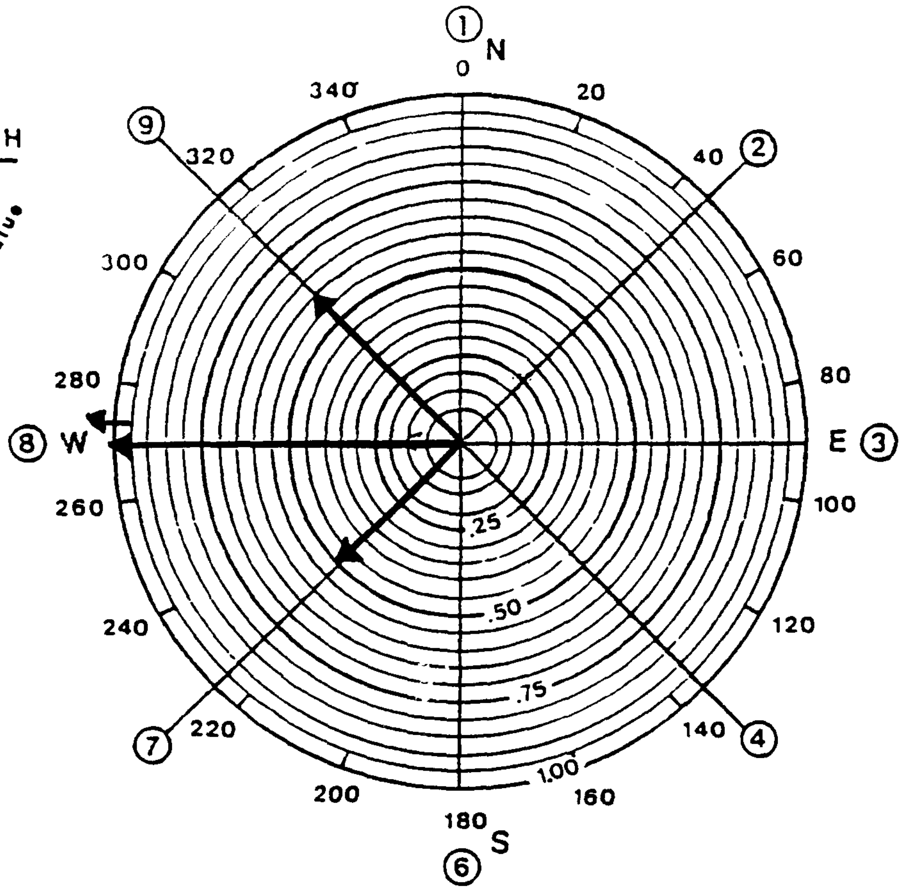
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-103	-103
+2/-7	17	-352	-369
+3/-8	13	-309	-322
+4/-9	13	-118	-131

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	-103	-103	0	0
+2/-7	17	-325	-342	-14	-.48
+3/-8	13	-251	-264	-29	-1
+4/-9	13	-85	-98	-17	-.59

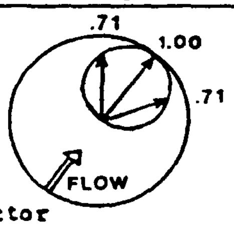


Use of Table

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-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: 273° Velocity: 3.2

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

FLOW METER
PUMP DATA

GROUNDWATER FLOW WORKSHEET

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

1092-005 Active Pumping

Operator: Millhouse	Date: 8-26-93
Station: KV-3	Time: 1205
Location: POL AREA - GALERA	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 17' BTOC; 14' BGS	

5 = 0.25 ft

Table of LCD Readout

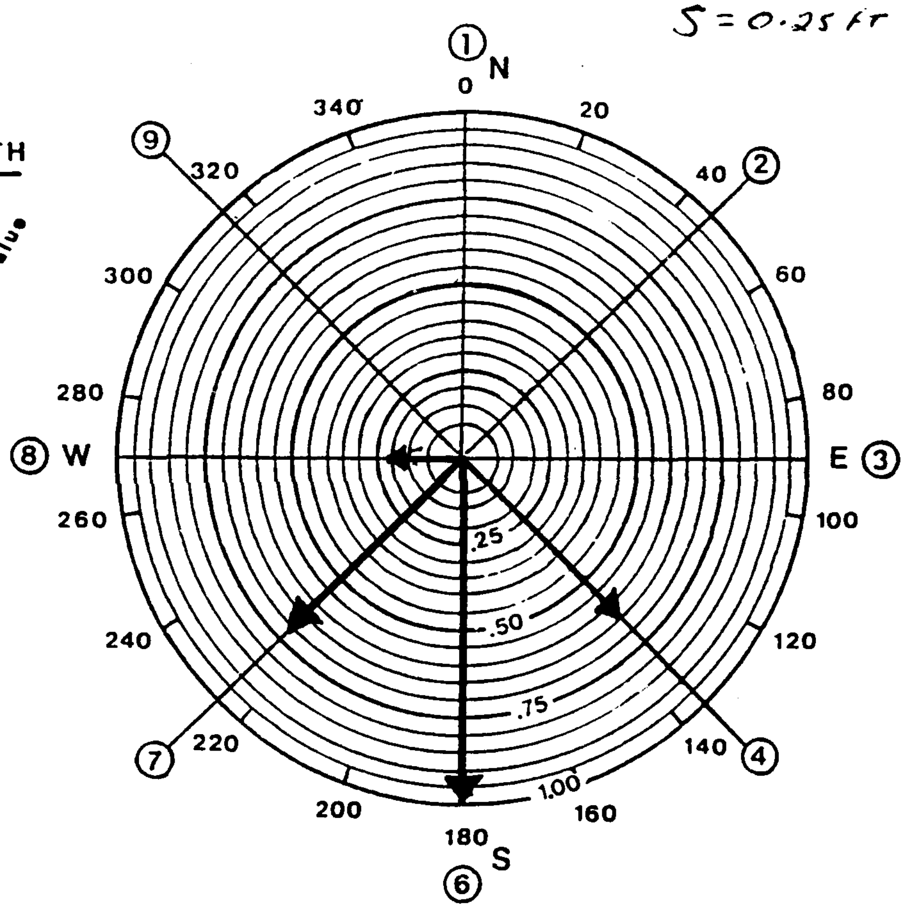
1→N

Probe pair	A start	B end	C B-A
+1/-6	5	-60	-65
+2/-7	4	-56	-60
+3/-8	5	47	42
+4/-9	-6	65	71

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	8	3	-34	-1
+2/-7	0	-73	-73	-24	-.71
+3/-8	0	56	56	-7	-.21
+4/-9	7	20	27	22	.65

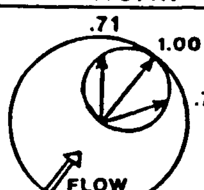


Use of Table

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-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:	Velocity: 5.1 ft/day

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-005 Active Pumping

Operator: Millhouse Date: 8-26-93

Station: KV-3 Time: 1029

Location: POC AREA - GALENA

Soil Conditions: MEDIUM SAND WITH GRAVEL

Depth to Measurement: 19' BTOC; 16' BLS

S = 0.26 FT

Table of LCD Readout

1→N

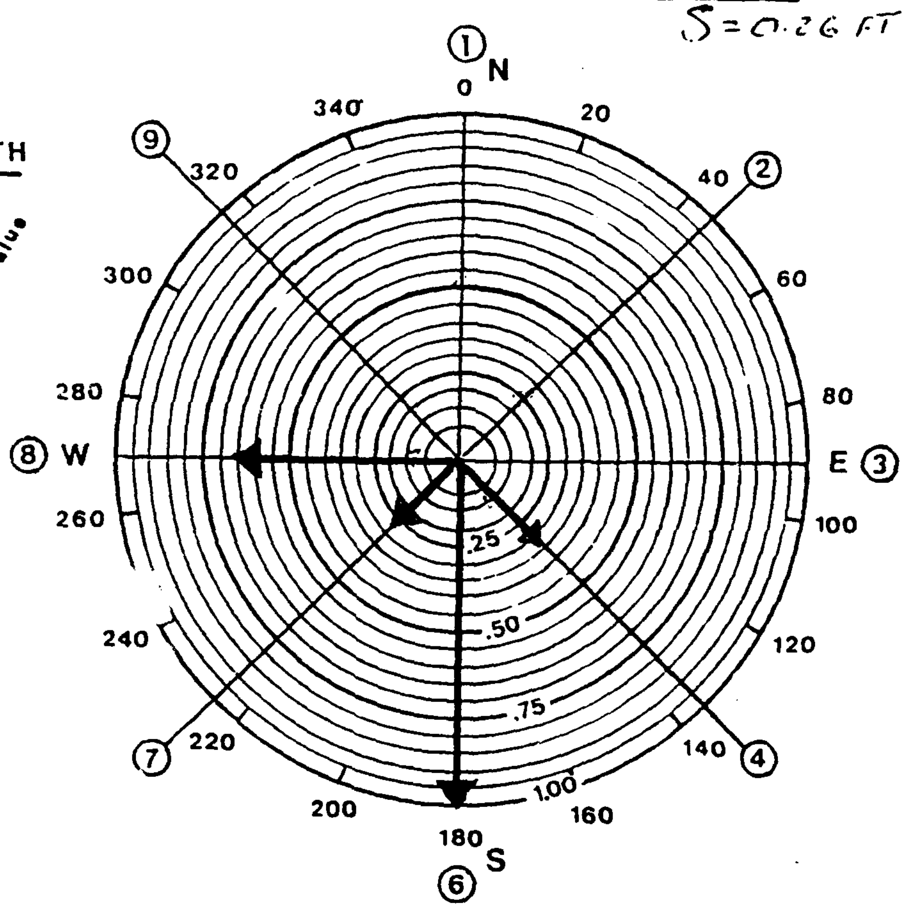
Probe pair	A start	B end	C B-A
+1/-6	5	-.5	-80
+2/-7	4	+69	+65
+3/-8	6	+106	+100
+4/-9	-6	132	138

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D
+1/-6	5	-45	-50
+2/-7	4	76	72
+3/-8	9	129	120
+4/-9	-8	120	128

F $\frac{N-S}{2}$	G $\frac{F}{max.\ value}$
-75	-1
-4	-.27
-10	-.67
5	.33

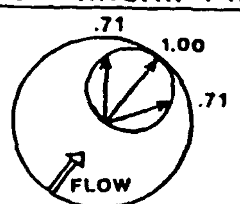


Use of Table

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-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: ______ Velocity: 2.3

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**

1092-005 Active Pumping

Operator: Millhouse	Date: 8-26-93
Station: KV-3	Time: 0925
Location: POC AREA - GALENA	
Soil Conditions: MEDIUM SAND + GRAVEL	
Depth to Measurement: 21' BTOC; 18' BLS	

S = 0.24 ft

Table of LCD Readout

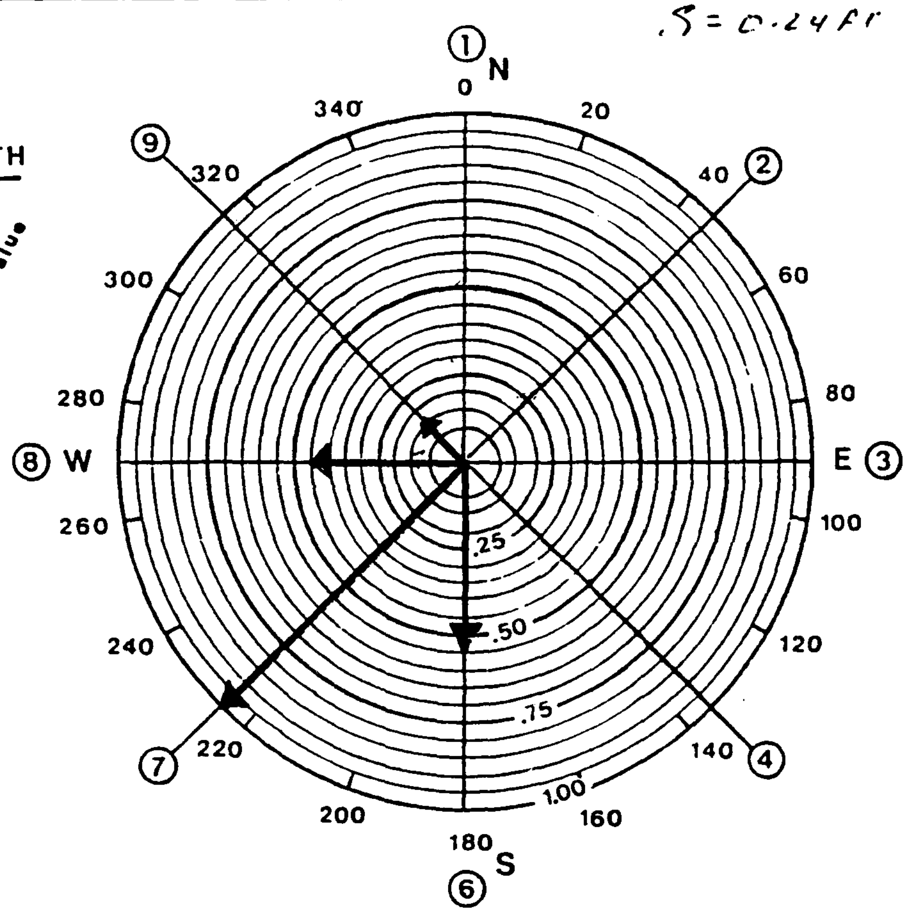
1 → N

Probe pair	A start	B end	C B-A
+1/-6	4	5	1
+2/-7	1	154	153
+3/-8	0	112	112
+4/-9	0	82	82

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	92	89	-44	-.54
+2/-7	0	314	314	-81	-1
+3/-8	1	184	183	-36	.44
+4/-9	-6	90	96	-7	-.16

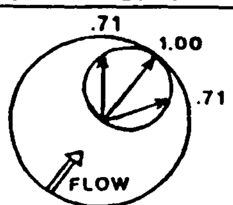


Use of Table

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-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: 225°	Velocity: 12.2 ft/day

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**

1092-004 Active Pumping

Operator: MillHouse	Date: 8-26-93
Station: KV-1	Time: 1618
Location: POL Area - Galena	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 26' BTOC; 23' BLS	

S = 0.43 FT

Table of LCD Readout

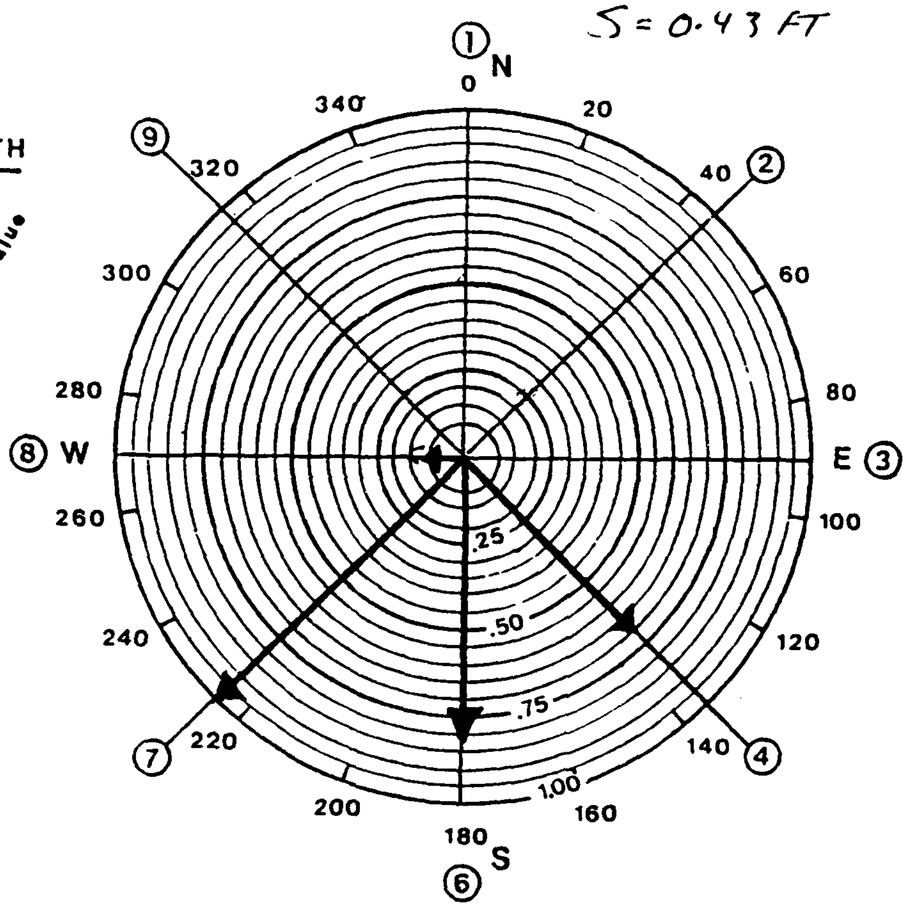
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-179	-179
+2/-7	16	-362	-378
+3/-8	14	-246	-260
+4/-9	15	22	7

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	-42	-42	-69	-.81
+2/-7	14	-195	-209	-85	-1
+3/-8	7	-234	-241	-10	-.12
+4/-9	8	-125	-133	+70	+.82

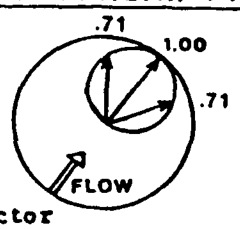


Use of Table

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-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: ________	Velocity: 9.4 ft/day

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

 9/82

GROUNDWATER FLOW WORKSHEET

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

1092-004 Active Pumping

Operator: Mill House	Date: 8-26-93
Station: KV-1	Time:
Location: Pol Aker · Galena	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 28' BTOC; 25' BGS	

S = 0.4551

Table of LCD Readout

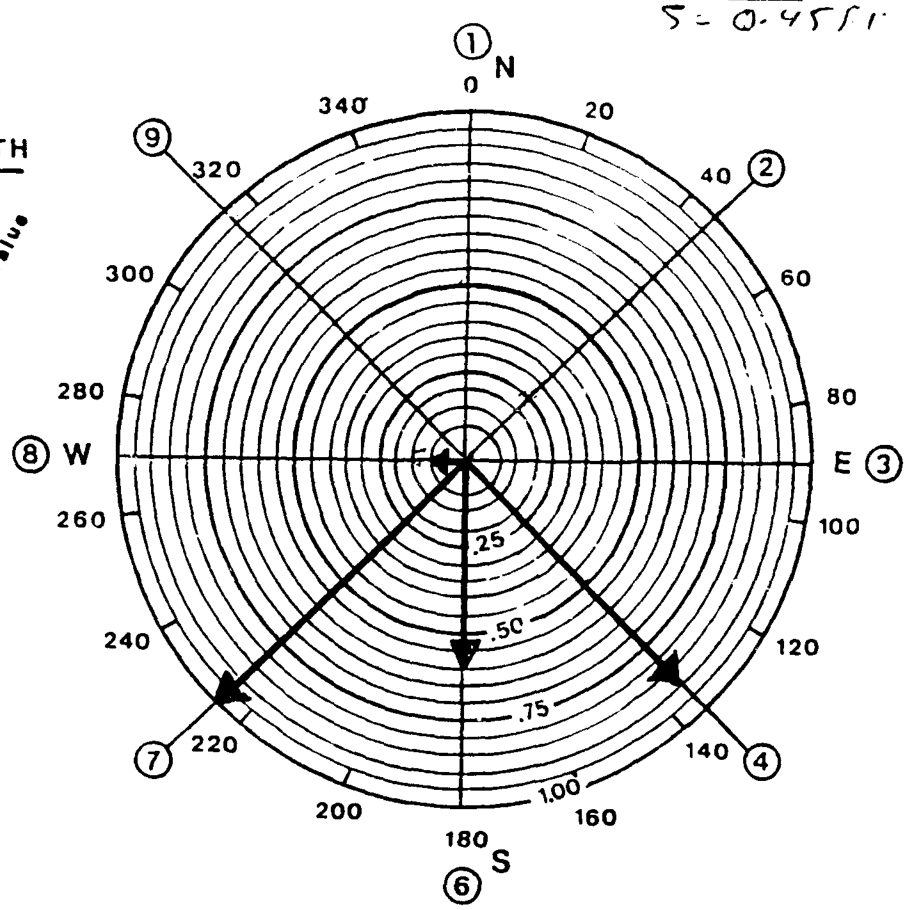
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-173	-173
+2/-7	15	-351	-366
+3/-8	12	-232	-244
+4/-9	13	+29	16

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	2	-66	-68	-53	-.6
+2/-7	21	-167	-188	-89	-1
+3/-8	15	-212	-227	-9	-.1
+4/-9	12	-129	-141	79	.88

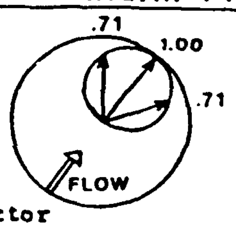


Use of Table

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-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:	Velocity: 9.9 FT/day

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

9/82

GROUNDWATER FLOW WORKSHEET

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

109.2-004 Active Pumping

Operator: Millhouse	Date: 8-26-93
Station: KV-1	Time: 1440
Location: POL Area – Galena	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 30' BTOC; 27' BLS	

S = 0.42 FT

Table of LCD Readout

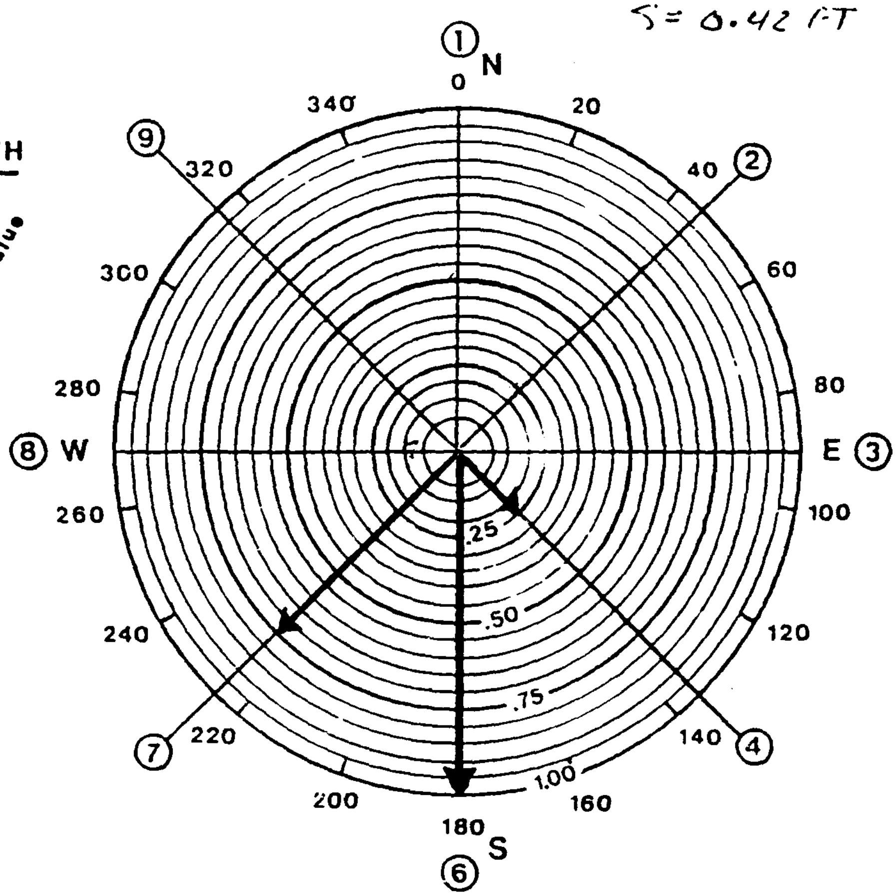
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	$\overline{200}$	$\overline{200}$
+2/-7	14	$\overline{360}$	$\overline{374}$
+3/-8	8	$\overline{209}$	$\overline{217}$
+4/-9	10	73	$\overline{83}$

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G $\frac{F}{\text{max. value}}$
+1/-6	0	99	99	-150	-1
+2/-7	12	$\overline{141}$	$\overline{153}$	$\overline{111}$	$\overline{.74}$
+3/-8	8	$\overline{203}$	$\overline{211}$	-3	$\overline{0.02}$
+4/-9	12	$\overline{147}$	$\overline{159}$	.38	.25

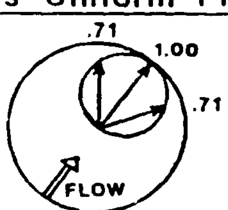


Use of Table

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-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: ______	Velocity: 16.7 ft/day

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**

1092-004 Active Pumping

Operator: Millhouse	Date: 8-26-93
Station: KV-2	Time: 1245
Location: POL AREA – GALENA	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 35'BTOC; 32'BLS	

S = 0.5111

Table of LCD Readout

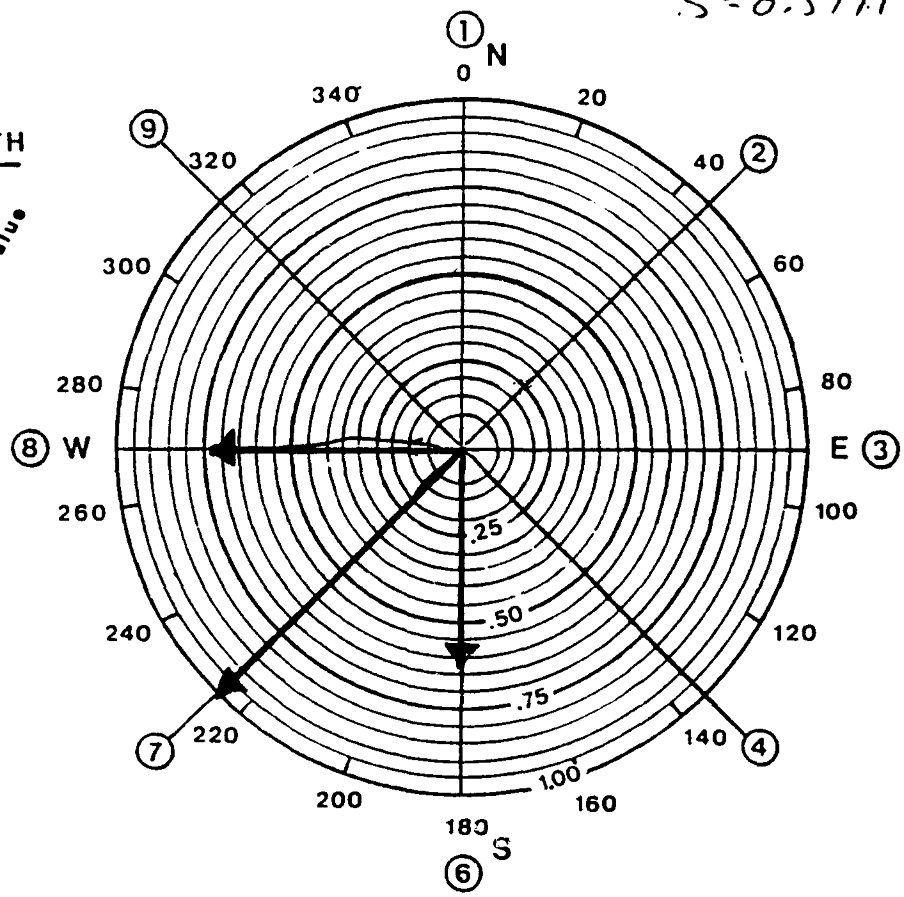
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-48	-48
+2/-7	13	-209	-222
+3/-8	9	-185	-194
+4/-9	12	-55	-67

ROTATE PROBE 180° AT SAME DEPTH

1→S

Probe pair	D start	E end	S E-D	F $\frac{N-S}{2}$	G F / max. value
+1/-6	0	+54	54	-51	-.62
+2/-7	13	-45	-58	-82	-1
+3/-8	6	-69	-75	-60	-.73
+4/-9	9	-56	-65	-1	.01

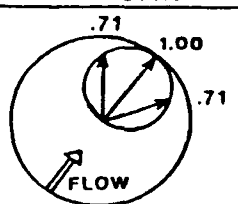


Use of Table

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-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:	Velocity: 9.1 FT/day

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

1092-004 Active Pumping

Operator: MillHouse	Date: 8-26-93
Station: KV-2	Time: 1212
Location: POL AREA - GALENA	
Soil Conditions: Medium Sand w/ Gravel	
Depth to Measurement: 37' BTOC; 34' BGS	

S = 0.50

Table of LCD Readout

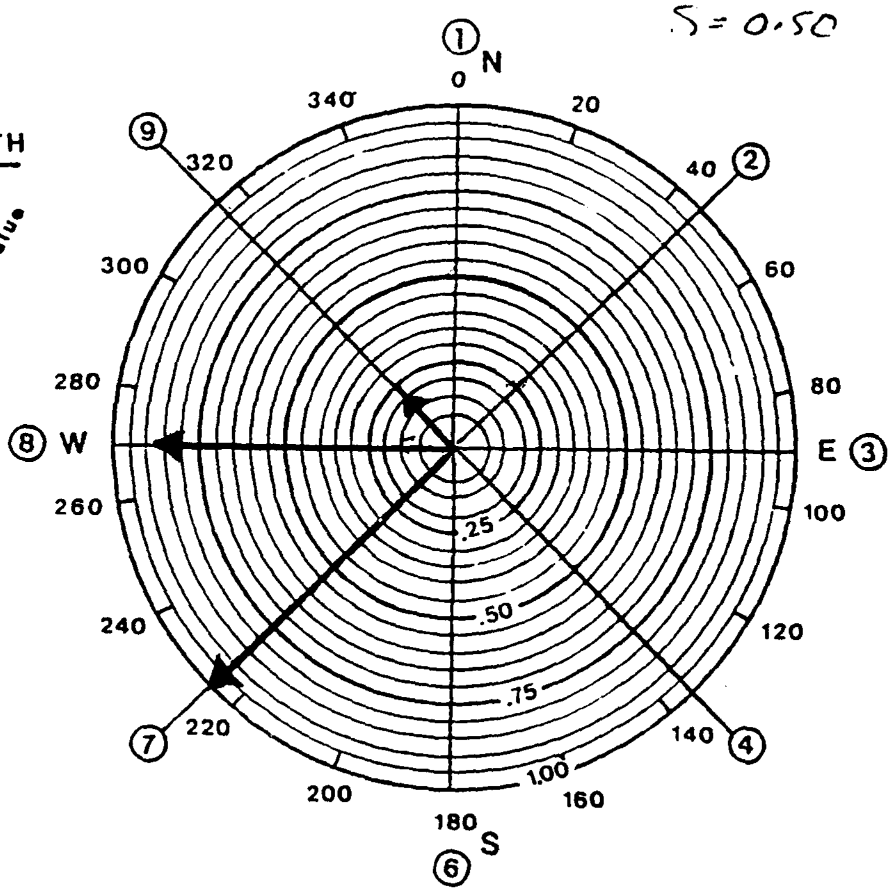
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-40	-40
+2/-7	14	-158	-172
+3/-8	10	-135	-145
+4/-9	12	-38	-50

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	-37	-2	-.02
+2/-7	10	6	-4	-84	-1
+3/-8	6	4	-2	.72	-.86
+4/-9	11	-5	-16	-17	-.20

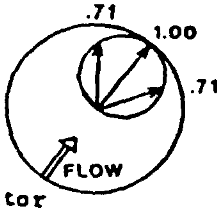


Use of Table

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-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:	Velocity: 9.4 ft/day

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

1092-004 Active Pumping

Operator: MillHouse	Date: 8-26-93
Station: KV-2	Time: 1020
Location: POL AREA - GALENA	
Soil Conditions: Medium Sand with Gravel	
Depth to Measurement: 39' BTOC; 36' BLS	

S = 0.45 FT

Table of LCD Readout

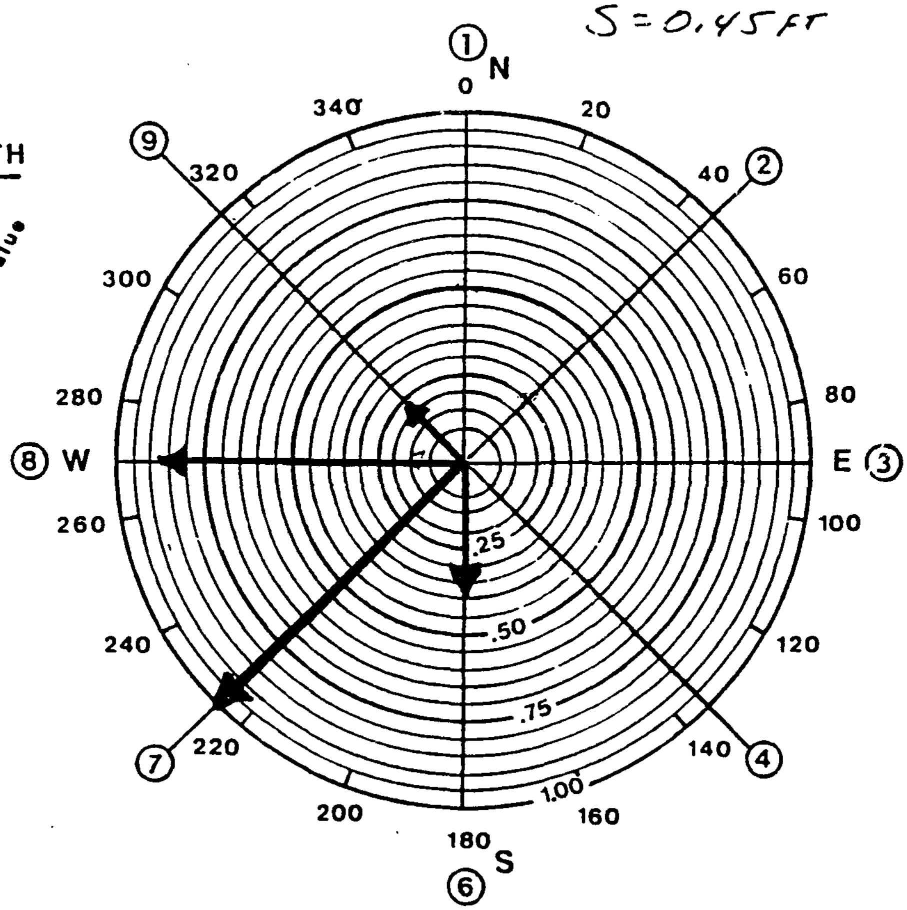
1→N

Probe pair	A start	B end	C B-A
+1/-6	0	-30	-30
+2/-7	12	-145	-157
+3/-8	7	-123	-130
+4/-9	12	-35	-47

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	4	63	59	-45	-.37
+2/-7	25	109	84	-121	-1
+3/-8	19	103	84	-107	-.88
+4/-9	15	24	9	-28	-.23

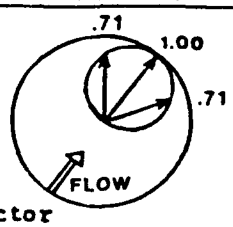


Use of Table

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-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: ______	Velocity: 13.4 Ft/day

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

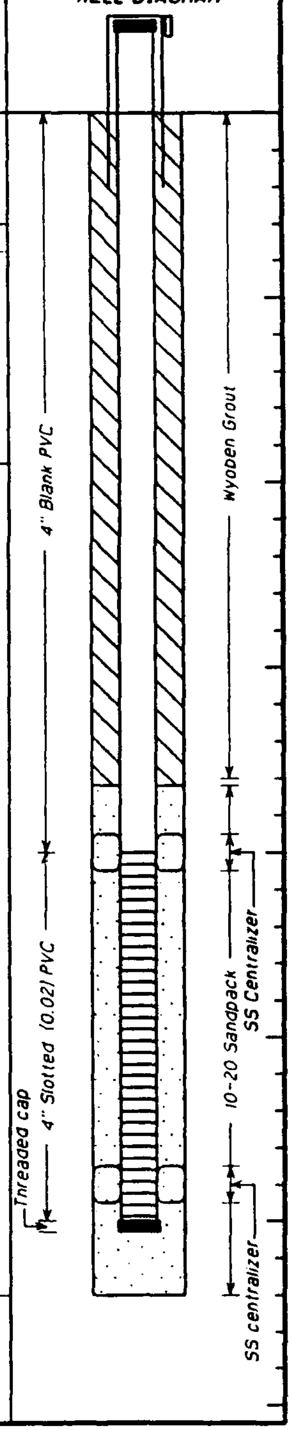
 9/82

MONITORING WELL LOGS

11 CIVIL ENGINEERING OPERATIONS SQ. OPERATING ENGINEERS	Log of Monitoring Well KV-1
PROJECT: *POL AREA*	LOCATION: *GALENA AFS AK*
PROJECT NO.: *53028*	SURFACE ELEVATION:
DATE STARTED: *5/5/93*	INITIAL H2o LEVEL: *23 ft. BLS*
DATE FINISHED: *5/7/93*	FINAL H2o LEVEL: *23 ft. BLS*
DRILLING METHOD: *12 in. Hollow Stem Auger*	TOTAL DEPTH: *32 Feet*
DRILLING COMPANY: *11 CEOS/CEOR*	GEOLOGIST: *JOE MILLHOUSE*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE (0–50)	SOIL CLASS	GEOLOGIC DESCRIPTION
					SM	silty Sand, fine sand, 2.5Y 5/4 light olive brown, damp, loose
	001	4	0			
					ML	Silt with sand, fine sand, non-plastic 2.5Y 5/0 gray, damp, soft
5	002	4	0		SM	silty fine Sand, as above, fibrous organic layers < 1mm thick, damp, loose 6.3-6.8' poorly graded Sand, fine, sugary texture
10	003	6	0		SP	poorly graded Sand, medium to fine, 2.5Y 5/4 light olive brown, damp, loose, sugary texture
	004	9	0			Poorly graded Sand with gravel, medium to fine sand, 1 inch maximum subrounded gravel, 2.5Y 5/4 ight olive brown, damp, loose, gravelly layer 13.5-14.0 ft.
15	005	10	0			
	006	9	0		SW	well graded Sand with gravel, 1 inch maximum subrounded gravel, damp, loose
20	007	7	0			as above, 3/4 inch maximum subrounded gravel
	008	7	-			▼ Water level while drilling less gravelly, saturated, loose, color change to 2.5Y 4/0 dark gray
25	009	6	-			little gravel, saturated, loose
	010	8	-			as above, saturated, loose
30	011	5	-			
35						Bottom of boring 32.0 feet. Total casing assembly 33.3'; Stickup 2.93'

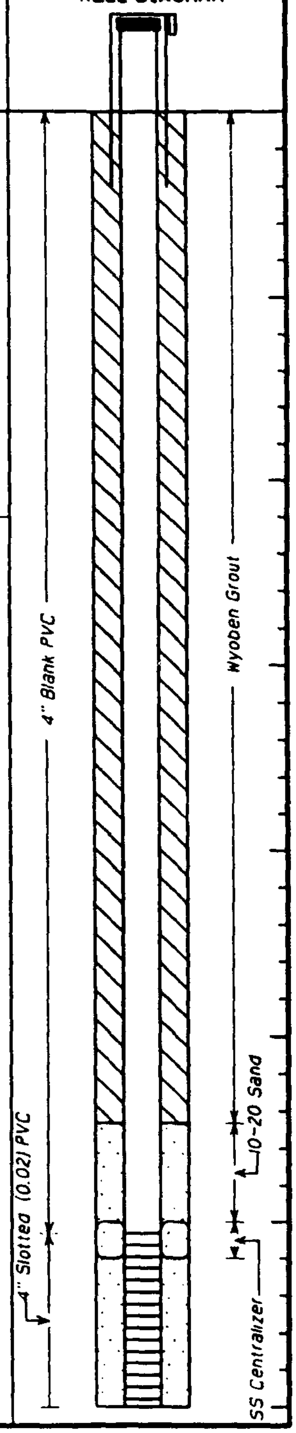
WELL DIAGRAM



11 CIVIL ENGINEERING OPERATIONS SQ. OPERATING ENGINEERS	**Log of Monitoring Well KV-2**
PROJECT: *POL AREA*	LOCATION: *GALENA AFS AK*
PROJECT NO.: *53028*	SURFACE ELEVATION:
DATE STARTED: *5/18/93*	INITIAL H2o LEVEL: *14 ft. BLS*
DATE FINISHED: *5/18/93*	FINAL H2o LEVEL: *14 ft. BLS*
DRILLING METHOD: *12 in. Hollow Stem Auger*	TOTAL DEPTH: *42 Feet*
DRILLING COMPANY: *11 CEOS/CEOR*	GEOLOGIST: *JOE MILLHOUSE*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE 0–50	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
						SM	silty Sand with fibrous organics, 2.5Y 5/4 light olive brown, damp, loose, finely laminated organic and silty sand 1 mm thick
5	001	3	0				
10	002	4	0				
						SP	poorly-graded Sand, medium, 2.5Y 5/4 light olive brown, damp, loose, uniform
						SW	⊻ Water level while drilling
15	003	8	0				well-graded Sand with gravel, 1/2 inch maximum subrounded gravel, 2.5Y 4/0 dark grey, damp, loose
20	004	8	-				as above, 3/4 inch maximum subrounded gravel
25	005	9	-				as above, saturated, loose
30	006	7	-				as above, uniform sand with gravel
35	007	8	-				

WELL DIAGRAM



11 CIVIL ENGINEERING OPERATIONS SQ.
OPERATING ENGINEERS

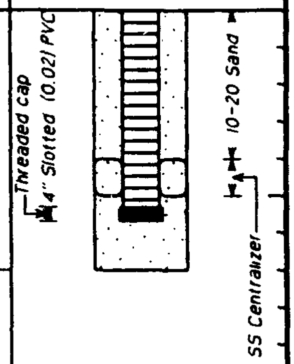
Log of Monitoring Well KV-2

PROJECT: *POL AREA*

LOCATION: *GALENA AFS AK*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE 0–50	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
						SW	as above, well-graded
40	008	-	-				as above
							Bottom of boring 42.0 feet. Total casing assembly 43.43'; Stickup 2.75'
45							
50							
55							
60							
65							
70							
75							

WELL DIAGRAM



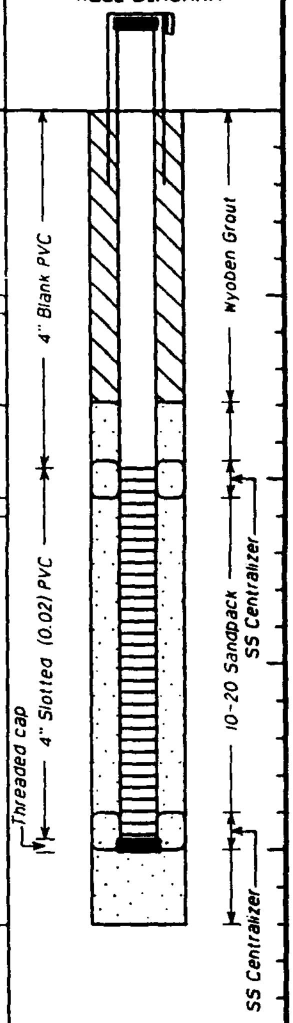
11 CIVIL ENGINEERING OPERATIONS SQ.
OPERATING ENGINEERS

Log of Monitoring Well KV-3

PROJECT: *POL AREA*	LOCATION: *GALENA AFS AK*
PROJECT NO.: *53028*	SURFACE ELEVATION:
DATE STARTED: *5/7/93*	INITIAL H2o LEVEL: *21 ft. BLS*
DATE FINISHED: *5/7/93*	FINAL H2o LEVEL: *21 ft. BLS*
DRILLING METHOD: *12 in. Hollow Stem Auger*	TOTAL DEPTH: *22 Feet*
DRILLING COMPANY: *11 CEOS/CEOR*	GEOLOGIST: *JOE MILLHOUSE*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	SOIL CLASS	GEOLOGIC DESCRIPTION
				SM	silty Sand, fine sand, 2.5Y 5/4 light olive brown, damp, very loose, trace fibrous organic
5	001	2	00	SP-SM	6" layer fine sand
	002	5	0	SM	silty fine sand as above, trace fibrous organics
10	003	4	0	SP	poorly-graded Sand, fine sand, 2.5Y 5/4 light olive brown damp, loose, sugary texture
				ML	4" layer brown silt, dilatent
				SP	poorly-graded Sand as above
15	004	10	0	SW	well-graded Sand with gravel, 3/4 inch maximum subrounded gravel, 2.5Y 4/0 dark grey, damp, loose
20	005	3	0		as above, less gravelly, color change to 2.5Y 4/0 dark grey when saturated ▼ water level while drilling
					Bottom of boring 22.0 feet. Total casing assembly 23.07'; Stickup 3.0'

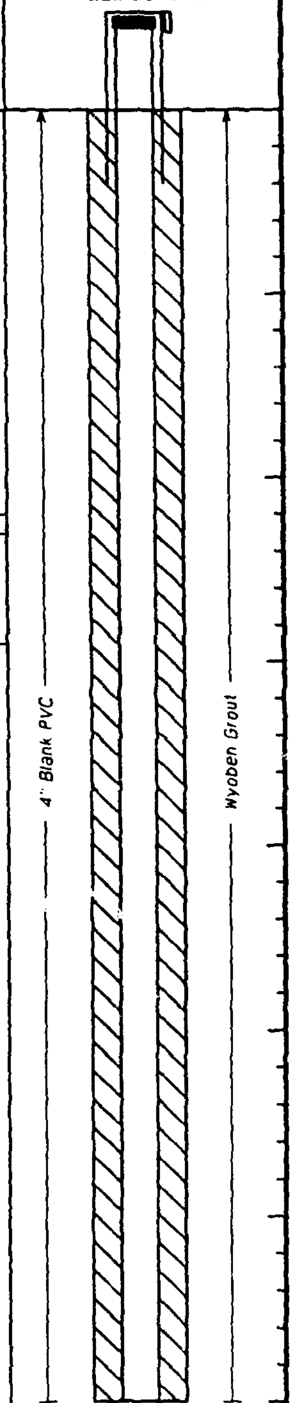
WELL DIAGRAM



11 CIVIL ENGINEERING OPERATIONS SQ. OPERATING ENGINEERS	Log of Monitoring Well KV-4A
PROJECT: *POL AREA*	LOCATION: *GALENA AFS AK*
PROJECT NO.: *53028*	SURFACE ELEVATION:
DATE STARTED: *5/21/93*	INITIAL H2o LEVEL: *13 ft. BLS*
DATE FINISHED: *5/21/93*	FINAL H2o LEVEL: *13 ft. BLS*
DRILLING METHOD: *12 in. Hollow Stem Auger*	TOTAL DEPTH: *52 Feet*
DRILLING COMPANY: *11 CEOS/CEOR*	GEOLOGIST: *JOE MILLHOUSE*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE 0–50	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0						SM	
5	001	3	0				silty Sand fine sand, 2.5Y 5/4 light olive brown, damp, loose, finely laminated with fibrous organics
							decreasing silt
10	002	4	0				
						ML	Silt with fine sand, wet, soft
						SP	▼ Water level while drilling poorly-graded Sand with little silt, medium to fine sand, 2.5Y 5/4 light olive brown, wet, loose
15	003	8	-			SW	well-graded Sand with gravel, 3/4 inch maximum subrounded gravel, 2.5Y 4/0 dark grey, saturated, loose
20	004	8	-				as above, 3/4 inch maximum subrounded gravel, 2.5Y 4/0 dark grey when saturated, 1' heave
25	005	9	-				as above, saturated, loose, 1' heave
30	006	7	-				no recovery
35	007	8	-				

WELL DIAGRAM



11 CIVIL ENGINEERING OPERATIONS SQ.
OPERATING ENGINEERS

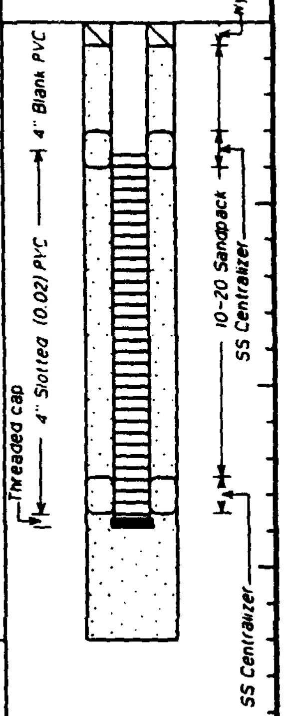
Log of Monitoring Well KV-4A

PROJECT: *POL AREA*

LOCATION: *GALENA AFS AK*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE (0–50)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
						SW	as above, well-graded, 1' heave
40	008	8	-				as above, soils appear uniform throughout, no change in drilling action, 1' heave
45	009	20					no recovery, .5' heave
50	010						
							Bottom of boring 52.0 feet. Total casing assembly 51.90'; Stickup 2.90'
55							
60							
65							
70							
75							

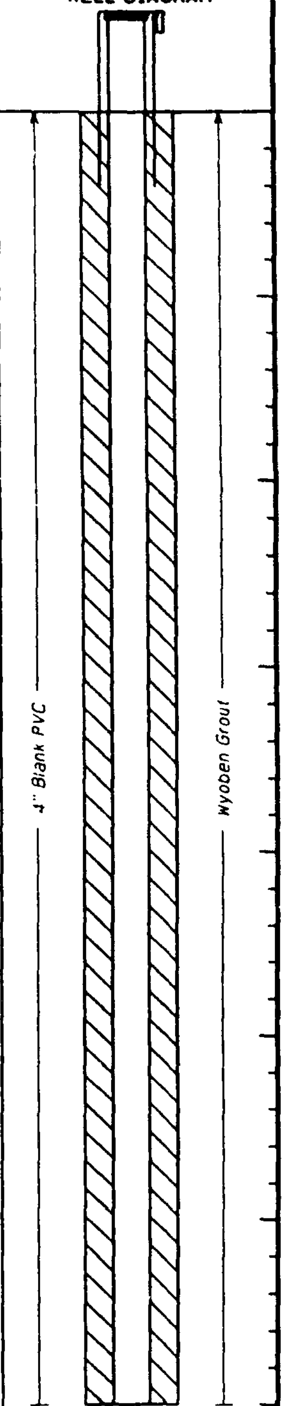
WELL DIAGRAM



11 CIVIL ENGINEERING OPERATIONS SQ. OPERATING ENGINEERS	**Log of Monitoring Well KV-5A**
PROJECT: *POL AREA*	LOCATION: *GALENA AFS AK*
PROJECT NO.: *53028*	SURFACE ELEVATION:
DATE STARTED: *5/8/93*	INITIAL H2o LEVEL: *20 ft. BLS*
DATE FINISHED: *5/8/93*	FINAL H2o LEVEL: *20 ft. BLS*
DRILLING METHOD: *12 in. Hollow Stem Auger*	TOTAL DEPTH: *67 Feet*
DRILLING COMPANY: *11 CEOS/CEOR*	GEOLOGIST: *JOE MILLHOUSE*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE 0–50	SOIL CLASS	GEOLOGIC DESCRIPTION
					SM	silty Sand fine sand, 2.5Y 5/4 light olive brown, damp, very loose, fibrous organics
5	001	3	0			
					SP	poorly-graded Sand, medium to fine sand, 2.5Y 5/4 light olive brown, damp, loose
10	002	4	0			
					SW	
15	003	7	0			well-graded Sand with gravel, 3/4 inch maximum subrounded gravel, 2.5Y 5/4 Light olive brown, damp, loose
20	004	8	-			▼ water level while drilling as above, 3/4 inch maximum subrounded gravel, 2.5Y 4/0 dark grey when saturated.
25	005	6	-			as above, saturated, loose, 1' heave
30	006	6	-			sand, as above, little recovery, 3' heave
35	007	-	-			

WELL DIAGRAM



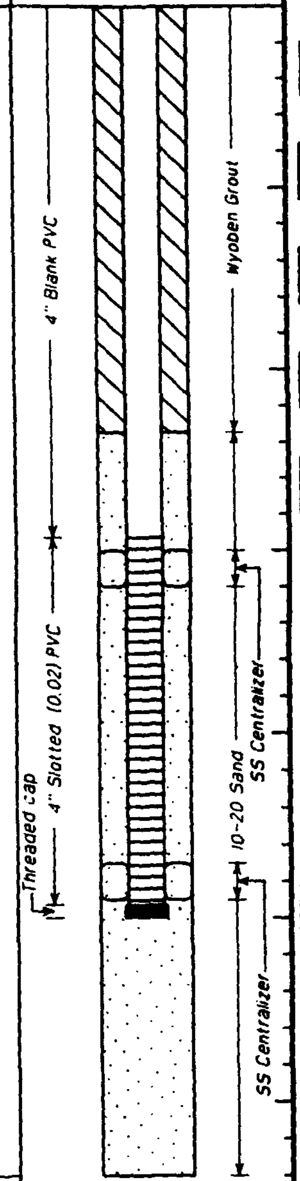
II CIVIL ENGINEERING OPERATIONS SQ.
OPERATING ENGINEERS

Log of Monitoring Well KV-5A

PROJECT: *POL AREA* **LOCATION:** *GALENA AFS AK*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE 0–50	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
						SW	
40	008	-	-				as above, soils appear uniform throughout, no change in drilling action, 1' heave
45	009	6	-				1-1/2 inch maximum gravel
50	010	8	-				as above, 1' heave
55	011	9	-				more gravelly, 1.5' heave
60	012	-	-				no sample
65							
							Bottom of boring 67.0 feet. Total casing assembly 63.00'; Stickup 3.00'
70							
75							

WELL DIAGRAM



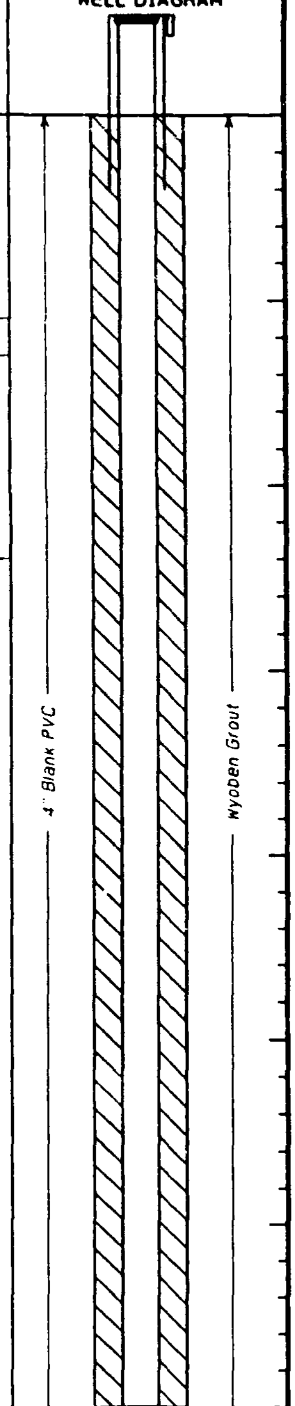
11 CIVIL ENGINEERING OPERATIONS SQ.
OPERATING ENGINEERS

Log of Monitoring Well KV-6A

PROJECT: *POL AREA*	LOCATION: *GALENA AFS AK*
PROJECT NO.: *53028*	SURFACE ELEVATION:
DATE STARTED: *5/13/93*	INITIAL H2o LEVEL: *19.75 ft. BLS*
DATE FINISHED: *5/13/93*	FINAL H2o LEVEL: *19.75 ft. BLS*
DRILLING METHOD: *12 In. Hollow Stem Auger*	TOTAL DEPTH: *72 Feet*
DRILLING COMPANY: *11 CEOS/CEOR*	GEOLOGIST: *JOE MILLHOUSE*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE (0–50)	SOIL CLASS	GEOLOGIC DESCRIPTION
0–5.5					ML	Silt with fine sand, 2.5Y 5/4 light olive brown, damp, very loose, some fibrous organics
5	001	2	0			
5.5–6.5					SM	finely laminated silty Sand
6.5–12					SP	poorly-graded Sand, medium to fine sand, 2.5Y 5/4 light olive brown, damp, loose, uniform sand
10	002	4	0			
12–35					SW	well-graded Sand with gravel, 1/2 inch maximum subrounded gravel, 2.5Y 5/4 Light olive brown, damp, loose
15	003	9	0			
20	004	4	-			▼ water level while drilling
						as above, 2.5Y 4/0 dark grey when saturated
25	005	3	-			as above, saturated, very loose
30	006	-	-			sand, as above
35	007	2	-			

WELL DIAGRAM



11 CIVIL ENGINEERING OPERATIONS SQ.
OPERATING ENGINEERS

Log of Monitoring Well KV-6A

PROJECT: *POL AREA* | LOCATION: *GALENA AFS AK*

DEPTH feet	SAMPLE NO.	BLOWS/FT.	PID (ppm) VALUES	PID (ppm) PROFILE (0–50)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
						SW	as above, little recovery, 2' heave
40	008	-	-				little recovery
45	009	4	-				little recovery
50	010	9	-				as above, little recovery
55	011	9	-				as above, well graded
60	012	-	-				as above
65	013	13	-				
70	014	20	-				
							Bottom of boring 72.0 feet. Total casing assembly 73.00'; Stickup 3.00'
75							

WELL DIAGRAM