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1097.01

February 18, 1994

Stephen W. Sommerhalter, Esq.
Buchalter, Nemer, Field & Younger
333 Market Street, 29th Floor
San Francisco, CA 94105

Re: Montgomery Ward Auto Service Center
7575 Dublin Blvd., Dublin, California

Dear Mr. Sommerhalter:

Enclosed is a copy of the report by Cypress Environmental entitled, "Groundwater Pumping Test Results Enea Plaza, 6700 - 6780 Amador Plaza Road, Dublin, California" dated February 11, 1994.

Note that Cypress Environmental did not have access to precise groundwater elevation data, and thus did not approximate a zone of capture for groundwater extraction at wells at the Enea Plaza site. But as noted at page 5, the depth to groundwater as measured in wells EW-1, MW-1 through MW-4 and PZ-1 on February 8, 1994 prior to beginning the constant-discharge test (table number 3) can be converted to groundwater elevations from the top-of-casing elevations which you have from the Kier & Wright survey. With that groundwater elevation data, the hydraulic gradient beneath the site can be calculated and, in turn, the gradient and the estimated transmissivity (discussed at pp. 6-11) can be used to approximate the zone of capture for groundwater extraction wells at Enea Plaza.

Very truly yours,

ANDREW J. PIUNTI

AJP/tmr

Enclosure

Cypress
Environmental

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Vee
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Groundwater Pumping Test Results
Enea Plaza
6700 - 6780 Amador Plaza Road
Dublin, California

2/94

Prepared for
Enea Plaza - A California General Partnership
c/o Enea Properties
6670 Amador Plaza Road
Dublin, California 94568

Prepared by
Cypress Environmental
Project 124-1.1
February 11, 1994

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GROUNDWATER PUMPING TEST RESULTS
ENEA PLAZA
DUBLIN, CALIFORNIA
February 11, 1994

1.0 INTRODUCTION

This report summarizes the results of the groundwater pumping tests conducted to characterize the hydraulic parameters of the aquifer beneath the Enea Plaza in Dublin, California. Discussions of purpose, scope of work, and findings are presented below.

1.1 Purpose

To design an extraction system that will effectively capture the dissolved chemical constituents present in groundwater beneath the site, the physical properties of the water-bearing zone or aquifer beneath the site must be characterized. Groundwater pumping tests were conducted to determine the optimum pumping or discharge rate, and transmissivity, hydraulic conductivity, and storativity of the aquifer. These parameters, along with the hydraulic gradient, can be used to design an effective remediation system for the site.

1.2 Scope of Work

Prior to conducting the groundwater pumping tests, one extraction well (EW-1) and one piezometer (PZ-1) were installed near existing monitoring well MW-1 (see Figure 1). Well EW-1 was developed and used as the extraction well during the groundwater pumping tests. Monitoring wells MW-1 through MW-4 and piezometer PZ-1 were used as observation wells for obtaining water level data during the pumping tests. Per the specifications of Keiley, Enea & Piunti, a step-discharge test and an 8-hour constant-discharge test were conducted on February 7 and 8, 1994, respectively. The following sections include discussions of extraction well and piezometer installation, and the groundwater pumping test results.

2.0 EXTRACTION WELL AND PIEZOMETER INSTALLATION

As stated above, one extraction well (EW-1) and one piezometer (PZ-1) were installed near existing monitoring well MW-1 (see Figure 1). The extraction well and piezometer were installed in essentially the same stratigraphic zone as monitoring wells MW-1 through MW-4. Because well MW-1 contained only 6.5 feet of water, a deeper well was needed to provide an adequate water column for performing the pumping tests. Well EW-1 and piezometer PZ-1 were installed up to 6.5 feet deeper than well MW-1. Table 1 summarizes the well construction details for the site monitoring wells, extraction well, and piezometer. The methods of extraction well and piezometer installation are discussed below.

2.1 Extraction Well and Piezometer Installation

Well EW-1 and piezometer PZ-1 were drilled and installed by HEW Drilling (HEW) of Palo Alto, California on February 4, 1994. The drilling and well/piezometer installation were supervised by Cypress Environmental's State-registered geologist. Installation of the well and piezometer was permitted by the Alameda County Zone 7 Water Agency.

The borehole for well EW-1 was continuously cored from depths of 1 foot to 22 feet (the total depth of the borehole). Upon completion, the borehole was reamed using 10-inch-diameter hollow-stem augers to facilitate installation of the 4-inch-diameter well casing. The borehole for piezometer PZ-1 was drilled using 8-inch-diameter hollow-stem augers. Because of its close proximity to well EW-1, piezometer PZ-1 was not continuously cored. Instead, soil samples for lithologic logging were collected at depths of 11 to 12.5 feet and 18 to 19.5 feet using a modified California split-spoon sampler. The soil core and drive samples were logged by Cypress Environmental's State-registered geologist according to the Unified Soil Classification System.

Each borehole was converted to a well or piezometer by installing Schedule 40 PVC casing. The casing diameters for well EW-1 and piezometer PZ-1 are 4 inches and 1 inch, respectively. Well screens (0.020-inch) were placed from the bottom of each hole to 10 feet below grade. The annular space around each casing was packed with No. 3 Lonestar sand from the bottom of the borehole to 1.5 feet above the well screens. Each well/piezometer was then sealed with 2 feet of hydrated bentonite pellets above the sand pack and cement grout above the bentonite to the ground surface. The well heads were secured with water-tight caps enclosed in traffic-rated surface vaults. Well EW-1 was locked with a Master lock; locking caps are not available for 1-inch-diameter wells/piezometers. Lithologic logs and construction details for well EW-1 and piezometer PZ-1 are provided in Appendix A.

All drill cuttings were contained in 55-gallon drums which were properly labeled and stored on site for future disposal.

2.2 Extraction Well Development

Well EW-1 was developed on February 6, 1994 to remove fines from the well and improve hydraulic communication with the aquifer. The well was developed using a 4-inch-diameter, vented surge block, a 2-inch-diameter PVC bailer, and a 1.7-inch-diameter, PVC, positive-displacement hand pump. Approximately 105 gallons (12.5 casing volumes) of groundwater were removed from the well over a 3.5-hour period. Temperature, electrical conductivity, and pH were monitored during development. In addition, total settleable solids were measured using Emhoff cones. Development was performed until the amount of sand and silt being produced had significantly decreased to 0.2 and 15 milliliters per liter, respectively. The well development data sheet is included in Appendix B.

The well development water was contained in 55-gallon drums which were subsequently pumped into a 5,000-gallon tanker truck along with the pumping test discharge. Integrated Wastestream Management, Inc. (IWM) will dispose of these materials at a permitted waste facility in February 1994.

2.3 Results of Subsurface Investigation

The soil types encountered in the borings for well EW-1 and piezometer PZ-1 are described on the lithologic logs provided in Appendix A. These logs indicate that the pumping test area is underlain by interbedded clays, silts, and clayey sands. Groundwater was first encountered in the recent borings at depths of 11 to 11.5 feet below the ground surface. The water-bearing zone is composed of clayey sands, silts, and clays with abundant open rootholes.

3.0 GROUNDWATER PUMPING TESTS

Groundwater pumping tests were performed by Cypress Environmental and Einarson Geoscience, Inc. on February 7 and 8, 1994. A step-discharge test was conducted to determine the optimum pumping or discharge rate, and an 8-hour constant-discharge test was conducted to estimate hydraulic parameters such as transmissivity, hydraulic conductivity, and storativity. The following sections include the methods used, data analysis, and a discussion of the results.

3.1 Pumping and Data Acquisition Equipment

A 3.75-inch-diameter, 1-horsepower, stainless-steel, submersible Grundfos pump was used to conduct the step-discharge and constant-discharge pumping tests. The pump was suspended in the well using 1-inch-diameter PVC pipe. The discharge rate of the pump was controlled by a valve on the pump outflow line. The outflow discharge rate was measured using a 0 to 10 gallon-per-minute (gpm) range rotameter and a totalizing meter. During each of the pumping tests, the flow rate was verified periodically by timing the groundwater flow through the flow totalizing meter. The discharge was collected in a 5,000-gallon tanker truck owned by IWM. IWM will dispose of the groundwater at a permitted facility in February 1994.

At regular intervals during the pumping tests, an electric well sounder was used to measure water levels in wells EW-1, MW-1 through MW-4, and PZ-1. Water levels in wells EW-1, MW-1, and PZ-1 were also measured using pressure transducers and a programmable Instrumentation Northwest Terra 8 datalogger. The pressure transducers, with full-scale ranges from 0 to 10 pounds per square inch (psi) or 0 to 20 psi, were used to measure water level changes in these wells. The datalogger was used to record and store the time-drawdown measurements from each pressure transducer. A Toshiba T1000 laptop computer was used to interface with the datalogger during the tests. All datalogs (entries) were printed in the field as a hard copy backup using a portable printer.

3.2 Step-Discharge Test

A step-discharge test was conducted in well EW-1 on February 7, 1994. The purpose of the step-discharge test was to estimate the maximum pumping rate that could be sustained during the subsequent constant-discharge pumping test. During the step-discharge test, well EW-1 was pumped at three pumping rates, or steps. The drawdown in the pumping well was monitored during each step using a pressure transducer and datalogger. The first step was conducted at a pumping rate of 2 gpm. This rate was maintained for approximately 53 minutes and resulted in 0.42 feet of drawdown. The flow rate was then increased to approximately 5 gpm for the second step. This second pumping rate was maintained for approximately 55 minutes and resulted in an additional drawdown of 3.39 feet. The pumping was terminated after the second step and the water level in well EW-1 was permitted to recover. The third step, which was initiated after the water level had fully recovered, was conducted for approximately 53 minutes at a flow rate of approximately 7 gpm. The total drawdown at the end of the third step was 7.21 feet. Figures 2 and 3 illustrate the time-drawdown data for the three steps.

Based on the results of the step-discharge tests in well EW-1, an optimal pumping rate of approximately 5 gpm was selected for use in the constant-discharge test.[1] It was thought that this pumping rate could be sustained over the 8-hour constant-discharge test without significantly drawing down the water level in the pumping well, while at the same time producing measurable water level changes in the nearby observation wells. In addition, use of a 5 gpm pumping rate minimized the draw of contaminated groundwater onto the site.

3.3 Constant-Discharge Test

Constant-discharge pumping tests are performed to investigate the hydraulic characteristics of aquifers. Hydraulic characteristics are determined by pumping a well at a constant rate and measuring the drawdown in the pumping well and in nearby observation wells. Information regarding hydraulic characteristics such as transmissivity, hydraulic conductivity, storativity, and boundary conditions may be determined. Boundary conditions include recharge boundaries and impermeable boundaries (Kruseman and de Ridder, 1990).

A constant-discharge test was performed on February 8, 1994 at the selected pumping rate of 5 gpm. Groundwater levels in wells EW-1, MW-1 through MW-4, and PZ-1 were monitored throughout the test. Pumping was conducted for 505 minutes (8 hours, 24 minutes), at which time the test was terminated. The cumulative drawdown in the pumping well and each of the observation wells is summarized in Table 2. Plots of the time-drawdown data for wells EW-1, MW-1, and PZ-1 are presented in Figures 4 through 9. These graphs were used to calculate hydraulic coefficients, as discussed in the following section.

The water levels in wells EW-1, MW-1, and PZ-1 were monitored after pumping was terminated. After approximately 17 minutes, the water level in well EW-1 recovered to 95 percent of its pre-pumping level. Over the same time period, water levels in wells MW-1 and PZ-1 recovered to 60 percent and 57 percent of their pre-pumping levels, respectively.

3.4 Data Analysis and Results

3.4.1 Depth to Groundwater Measurements

The depths to groundwater were measured in wells EW-1, MW-1 through MW-4, and PZ-1 on February 8, 1994, prior to beginning the constant-discharge test. These pre-pumping data, which are presented in Table 3, can be converted to groundwater elevations if top-of-casing elevations are available. By using groundwater elevation data, the hydraulic gradient beneath

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[1] The results of the step-discharge test indicated a flow rate of 7 gpm would deplete the available water column (8 feet) in the pumping well before the 8-hour constant-discharge test was completed (see Figure 3).

the site can be calculated. In turn, the gradient and the estimated transmissivity (discussed below) can be used to approximate the zone of capture for groundwater extraction wells at this site.

3.4.2 Constant-Discharge Test Results

Time-drawdown measurements made during the constant-discharge test provide a means of calculating aquifer coefficients such as transmissivity and storativity. Transmissivity (T) is a measurement of the ability of an aquifer to transmit water to a well. Transmissivity divided by the thickness of the aquifer yields hydraulic conductivity (K). Hydraulic conductivity is an important parameter needed to (1) design groundwater pumping systems, (2) model the movement of groundwater, and (3) model the fate and transport of chemical compounds contained in groundwater. Transmissivity (and consequently hydraulic conductivity) can be calculated from time-drawdown measurements made in either the pumping well or in observation wells. Storativity (S) is a dimensionless number that represents the volume of water released from storage in a unit thickness of the aquifer per unit decline in the water level in the well. Values of storativity range from 0.0005 in confined aquifers to 0.2 in unconfined aquifers (Driscoll, 1986). Storativity can be calculated only from time-drawdown or recovery measurements made in observation wells.

In addition to providing a means of determining aquifer coefficients, pumping tests also provide valuable information regarding the physical boundaries of the aquifer. For example, as pumping continues, the cone of depression in the well becomes wider. If the cone of depression encounters an impermeable boundary (e.g., a fault, bedrock wall, or pinched-out sand channel), the cone of depression must increase vertically in order to provide a constant flow of water to the well. Thus, an impermeable boundary (also referred to as a negative boundary) can be identified during a pumping test by a sudden increase in the drawdown. Conversely, recharge boundaries (e.g., streams or larger, more permeable sand channels) can be recognized by decreases in the drawdown rate in the pumping well. Time-drawdown data obtained after a hydraulic boundary is encountered cannot be used to calculate aquifer coefficients (Driscoll, 1986).

The most widely used methods of calculating aquifer coefficients are graphical straight-line or curve-matching projections of time-drawdown data. These methods are based on analytical solutions to complex three-dimensional differential equations governing flow in porous media. In order to solve the flow equations analytically, several simplifying assumptions are made regarding the aquifer boundaries and homogeneity. A complete discussion of these assumptions is presented in Driscoll (1986) and Kruseman and de Ridder (1989). In reality, very few aquifers fulfill all of the assumptions of the analytical solutions. This is true of materials like those underlying the Enea Plaza which are heterogeneous, anisotropic, and possibly of limited lateral extent. Therefore, the limitations of the analytical solutions should be kept in mind, and the aquifer coefficients calculated in the following sections should be considered estimates.

Casing Storage Effects

Casing storage effects are observed early in pumping tests as the water stored within the casing is removed. As the water level in the casing declines, water begins to enter the well from the surrounding formation. With time, more and more of the well's yield comes from the surrounding formation (Driscoll, 1986). Casing storage is important because, with most analytical solutions, drawdown data can only be analyzed after the hydraulic effects of casing storage are negligible. To determine when the effects of casing storage are negligible, an equation developed by D. C. Schafer (Driscoll, 1986) may be used. The equation is as follows.

(Equation 1) $$t_c = \frac{0.6\,(d_c^2 - d_p^2)}{Q/s}$$

where:

t_c = time when casing storage effect becomes negligible (minutes)
d_c = inside diameter of well casing (inches [in])
d_p = outside diameter of pump column pipe (in)
Q/s = specific capacity in gpm per foot (gpm/ft) of drawdown at time t_c

To use Equation 1, an initial drawdown is selected and a t_c calculated. Then the drawdown is noted at that time and the actual drawdown value is substituted into the equation. This process is repeated until the actual and calculated time values coincide. Casing storage effects were calculated using this equation except that an effective radius, which includes the fluid stored in the wellbore sandpack, was used instead of d_c, the inside diameter of the well casing. Using an effective radius provides a more accurate estimation of t_c, especially in fine-grained formations.

Following the above equation, casing storage for well EW-1 during the constant-discharge test was calculated to be negligible after approximately 5 minutes. Time-drawdown data after 5 minutes were therefore used to calculate values of transmissivity and storativity using conventional analytical solutions.

Impermeable/Recharge Boundary

No obvious impermeable (negative) or recharge (positive) boundaries were encountered during the 8-hour constant-discharge test at this site. However, it is possible that a boundary effect could be encountered if pumping were continued for a longer time.

Selection of Analytical Method

Three methods were used to analyze the time-drawdown data: the Cooper-Jacob straight-line method, the Theis curve-matching method, and a distance-drawdown plot. The Cooper-Jacob and Theis methods are typically used for confined aquifer conditions. Although the aquifer beneath the site is unconfined to semi-confined, these methods were deemed appropriate for use in this case. In fine-grained formations, such as those encountered at this site, gravity drainage of the dewatered aquifer may take weeks or even months. Therefore, the initial drawdown measured during the first few days of pumping responds as in a confined aquifer (Kruseman and de Ridder, 1989). Because of the short duration of this pumping test and the fine-grained materials underlying the site, the Cooper-Jacob and Theis methods were used to analyze the portion of the EW-1, MW-1, and PZ-1 time-drawdown data after casing storage effects became negligible (i.e, after 5 minutes). In addition, a distance-drawdown plot was constructed using data from all the observation wells at the site that were influenced during the 8-hour pumping test (i.e., MW-1, MW-3, MW-4, and PZ-1). The water level in well MW-2 did not change during the course of the 8-hour pumping test.

A computer program, AQTESOLV™ (Duffield and Rumbaugh, 1991), was used to plot and analyze the time-drawdown data. By using the program, a straight line was fitted to the semi-log data (drawdown vs. log time; Cooper-Jacob method), or a curve was matched to the log-log data (log drawdown vs. log time; Theis method). AQTESOLV™ then automatically calculated the aquifer coefficients based on the fitted line or curve match. The aquifer coefficients calculated using these methods are presented in Table 4. A detailed discussion of the analyses, including equations used to manually calculate the aquifer coefficients, is presented in the following sections.

Cooper-Jacob Straight-Line Method

Time-drawdown data from wells EW-1, MW-1, and PZ-1 were used to calculate the transmissivity of the materials underlying the site using the modified nonequilibrium Cooper-Jacob straight-line method (Cooper and Jacob, 1946). Hydraulic conductivity values were calculated by dividing the transmissivity values by the thickness of the saturated formation (estimated to be 13 feet based on lithologic logs[2]). The equation for calculating transmissivity (T) using the Cooper-Jacob method is shown in Equation 2.

(Equation 2) $$T = \frac{264Q}{\Delta s}$$

where:

T = transmissivity (gallons per day per foot [gpd/ft])
Q = pumping rate (gpm)
Δs = slope of the time-drawdown graph expressed as the change in drawdown between any two times on the log scale whose ratio is 10 (i.e., one log cycle) (Driscoll, 1986)

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[2] The saturated formation interval is considered to include the clayey sand, silt, and clay with rootholes between depths of about 9 and 22 feet.

The equation for calculating storativity (S) according to the Cooper-Jacob modified nonequilibrium method is as follows:

(Equation 3) $$S = \frac{0.3\,Tt_o}{r^2}$$

where:

S = storativity, dimensionless
T = transmissivity (gpd/ft)
t_o = intercept of the straight line at zero drawdown, in days
r = distance, in feet, from the pumped well to the observation well where the drawdown measurements were made

The Cooper-Jacob method is valid only when the *u* value of the Theis equation is less than 0.05 (Driscoll, 1986). *u* is defined as:

(Equation 4) $$u = \frac{1.87\,r^2S}{Tt}$$

where:

r = radial distance between the center of pumped well and the point where drawdown is measured (ft)
S = storativity
T = transmissivity (gpd/ft)
t = time (days [d]) after which the analytical method (Equations 2 and 3) is valid

The Cooper-Jacob analyses of time-drawdown data from wells EW-1, MW-1, and PZ-1 are presented in Figures 4, 6, and 8, respectively. A best-fit straight line was drawn along drawdown data collected after the effects of casing storage were negligible. The resulting calculated transmissivity values range from 5.3×10^4 to 1.6×10^5 gpd/ft (5 to 15 feet squared per minute [ft^2/min]. Hydraulic conductivity was calculated by dividing the transmissivity by the saturated thickness of 13 feet. The resulting hydraulic conductivity values range from 1.92×10^{-1} to 5.82×10^{-1} centimeters per second (cm/sec).

To check the assumptions of the Cooper-Jacob method, values of *u* were calculated for wells EW-1, MW-1, and PZ-1. Using the average of the storativity values calculated from time-drawdown data (0.025), *u* is less than 0.05. Therefore, the Cooper-Jacob straight-line method can be applied.

Theis Curve-Matching Method

Time-drawdown data from wells EW-1, MW-1, and PZ-1 were also analyzed using the Theis nonequilibrium equation (Theis, 1935). The equation used to calculate transmissivity is presented below in Equation 5.

(Equation 5) $$T = \frac{114.6QW(u)}{s}$$

where:

T = transmissivity (gpd/ft)
Q = pumping rate (gpm)
$W(u)$ = Well function of u, representing an exponential integral
s = drawdown, in feet, at any point in the vicinity of the well discharging at a constant rate (Driscoll, 1986)

The function *u*, which is solved to determine values of storativity (S), is defined above in Equation 4.

Using the manual curve-matching features of AQTESOLV™, the Theis type curve was superimposed on time-drawdown data from wells EW-1, MW-1, and PZ-1. The resulting transmissivity values range from 4.2 x 10^4 to 1.6 x 10^5 gpd/ft (4 to 15 ft^2/min) and hydraulic conductivity values range from 1.52 x 10^{-1} to 5.92 x 10^{-1} cm/sec. The calculated value of storativity from observation well MW-1 and piezometer PZ-1 is 0.03 and 0.02, respectively. The Theis analyses of time-drawdown data from wells EW-1, MW-1, and PZ-1 are presented in Figures 5, 7, and 9, respectively.

Distance-Drawdown Analysis

Using data from three observation wells MW-1, MW-3, MW-4, and PZ-1, a graph of drawdown versus distance from the pumping well EW-1 was constructed (see Figure 10). The drawdown data for wells MW-1 and PZ-1 are from approximately 428 minutes after the onset of pumping. Because the depths to water in the more distant wells MW-3 and MW-4 were measured by hand and not recorded automatically, the time selected from these two wells is approximately 15 minutes later (at time equals 443 minutes). A distance-drawdown plot is a useful tool in estimating the drawdown at any point from the pumping well at a given time. By extrapolating the slope of the straight line to the "zero" intercept, one may estimate where the area of influence (i.e., the cone of depression) is negligible.

Transmissivity is calculated from distance-drawdown of plots using the following equation:

(Equation 6) $$T = \frac{528\ Q}{\Delta s}$$

where:

T = coefficient of transmissivity (gpd/ft)
Q = pumping rate (gpm)
Δs = slope of the distance-drawdown graph expressed as the change in drawdown, in feet, between any two values of distance on the log scale whose ratio is 10.

Using Equation 6, and a Δs of 0.14 feet taken from the graph presented in Figure 10, a transmissivity value of 1.9×10^4 gpd/ft (1.75 ft^2/min) was calculated. The corresponding hydraulic conductivity is 6.8×10^{-2} cm/sec.

3.5 Discussion

The hydraulic coefficients calculated from the constant-discharge test using the Cooper-Jacob and Theis methods are summarized in Table 4. Transmissivity values calculated from data collected on February 8 range from 4.2×10^4 to 1.6×10^5 gpd/ft (4 to 15 ft^2/min). There is close agreement between the calculated hydraulic coefficients of the pumping well and the observation well and piezometer. In general, data collected from observation wells are considered to be more reliable than data collected from a pumping well. This is because observation wells are less affected by casing storage, skin effects, and diminished well efficiency, than pumping wells. The transmissivity calculated using the distance-drawdown plot is 1.9×10^4 gpd/ft (1.75 ft^2/min); this value is an order of magnitude greater than the transmissivities calculated using the Cooper-Jacob and Theis methods.

The calculated permeabilities of the geologic materials at this site are higher than expected for the types of materials logged in the boreholes. The hydraulic conductivity values calculated by the Cooper-Jacob and Theis methods range from 1.52×10^{-1} to 5.92×10^{-1} cm/sec. The hydraulic conductivity calculated using the distance-drawdown data is 6.8×10^{-2} cm/sec. These values are more typical of clean sands than of the clayey sands, silts, and clays that characterize the stratigraphy at the site. It is likely that much of the soil permeability at this site is secondary and is derived from the abundant open rootholes that penetrate the soils.

Storativity values calculated from the MW-1 and PZ-1 data are 0.03 and 0.02, respectively. These values are lower than typical of an unconfined aquifer, where storativity is typically in the range of 0.1 to 0.2, and are more representative of a semi-confined aquifer. However, as discussed above, the drawdown data during these tests may represent conditions prior to gravity drainage of the aquifer. The source of the water pumped from the well may therefore be the same as water pumped from a confined aquifer, namely water released from expansion of the water and compression of the aquifer (Todd, 1980).

No obvious impermeable (negative) or recharge (positive) boundaries were encountered during the 8-hour constant-discharge test at this site. However, it is possible that a boundary effect could be encountered if pumping were continued for a longer time.

Finally, it should be emphasized again that the water-bearing zone beneath the site is significantly different than the ideal aquifers upon which the analytical solutions of groundwater flow were conceived. The fine-grained sediments underlying the site are heterogeneous, anisotropic, and of limited lateral extent. The limitations of the analytical solutions should be kept in mind, and the aquifer coefficients presented in this report should be considered estimates rather than precise numbers.

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Table 1 Well Construction Details									
Well	Installation Date	Distance from EW-1 (feet)	Well Depth (feet)	Borehole Diameter (inches)	Casing Diameter (inches)	Screened Interval (feet)	Filter Pack Interval (feet)	Bentonite Interval (feet)	Cement Seal Interval (feet)
MW-1	1/29/93	6.5	15.5	10	4	10 - 15	8 - 16	6.5 - 8	0 - 6.5
MW-2	1/29/93	355	13	10	4	7 - 12.5	5 - 13	3 - 5	0 - 3
MW-3	1/29/93	124	16	10	4	10 - 15	7.9 - 16	5.9 - 7.9	0 - 5.9
MW-4	NA	121	NA	NA	NA	NA	NA	NA	NA
EW-1	2/4/94	0	22	10	4	10 - 22	8.5 - 22	6.5 - 8.5	0 - 6.5
PZ-1	2/4/94	10	20	8	1	10 - 20	8.5 - 20	6.5 - 8.5	0 - 6.5

Notes: NA = Not available

Table 2
Cumulative Drawdown Data from 8-Hour Constant-Discharge Test

Well	Distance from EW-1	Cumulative Drawdown at End of Test
EW-1	0 feet	1.40 feet
MW-1	6.5 feet	0.28 feet
PZ-1	10 feet	0.25 feet
MW-4	121 feet	0.10 feet
MW-3	124 feet	0.07 feet
MW-2	355 feet	0 feet

Table 3
Depth to Groundwater Measurements

Well	Date	Depth to Water (feet)
MW-1	2/6/94	9.02
	2/8/94	8.72
MW-2	2/7/94	8.63
	2/8/94	8.50
MW-3	2/6/94	9.85
	2/8/94	9.61
MW-4	2/8/94	8.82
EW-1	2/6/94	9.22
	2/8/94	8.92
PZ-1	2/6/94	9.53
	2/8/94	9.25

Note: Depths to groundwater measured from top of casing

Table 4
Constant-Discharge Test Summary

Well	Method of Analysis	Transmissivity (T, gpd/ft)	Transmissivity (T, ft^2/min)	Saturated Thickness (b, feet)	Hydraulic Conductivity (K, cm/sec)	Storativity (S)
EW-1	Cooper-Jacob	5.3×10^4	5	13	1.92×10^{-1}	--
	Theis	4.2×10^4	4	13	1.52×10^{-1}	--
MW-1	Cooper-Jacob	1.6×10^5	15	13	5.82×10^{-1}	0.03
	Theis	1.6×10^5	15	13	5.92×10^{-1}	0.03
PZ-1	Cooper-Jacob	1.5×10^5	14	13	5.36×10^{-1}	0.02
	Theis	1.5×10^5	14	13	5.36×10^{-1}	0.02

Notes: Transmissivity (T) is in gallons per day per foot or feet squared per minute; values are rounded to the nearest whole number
Hydraulic conductivity (K) is in centimeters per second
Storativity (S) is unitless

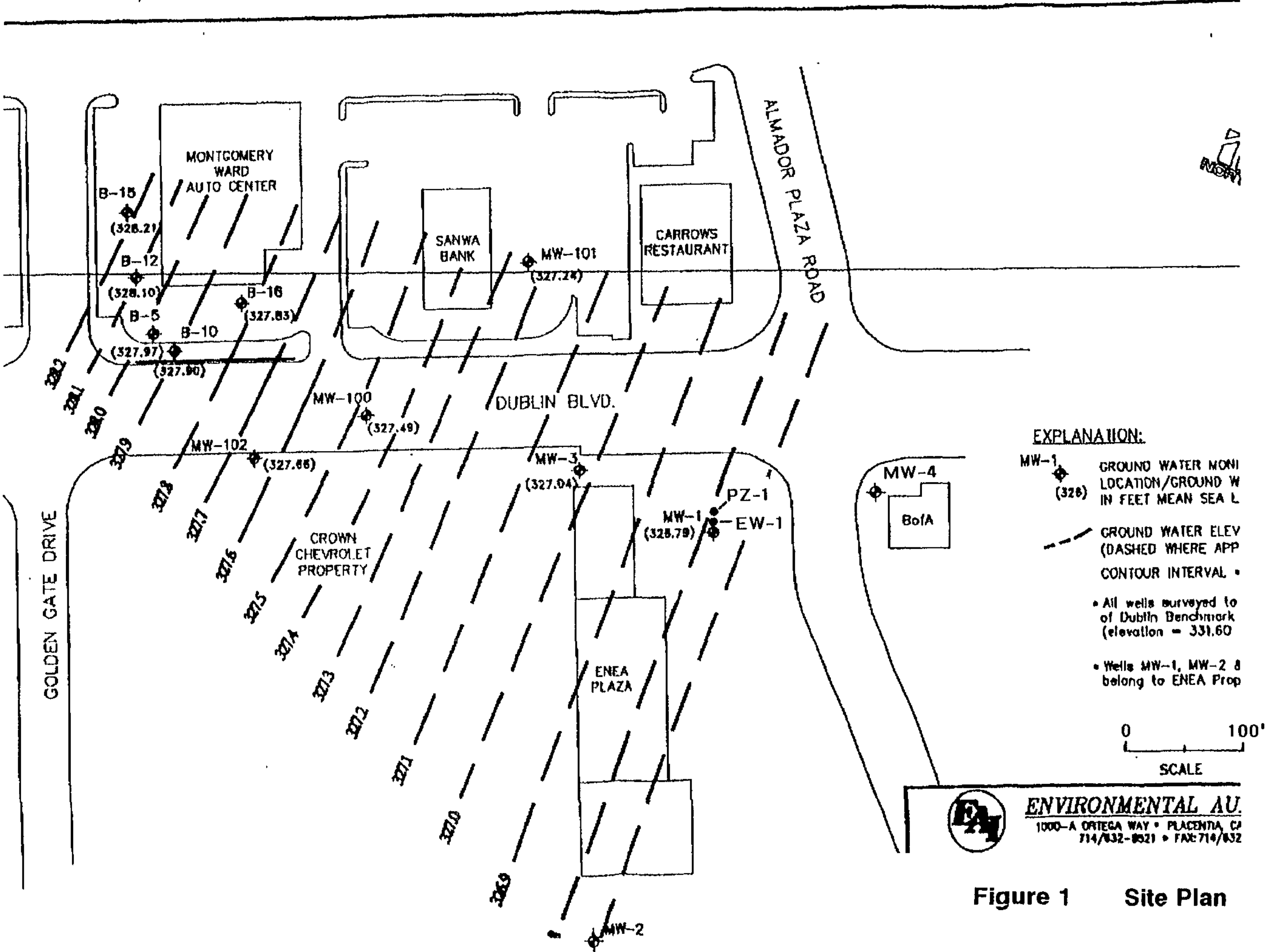


Figure 1 Site Plan

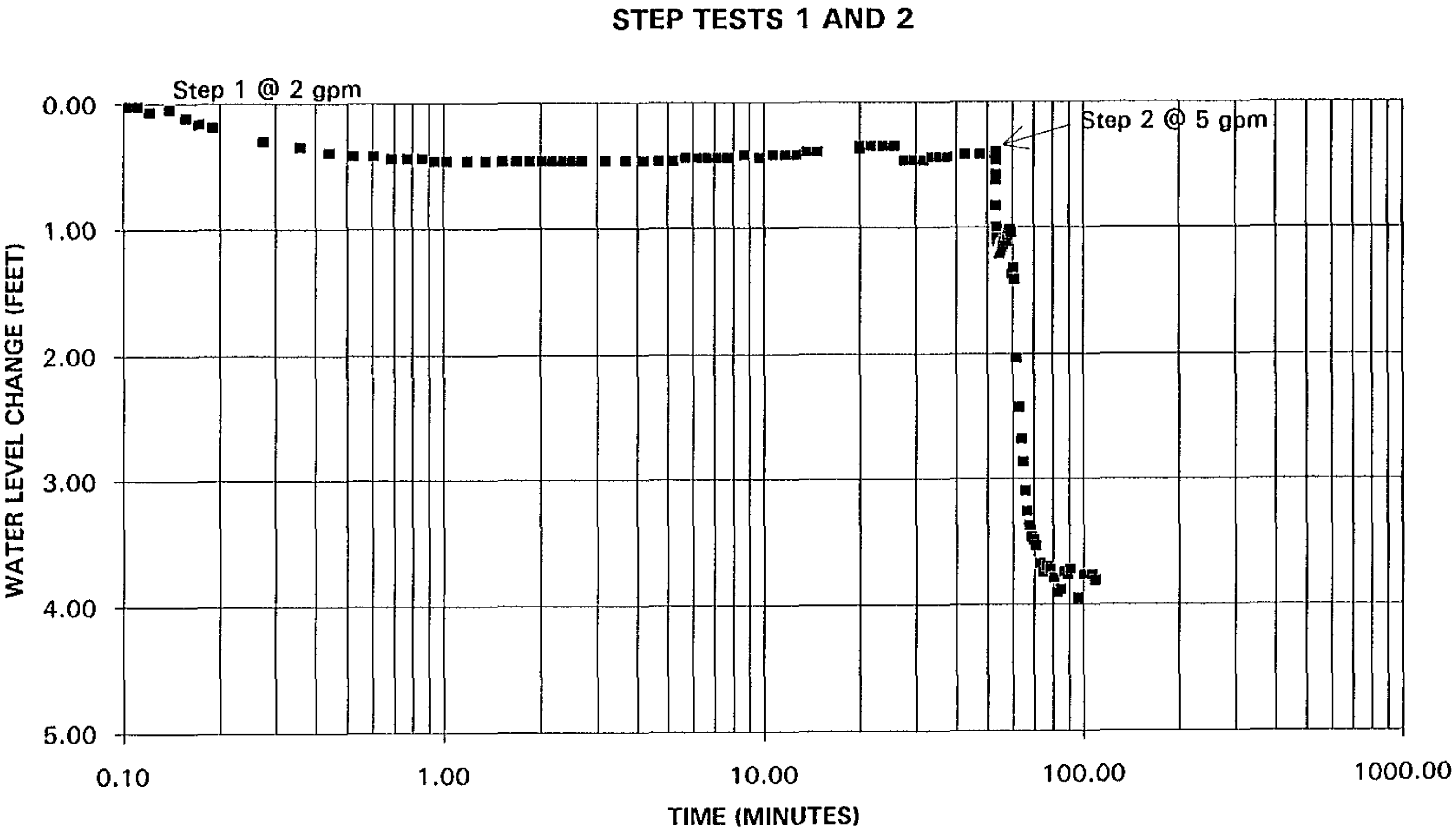


Figure 2 **Step Tests 1 and 2**

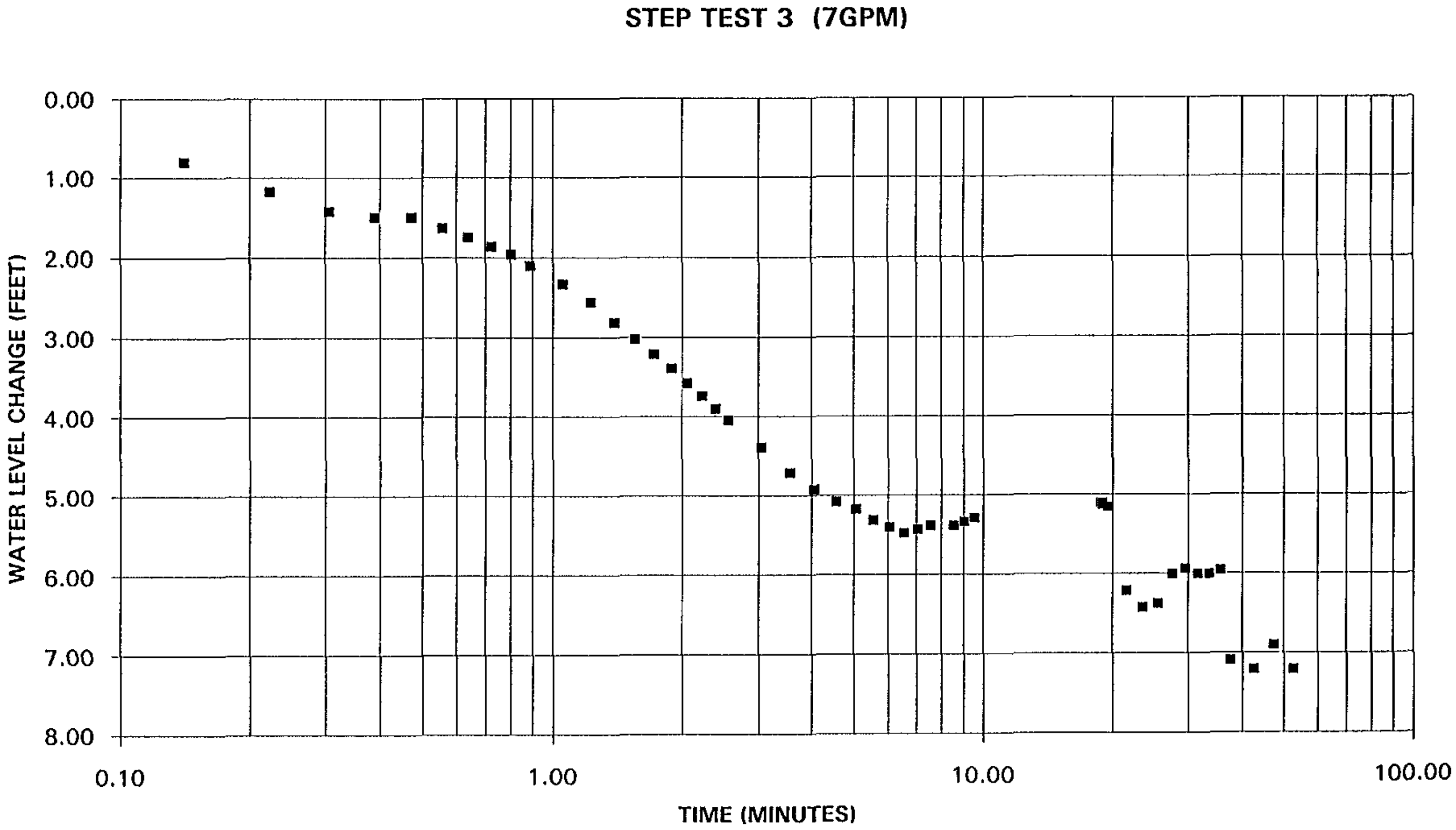


Figure 3 **Step Test 3**

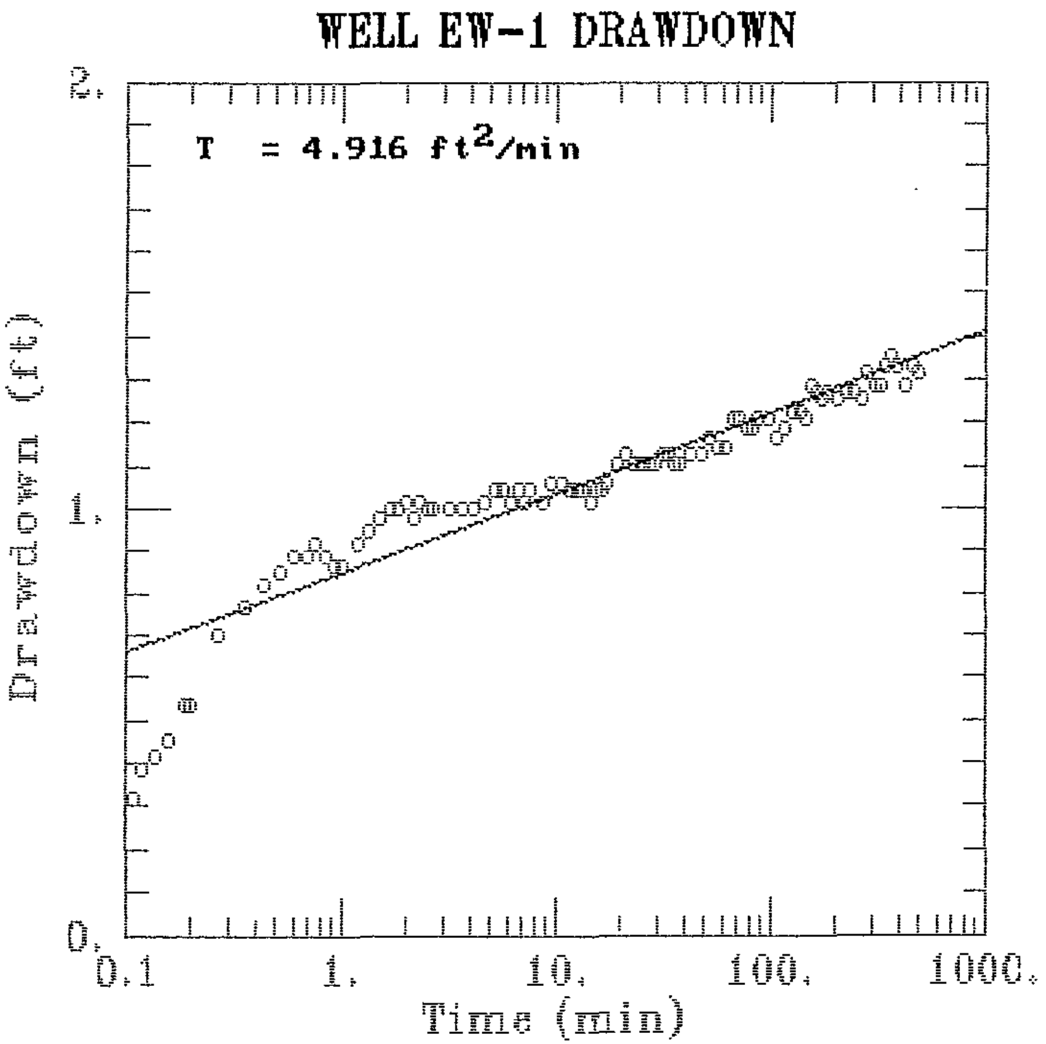


Figure 4 EW-1: Drawdown vs. Log Time (Cooper-Jacob)

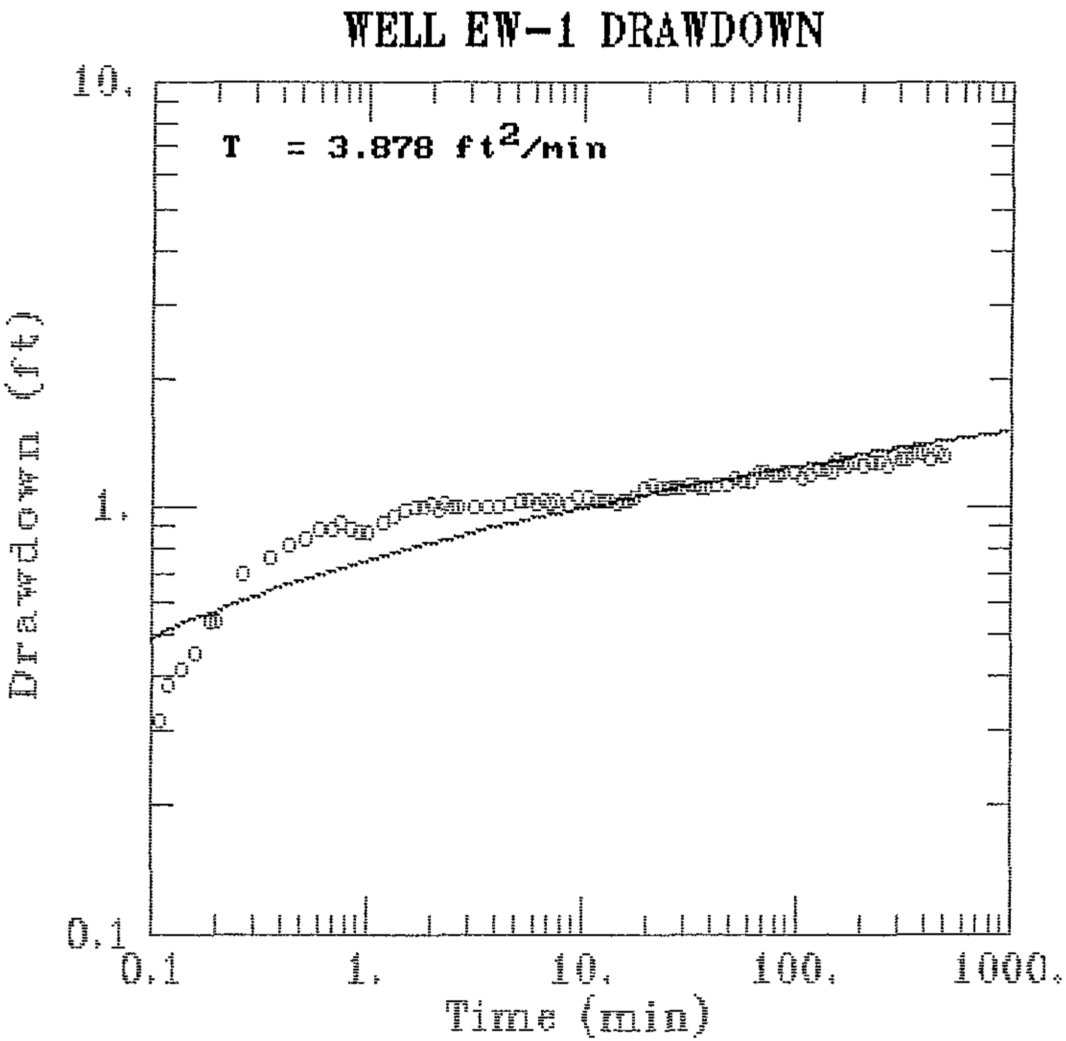


Figure 5 EW-1: Log Drawdown vs. Log Time (Theis)

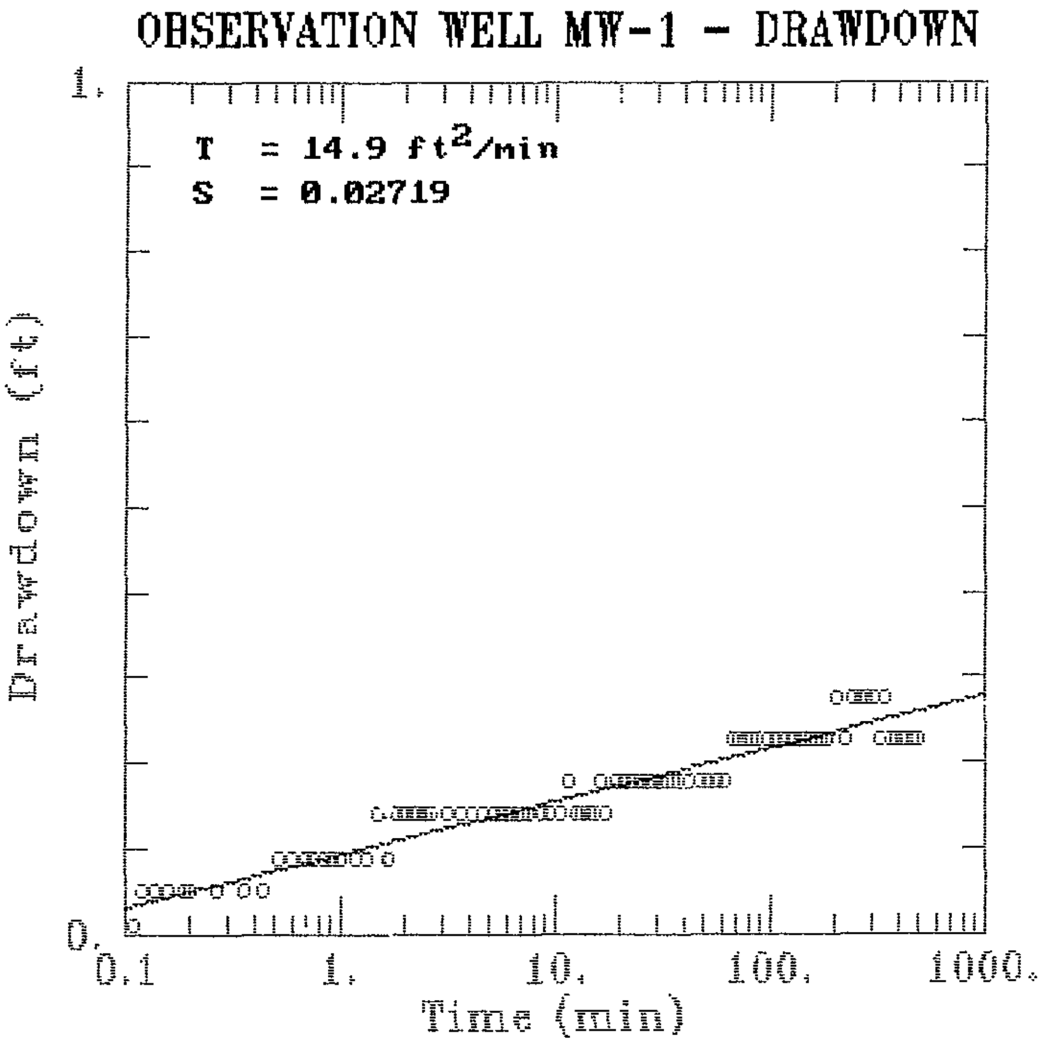


Figure 6 MW-1: Drawdown vs. Log Time (Cooper-Jacob)

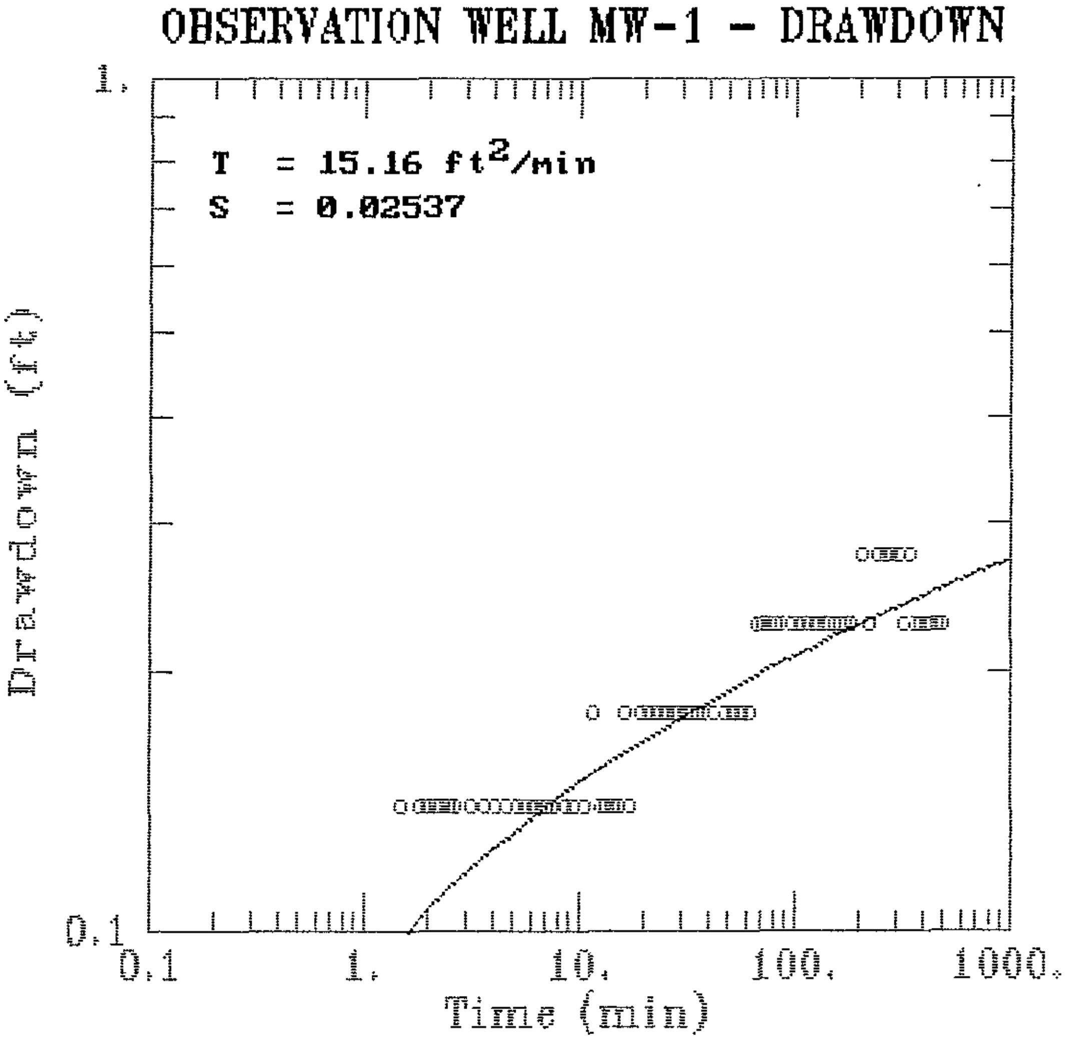


Figure 7 MW-1: Log Drawdown vs. Log Time (Theis)

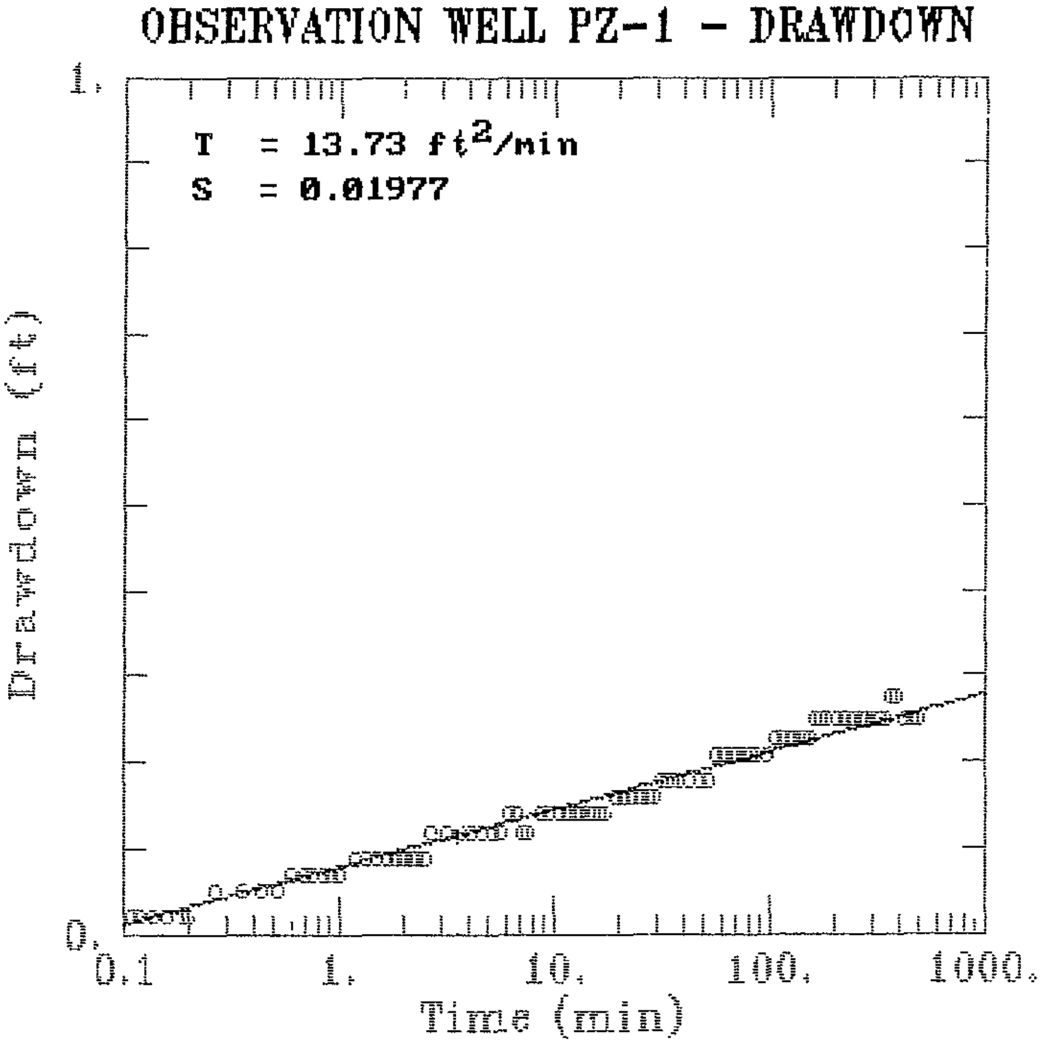


Figure 8 PZ-1: Drawdown vs. Log Time (Cooper-Jacob)

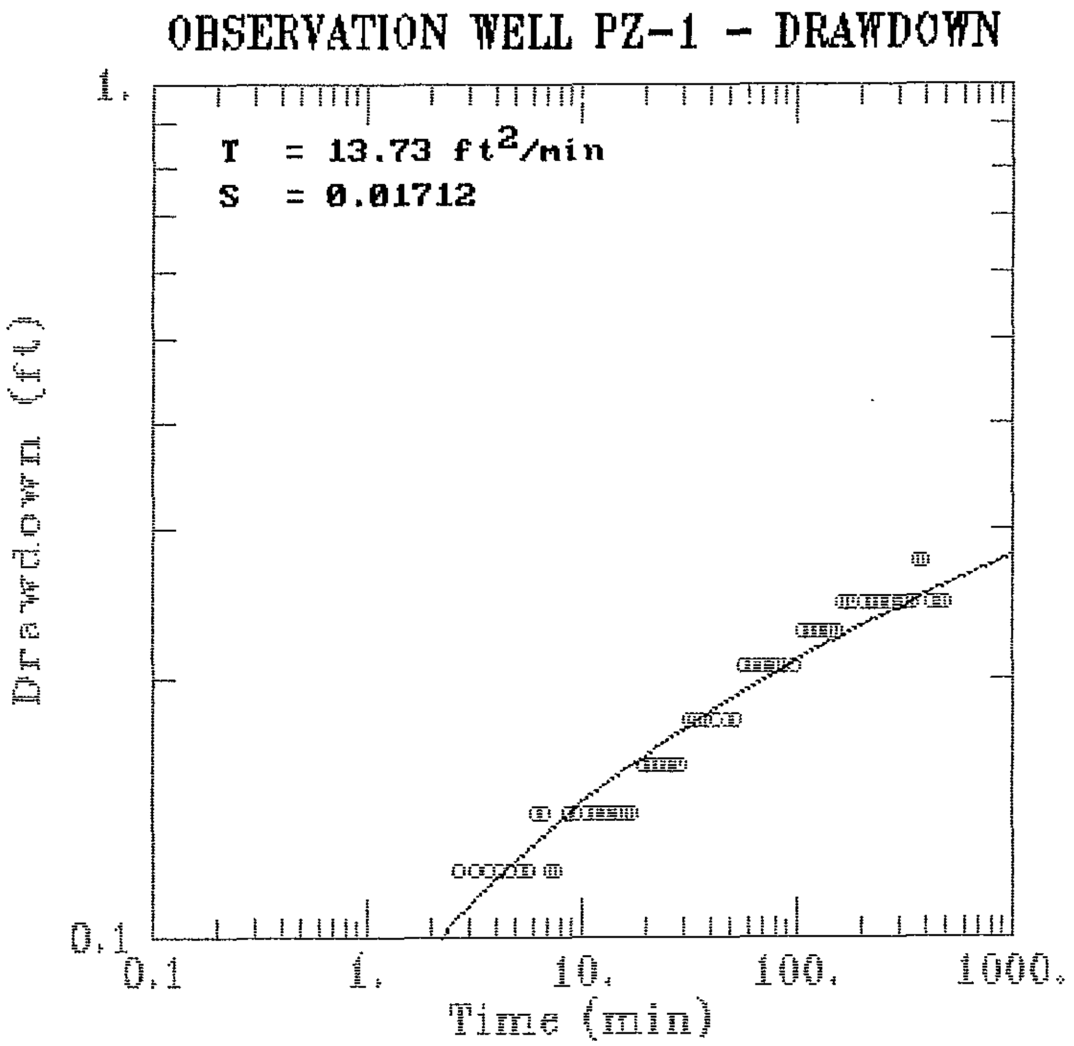


Figure 9 PZ-1: Log Drawdown vs. Log Time (Theis)

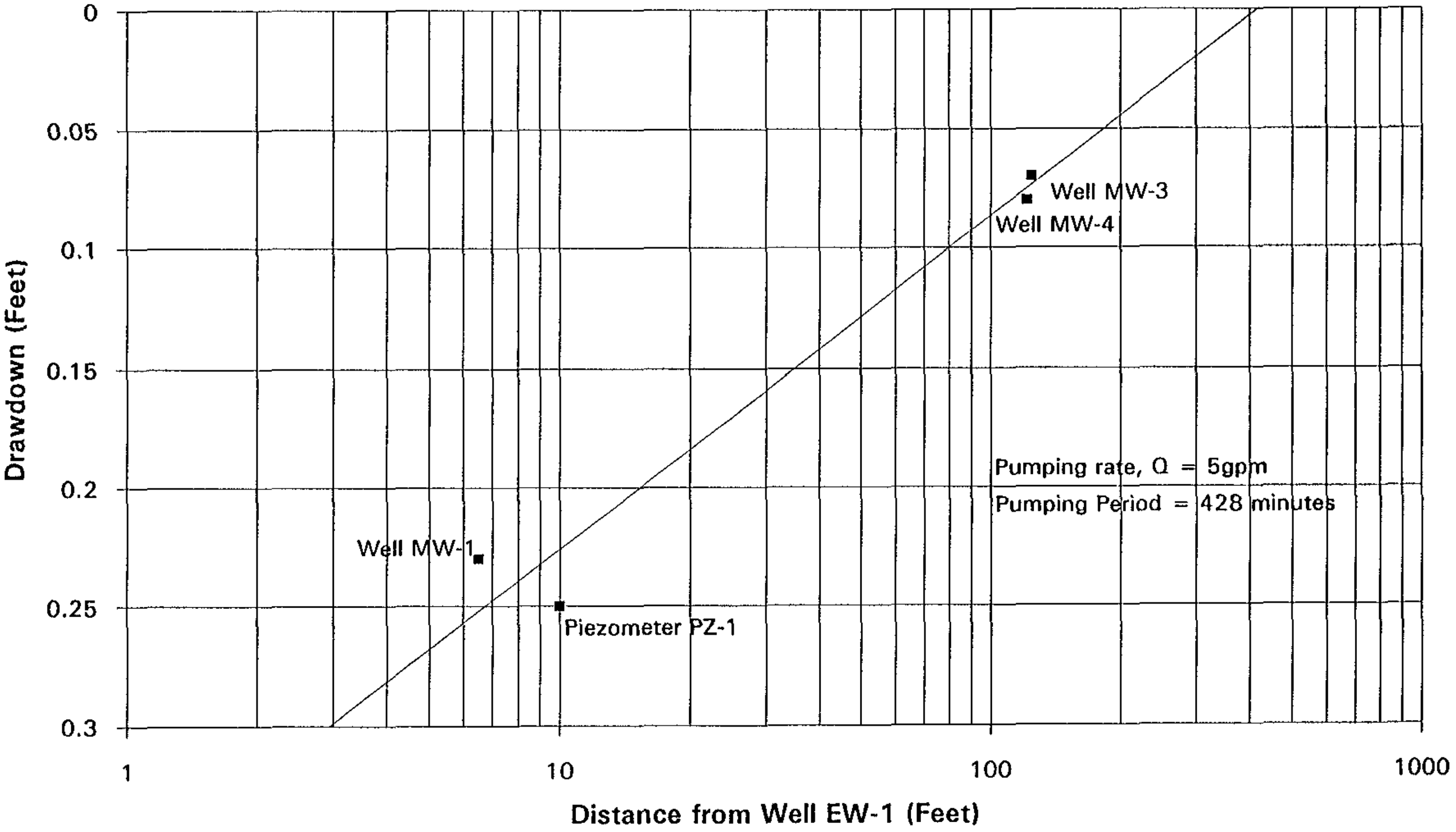


Figure 10 Distance-Drawdown

LOG OF EXPLORATORY BORING

PROJECT No. ______ DATE 2/4/94
CLIENT Enea Plaza
LOCATION Amador Plaza Rd., Dublin
LOGGED BY JK DRILLER HEW/ Jeff

BORING No. EW-1
Sheet 1 of 1

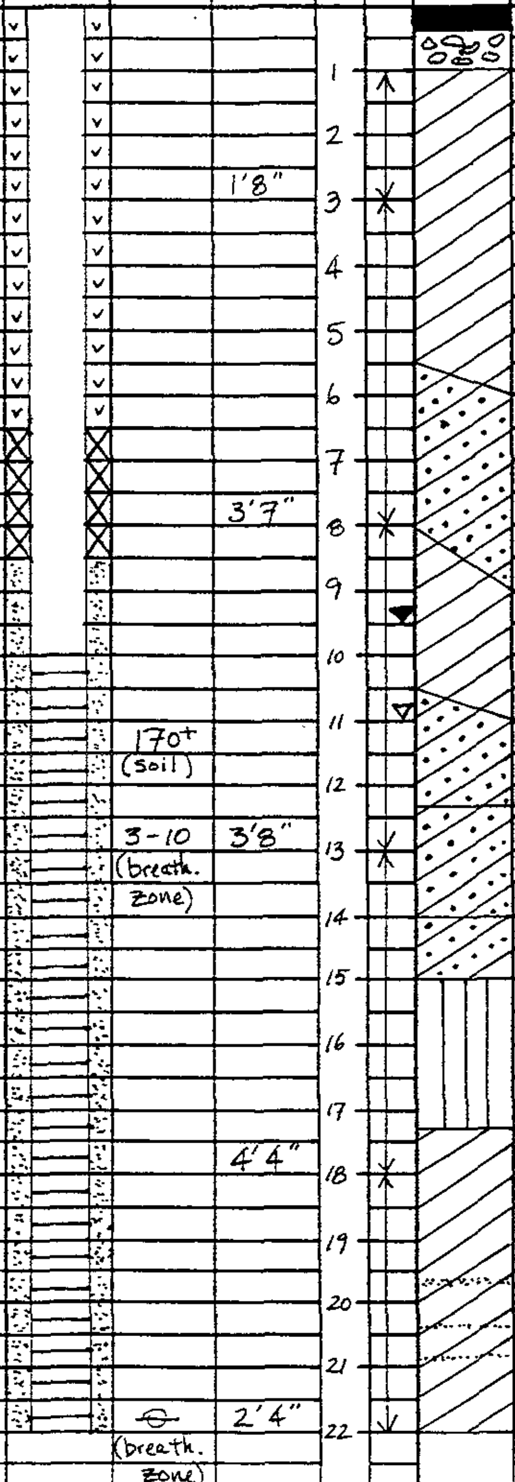
Field location of boring:

Ground Elev. Datum

Drilling method Continuous core (3" diam.) Reamed to 10" w/ HSA
Hole dia. 10"

Casing installation data Sch 40 PVC (4" diam) 0.020" screens from 10'-22'; blank 0-10'; No. 3 Lonestar sand 8.5'-22'; bentonite pellets 6.5'-8.5'; Cement 0-6.5'

Water level				
Time				
Date				



Pocket Torr vane TSF	Pocket Penetrometer TSF	Well Design	PID (ppm)	Recovery	Depth	Sample	Soil Group Symbol (U.S.C.S.)	DESCRIPTION
								Asphalt (4")
								Baserock (8"), gravel to 1" w/ medium sand
					1			CLAY (CL), black (2.5Y N2), trace-10% coarse
								sand - fine gravel, rare gravel to 3", very stiff,
					2			moist
				1'8"				
					3			
					4			
								@ 5': color change to very dark gray brown
					5			(2.5Y 3/2), slight mottling
					6			
								CLAYEY SAND - SANDY CLAY (SC-CL), olive brown
					7			(2.5Y 4/3), 40-50% clay, very fine-fine sand,
								some mottling w/ white caliche, loose-dense, moist
				3'7"	8			
								Increasing clay w/ depth
					9			
								CLAY (CL), dark gray brown (2.5Y 4/2), 10-30%
					10			very fine sand, soft, damp
								Increasing moisture w/ depth; grading to clayey sand
					11			
			170+ (soil)					CLAYEY SAND (SC), dark gray brown (2.5Y 4/2),
					12			20-40% clay, very fine sand, open rootholes,
								loose, wet, strong petroleum odor
			3-10 (breath. zone)	3'8"	13			CLAYEY SAND (SC), as above, heavily mottled,
								dense, moist to wet, wet in lenses
					14			
								CLAYEY SAND (SC), dark gray brown (2.5Y 4/2),
					15			30-40% clay, very fine sand, open rootholes, loose,
								wet, moderate petroleum odor
					16			CLAYEY SILT (ML), dark gray brown (2.5Y 4/2),
								abundant mottling, very clayey, trace fine sand,
					17			open rootholes, soft, moist, wet in rootholes,
								moderate petroleum odor
				4'4"	18			CLAY (CL), very dark gray brown (2.5Y 3/2)
								mottled w/ light olive brown (2.5Y 5/4) and
					19			very dark gray (2.5Y N3), very stiff, damp-
								moist
					20			
								@ 19'8", 20'4", 20'9" - thin (2"-4")
					21			interbeds of clayey sand, very dark gray brown
								(2.5Y 3/2), 20-40% clay, very fine sand,
			0 (breath. zone)	2'4"	22			loose, wet, moderate odor
								TD = 22'

LOG OF EXPLORATORY BORING

PROJECT No. ______ **DATE** 2/4/94
CLIENT Enea Plaza
LOCATION Amador Plaza Rd., Dublin
LOGGED BY JK **DRILLER** HEW/Jeff

BORING No. PZ-1
Sheet 1 **of** 1

Field location of boring:

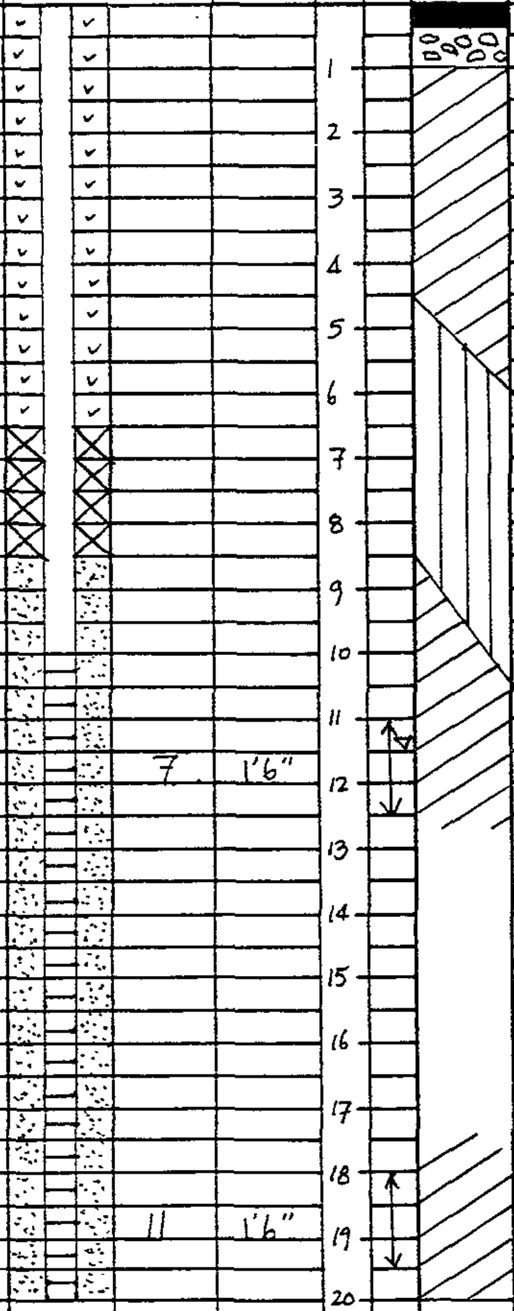
Ground Elev. **Datum**

Drilling method HSA
Hole dia. 8"

Casing installation data Sch. 40 PVC (1" diam.) 0.020" screens from 10'-20'; blank 0-10'; No. 3 Lonestar sand 8.5'-20'; bentonite pellets 6.5'-8.5'; cement 0-6.5'

Water level				
Time				
Date				

Pocket Torr vane TSF	Pocket Penetrometer TSF	Well Design	Blows/ft. or Pressure PSI	Recovery	Depth	Sample	Soil Group Symbol (U.S.C.S.)
			7	1'6"	12		
			11	1'6"	19		



DESCRIPTION

Asphalt (4")
Baserock (8") gravel to 1" w/ medium sand
CLAY (CL), black (2.5Y N2), trace-10% coarse sand-fine gravel, very stiff, damp

@ 3.5': color change to very dark gray brown (2.5Y 3/2), silty, increase of silt w/ depth, softer w/ depth

SILT (ML), dark olive brown (2.5Y 3/3), clayey, trace fine sand, soft, moist

CLAY (CL), very dark gray (2.5Y N3) mottled w/ olive brown (2.5Y 4/3), trace-20% very fine sand, stiff, moist, open rootholes filled w/ water at 11.5'

CLAY (CL), very dark gray (2.5Y N3) mottled w/ very dark gray brown (2.5Y 3/2), thin lenses or layers of very clayey-silty very fine sand, abundant rootholes, stiff, moist, wet in open rootholes and in sandy lenses.

TD = 20'

WELL DEVELOPMENT FORM
EINARSON GEOSCIENCE, INC.

Project No. EPD101
Date: 2/6/94
Site Location: Erea Plaza, Dublin CA
Well: EW1
Name: D Mason
Depth/Diameter: 22/4"
Development Method: surge / pump / bail*
Initial DTW: 9.22' Below T.O.C.
Total Water Removed: 105
Final DTW: 9.26' Below T.O.C.
Water Contained? Yes - 55-gal drums.
Hydac #: 2 E 61
Important! Estimate of specific capacity or recharge to well:

1 csg vol = 8.4 gallons

Time PM	Cum. Vol. Removed	Sand/Silt (ml/1,000ml)	Temp.	EC	pH	DTW (TOC)	Appearance/Comments
1:25	—					9.22	Before development: pump @ 20'
1:35	5	.3/220	61.0	18,200	7.42	NM	V. turbid; milk chocolate color
1:40	15	.07/43	—	—	—	9.26	" "
1:55	25	.1/40	—	—	—	NM	Surge
2:15	35	.0.5/40					pump @ 21.5'
2:20	40	—					pump @ 19'
2:30	55	—	58.3	15,000	7.95		pump @ ~~15'~~ 17
2:50	61	—					pump @ 15'
3:00	67	—					Surge; pump @ 21'
3:05	73	.0.5/40					Surge. "
3:20	75					9.23	Surge; pump @ 13'
3:45	90	.0.5/35	59.5	15,500	7.95	9.26	pump @ 21'
4:00	105	.0.2/15	—	—	—	9.26	pump level incrementally
							raised up to 13' BGL;
							much cleaner in upper screened
	105 gallons = 12½ csg vols.						interval even after surging

* EQUIPMENT:
1) 4" vented surge block on SS hoist & reel
2) 1.7" hand-operated PVC positive displacement pump
3) 2" PVC bailer

WATER LEVEL DATA SHEET
EINARSON GEOSCIENCE, INC.

Well: EW-1

Project: ENEA PLAZA	Datalogger channel CH1
Project No. EPD101	Transducer range & serial No. 20 PSI
Date(s): 2/7/94	Datalogger conversion 9.24
Name: D Mason	Datalogger offset 10.9494 (2/7); 8.2698 (2/8)
Weather: Scatt. Clouds.	Sounder #: JK

Well	Date	Time	DTW (TOC)	Well Depth	Meas. By	Comments ~~TEST START~~ 13:10:33
EW-1	2/7	12:57	—	—	DM	Check flow rate w/ totalizer meter against flow meter
	2/9,	1136	8.96	NM	DM	
	2/9.	12:45	8.92	NM	JK	
		1316	10.07		DM	
		1356	10.12		DM	
		1438	10.23			Flow rate check 5gpm guey= 5.3 gpm.
		1510	10.21			Flow rate check 5.2gpm
		1541	10.24			
		1608	10.28			
		1634	10.29			
		1645	—			Flow rate check (2 seconds short of 5GPM)
		1730	10.32			
		1830	10.33			
		1934	10.40			Flow rate check (3 sec short of 5gpm = 5.3)
		2058	10.40			

EW-1

CH3 MW-1

WATER LEVEL DATA SHEET
EINARSON GEOSCIENCE, INC.

Well: MW-1

Project: ENEA PLAZA, DUBLIN, CA
Datalogger channel CH#3
Project No. EPD101
Transducer range & serial No. 20 PSI
Date(s): 2/7/94 2/8/94
Datalogger conversion 9.24
Name: D MASON
Datalogger offset ~~6.1908~~ 6.237 (2/7); 4.9896 (2/8)
Weather: cool, cloudy
Sounder #: JK

Well	Date	Time	DTW (TOC)	Well Depth	Meas. By	Comments
						TEST START = 13:10:33
MW-1	2/7	0920	8.04	—	DM	Before pumping (15' - 8.5' = 6.5' H_2O col.)
MW-1	2/8	1109	8.72	—	"	Before pumping on 2/8/94
			~~8.93~~			
		1320	8.84			
		1356	8.91			
		1439	8.93			
		1511	8.94			
		1542	8.95			
		1610	8.96			
		1635	8.95			
		1731	8.96			
		1833	8.97			
		1935	8.99			
		2041	9.02			

MW-1

MW-2
(fa

WATER LEVEL DATA SHEET
EINARSON GEOSCIENCE, INC.

Well: MW-2
(farthest from EW-1)

Project: ENEA PLAZA	Datalogger channel N/A
Project No. EPP101	Transducer range & serial No. N/A
Date(s): 2/8/94	Datalogger conversion N/A
Name: D Mason	Datalogger offset N/A
Weather: cool, cloudy, windy	Sounder #. 3

Well	Date	Time	DTW (TOC)	Well Depth	Meas By	Comments TEST START = 13:10:33
MW-2	2/8	1102	8.50	NM	DM	Before pumping.
		1317	8.49		JK	
		1356	8.50		JK	
		1438	8.51		JK	
		1517	8.51		DM	
		1549	8.51			
		1614	8.51			
		1640	8.50			?change in WL?
		1740	8.51			
		1840	8.50			
		1940	8.52			?
		2049	8.51			
		2108	8.51			NO CHANGE

MW-2

MW-3

WATER LEVEL DATA SHEET
EINARSON GEOSCIENCE, INC.

Well: MW-3

Project: ENEA PLAZA	Datalogger channel N/A
Project No. EPD101	Transducer range & serial No. N/A
Date(s): 2/8/94	Datalogger conversion N/A
Name: D MASON	Datalogger offset N/A
Weather: cool, cloudy, windy	Sounder #: JK

Well	Date	Time	DTW (TOC)	Well Depth	Meas. By	Comments TEST START @ 13:10:33
MW3	2/8	1112	9.61	NM	DM	
|	|	1323	9.61	|	|	
|	|	1359	9.62	|	|	
|	|	1442	9.62	|	|	
|	|	1514	9.63	|	|	
|	|	1545	9.64	|	|	
|	|	1611	9.64	|	|	
|	|	1636	9.64	|	|	0.03' change
|	|	1734	9.65	|	|	
|	|	1836	9.65	|	|	
|	|	1937	9.67	|	|	0.06' change.
|	|	2043	9.68	|	|	Max ∇ change → 0.07'
|	|	2102	9.67	|	|	

MW-3

WATER LEVEL DATA SHEET
EINARSON GEOSCIENCE, INC.

Well: MW-4

Project: ENEA PLAZA	**Datalogger channel** N/A
Project No. EPD101	**Transducer range & serial No.** N/A
Date(s): 2/8/94	**Datalogger conversion** N/A
Name: D Mason	**Datalogger offset** N/A
Weather: cool, cloudy	**Sounder #:** EGI #3

Well	Date	Time	DTW (TOC)	Well Depth	Meas. By	Comments TEST START 13:10:33
MW-4	2/8	1350	8.82	NM	DM	After pumping began (40 mins after)
		1401	8.82		JK	
		1445	8.83		JK	
		1523	8.83		DM	
		1553	8.86			
		1618	8.86			0.04' DD
		1645	8.87			0.05' DD.
		1742	8.87			
		1845	8.88			0.06 DD
		1945	8.89			0.07' DD
		2053	8.90			0.08
		2014	8.92			0.10' DD

MW-4

WATER LEVEL DATA SHEET
EINARSON GEOSCIENCE, INC.

Well: PZ-1

Project: ENEA PLAZA, DUBLIN, CA
Datalogger channel CH2
Project No. EPD101
Transducer range & serial No. 10 PSI
Date(s): 2/7 & 8/94
Datalogger conversion 4.62
Name: D MAZON
Datalogger offset ~~9.12451~~ ~~7.0455~~ 9.1014 (2/7) 7.9002 (2/8)
Weather: cloudy, cool
Sounder # JK

Well	Date	Time	DTW (TOC)	Well Depth	Meas. By	Comments ~~TEST START~~ 13:10:33
PZ-1	2/7	0920	9.37	—	DM	Before pumping
	2/8	1121	9.25	—		Before pumping on 2/8.
		1318	9.35			
		1357	9.41			
		1440	9.45			
		1513	9.45			
		1544	9.46			
		1608	9.47			
		1634	9.48			
		1732	9.48			
		1835	9.50			
		1935	9.51			
		2040	9.55			

Page 1 of 1

PZ-1