Appendix C

Technical Memorandum: Results of Aquifer Tests Performed on the Exposition 'A' and 'B' Groundwater Zones, December 2001

FINAL TECHNICAL MEMORANDUM

Date: March 2002

Prepared For: Rose Marie Caraway
USEPA Region IX

Prepared By: T N & Associates
Jacques Marcillac, Project Geologist
Tim Garvey, Project Manager

Re: Results of Aquifer Tests Performed on the Exposition 'A' and 'B' Groundwater Zones, December 2001 Pemaco Superfund Site 5050 East Slauson Avenue, Maywood, California.

Cc: John Hartley, United States Army Corps of Engineers

INTRODUCTION

T N & Associates, Inc. (TN&A) has prepared this technical memorandum to document field activities and results associated with aquifer tests performed in December 2001 for the Pemaco Superfund Site located in Maywood, California. The Exposition Aquifer, within the study area, is not a viable aquifer, because the groundwater yield does not produce economically significant quantities of water to local production wells. However, there are five distinct saturated zones present between 65 and 180 feet beneath the site and surrounding area that are stratigraphically equivalent with the more regional Exposition Aquifer. These zones are identified as Exposition Zones 'A' through 'E' for the purposes of this project. The aquifer testing focused on the upper most saturated intervals (Exposition 'A' and 'B' Zones) of the stratigraphically equivalent Exposition Aquifer. Analytical results obtained during the Remedial Investigation (RI) indicated that these groundwater zones contain the highest concentrations of COPCs at the site. The aquifer test results will facilitate the selection of the most appropriate remedial technologies for these groundwater zones during the Feasibility Study (FS) phase of the project. This work was accomplished under contracts issued to TN&A by the U.S. Army Corps of Engineers Rapid Response, at the request of the United States Environmental Protection Agency (USEPA), Region IX.

The Pemaco Superfund Site is comprised of 1.4 acres located in a mixed industrial and residential neighborhood in Maywood, Los Angeles County, California (Figure 1). Pemaco, Inc. formally operated as a custom chemical blender between the 1950's and 1991. A wide variety of chemicals were used on-site including chlorinated and aromatic solvents, flammable liquids, oils and specialty chemicals. These chemicals were stored in drums, aboveground storage tanks (ASTs) and underground storage tanks (USTs). The site was abandoned by its owner and the stored chemicals, drums, ASTs and USTs were removed by 1998 under the supervision of the USEPA, Region IX. Environmental assessments performed between 1990 and 1999 have identified soil and groundwater contamination that originated from the use and storage of chemicals at the property. A soil vapor extraction (SVE) system was installed as an interim measure in 1998 and operated until 1999, when it was shut down due to community concerns with the associated thermal oxidation unit that was used as a part of the SVE.

The site entered into the Superfund program in 1999, and a full-scale RI was performed between January 2001 and November 2001. The City of Maywood, in conjunction with the Trust for Public Land, is planning to use the Pemaco property along with adjacent properties to build a public recreational park. This project is termed the Maywood Riverfront Park project. Future remedial activities of the Pemaco site and adjacent sites will be integrated with the existence of this park.

Hydrogeologic Conditions

The hydrogeologic units involved with the aquifer tests are comprised of two distinct groundwater zones that have been arbitrarily named the Exposition 'A' and 'B' Zones. These are not technically aquifers because they are not capable of producing economically significant quantities of water, even if they were screened together.

Exposition 'A' Zone

The 'A' Zone is typically found between 65 feet bgs to 75 feet bgs. It is comprised of light olive gray to dark greenish gray fine silty and poorly graded sands locally interbedded with well-graded sands with silt. The thickness of this zone is highly variable ranging from 3 inch- to 10 foot-thick. The thickest 'A' zone intervals are comprised of interbedded poorly graded silty sands and well-graded sands. The thinnest intervals of the 'A' zone are a series of 1 inch- to 3 inch-thick saturated silty sands interbedded with silts and clays from 0.5 foot- to 1 foot-thick. Overall, the 'A' zone can be characterized as a series of semi-discontinuous saturated sand lenses.

Exposition 'B' Zone

The 'B' zone is typically found between 80 to 90 feet bgs. It is comprised of fine silty sands, poorly graded sands and poorly graded sands with silt ranging from 1.5 to 10-feet thick. The fine-grained silty sands are typically light olive gray mottled with moderate yellowish brown or moderate olive brown. Some of the thicker portions of the unit have interbeds of silt/clay to 4 feet thick. The 'B' zone is continuous throughout the site vicinity, except in the area along District Blvd., south of 60th Street, where it pinches out.

A secondary saturated silty sand lens located between 90 and 92 feet bgs was consistently observed during the coring of borings MW-16 through MW-18 and RW-01 located in the southernmost portion of the Pemaco site (Figure 2). This secondary lens is isolated from the 'B' Zone described above by an overlying interval of fat clay from 1 to 3 feet thick. Well MW-17-95 was screened solely in this zone for aquifer test purposes. This zone was informally named the 'B_2' Zone.

DESCRIPTION OF FIELD ACTIVITIES

An aquifer pumping test was performed between December 13th and December 20, 2001 at the Pemaco site, primarily targeting the 'B' Zones ('B_1' and 'B_2') of the stratigraphically equivalent Exposition Aquifer, which lies approximately 80 to 90 ft below the site. The test also established if a hydraulic connection between the 'A' (approximately 65 to 75 ft bgs) and 'B' groundwater zones exists.

Four types of aquifer tests were performed to evaluate the hydrogeologic characteristics of the Exposition 'A' and 'B' groundwater zones. They included slug, step-drawdown, constant rate, and recovery tests. An additional "stress" pumping test was performed on the 'B' Zone to determine maximum sustainable pumping rates. These tests quantified parameters such as hydraulic conductivity, transmissivity, storage coefficient, well efficiency, and optimum pumping rates. These parameters were then used to calculate the effective radius of capture (ROC) for recovery wells that may be required for remediation purposes, establish the well design and configuration, and engineer the remediation equipment.

General details of methods and procedures to be followed for the above tests are described in TN&A's Standard Operating Practice TNFLD008H document included as Attachment A. Details of the aquifer test and evaluation methods are described in the sections below.

Aquifer Test Setup/Well Installation

A major part of the aquifer test setup involved the installation of one groundwater pumping well ("recovery well" or RW-01), six double-nested monitoring wells (MW-14, MW-15, MW-16, MW-18, and MW-19), and one triple-nested monitoring well (MW-17) which were installed in November 2001. Recovery well RW-01 is screened within both the 'B_1' and 'B_2' "portions" of the 'B' groundwater zone. The surrounding monitoring wells are screened within both the 'A' and 'B' Zones. Locations for the wells are shown in Figure 2. These wells were designed for aquifer testing and were screened in accordance with the stratigraphy and saturated intervals. Screen intervals and construction details are provided in Table 1. Screening samples from water samples collected from these wells are provided in Table 4.

Aquifer Test Procedures

Prior to the start of the aquifer tests, field personnel gauged the depth to water in the pumping well and each monitoring well. Slug tests were initially performed on the 'A' Zone observation wells to obtain individual data sets for wells within this zone to be used for later comparison to 'B' Zone hydrogeologic properties.

After water levels returned to static, pre-test levels within the 'A' Zone wells that were subjected to slug tests, pressure transducers were installed in all of the selected 'A' and 'B' Zone wells selected for the step, constant, and recovery pumping tests. Pressure transducers were either connected to a data logger or operated independently. Thirty-pound per square inch (psi) pressure transducers were installed in pumping well RW-01 and all of the observation wells, with exception to MW-14-80 and MW-14-90 which were deployed with 15-psi pressure transducers. Four of the pressure transducers (RW-01, MW-03, MW-19-70, and MW-19-85) were connected to an In-Situ Inc. Hermit® 2000 8-channel data logger via vented, Teflon®-coated cables. Distal wells (MW-02, MW-14-80, MW-14-90, MW-15-70, MW-15-85, MW-16-70, and MW-16-85, MW-17-70, MW-17-85, MW-17-95, MW-18-70, MW-18-85) were monitored utilizing independent, in-well transducers/data loggers (In-Situ Inc. Mini-Troll®). These units were connected to a laptop computer to set up the logging parameters and to retrieve data at each test step. Periodically, the wells were gauged manually with an electronic water level meter (Table 2).

Aquifer pump testing was then conducted and involved pumping groundwater from the recovery well (screened in the 'B' Zone) at predetermined rates to measure the induced stress in the aquifer(s). During pumping and subsequent recovery, water level measurements versus time were obtained electronically with digital data logging instrumentation. This electronic data was used to calculate hydraulic properties of the aquifer system.

Water produced from the recovery well flowed past a series of flow meters and sample ports, before flowing through granular activated carbon to remove VOCs, primarily trichloroethene (TCE), from the water stream (Note: concentrations of acetone from monitoring wells in the area of the pilot test are well below discharge criteria). Water was then stored in an aboveground storage tank (21,000 gallon capacity) that was placed temporarily on site for the test. The water was subsequently drummed, sampled for waste characterization, and disposed of to an appropriate facility licensed to receiving such waste. A schematic diagram showing the layout of the test is shown in Figure 3. A complete list of equipment is contained in Table 3. Each test will be more thoroughly discussed in the following sections.

Slug Testing

Slug tests were performed to obtain order-of-magnitude approximations of hydraulic conductivity of the 'A' Zone. The tests were conducted in the following wells: MW-14-80, MW-14-90 ('B_1' Zone), MW-15-70, MW-16-70, and MW-18-70. The slug was adequately sized to produce an initial vertical displacement of at least 2 feet in each well, provided there was sufficient water column. Each test lasted approximately 1 to 2 hours. Details of test procedures are presented in Section 3.0 of the Standard Operating Practice TNFLD008H document contained in Attachment A.

Step-Drawdown Testing

Step-drawdown testing was performed by pumping at various discharge rates for predetermined time steps. This test was used to evaluate the well yield, specific capacity of the well, and to establish an optimum pumping rate for the constant rate test. The time steps for each discharge rate was approximately 2 hours, with pumping rates increasing at from 0.5 gallon per minute (gpm) to 0.8 gpm to 1.137 gpm. During this phase of testing, drawdown data was collected from both the pumping and observation wells. Additional details are presented in Section 4.7 of the Standard Operating Practice TNFLD008H document contained in Attachment A.

Constant-Rate Aquifer Test

Based on observations from pumping steps described above, the optimum pumping rate was determined to be approximately 1.0 gpm for 'B' Zone wells. The data logger and Trolls were designed to collect water level data at time intervals that facilitate accurate interpretation, without overloading their respective memory. To keep the test simple and allow the greatest flexibility in data reduction and management, water level readings were automatically logged at 60-second intervals throughout the test. For the 72-hour duration, this resulted in 21,367 data sets.

Aquifer Recovery Test

Following the constant-rate discharge test, the pump in RW-01 was shut off and groundwater recovery rates in pumping well RW-01 and each observation well was recorded until the aquifer recovery was complete. Total recovery occurred in approximately 17 hours.

As discussed above, the water levels versus time were measured to determine the natural effects on the aquifer as well as the induced effects caused by pumping. During the aquifer testing, groundwater samples were collected and analyzed by a fixed laboratory for concentrations of VOCs (EPA Method 8260B) per methods described in the SAP. Results are summarized in Table 4A.

For the aquifer test, data was obtained and managed in both electronic and paper format. Data obtained by electronic data loggers in the field were downloaded to PCs in ASCII format, then converted to formats used by analytical software (e.g. AQTESOLV™, see below).

Data obtained manually in the field was recorded on field data sheets and in project field notebooks per the SAP. Additional field data sheets for the aquifer test are included in Attachment B.

Water level data recorded during various pumping conditions was downloaded, tabulated, and graphed. Graphs were annotated with pertinent information and were evaluated to determine 1) extent of groundwater capture at the various pumping configurations within the shallow zone, and 2) whether any aquifer properties (i.e. transmissivity, hydraulic conductivity) can be derived from the data.

"Stress" Test

A final "stress" pumping test was performed on the 'B' Zone to determine maximum sustainable pumping rates.

A stress pumping test can be performed to determine the transmissivity or degree of leakage between an unconfined aquifer and a deeper leaky confined aquifer. In this test, the pumped well is located in the lower aquifer while the observation wells are located in the overlying aquifer which is separated by a less permeable aquitard layer.

FIELD OBSERVATIONS

During the step-drawdown test, drawdown was observed in all 'B' Zone wells (MW-14-90, MW-15-85, MW-16-85, MW-17-85, MW-17-95, MW-18-85, and MW-19-90) during the initial discharge rate of 0.5 gpm, except for MW-14-80 which demonstrated a rise in head of 0.1 feet. Alternatively, all 'A' Zone wells (MW-15-70, MW-18-70, and MW-19-70), demonstrated a rise in head during the initial discharge rate of 0.5 gpm except MW-16-70, which fell 0.01 feet and MW-17-70 which did not show a fall or rise in head.

During the intermediate discharge rate (0.8 gpm) of the step-drawdown test, drawdown was observed in all of the wells within the 'A' Zone (average 0.085 feet), while the 'B' Zone wells indicated a slight rise in head (approximately half of their initial drawdown). The final step-drawdown of 1.137 gpm produced similar results as the intermediate step-drawdown for both zones. All wells screened within the 'A' zone demonstrated a fall in head ranging from 0.01 feet to 0.2 feet. All 'B' Zone wells demonstrated a continued rise in head ranging from 0.02 feet to 0.64 feet, except for MW-14-80 which had a drawdown of 0.13 feet and MW-17-95 which had a drawdown of 2.18 feet.

Based on these observations, it is believed that MW-14-80 is actually screened within the 'A' groundwater zone and MW-14-90 is screened with the 'B_1' groundwater zone. It was previously believed that MW-14-80 was screened within the 'B_1' groundwater zone and MW-14-90 was screened within the 'B_2' groundwater zone, a 1-foot sand-stringer found beneath the typical 'B' Zone. In addition, this data suggests that a hydraulic connection between the 'A' and 'B' Zones exists, although MW-03 and MW-04, which are screened in both the 'A' and 'B' Zones, may be influencing this connection.

DATA ANALYSIS AND RESULTS

Procedures

Drawdown, pumping, and recovery test data from the observation wells and recovery test data from extraction well RW-01 were analyzed using the hydrogeologic software application AQTESOLV™ for Windows (Duffield and Rumbaugh, 1999). From this analysis, the transmissivity (T), storage coefficient (S or S_y), and resulting hydraulic conductivity (K) of the water-bearing zone(s) were calculated.

The program is capable of analyzing both pumping and recovery test data. Various methods were used to analyze the plots including the following:

- Theis method for unconfined aquifers;
- Hantush (1960) method for leaky aquifers;
- Theis residual drawdown method for confined aquifers for analysis of recovery data, and
- Bouwer-Rice method for slug test analysis.

Based on the stratification and general geometric configuration of the aquifer system, the Hantush (1960) method for leaky aquifers was used for the final analysis. This analysis method consistently provided results that match the lithologic and hydraulic attributes of the respective aquifer zones.

All curve-fitting methods have certain assumptions that must be considered when interpreting pumping and recovery test data. These assumptions and generalizations are related to the formula used to determine the water bearing zone parameters. In most cases, the field scenario will not have an absolute fit to the assumptions of a particular method. Therefore, the importance of each of the assumptions is critical when choosing the most appropriate method of analysis.

The general assumptions of the Theis, Hantush, and Bouwer-Rice methods are as follows:

- The aquifer material is considered porous, obeying Darcy's law of laminar flow;
- The aquifer is considered homogeneous, isotropic, and of uniform thickness over the area of influence;
- The aquifer is infinite in areal extent;
- Groundwater flow through the aquifer is horizontal;
- Groundwater is released from internal storage instantaneously upon decline in head;
- Storage in the well bore is assumed negligible (diameter of the well is small);

- The pumping well is screened over the entire thickness of the aquifer and receives water from the entire thickness by horizontal flow;
- The slope of the piezometric surface is assumed to be flat during the test (no natural recharge that would affect test results);
- The pumping rate is assumed constant throughout the duration of pumping; and
- The flow to the well is in an unsteady state.

Once the transmissivity value of the water bearing unit has been calculated from the curve matching method, an appropriate hydraulic conductivity value can be obtained by dividing transmissivity by the aquifer thickness (b): $K = T/b$

where: b = thickness of the water-bearing unit (aquifer) within the well casing (i.e. total depth minus depth to water).

During this analysis, the thickness of the aquifer was based on the geologic logging of the respective borehole. The aquifer thickness ranged from approximately 1 to 9 feet (see Table 5). Alternatively, transmissivity can be calculated from a measured hydraulic conductivity value by solving for T: $T = Kb$.

Transmissivity

Transmissivity is the rate at which water of a specific viscosity and density (assumed fresh) is transmitted through a width of an aquifer or aquitard (similar to a window or slice) at a specific hydraulic gradient. The aquifer drawdown and recovery curves (presented in Attachment C) were analyzed using the AQTESOLV™ for Windows software. The calculated transmissivities from the plots showed transmissivity values ranging from 8.281E-4 ft^2/min to 1.938 E-1 ft^2/min with an average of 9.007E-02 ft^2/min. The results of the analyses are presented in Table 5.

Storativity

The storage coefficient, or storativity, is defined as the volume of water stored or released per unit area of aquifer given unit head change (decline or rise in peizometric surface). Storativity can be calculated by solving for $S = S_s$ (specific storage) * b, where b is the aquifer thickness. Due to the phenomenon of well annulus storage, only storativity values derived from the observation well data are considered valid. The storage coefficients were obtained from the computerized curve matching (Attachment C). The calculated storativity values from the observation wells for drawdown and recovery indicate the aquifer system is confined to semi-confined. Storage values were low, averaging approximately 2.092E-02 [unitless].

Hydraulic Conductivity

Hydraulic conductivity can be defined as the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient (i) perpendicular to the direction of flow

(Kruseman and De Ridder). K is given by:

$$K = \frac{k\,r\,g}{\mu}$$

where: k = intrinsic permeability (function of the medium)
r = density of the fluid
g = gravitational constant
μ = dynamic viscosity

Hydraulic conductivity can be calculated using Darcy's Law, a simplified relationship that does not consider the properties of the porous medium or the fluid passing through it. Darcy's Law states:

$$Q = KiA \quad \text{or} \quad K = Q/iA$$

where: Q = pumping test volume discharge rate
i = average hydraulic gradient beneath the site
A = cross sectional area normal to groundwater flow direction

Alternatively, knowing the saturated aquifer thickness (b), hydraulic conductivity (K) can be calculated using the transmissivity (T) values deduced from the aquifer drawdown and recovery curves as follows: K = T/b.

Along with the pumping well, the observation wells represent hydraulic conductivity values at varying distances and directions from the pumping well. These hydraulic conductivity values are estimated to range from 8.281E-04 ft/min to 1.046E-01 ft/min with an average of approximately 2.504E-02 ft/min which is consistent with the low to moderate permeability materials that comprise aquifer beneath the site. Hydraulic conductivity values for each well are presented on Table 5. Minimum and maximum hydraulic conductivity values for both the 'A' and 'B' Zones are listed in the table below. Outliers were excluded when calculating averages to create values representative of observed site conditions.

Zone	Hydraulic Conductivity (ft/min)
Average 'A' and 'B'	2.504E-02
'A' Average	1.461E-03
'A' Minimum	8.281E-04
'A' Maximum	2.277E-03
'B_1' and 'B_2' Average	2.818E-02
'B_1' Average	3.343E-02
'B_1' Minimum	1.078E-03
'B_1' Maximum	1.046E-01
'B_2' Average*	6.626E-03

*Only one well (MW-17-95) is screened within the 'B_2' Zone; therefore, no minimum and maximum are provided.

Groundwater Velocity

Groundwater flow through an aquifer occurs only through the pore spaces of the aquifer medium. Since many of these pores are clogged or not interconnected, groundwater flow velocity must account for the effective porosity of the aquifer material. The average rate for groundwater flow through the pores (seepage velocity) is provided by the following equation:

$$V_s = Ki/n_e$$

where: V_s = seepage velocity
K = Hydraulic conductivity (see above)
i = average hydraulic gradient beneath the site (0.005 for 'A' Zone; 0.0063 for 'B' Zone)
n_e = effective porosity (54.4 percent effective porosity for site soils 45 to 66 ft bgs)

The estimated seepage velocity at the site is as follows:

Zone	Seepage Velocity (ft/min)	Seepage Velocity (ft/day)	Seepage Velocity (ft/yr)
Average 'A' & 'B'	2.858E-04	4.116E-01	150.20
'A' Zone (average)	1.343E-05	1.933E-02	7.06
'A' Zone (minimum)	7.611E-06	1.096E-02	4.01
'A' Zone (maximum)	2.093E-05	3.0137E-02	10.99
'B_1' and B_2' (average)	3.261E-04	4.697E-01	171.40
'B_1' Zone (average)	3.869E-04	5.571E-01	203.30
'B_1' Zone (minimum)	3.56E-05	5.121E-02	18.69
'B_1' Zone (maximum	1.21E-03	1.743	636.22
'B_2' Zone (average)*	7.667E-05	1.104E-01	40.30

*Only one well (MW-17-95) is screened within the 'B_2' Zone; therefore, no minimum and maximum are provided.

It should be noted that outliers were excluded when calculating seepage velocities to create a value representative of observed site conditions.

Observed Influence

The maximum drawdown recorded for the observation wells was 2.82 feet in MW-16-90 located 10.4 feet from the monitoring well. Since the drawdown in the pumping well was 13.93 feet, a relatively steep cone of depression existed between the two wells during the test. A cone of depression will continue to expand with longer pumping until reaching steady-state conditions controlled by such characteristics as hydraulic gradient and transmissivity of the soil. Low transmissivities such as were observed within soils at this site, create steep cones radially around the pumping well(s).

At the furthest observation well (MW-14), located 111.2 feet up-gradient from the pumping well, the maximum logged drawdown was 0.47 feet. Maximum logged drawdown values are provided in Table 6. Drawdown is illustrated on Figure 4 to depict the areal extent and magnitude of the cone of depression after 4,322 minutes of pumping at RW-01.

Drawdown eventually stabilized during pumping in all of the observations wells, although it was observed that the 'A' Zone observation wells had an initial rise in head during the first discharge rate (0.5 gpm) of step-drawdown test. This may be contributed to residual effects of the slug test that was performed prior to the pumping tests. Graphs 1 through 5 illustrate the 'A' Zone observation wells during the pump test. Regardless of the rationale for the initial rise in head of wells screened within the 'A' Zone, the eventual and continuous drawdown of the 'A' Zone during the pumping test indicates a hydraulic connection between the Exposition 'A' and 'B' Zones. However, it should be noted that the data may have been disrupted by the presence of monitoring wells MW-3 and MW-4 which are screened in both the 'A' and 'B' Zones.

Radius of Capture (Drawdown)

To effectively implement remediation measures, it is essential to define the portion of the water-bearing unit that contributes water to the well. This portion of the water-bearing unit is known as the radius of capture (Keely and Tsang). The radius of capture is defined as the radius at which a stagnation point (or watershed point) is created.

The radius of capture in the down-gradient direction can be numerically estimated from the following equation:

$$r = \frac{Q}{(2\Pi Ti)}$$

where: r = radius of capture in the down gradient direction (ft)
Q = pumping test average discharge rate (ft^3/min.)
T = transmissivity of the water bearing unit (ft^2/min.)
i = average hydraulic gradient beneath the site (unitless)
Π = mathematical constant representing the ratio of the circumference of a circle to its diameter (3.14159)

The maximum width of the capture zone in the cross-gradient direction is equal to 2Π times the down gradient radius of capture (Todd, 1980).

Using the transmissivity obtained from the distance-drawdown plots (Attachment C) along with the gradient and pumping rate for the test, down-gradient capture can be calculated using the above values:

Q = 0.152 ft^3/min (1.137 gpm)
T = 9.007E-02 ft^2/min ('A' and 'B' Zone Average);
= 2.599E-03 ('A' Zone Average);
= 9.642E-02 ('B_1' and 'B_2' Average);

= 1.155E-01 ('B_1' Average);
= 6.626E-03 ('B_2' Average).
i = 0.005 for 'A' Zone; 0.0063 for 'B' Zone.

Using the above equation, estimated radius of capture (at a flow rate of 1.137 gpm) in the down-gradient direction is:

Zone	Downgradient Radius of Capture (ft/min)
Average 'A' and 'B'	123.90
'B_1' and 'B_2' Average	139.90
'B_1' Average	46.43
'B_2' Average	730.03

The above calculations were performed for each of the transmissivity values obtained from the from the AQTESOLV™ for Windows and distance-drawdown plots (Attachment C).

Based on this estimated radius of capture, the maximum cross-gradient width of the capture zone is estimated using the following equation: $2\Pi r$ = width of capture zone (feet). The cross-gradient width of the capture zone for each zone is presented in the following table:

Zone	Cross-gradient Width of Capture (ft/min)
Average 'A' and 'B'	389.10
'B_1' and 'B_2' Average	439.70
'B_1' Average	145.90
'B_2' Average	2,249.40

Cross-gradient capture width was also calculated for each of the transmissivity values obtained from the AQTESOLV™ for Windows and distance-drawdown plots (Attachment C).

CONCLUSIONS

A series of groundwater slug, pumping, and recovery tests were performed at the Pemaco site between December 12th and 24th, 2001. Types of tests performed included:

- Background/diurnal logging of "static" groundwater levels in the 'A' and 'B' Zones
- Slug testing of five 'A' Zone wells
- Step-drawdown pump testing of the 'B' zone while monitoring 'A' Zone and 'B' Zone well

- Constant-rate pump testing (72 hrs) of the 'B' zone while monitoring 'A' and 'B' Zone wells
- Post-pumping recovery monitoring of all wells monitored during pumping test
- "Stress" pumping of the 'B' Zone to determine maximum sustainable pumping rates.

Results of data analysis are:

- Sustainable pumping rates from the 'B' zone are approximately 1 gallon per minute (gpm) and approximately 0.5 gpm from the 'A' zone. Theoretical maximum yield for the 'B' Zone is 1.4 gpm (see Graph 6).
- Calculated hydraulic conductivity (K) values for the 'A' zone range from 8.3 E-04 to 2.3 E-03.
- Calculated hydraulic conductivity (K) values for the 'B_1' zone range from 1.1 E-03 to 1.1 E-01.
- Calculated hydraulic conductivity (K) values for the 'B_2' zone average 6.6 E-03.

Based on cross section observations and hydrogeologic data produced during the tests, it is believed that MW-14-80 is actually screened within the 'A' groundwater zone and MW-14-90 is screened with the 'B_1' groundwater zone. (It was previously believed that MW-14-80 was screened within the 'B_1' groundwater zone and MW-14-90 was screened within the 'B_2' groundwater zone, a 1-foot sand-stringer found beneath the typical 'B' Zone.)

The eventual and continuous drawdown of the 'A' Zone during the pumping test suggests a hydraulic connection between the Exposition 'A' and 'B' Zones, although MW-03 and MW-04, which are screened in both the 'A' and 'B' Zones, may be influencing this connection.

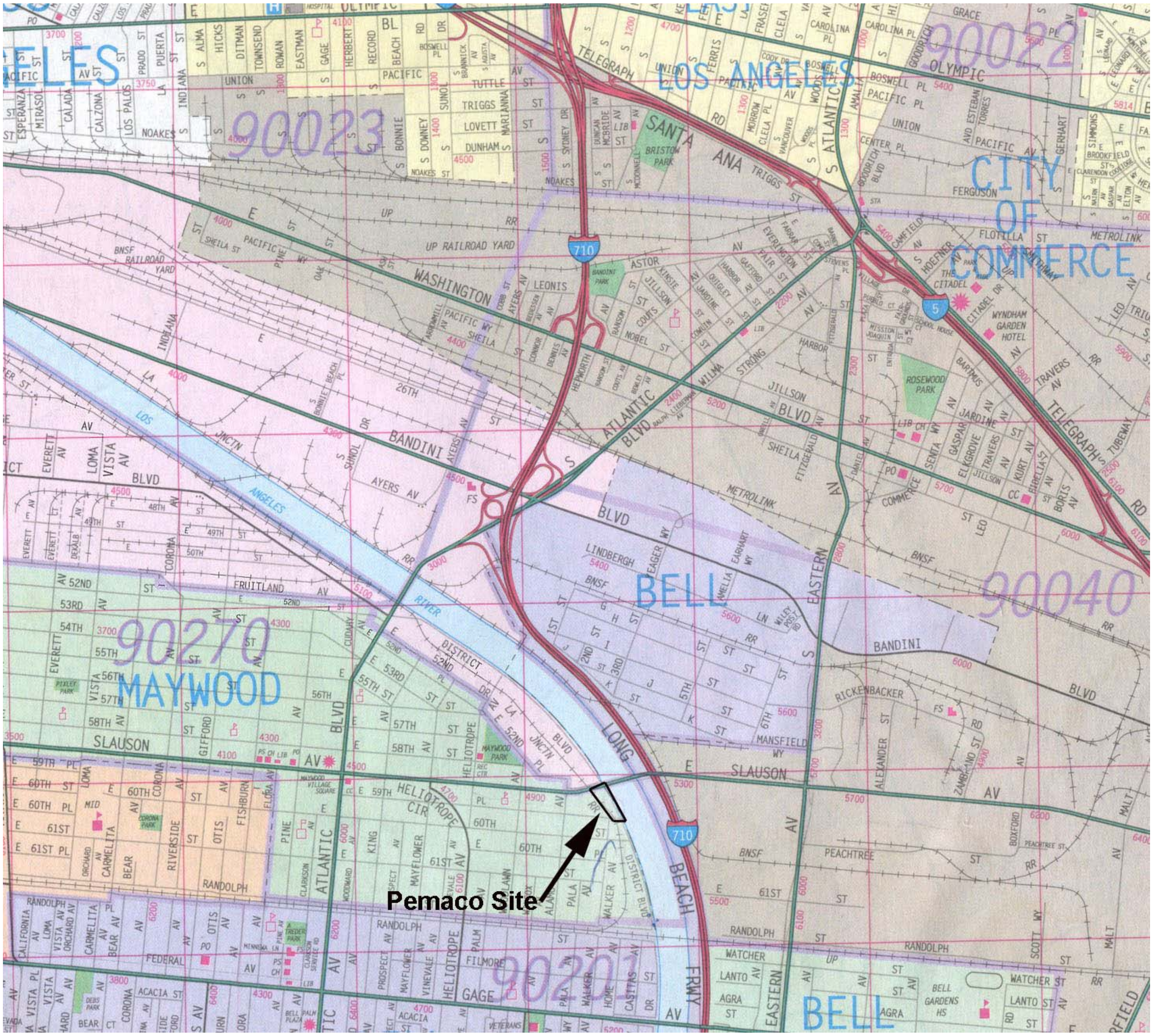
FIGURES

TABLES

GRAPHS

ATTACHMENTS

FIGURES



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1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

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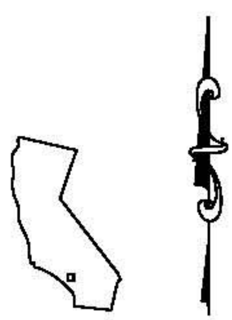
LEGEND



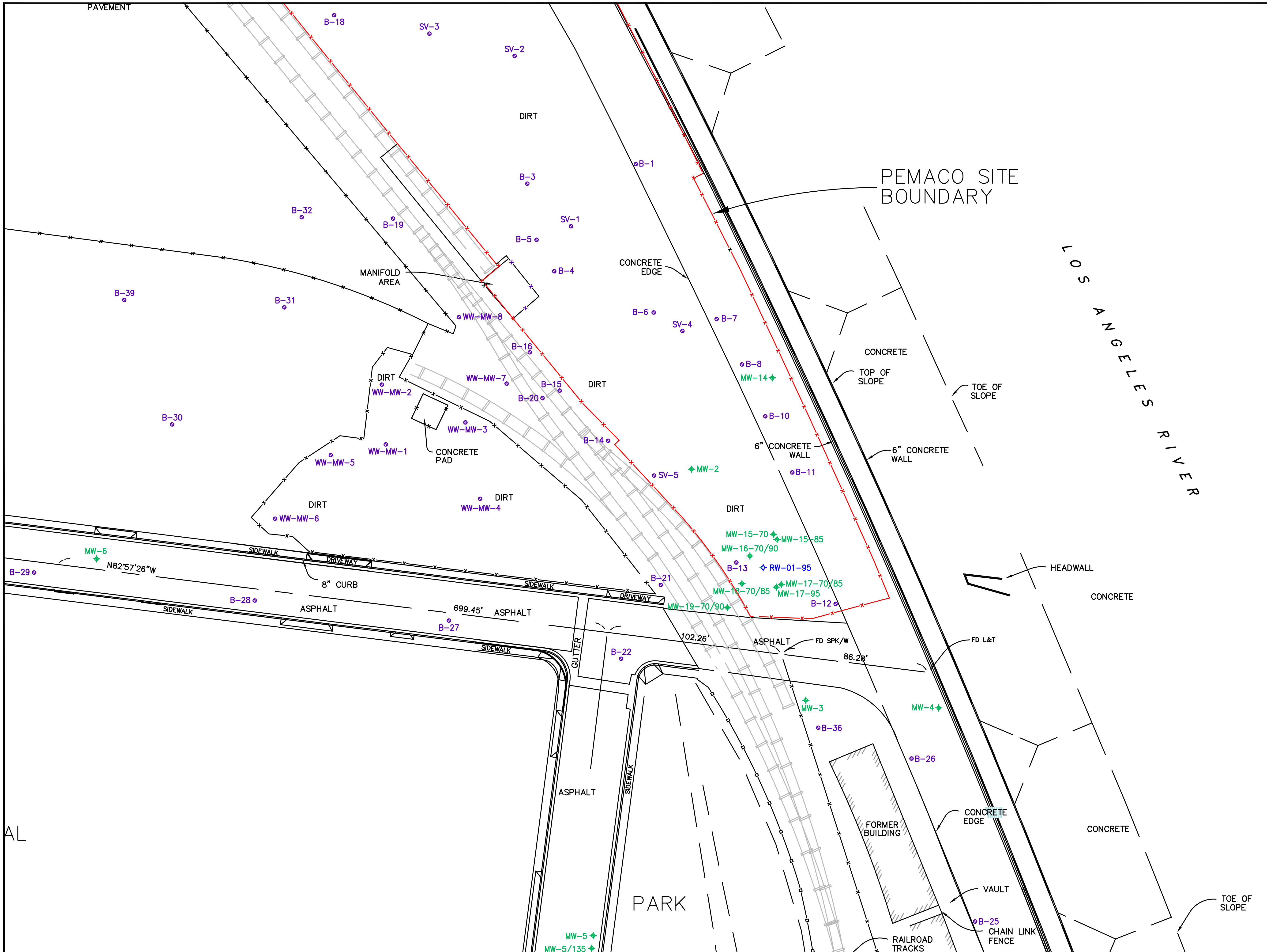
DATE: 11/5/2000	FILE NAME: PEMACO-SL	APPROVED BY:

SITE LOCATION MAP

PEMACO, INC.
MAYWOOD, CALIFORNIA

TN & A — T N & Associates, Inc. — Engineering and Science

FIGURE 1



LEGEND

- PEMACO SITE BOUNDARY FENCE
- B-6 — MONITORING WELL, PERCHED ZONE (<35 FEET BGS.)
- SV-02 — MONITORING WELL, PERCHED ZONE (<35 FEET BGS.)
- MW-2 — MONITORING WELL, UPPER EXPOSITION AQUIFER (WELLS SCREENED IN INTERVAL BETWEEN 60 FEET AND 170 FEET BGS.)
- RW-01 — RECOVERY WELL LOCATION

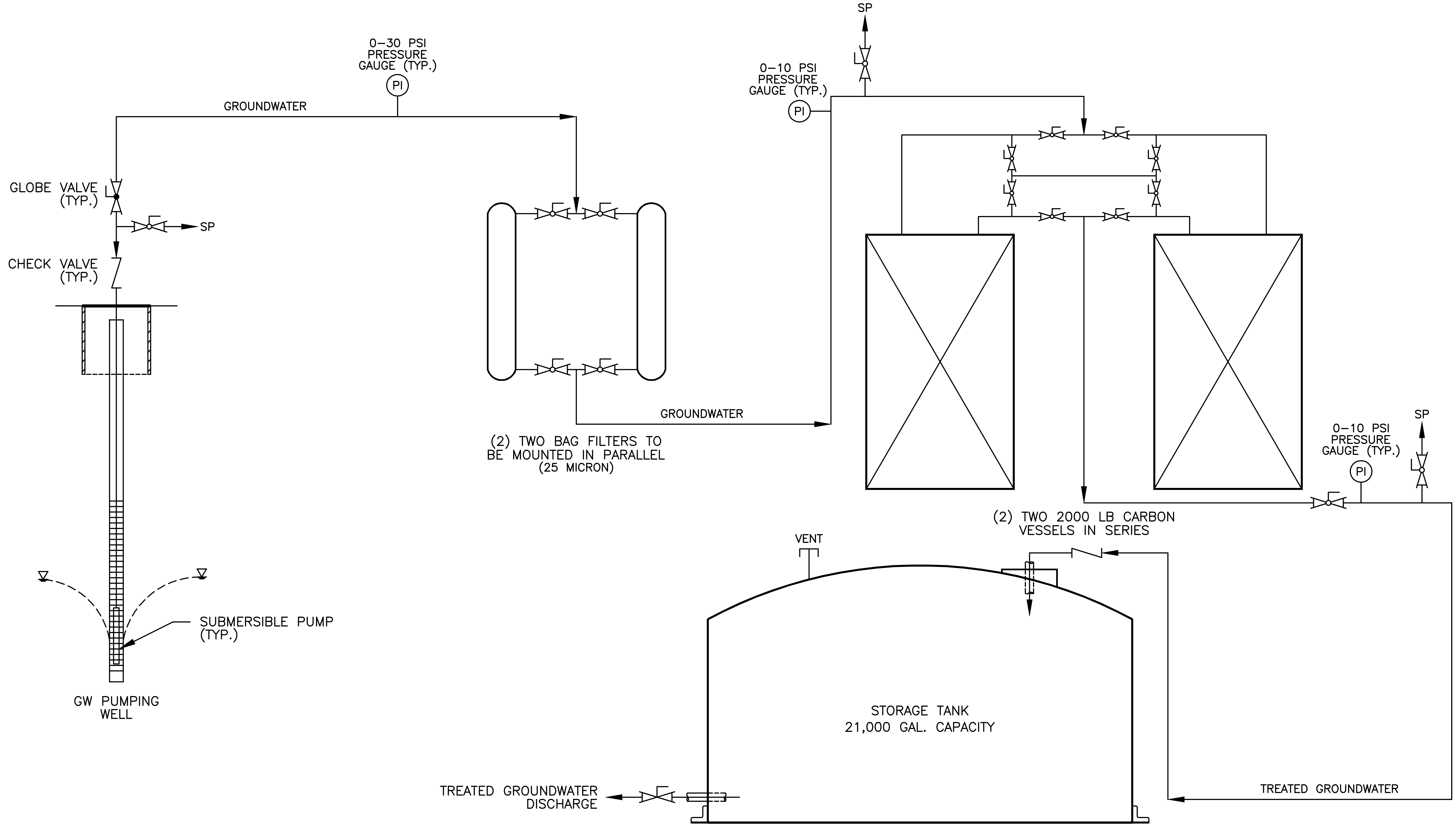
DATE:	FILE NAME:	APPROVED BY:
03/07/2003	PEMACO-40-BASE.DWG	

WELL LOCATIONS FOR AQUIFER PUMPING TEST EXPOSITION 'A' AND 'B' ZONES

PEMACO SUPERFUND SITE
5050 EAST SLAUSON AVENUE
MAYWOOD, CALIFORNIA

TN&A T N & Associates, Inc.
Engineering and Science

FIGURE 2



SYMBOL LEGEND

Symbol	Description	Symbol	Description
SP	SAMPLE PORT		GLOBE VALVE
	BALL VALVE		CHECK VALVE
	GATE VALVE	PI	PRESSURE INDICATOR

DATE:	FILE NAME:	APPROVED BY:
9/21/01	PEMACO_FLWDIA	

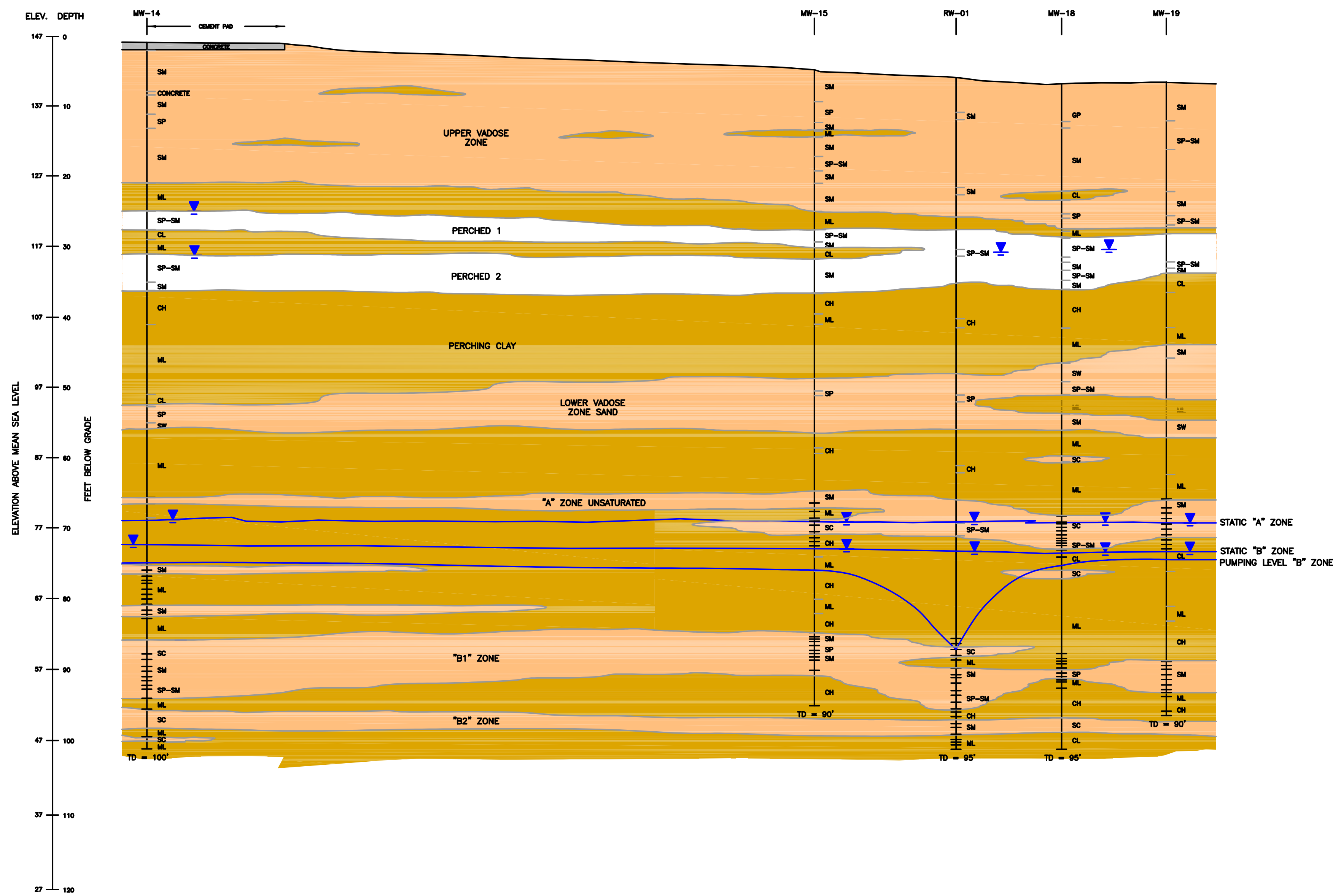
SCHEMATIC OF EQUIPMENT LAYOUT
PEMACO AQUIFER TEST
EXPOSITION 'A' AND 'B' ZONES

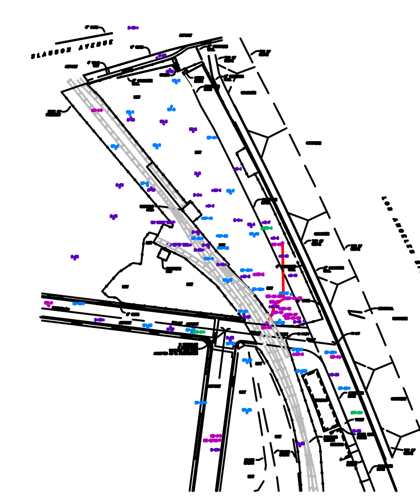
PEMACO, INC.
5050 EAST SLAUSON AVENUE
MAYWOOD, CALIFORNIA

TN &A T N & Associates, Inc.
Engineering and Science

FIGURE: 3

PEMACO_FLWDIA.DWG (1:1)





CROSS SECTION INDEX MAP

LEGEND

WELL SCREEN INTERVAL

COARSE-GRAINED LITHOSOMES

FINE-GRAINED LITHOSOMES

FILL MATERIAL

POTENTIOMETRIC SURFACE LEVEL

NOTES:

1. ALL MONITORING WELLS WERE GAUGED DECEMBER 17, 2001 PRIOR TO START OF THE PUMPING TEST.
2. GROUNDWATER DATA COLLECTED CONTINUOUSLY THROUGHOUT PUMPING TEST.

10

0 10

APPROX. SCALE IN FEET

DATE: 03/06/2003	FILE NAME: PEM-XSEC.DWG	APPROVED BY:

SOURCE AREA CROSS SECTION AND CONE OF DEPRESSION DURING PUMP TEST

PEMACO SUPERFUND SITE
5050 EAST SLAUSON AVENUE
MAYWOOD, CALIFORNIA

TN & A T N & Associates, Inc. Engineering and Science

FIGURE 4

TABLES

Table 1
Well Construction Data - Exposition Aquifer Wells Used for Aquifer Tests Pemaco Superfund Site
5050 E. Slauson Avenue, Maywood, California

Well I.D.	Associated Hydrogeologic Unit	Date Installed	Northing	Easting	Top of Casing Elevation	Vault Cover Elevation	Ground Surface Elevation	Casing Diameter (inches)	Well Material	Screening Interval	Screen Slot Size (inches)	Filter Pack Sand Size	Constructed Total Depth	Measured Total Depth (from top of casing)
MW-14-80	B Zone	11/14/01	1817059.40321135	6509595.86566360	146.02	146.33	146.34	2	Schedule 40 PVC	76 - 81	0.010	2/16	81	80.55
MW-14-90	B Zone	11/14/01	1817059.40321135	6509595.86566360	145.93	146.33	146.34	2	Schedule 40 PVC	87 - 92	0.010	2/16	92	92.35
MW-15-70	A Zone	11/28/01	1816968.13830192	6509596.53768024	142.52	142.97	142.70	2	Schedule 40 PVC	63 - 68	0.010	2/16	68	68.43
MW-15-85	B Zone	11/19/01	1816965.16498740	6509598.63270074	141.94	143.06	142.70	2	Schedule 40 PVC	80 - 85	0.010	2/16	85	85.45
MW-16-70	A Zone	11/15/01	1816955.55635096	6509582.80914877	140.80	141.27	140.90	2	Schedule 40 PVC	63 - 68	0.010	2/16	68	68.61
MW-16-90	B Zone	11/15/01	1816955.55635096	6509582.80914877	140.77	141.27	140.90	2	Schedule 40 PVC	84 - 89	0.010	2/16	89	89.32
MW-17-70	A Zone	11/26/01	1816938.93248240	6509601.14853236	141.27	141.80	141.60	2	Schedule 40 PVC	63 - 68	0.010	2/16	68	68.46
MW-17-85	B Zone	11/26/01	1816935.67191000	6509602.55643000	141.28	141.76	141.50	2	Schedule 40 PVC	78 - 83	0.010	2/16	83	83.44
MW-17-95	B Zone	11/28/01	1816934.37572000	6509598.87584000	140.85	141.38	141.20	2	Schedule 40 PVC	90 - 92.5	0.010	2/16	92.5	93.15
MW-18-70	A Zone	11/16/01	1816939.40304123	6509578.15832437	139.49	140.03	139.80	2	Schedule 40 PVC	62 - 67	0.010	2/16	67	66.98
MW-18-85	B Zone	11/16/01	1816939.40304123	6509578.15832437	139.29	140.03	139.80	2	Schedule 40 PVC	81 - 86	0.010	2/16	86	85.40
MW-19-70	A Zone	11/27/01	1816925.50580914	6509569.71093735	139.25	139.98	139.80	2	Schedule 40 PVC	62 - 67	0.010	2/16	67	69.57
MW-19-90	B Zone	11/27/01	1816925.50580914	6509569.71093735	139.59	139.98	139.80	2	Schedule 40 PVC	82 - 87	0.010	2/16	87	88.43
RW-01-95	B Zone	11/20/01	1816948.78059864	6509590.56447219	141.14	141.49	141.20	6	Stainless Steel, V-wrap	80 - 95	0.020	2/12 and 2/16	95	94.55

Table 2
Groundwater Elevation Data During Aquifer Pump Test
Pemaco Superfund Site Maywood, CA

Date	Discharge Rate (gpm)	Time	Elapsed Time of Test	RW-01	MW-02	MW-03	MW-14-80	MW-14-90	MW15-70	MW-15-85	MW-16-70	MW-16-85	MW-17-70	MW-17-85	MW-17-95	MW-18-70	MW-18-85	MW-19-70	MW-19-85
				Total Water Column Above Transducer (feet)															
12/17/2001	0.0	950	0:00:00	26.021	11.712	--	9.029	12.548	4.474	10.895	5.3	9.256	4.661	9.853	9.742	8.409	9.907	--	--
	0.5	1020	0:05:00	23.01	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1030	0:15:00	21.793	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1045	0:30:00	20.968	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1100	0:45:00	20.585	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1112	0:57:00	20.451	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1115	1:00:00	20.411	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1130	1:15:00	20.34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1145	1:30:00	20.308	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1200	1:45:00	20.263	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5	1215	2:00:00	20.231	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.5 TO 0.8	1230	2:15:00	20.234	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8	1243	2:28:00	--	--	--	--	12.299	--	--	--	--	--	--	--	--	--	--	--
	0.8	1245	2:30:00	18.487	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8	1250	2:35:00	--	11.514	--	--	--	--	9.425	--	7.457	4.645	8.96	9.657	--	8.475	--	--
	0.8	1300	2:45:00	17.713	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8	1315	3:00:00	17.402	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8	1338	3:23:00	17.203	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8	1345	3:30:00	17.063	--	--	9.129	12.192	4.485	--	5.237	--	--	--	--	5.444	--	--	--
	0.8	1350	3:35:00	--	11.448	--	--	--	--	9.164	--	7.061	4.597	8.679	9.553	--	8.167	--	--
	0.8	1400	3:45:00	16.868	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8	1420	4:05:00	16.782	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8	1430	4:15:00	16.763	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	0.8 TO 1.0	1435	4:20:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1445	4:30:00	15.639	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1450	4:35:00	--	--	--	9.135	12.148	4.461	--	5.2	--	--	--	--	5.417	--	--	--
	1.0	1455	4:40:00	--	11.419	--	--	--	--	8.904	--	6.752	4.565	8.527	9.437	--	7.916	--	--
	1.0	1500	4:45:00	15.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1510	4:55:00	--	--	10.021	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1511	4:56:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.157
	1.0	1513	4:58:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.611	--
	1.0	1518	5:03:00	14.842	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1530	5:15:00	14.713	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1545	5:30:00	14.578	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1600	5:45:00	14.549	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1605	5:50:00	--	--	--	9.125	12.071	4.418	--	5.138	--	--	--	--	5.376	--	--	--
	1.0	1610	5:55:00	--	11.377	--	--	--	--	8.747	--	6.523	4.511	8.346	9.282	--	7.74	--	--
	1.0	1615	6:00:00	14.483	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1625	6:10:00	--	--	9.979	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1628	6:13:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8.015
	1.0	1630	6:15:00	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.572	--
	1.0	1645	6:30:00	14.467	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12/18/2001	1.0	1100	24:45:00 AM	13.241	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1105	24:50:00 AM	--	--	--	9.046	--	4.269	--	4.99	--	--	--	--	--	--	--	--
	1.0	1110	24:55:00 AM	--	--	--	--	11.984	--	--	--	--	--	--	--	5.172	--	--	--
	1.0	1120	25:05:00 AM	--	11.271	--	--	--	--	8.625	--	6.352	--	--	--	--	7.608	--	--
	1.0	1125	1:10:00	--	--	--	--	--	--	--	--	--	--	8.229	7.695	--	--	--	--
	1.0	1130	25:15:00 AM	--	--	--	--	--	--	--	--	--	4.391	--	--	--	--	--	--
	1.0	1145	25:30:00 AM	--	--	9.902	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1205	25:50:00 AM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.506	--
	1.0	1215	25:55:00 AM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.905
	1.0	1315	26:55:00 AM	13.238	--	--	9.112	--	--	--	--	--	--	--	--	--	--	--	--

Table 2
Groundwater Elevation Data During Aquifer Pump Test
Pemaco Superfund Site Maywood, CA

				RW-01	MW-02	MW-03	MW-14-80	MW-14-90	MW15-70	MW-15-85	MW-16-70	MW-16-85	MW-17-70	MW-17-85	MW-17-95	MW-18-70	MW-18-85	MW-19-70	MW-19-85
Date	Discharge Rate (gpm)	Time	Elapsed Time of Test	*Total Water Column Above Transducer (feet)*															
	1.0	1340	27:10:00 AM	--	--	--	--	--	4.333	--	--	--	--	--	--	--	--	--	--
	1.0	1345	27:15:00 AM	--	--	--	--	--	--	--	5.051	--	--	--	--	--	--	--	--
	1.0	1355	27:25:00 AM	--	--	--	--	12.043	--	--	--	--	--	--	--	5.227	--	--	--
	1.0	1530	5:00:00	--	11.288	--	--	--	--	8.678	--	6.404	4.43	8.286	7.615	--	7.665	--	--
12/19/2001	1.0	1024	48:09:00 AM	--	--	9.902	--	--	--	--	--	--	--	--	--	--	--	--	--
	1.0	1028	48:13:00 AM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.931	--
	1.0	1031	48:16:00 AM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.939
12/20/2001	0.0	815	70:00:00 AM	25.788	11.649	10.327	9.104	12.675	4.507	10.995	5.336	9.331	4.702	9.964	8.857	5.417	10.005	6.466	9.643

Notes: TDWAT = total depth to water above troll

Table 3
Description of Equipment Used During Aquifer Tests
Pemaco Superfund Site, Maywood, CA

Equipment Type	Description
Test Pump	Two alternative pumping systems are proposed. The preferred option would be a variable frequency, submersible, down-hole pump. Alternatively, a standard submersible down-hole pump, controlled by valving may be utilized. Either pump would be four inches in diameter, 120 volt, and capable of pumping up to 20 gallons per minute under 150 feet of head.
Valving	Three types of valves will be used during the aquifer testing. ♦ Backflow prevention/check valve connected to the discharge port of the pump. ♦ Two-inch gate valve to increase head (restrict flow). This valve will be located at the surface, adjacent to the flow and monitoring devices. ♦ 1/8-inch needle valve for sample collection ports.
Flow Meter	In line acrylic tube flow meter (2-20 gpm). This type of a meter is a direct-read round tube meter measuring approximately 11 inches in height.
Totalizing Meter	Cast bronze totalizing flow meter. Similar to the acrylic tube flow meter, this meter will measure the flow rate and total volume of water pumped during each time step and for the entire duration of the test.
Sampling Ports	The sampling ports will be 1/8-inch stainless steel valves with attached teflon tubing. These ports will be used to decant water samples into containers for field measurements and laboratory analyses.
Discharge Hose and Conveyance Piping	The discharge hose will consist of 2-inch diameter, flexible helix reinforced, SBR rubber hose. The small sections of conveyance piping will be 2-inch diameter Schedule 40 PVC. The rigid pipe sections will be used for manifolding the meters and monitoring equipment.
Storage Tank(s)	The pumping rate is anticipated to range from 5 to 20 gallons per minute for the 72-hour test duration. Assuming an average flow rate of 15 gpm, a total of 64,800 gallons of water will be pumped. Three 21,000 gallon aboveground storage tanks will used to store the pumped water. If additional storage is needed (e.g. in the event that treated water is not meeting discharge requirements and stored water requires recirculating through new carbon), additional storage tanks can be procured and delivered to the site within 12 hours.
Filters	Two No. 2 -sized bag filters connected in series. The nominal filter dimensions are 7-inch diameter by 32-inch length, capable of handling flow up to 180 gpm. The bag material will be polypropylene felt, with filtration to 10 microns. The filters will be positioned between the recovery well and the carbon vessels.
Liquid-Phase Granular Activated Carbon	Based on the VOC concentrations in the groundwater at the proposed pumping well location, the mass of dissolved VOCs can be effectively removed with 1000 to 1500 pounds of granular activated carbon. Two vessels, each containing 2,000 pounds of virgin coconut shell carbon, will be used to treat the groundwater prior to discharge.
Miscellaneous	The field crew will have miscellaneous fitting, piping, hardware, and tools to make necessary retrofits and modification during the test.
Data Logger	In-Situ Inc. Hermit 2000, eight channel, electronic data logger. This data logger is fully automated and will measure barometric pressure at the predetermined time intervals.

Table 3 (continued)
Description of Equipment Used During Aquifer Tests
Pemaco Superfund Site, Maywood, CA

Equipment Type	Description
Water Level Meter	Solinst® Model 122 Interface Probe. Battery operated, 150 foot, electronic tape. The groundwater interface is indicated by a light and audible tone. The Model 122 Interface Meter is CSA approved for use in hazardous locations Class I, Groups C&D.
Flow Meter	Down hole heat-pulse flow meter to measure horizontal flow and direction in the observation wells.
pH, Conductivity, and Temperature Meter	Orion Multimeter 250a or Equivalent. Wide pH range plus conductivity measured in millivolts. Simultaneously displays temperature and pH. Simple 2-point auto-calibration. Fully waterproof
Turbidity Meter	Model DR-15CE. Manual three user-selectable ranges from 0-1000 NTU, resolution to 0.01 NTU.

Table 4
Screening Samples from Aquifer Test Wells, Installed Nov.-Dec. 2001 (ug/L)
Pemaco Superfund Site
5050 E. Slauson Avenue, Maywood, California

Sample ID	MW-14-80	MW-14-90	MW-17-70	MW-17-85	MW-17-95	MW-19-70	MW-19-85	PEL-1*
Date Sampled	11/28/01	11/28/01	12/05/01	12/14/01	12/13/01	12/06/01	12/06/01	11/28/01
Acetone	**610**	**260**	**2,300**	**2,600**	**210**	**1,800**	<10	**310**
Benzene	<5.0	<1.0	**0.92**	<100	<10	<25	<0.5	**5.1**
2-Butanone	<100	**4**	<1	<2000	<100	<500	**3.8**	<1.0
Carbon Disulfide	**6.7**	<10	<10	**140**	<100	<500	<1.0	<10
Chloroform	<10	**0.63**	**5.1**	<200	<10	<50	**5.7**	**4.5**
1,1-Dichloroethane	<10	**0.95**	**1.3**	<200	<10	<50	**1.8**	<1.0
1,2-Dichloroethane	<5.0	<0.5	<0.5	<100	<5.0	<25	<0.5	<0.5
1,1-Dichloroethene	<10	**3.6**	**9.5**	<200	<10	<50	**2.3**	<1.0
cis-1,2-Dichloroethene	**13**	**43**	**330**	<200	**31**	**85**	**59**	<1.0
trans-1,2-Dichloroethene	<10	T	**23**	<200	<10	<50	**1.8**	<1.0
Tetrachloroethene	<10	**2**	**9.1**	<200	<10	<50	**1.8**	<1.0
Toluene	<10	<1.0	**3**	<200	<10	<50	**1.2**	<1.0
1,1,2-Trichloroethane	<10	<1.0	**0.97**	<200	<10	<50	<1.0	<1.0
Trichloroethene	**4,700**	**4,700**	**27,000**	**21,000**	**1,400**	**5,000**	**2,000**	<1.0
Vinyl Chloride	<5.0	**0.73**	**27**	<100	<5.0	<25	**3.6**	<0.5
p/m-Xylenes	<10	<1.0	**0.4**	<200	<10	<50	<1.0	<1.0

Notes:
1. Only detected analytes are listed
2. All analyses by EPA Method 8260B, except for Ethyl Acetate and 1-Propanol which were anayzed by EPA Method 8015M
3. -- = not analyzed for parameter
4. * = Sample "PEL-1" was a water sample collected from a 10 oz. Certified clean sampling jar in which 15 time-release coated bentonite pellets were placed. The jar was then filled with lab grade DI water. The sample was collected from this water after a 4-hour resonance time.

Table 4A
Groundwater Samples Collected During Aquifer Test, December 2001 (ug/L)
Pemaco Superfund Site
5050 E. Slauson Avenue, Maywood, California

Sample ID	RW-1-4hrs	RW-1-24hrs	RW-1-51hrs
Date Sampled	11/17/01	11/18/01	11/19/01
Acetone	<10	<10	<10
Benzene	**0.52**	**0.5**	<0.5
2-Butanone	**33**	<10	<10
Carbon Disulfide	<10	<10	<10
Chloroform	<1.0	<1.0	<1.0
1,1-Dichloroethane	**1.4**	**1.3**	**1.4**
1,2-Dichloroethane	<0.5	<0.5	<0.5
1,1-Dichloroethene	**11**	**9.7**	**9.6**
cis-1,2-Dichloroethene	**170**	**160**	**160**
trans-1,2-Dichloroethene	**11**	**11**	**11**
Tetrachloroethene	**8.3**	**7.9**	**8.2**
Toluene	<1.0	<1.0	<1.0
1,1,2-Trichloroethane	<1.0	<1.0	<1.0
Trichloroethene	**13,000**	**13,000**	**13,000**
Vinyl Chloride	**6.2**	**5.7**	**5.3**
p/m-Xylenes	<1.0	<1.0	<1.0

Notes:
1. Only detected analytes are listed
2. All analyses by EPA Method 8260B

Table 5
Summary of Numeric Aquifer Properties
Pemaco Superfund Site
Maywood, California

Aquifer Zone	Well ID (screen)	Test Type	Slug Volume (gal)	Initial Displace-ment	Pumping Rate (Q) (gpm)	Aquifer Thickness (t) (feet)	Solution Method [Aqtesolv]	Trans-missivity (T) (ft2/min)	Storage Coefficient (S) (unitless)	Hydraulic Conductivity (K) (ft/min)	Downgradient Radius of Capture (feet)	Crossgradient Width of Capture (feet)	Seepage Velocity (ft/year)
"A" Zone	MW-14-80	Slug - Withdrawal	1.844	2.988	NA	1	Bouwer-Rice	1.303E-03	NA	1.303E-03	---	---	6.3
	MW-15-70	Slug - Withdrawal	1.396	0.615	NA	3	Bouwer-Rice	6.831E-03	NA	2.277E-03	---	---	11.0
	MW-16-70	Slug - Withdrawal	1.102	0.920	NA	1	Bouwer-Rice	8.281E-04	NA	8.281E-04	---	---	4.0
	MW-18-70	Slug - Withdrawal	1.094	1.237	NA	1	Bouwer-Rice	1.435E-03	NA	1.435E-03	---	---	6.9
"A" + "B" Zone	MW-3 A + B	Pumping	NA	NA	1.137	4.5	Hantush, 1960	1.466E-01	2.926E-04	3.258E-02	29.2	91.8	177.8
		Recovery	NA	NA	1.137	4.5	Hantush, 1960	1.104E-01	7.531E-04	2.453E-02	38.8	121.8	133.9
"B_1" Zone	MW-2	Pumping	NA	NA	1.137	5	Hantush, 1960	9.690E-02	1.647E-05	1.938E-02	44.2	138.8	117.9
		Recovery	NA	NA	1.137	5	Hantush, 1960	1.053E-01	9.832E-04	2.106E-02	40.7	127.7	128.1
	MW-14-90	Slug - Withdrawal	1.847	2.480	NA	5	Bouwer-Rice	5.390E-03	NA	1.078E-03	---	---	6.6
		Pumping	NA	NA	1.137	5	Hantush, 1960	1.276E-01	4.393E-07	2.552E-02	37.9	119.1	155.2
		Recovery	NA	NA	1.137	5	Hantush, 1960	1.489E-01	3.606E-05	2.978E-02	32.5	102.1	181.1
	MW-15-85	Pumping	NA	NA	1.137	5	Hantush, 1960	8.090E-02	1.020E-10	1.618E-02	59.8	187.9	98.4
		Recovery	NA	NA	1.137	5	Hantush, 1960	6.820E-02	6.450E-06	1.364E-02	70.9	222.9	83.0
	MW-16-85	Pumping	NA	NA	1.137	5	Hantush, 1960	7.630E-02	2.672E-08	1.526E-02	63.4	199.2	92.8
		Recovery	NA	NA	1.137	5	Hantush, 1960	8.150E-02	2.890E-07	1.630E-02	59.4	186.5	99.1
	MW-17-85	Pumping	NA	NA	1.137	2.5	Hantush, 1960	1.938E-01	1.000E-10	7.752E-02	25.0	78.4	471.5
		Recovery	NA	NA	1.137	2.5	Hantush, 1960	1.570E-01	1.272E-10	6.280E-02	30.8	96.8	382.0
	MW-18-85	Pumping	NA	NA	1.137	1	Hantush, 1960	1.046E-01	1.767E-01	1.046E-01	46.3	145.3	636.2
		Recovery	NA	NA	1.137	1	Hantush, 1960	7.197E-02	1.322E-05	7.197E-02	67.2	211.2	437.8
	MW-19-85	Pumping	NA	NA	1.137	4.5	Hantush, 1960	1.884E-01	1.000E-10	4.187E-02	25.7	80.7	254.7
		Recovery	NA	NA	1.137	4.5	Hantush, 1960	1.050E-01	9.417E-11	2.333E-02	46.1	144.8	141.9

Table 5
Summary of Numeric Aquifer Properties
Pemaco Superfund Site
Maywood, California

Aquifer Zone	Well ID (screen)	Test Type	Slug Volume (gal)	Initial Displace-ment	Pumping Rate (Q) (gpm)	Aquifer Thickness (t) (feet)	Solution Method [Aqtesolv]	Trans-missivity (T) (ft2/min)	Storage Coefficient (S) (unitless)	Hydraulic Conductivity (K) (ft/min)	Downgradient Radius of Capture (feet)	Crossgradient Width of Capture (feet)	Seepage Velocity (ft/year)
"B_2" Zone	MW-17-95	Pumping	NA	NA	1.137	1	Hantush, 1960	6.691E-03	2.005E-01	6.691E-03	723.1	2271.7	40.7
		Recovery	NA	NA	1.137	1	Hantush, 1960	6.560E-03	1.703E-02	6.560E-03	737.5	2317.1	39.9
"$B_1 + B_2$"	RW-1	Recovery	NA	NA	1.137	9	Hantush-Jacob	2.766E-02	1.232E-03	3.073E-03	174.9	549.6	18.7

Notes: Pumping rate is average for entire pumping duration
Aquifer thickness assumed to be actual logged thickness adjacent to corresponding screened intervals.
Bouwer-Rice = Bouwer and Rice (1976) developed an empirical relationship for calculating hydraulic conductivity due to an instantaneous change in water level.
Hantush, 1960 = Analytical solution for pumping from a leaky aquifer system, assuming storage in the aquitard(s).

Table 6
Aquifer Drawdown Test Results
Pemaco Superfund Site, Maywood, California

Groundwater Elevation (feet above MSL)				
Well ID	**Static**	**Steady State** (1 GPM)	**Δ GW Elevation** (measured)	**Δ GW Elevation** (transducer)
RW-1	73.62	60.24	13.38	13.93
MW-2	79.02	78.89	0.13	0.46
MW-3	76.56	76.30	0.26	0.26
MW-14-80	77.66	77.63	0.03	-0.13
MW-14-90	73.19	72.82	0.37	0.47
MW-15-70	78.21	78.15	0.06	0.14
MW-15-85	73.26	71.20	2.06	2.18
MW-16-70	77.89	77.60	0.29	0.24
MW-16-90	73.82	71.00	2.82	2.82
MW-17-70	77.89	77.67	0.22	0.18
MW-17-85	74.85	73.73	1.12	1.52
MW-17-95	57.61	55.00	2.61	2.57
MW-18-70	78.00	77.77	0.23	0.18
MW-18-85	74.12	71.97	2.15	2.20
MW-19-70	77.78	77.71	0.07	-0.72
MW-19-90	74.39	72.82	1.57	1.54

Notes:

MSL = Mean Seal Level

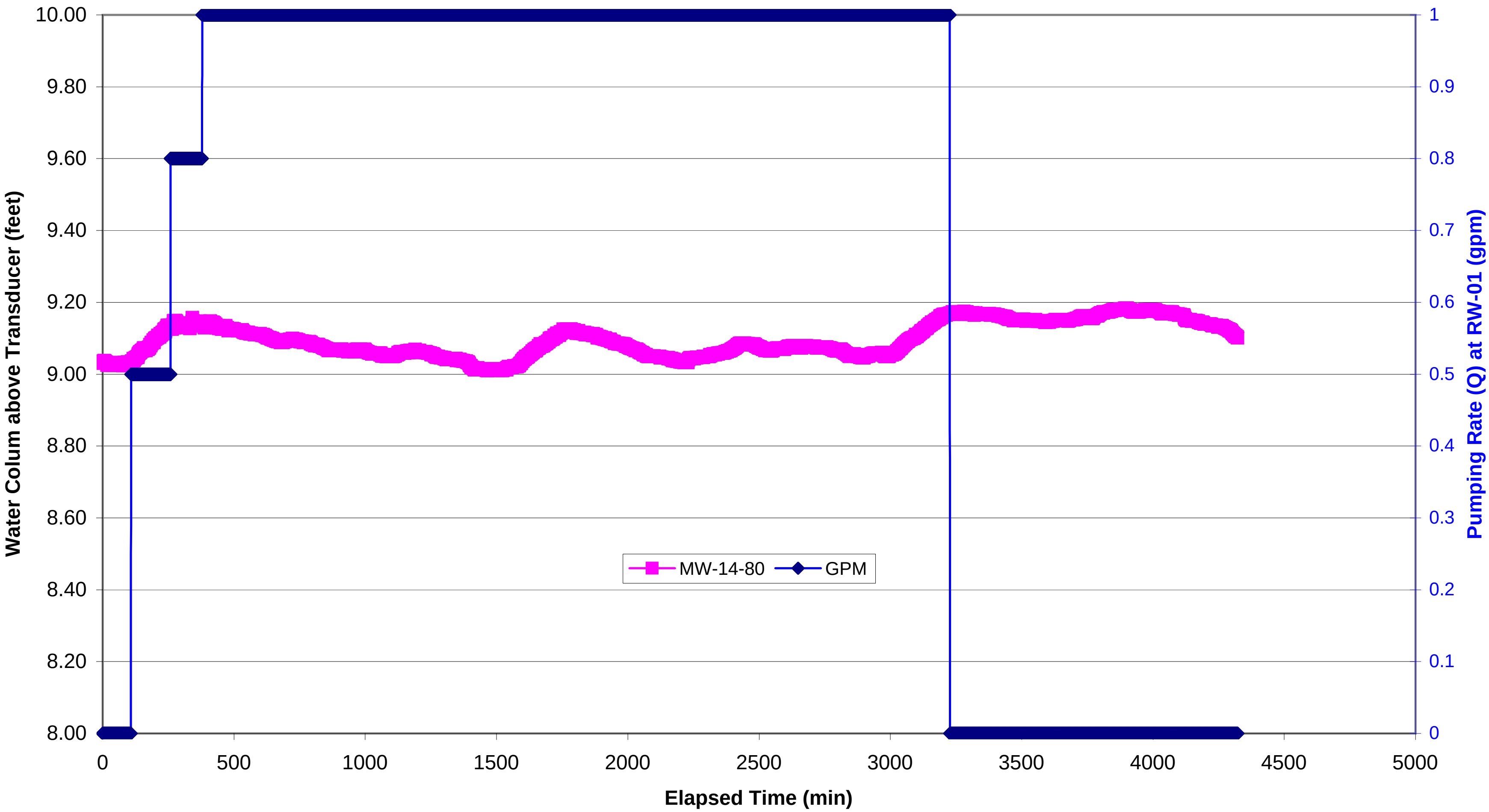
GPM =Gallons per Minute

Static levels measured on December 17, 2001

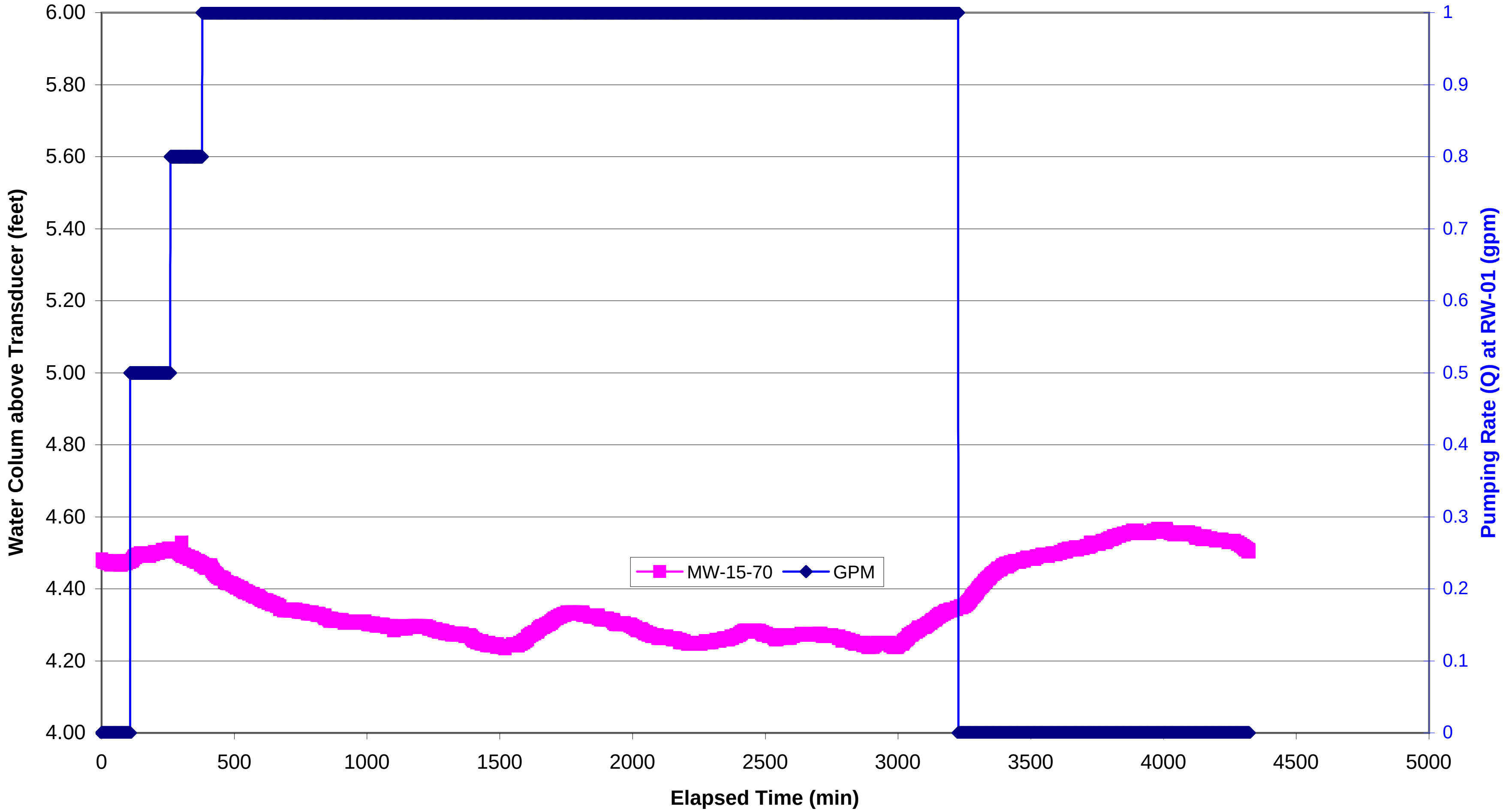
Steady state levels measured during pumping test on December 19, 2001

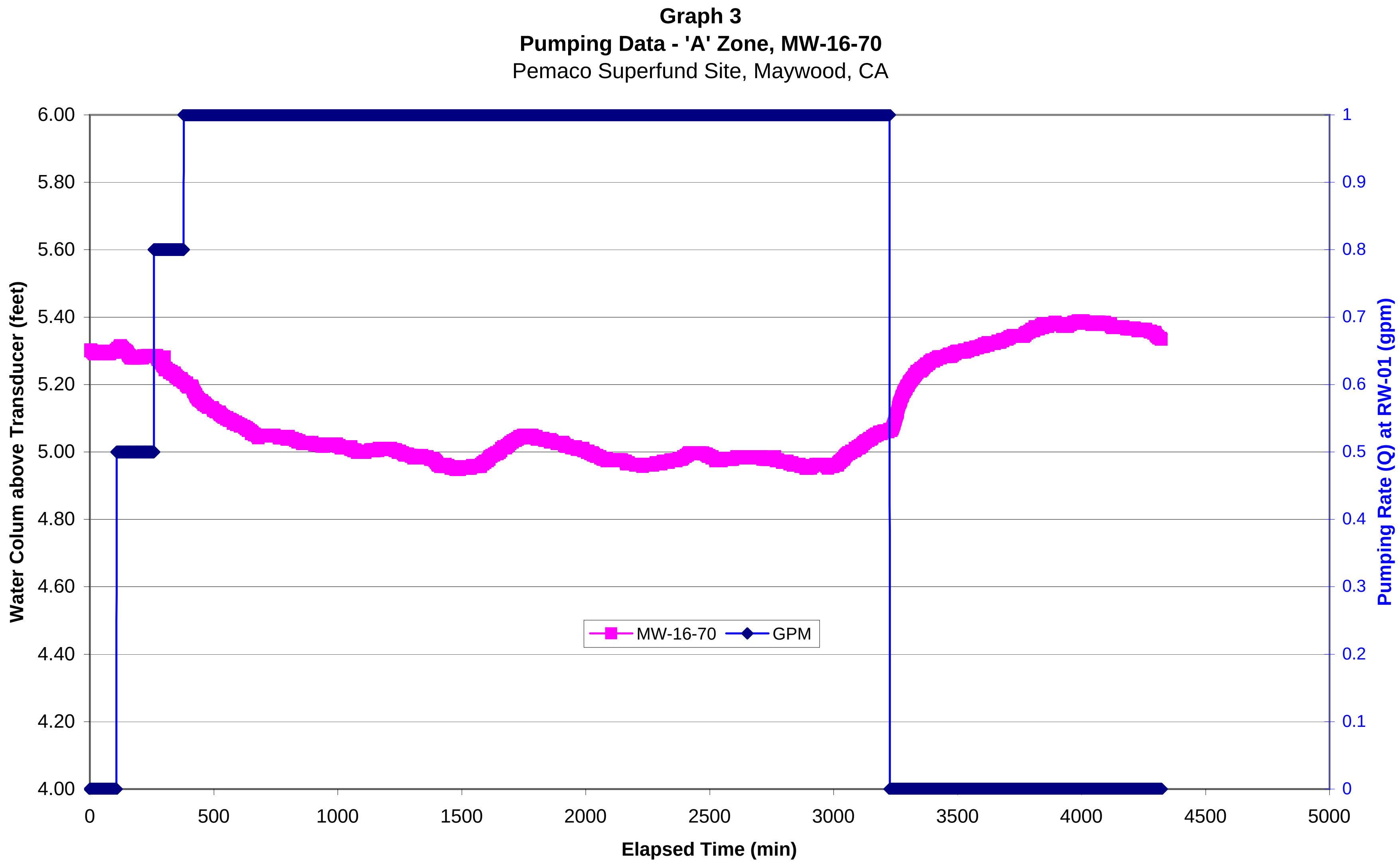
GRAPHS

Graph 1
Pumping Data - 'A' Zone, MW-14-80
Pemaco Superfund Site, Maywood, CA



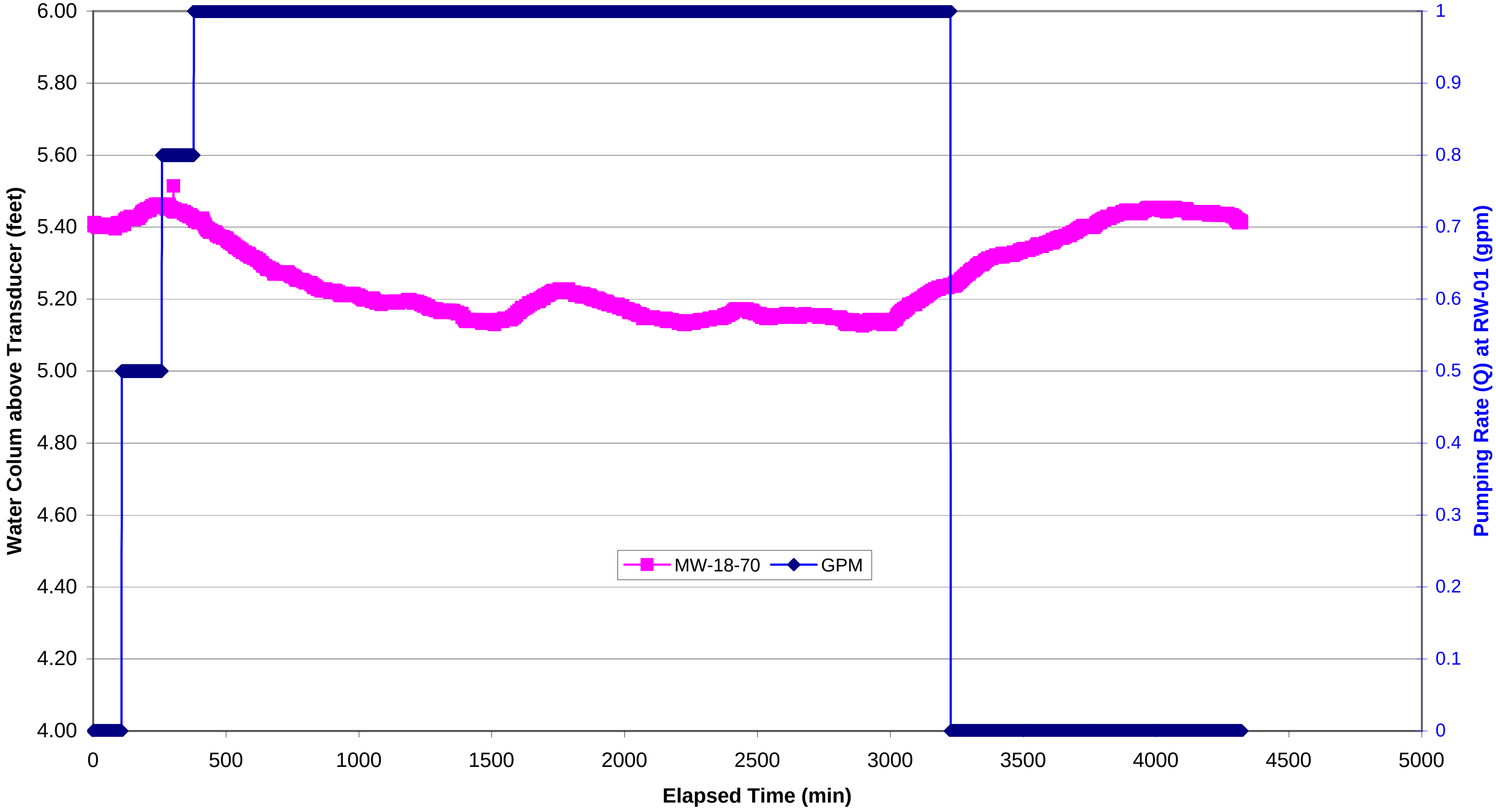
Graph 2
Pumping Data - 'A' Zone, MW-15-70
Pemaco Superfund Site, Maywood, CA



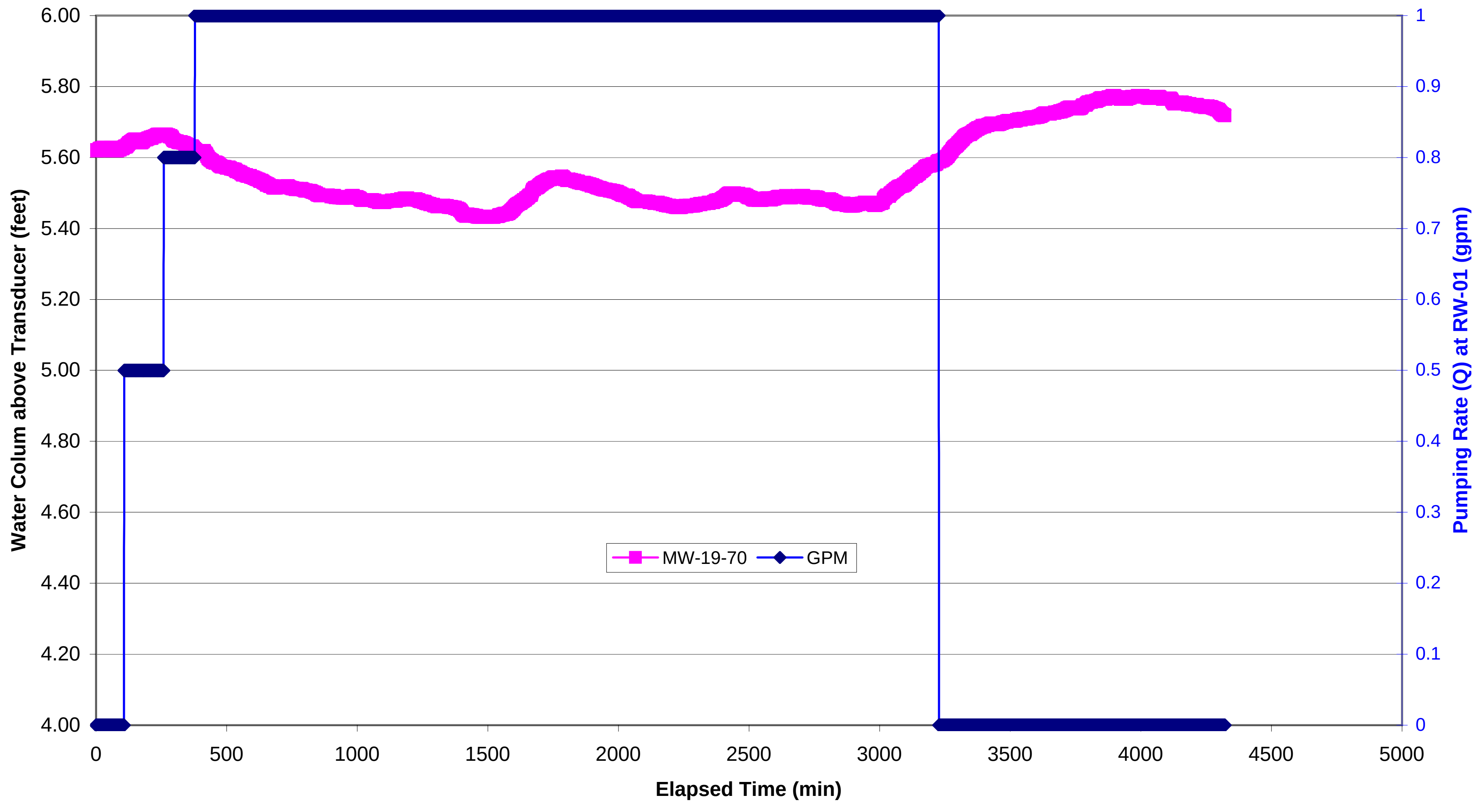


Graph 3
Pumping Data - 'A' Zone, MW-16-70
Pemaco Superfund Site, Maywood, CA
6.00
5.80
5.60
5.40
5.20
5.00
4.80
4.60
4.40
4.20
4.00
Water Colum above Transducer (feet)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pumping Rate (Q) at RW-01 (gpm)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Elapsed Time (min)
MW-16-70
GPM

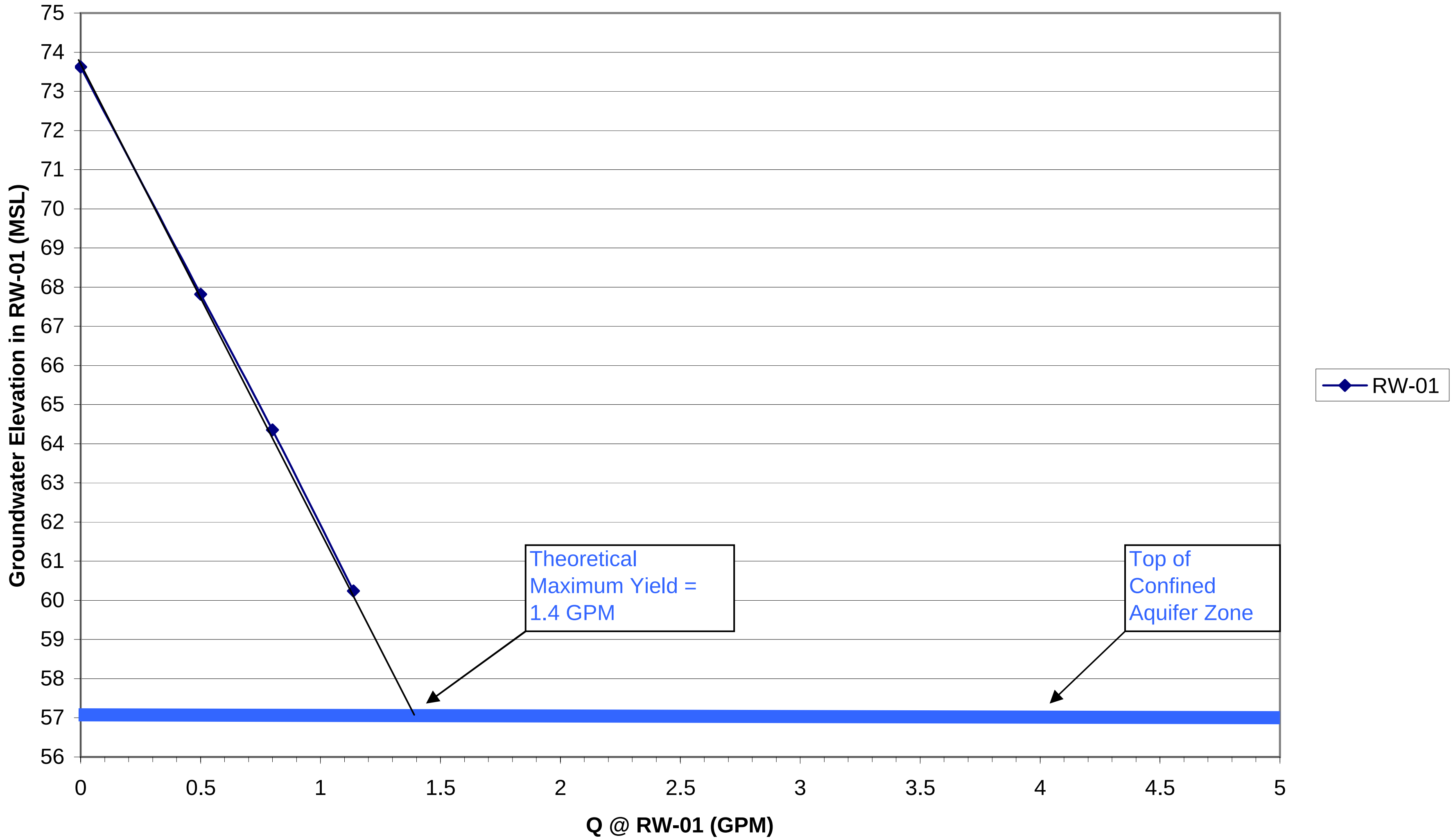
Graph 4
Pumping Data - 'A' Zone, MW-18-70
Pemaco Superfund Site, Maywood, CA



Graph 5
Pumping Data - 'A' Zone, MW-19-70
Pemaco Superfund Site, CA



Graph 6
Results of Step Test - RW-01



ATTACHMENT A

Standard Operating Procedures:
In Situ Hydraulic Conductivity Testing

STANDARD OPERATING PRACTICE TNFLD008H

In Situ Hydraulic Conductivity Testing

TABLE OF CONTENTS

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STANDARD OPERATING PRACTICE TNFLD008H

In Situ Hydraulic Conductivity Testing

1.0 INTRODUCTION

The objective of this SOP is to describe procedural guidelines for the hydraulic testing and equipment standards for groundwater monitoring wells. Site-specific procedures will depend on project objectives, geologic conditions, and appropriate state and federal regulations and standards.

2.0 OVERVIEW

Hydraulic testing will be conducted to estimate aquifer parameters and to further estimate groundwater flow velocities, associated contaminant transport, and remedial design considerations. Aquifer hydraulic characteristics can be estimated to different precision, and for different hydrogeologic conditions, using three basic testing categories:

- Single-Well Aquifer (Slug) Testing;
- Multiple-Well Aquifer (Pumping) Testing; and
- Bail-Down and Pressure Testing.

3.0 SINGLE-WELL AQUIFER (SLUG) TESTING

3.1 Objectives

The objective of this section is to provide procedures by which single-well aquifer (slug) test are to be designed, conducted, and analyzed.

3.2 Slug Test Design

Slug tests are utilized to obtain order-of-magnitude approximations of hydraulic conductivity in the portion of the aquifer immediately surrounding the well screens. Testing programs will be designed with consideration for potential aquifer heterogeneity, well construction variability, and ultimate use of results. The materials to be used in slug testing and the methods for data collection are determined based on the following factors:

- Estimated hydraulic conductivity of the aquifer to be tested (i.e., the anticipated rate of recover to slug entry and/or removal),
- depth to the water table,
- types of contaminants, and
- well construction details.

No water or other liquid shall be introduced into wells.

The time required for a slug test to be completed is a function of the volume of the slug, the transmissivity of the formation, and the well casing size. The slug volume will be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.

Preparations for testing will include:

Office

- Review associated SOP documents and information on the wells to be tested (depth to water, depth of well, screened interval, casing size);
- Coordinate schedules with sampling and other efforts;
- Review the operator manual provided with the electronic data-logger, if appropriate;
- Check out and ensure the proper operation of all field equipment. Ensure that the electronic data logger is fully charged, if applicable. Test the electronic data logger and pressure transducers using a container of water (e.g., sink, bucket of water);
- Obtain appropriate sampling log book and assemble a sufficient number of field forms to complete the field assignment; and
- Review appropriate sections of the Site-Wide Health and Safety Plan.

Field

- Locate monitoring wells to be tested and appropriate decontamination areas;
- Assemble appropriate testing equipment;
- Decontaminate the transducers and cable as specified in SOP No. 13;
- Collect initial water level measurement from the monitor well and record in the field log book; and
- Before beginning the slug test, enter and record information in the electronic data logger. The type of information will vary depending on the model used. When using different models, consult the operator’s manual for the proper data entry sequence to be used.

3.3 Slug Test Execution

The following general procedures will be used to collect and report slug test data. The procedures required for a particular slug test may vary slightly from those described, depending on site conditions. Modifications to the test procedures shall be documented in the field logbook.

A. When the slug test is performed using an electronic data logger and pressure transducer, most of the data will be electronically stored internally or on computer diskettes or tape. The information will be transferred directly to a computer and analyzed. A copy of field notes with supplemental information and a computer printout of the data shall be maintained in the files as documentation.

B. The field logbook is used to record observations and supplemental information. At a minimum, the following information shall be recorded for each test:

1. Site location. Brief description of the general location of the well.
2. Well or piezometer ID. Unique number assigned to each well or piezometer where measurements are taken.
3. Date of the test.
4. Slug dimensions. Dimensions of the slug or displacement object in tenths of feet. (The slug will be adequately sized to insure an initial displacement of at least 2 feet, provided there is sufficient water column within the well.)
5. Personnel. Initials of personnel performing field measurements or collecting samples.
6. Test type. The slug device is either inserted (falling head) or withdrawn (rising head) from the monitor well. Note the appropriate test type (Recommend running both - slug in and complete test - once water levels have stabilized slug out and complete test - one of the two will usually work).
7. Comments. Include appropriate observations or information concerning antecedent weather conditions, sequence of events, or work being conducted at the site.
8. Elapsed time (min:sec). Cumulative time readings from beginning of test to end of test in minutes and seconds.
9. Representative depth-to-water measurements. Depth of water levels will be recorded to hundredths of feet below the measuring point. Initial and final depth to water shall be measured using an electric tape water level. Test data may be recorded using a pressure transducer and electronic data logger.

C. Procedures for conducting a slug test:

1. Measure the pre-test water level in the well and record in the field logbook and on the data sheet. The point and time of measurement shall be noted in the field logbook.
2. Cover sharp edges of the well casing with an insert to protect the transducer cable.
3. Connect the transducer cable to the electronic data logger.
4. Slowly lower the transducer and cable down the well to a depth below the slug submergence for the test, but at least 6 inches from the bottom of the well. Be sure this depth of submergence is within the design range stamped on the transducer. Securely fasten the transducer cable to a stationary object to keep the transducer at a constant depth.

5. Display the initial water level on the recording device according to manufacturer's instructions. Record the initial water level on the test data sheet.
6. Flag the slug/rope assembly so that easy identification can be made of how much rope must be left out to fully immerse the slug beneath the static water level, and how much rope to pull back to suspend the slug above the static water level.
7. Immediately after commencement of recording data on the data logger, "instantaneously" introduce the slug and the rope to minimize slug movement. While results obtained from analysis of these "falling head" data may not be theoretically valid, continue to record and monitor head recovery until water returns to static levels. From a practical standpoint, data will be recorded until the displacement head has been reduced to 10 percent or less of maximum displacement, and monitoring will be continued until only 1 to 2 percent displacement remains.
8. If the head data are recorded manually, equate the moment of maximum head change to time zero, and measure and record the depth to water and the time at each reading. Depths will be measured to the nearest 0.01 feet. The number of depth-time measurements necessary to complete the test are variable. Measurements will be frequent enough so that the change in water level between two successive measurements is less than 5 percent of the initial change in water level. It is critical to make as many measurements as possible in the early part of the test.
9. After effective static water level has been reached, a second slug test may be performed on the well by instantaneously removing the slug from the water column. This type of slug test is referred to as a rising head slug test. If such a test is to be conducted, the slug will be withdrawn to the predetermined suspension level and the rope tied off to minimize slug interference with the transducer cable (if applicable), or the slug will be fully withdrawn to permit access for water-level measurement.
10. Continue measuring and recording depth-time measurements until the water level returns to within 10 percent of equilibrium conditions.
11. If the well is used as a monitoring well, precautions will be taken to prohibit contamination of the wells by material introduced into the well. Bailers, slug/rope assemblies, and measuring devices will be cleaned thoroughly before each test in accordance with SOP No. 13. If tests are performed on more than one monitor well, care must be taken to avoid cross-contamination of the wells.

Slug tests must be conducted on relatively undisturbed wells. If a test is conducted on a well that has recently been pumped for water sampling purposes, the measured water level will be within

0.1 foot of the water level before sampling. At least one week will elapse between the drilling and development of a well and the performance of a slug test.

3.4 Post Operation

Field

- Decontaminate equipment and dispose of rope according to SOP No.13;
- If using an electronic data logger:
  1. Stop logging sequence,
  2. Save data to memory,
  3. Disconnect battery at the end of the testing activities; and
- Replace testing equipment in storage containers.

Office

- Inventory sampling equipment and supplies,
- Repair or replace all broken or damaged equipment,
- Replace expendable items,
- Return equipment to storage area, and report incidents of malfunctions or damage,
- Review field log book for completeness,
- Deliver original forms, logger data, and logbooks to supervising personnel with copies to file,
- Interpret slug test results. Analyze slug test using appropriate software packages or graphical solutions, and
- Send data logger or pressure transducers to factory for recalibration, if needed.

3.5 Bail-Down and Pressure Testing

Procedures for bail-down and pressuring testing will be developed, as the work is needed.

4.0 MULTIPLE-WELL AQUIFER (PUMPING) TESTING

4.1 Objectives

This section presents general guidelines for performing multiple well aquifer pumping tests.

4.2 Pumping Test Design

An aquifer test is a controlled field experiment designed to evaluate the performance characteristics of a well and the hydraulic properties of the associated aquifer(s). Such tests provide the best method for characterizing aquifer hydraulic properties when properly designed, performed, and conducted. They provide estimates for both transmissivity (T) and storage coefficient (S) over a large and representative volume of aquifer. Optimal performance of aquifer tests requires clear definition of three sets of requirements:

1. An understanding of the hydrogeological system being tested (i.e., confined or unconfined conditions and areal extent of aquifer).
2. The operational goals of the test (i.e., what information is needed from the test).
3. Identification of an analytical method that describes the aquifer conditions and can be used to reduce the data.

Aquifer tests are multifaceted, interdisciplinary efforts requiring coordination between technical personnel. Whereas, the more complex tests are more difficult logistically and often more expensive, they generally yield much more information. Some essential hydrologic information, such as rates of leakage through confining layers can be obtained only by performing the more sophisticated aquifer tests.

4.3 Control Procedures of Aquifer Test Programs

The technical complexity of aquifer testing combined with the institutional concerns such as storage of contaminated water, requires procedures for general control of aquifer test programs. A seven-step control procedure is defined below. An experienced hydrogeologist or groundwater hydrologist assigned to the project must conduct detailed planning for, and supervision of, site-specific aquifer pumping tests. The procedure presented here is primarily intended for project or task managers who require an aquifer test to be performed as part of a multi-disciplined project.

1. Define test program requirements:
   a) Describe the hydrogeologic system to be tested (e.g., porous, heterogeneous aquifer).
   b) Define the operational goals and requirements for the test (e.g., transmissivity, confined or unconfined nature of aquifer, and/or leakage coefficients of aquitards).
   c) Identify a method by which the data may be interpreted, according to the known hydrogeologic conditions and operational requirements.
2. Evaluate operational constraints.
3. Design the test methods and develop an aquifer test plan.
4. Conduct pre-test activities.
5. Initiate test and collect data.
6. Interpret the data with the chosen model or appropriate analytical method.
7. Evaluate the need for further testing.

The following sections detail the information required for each step in the procedure.

4.4 Defining Test Program Requirements

Describe the Hydrogeologic System To Be Tested: An aquifer test is interpreted by comparing field results with those expected from mathematical analogs. Therefore, the hydrogeology of the system to be tested will be defined as well as possible. Important factors include the following:

- Aquifer lithology and hydraulic characteristics (volume and nature of interstitial pores);
- Groundwater occurrence (confined, unconfined);
- Aquifer thickness, extent, and uniformity;
- Boundary conditions (nearby streams, ponds, no-flow boundaries);
- Aquifer isotropy and homogeneity;
- Well screen placement;
- Anticipated flow rates and type of flow (transient, steady state);
- Potential for leakage from confining units; and
- Well characteristics (available drawdown, screen transmitting capacity, well efficiency).

Define Operational Goals of the Test: The information that is desired at the completion of the test will be well defined. Generally, the greater the accuracy and amount of information desired, the greater the complexity of the test. For example, the hydraulic conductivity of a test zone can be estimated on a local basis from a brief, inexpensive slug test (as described in Section 7.1), but the evaluation of leakage from confining units requires more complex aquifer pump testing. Some common test goals include:

- Estimating aquifer yield for water supply needs;
- Defining aquifer characteristics for groundwater assessment (usually driven by RCRA, Comprehensive Environmental Response Compensation and Liability Act [CERCLA] or other regulatory program);
- Defining aquifer characteristics for the siting of future waste disposal facilities; and
- Defining aquifer hydraulic characteristics for remedial action (extraction wells, hydraulic control, etc.).

Aquifer testing data needed for developing water supplies range from a single well performance test to a detailed aquifer characterization where a field of multiple wells is required. Where corrective or remedial actions are required, more detailed information is generally required. More complex aquifer tests are usually required to define this information. A relatively detailed conceptual model of the hydrogeologic system is needed to develop the optimal pumping strategy. The objectives of each project, the funding available, and other institutional concerns must be evaluated to develop the best aquifer testing approach.

Various types of aquifer test programs may be developed. The data generated vary according to the type of program. Some of the parameters that may be defined by an aquifer testing program are:

- Transmissivity (T);
- Storage coefficient/specific yield (S, Sy);

- Hydraulic conductivity (K);
- Vertical hydraulic conductivity of confining units (Kv);
- Groundwater yield from confining units;
- Hydraulic resistance of confining units;
- Specific capacity of a well; and
- Well losses and efficiency.

The parameters defined during the aquifer test program must be selected based upon the objectives of the project, and the test methodology must be designed to yield the desired parameters. The desired areal extent of the test must also be considered when selecting the test method, discharge rate, and test duration.

Identify Testing and Data Reduction Methodology: Based on the criteria identified in the preceding two subsections, a method that fulfills the operational goals and adequately represents the hydrogeologic system must be identified. A large number of tests are available; many are summarized in Driscoll (1986) and Kruseman and DeRidder (1994).

Evaluate Operational Constraints: Once the technical basis of a program is established by the procedure described in the previous section, the plan must be expanded to address other site specific requirements, such as shutdown of nearby water supply wells and 24-hour access to the site. In addition, environmental compliance requirements (notably requirements for discharge and disposal of any contaminated fluids) must be identified and fulfilled.

Define the Test Method and Testing Plan: An Aquifer Test Plan will be prepared prior to testing. The plan will define all site-specific concerns, such as site accessibility, water disposal, and 24-hour-per-day working conditions. The plan will also address specific technical concerns. Based upon the site hydrogeology, the chosen analytical method will be used to simulate the range of conditions expected to occur. This simulation will be used to determine observation well locations and screen settings, the length of time to run the test, and the effects of boundary conditions.

Conduct Pretest Activities: Prior to conducting the test, all activities scheduled for completion prior to test startup will be performed. These activities may include installing additional observation wells, further defining the fluids management program, installing pumping and monitoring devices such as flow meters and pressure transducers, and performing a short term preliminary aquifer test. Specific pretest activities for some pumping tests are defined in the following paragraphs. Pretest activities may define needed modifications to the aquifer test plan.

Initiate Test and Collect Data: After completion of all previous procedures and pretest activities, the aquifer test will be conducted according to the aquifer test plan (with modifications). Procedures for the most common tests are presented below.

Interpret Data with Chosen or Appropriate Analytical Method: After data are collected they will be analyzed and interpreted with an appropriate analytical method or model. General data interpretation methods for curve-matching techniques are discussed below.

Evaluate the Need for Additional Testing: After data are compiled and interpreted, they will be evaluated to determine if additional testing is warranted. Events indicating the need for additional testing include evidences of interference from nearby pumping or special boundary conditions.

Test Site Selection: Selecting an appropriate test site will prevent difficulties often encountered during test data evaluation. In some cases, existing wells may be used or the hydrologic factors of a specific location may be of concern, thus predetermining the test site. However, the test site is usually dictated by the project needs and the test must be designed to accommodate site logistics.

Well field design and construction is dependent on the hydrogeology of the area and the hydrogeologic units of concern. Factors such as aquifer type, transmissivity and stratification will be taken into consideration by an experienced hydrogeologist when determining screen interval, number of wells, and well locations. Piezometers may be constructed in adjacent hydrogeologic units to determine any hydrologic connection these units have with the aquifer of concern.

4.5 General Testing Procedures

Water Level Measurements

The preferred method of collecting aquifer test data is by the use of pressure transducers to ensure fast, accurate (at least to one hundredth of a foot), time-drawdown measurements. Other methods as described in Section 10.7 may also be used to collect water level measurements when conducting multiple well, constant discharge tests. The same device will be used for measuring water levels in a particular well throughout the duration of a test. A reference point from which all water level measurements are made will be designated on the casing of each well. The reference point will be surveyed for vertical and horizontal location, in accordance with SOP No.11. The exact time all water level measurements are taken will be recorded on a 2400-hour time scale.

Decontamination

Any equipment used in production or monitoring wells must be thoroughly cleaned prior to use. Cleaning procedures are based upon site specific conditions and the needs of the project. The actual cleaning procedure will be determined by the project manager and defined in the aquifer test data. Cleaning may consist of little or no cleaning, (if the well is to be used only for aquifer testing), disinfecting (if the well is a water supply well), steam cleaning, or more rigorous cleaning procedures, as described in SOP No.13.

4.6 Aquifer Pretest

Background

An aquifer pretest will be conducted prior to conducting multiple well constant rate aquifer tests. The purpose of this test is to collect all available background information of the hydrogeologic system in question, ensure that all equipment is in good working order, and confirm that all pumping settings and water level measuring devices are prepared for the start of the actual test. This pre-test will be conducted far enough in advance of the start of the actual test to allow the water levels to recover and stabilize, and to collect sufficient pretest trend data.

Often, the pretest is a step drawdown test. This is done to observe aquifer responses at various flow rates. The following five questions of concern will be answered at the completion of the pretest:

1. What is the maximum anticipated drawdown at various discharge rates?
2. What discharge rates occur in various pump speeds or valve settings?
3. What is the best method to measure yield?
4. Is the discharge pipe far enough from the radius of influence to avoid recharging the aquifers of concern?
5. Are the observation wells yielding usable drawdown data at various discharge rates? The pretest is also used to test equipment, and to finalize valve settings so that the discharge rates are established at the beginning of the constant rate aquifer test.

Field Method for Aquifer Pretest

1. Prepare test setup for duration of test.
2. Decontaminate all equipment to be inserted into the well, if required.
3. Measure and record the pre-test water levels and the exact time of each reading.
4. Set up pump and discharge lines. The pump or intake must be set below the anticipated drawdown and within the pump lifting capacity. Discharge must be directed outside of the radius of influence of the cone of depression. If pumping from a contaminated area, all water must be discharged in a manner compliant with applicable or relevant and appropriate requirements.
5. Determine the best method to measure yield. Orifices, weirs, and totalizing flow meters are the most common methods. Specifications for constructing orifices, and weirs are presented in Driscoll (1986). All discharge measuring devices will be manually checked for accuracy, if possible, by filling a container of known volume and recording the time required to fill it.
6. Initiate pumping, record time, and immediately monitor water levels in the pumping well. For all aquifer tests involving pumping, it is important that the water level in the pumping well be monitored before, during, and after pumping. (consider installing a stilling well (i.e. a 1-inch PVC well) in the pumping well to damp the turbulent effects of pumping) Water levels and the time of each measurement since pumping began will be recorded. Discharge rates will be monitored every five minutes. Monitor wells nearest the pumping well will be monitored early in the test to see

when a response to pumping is observed. As the radius of influence expands, more distant monitoring wells will be monitored.

7. Semilog and arithmetic data plots of drawdown vs. time will be developed in the field based on test results.
8. After water levels begin to stabilize, the discharge rate will be increased to approximately 25 percent of the maximum possible anticipated discharge.
9. Continue monitoring water levels and discharge rates in the systematic manner established at the beginning of the test.
10. Conduct the test at several pumping rates. Each pumping rate will be run until water levels stabilize. The final rate will be approximately equal to the maximum possible discharge rate at which total available drawdown is attained.
11. At the completion of the test, all pump valves will be at the settings desired for the actual test.

4.7 Step Drawdown Tests

Background

Step drawdown tests are used to evaluate the effects of pumping in a well at various discharge rates. Information gained from step drawdown tests include:

- Values of specific capacity at various discharge rates;
- Optimum discharge rates for pumping wells;
- The amount of well loss attributable to laminar and turbulent flow components, respectively;
- The effect of various discharge rates on turbulent flow; and
- Aquifer parameters such as transmissivity (T), hydraulic conductivity (K), and storage coefficient (S) (if data is obtained from observation wells) and projected future pumping costs.

A properly conducted test will include steps of equal length and constant discharge.

Field Method for Step Drawdown Tests

1. Obtain water level data and the barometric pressure at the time of the reading for a minimum of one week prior to the start of the test.
2. Make sure that the outlet of the discharge is located far enough from the well to avoid recharging the aquifer being tested.
3. Conduct an aquifer pretest as described above. At least four to five possible discharge rates in increasing order will be determined during the pretest.
4. After allowing sufficient time for water levels to recover to pretest levels, the test may be conducted.
5. Measure static water level and record the date and time of reading.

6. Measure the barometric pressure every half hour.
7. Insert transducers at a depth below the maximum anticipated drawdown and at least one foot above the bottom of the well.
8. Initiate pumping at the lowest discharge rate to be used. At the exact moment pumping begins, begin recording water levels in the pumping well and the exact time since pumping began. As many measurements as possible will be obtained during the first five minutes of the test. Water levels will then be obtained at increasing time intervals, beginning with one minute and increasing slowly to a maximum of 10 minutes. Intervals will never exceed the time required for water levels to change by 0.2 feet. Water levels will be measured in observations wells early enough to obtain initial drawdown data. Early drawdown data is especially critical in determining aquifer coefficients.
9. Measure and record discharge rates at the same frequency water level measurements are obtained. The entire test generally runs from eight to 72 hours.
10. After running the initial step for one to two hours and stabilization of water level, increase the discharge to the second desired rate. Measure the water levels and discharge rates at the same intervals as taken in the first step.
11. Continue the test through a minimum of two additional steps conducted in a manner similar to the first two.
12. Drawdown data will be plotted in the field to ensure stabilization of water levels during each step.

Data Analysis and Interpretation

The following information is required to analyze data and will be collected during the test:

- Discharge rates of pumping well;
- The number of water level data during the course of the test (each record will specify water level and the exact time since pumping began);
- Distance from pumping well to each observation well;
- Description and elevation of each measuring point;
- Total depth and screen interval of pumping and monitoring wells;
- Well materials and construction details of all wells; and
- Barometric pressure at 30-minute intervals.

Analysis of step drawdown pumping test shall be completed under the direction of an experienced hydrogeologist or groundwater hydrologist registered in the state) by an experienced hydrogeologist or groundwater hydrologist and reviewed by senior personnel. Drawdown data will be corrected for regional trends, barometric pressure, or any other influencing factors. Most common methods of analysis are described in Bear (1979), Bierschenk (1964), and Rorabaugh (1953). However, appropriate methods of analysis are dependent on the type of aquifer being tested and well field construction and design.

4.8 Single and Multiple Well Constant Yield Tests

Background

Constant yield aquifer tests are conducted to estimate aquifer coefficients such as transmissivity and storativity (specific yield for unconfined aquifers), and hydraulic conductivity. Constant yield aquifer tests can also be used to predict:

- The drawdown in a well at future times and at varying discharge rates;
- The effect of new withdrawals on existing wells;
- The radius of the cone of influence for individual or multiple wells (multiple well tests);
- The hydraulic characteristics of confining beds;
- The position and nature of aquifer boundaries; and
- The degree of vertical and horizontal anisotropy.

A value for storage coefficient cannot be obtained from tests in which only the pumping well is monitored.

Field Method for Single or Multiple Well Constant Rate Tests

1. Obtain water level data for a minimum of one week prior to the start of the test.
2. Make sure that the outlet of the discharge is located far enough from well to avoid recharging of the aquifer being tested.
3. Conduct a pretest as described above. A minimum of two days will be allowed for water to return to static conditions prior to starting the actual test.
4. Measure and record the static water level in all wells to be monitored and the exact time of each measurement, including an appropriate background well outside of the zone of influence.
5. Insert transducers below the depth of maximum anticipated drawdown and at least 1 foot from the bottom of the well.
6. Initiate pumping at a discharge rate determined during the pretest. Record as many measurements as possible and the exact time since pumping began for each measurement during the first five minutes of the test. Measurements will then be obtained every 30 seconds to 10 minutes, then at increasing intervals beginning at one minute and increasing slowly to a maximum of ten minutes, thereafter. Intervals will never exceed the time required for water levels to change by 0.2 feet. Recommend a pumping rate which does not produce a drawdown in the well greater than 66% (2/3) of the length of the water column in the well.
7. Periodically record discharge rates throughout the test (every five minutes for the first hour and with each water level measurement thereafter).
8. Monitor barometric pressure every 15 minutes for the first 60 minutes of the test and every 30 minutes thereafter.

9. Measure and record any amounts of precipitation that occur during the test.
10. Develop log-log and semilog plots of the test data in the field.
11. The test will last for at least 48 hours in an unconfined aquifer and 24 hours in a confined aquifer. Field data plots will be evaluated prior to termination of the test for variations in drawdown.

Data Analysis and Interpretation

The following information is required to analyze data and will be collected during the test:

- Discharge rate of pumping well;
- Water level data during the course of the test (each record will specify water level, pumping or observation well ID, and the exact time since pumping began);
- Distance from pumping well to each observation well;
- Description and elevation of each measuring point;
- Total depth and screen interval of pumping and observation wells;
- Well materials and construction details of all wells; and
- Barometric pressure at 30-minute intervals.

Analysis of aquifer pumping test shall be completed by an experienced hydrogeologist or groundwater hydrologist and reviewed by the Project or Task Manager. Drawdown data will be corrected for regional trends, barometric pressure, or any other influencing factors. Most common methods of analysis are described in Driscoll (1986), Lohman (1972), or Kruseman and DeRidder (1994). Several computerized solution techniques are also available. However, appropriate methods of analysis are dependent on the type of aquifer being tested and well field construction and design.

5.0 REFERENCES

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ATTACHMENT B

Field Data Sheets

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 2

Pumped Well No. RW-1　　Date 12/17/01
Observation Well No. -　　Weather SUNNY
Owner U.S. EPA　　Location PEMACO
Observers: T. GARVEY, J. MARCILLAC, J. EVENSEN
D.L. - A　CH. - 8
Measuring Point is — which is — feet above/below surface.
Static Water Level 67.52 feet below land surface.
Distance to pumped well 0 feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15.
Water Measurement Technique Data Loggers - Hermit + Troll
Recorded by GARVEY -. Temperature during test ~60°F.

12/17

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	~~Depth to Water Below Land (feet)~~ TDB W	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
9:50	0	26.021		0.0		
10:20	0:05:00	23.010		0.5	----→	46.2 Hz
10:30	0:15:00	21.793		0.5		
10:45	0:30:00	20.968		0.5		
11:00	0:45:00	20.585		0.50		
11:12	0:57:00	20.451		0.50		
11:15	1:00:00	20.411		0.50		
11:30	1:15:00	20.340		0.50		
11:45	1:30:00	20.308		0.50		

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well – Bearing – Page 2 of 2

Pumped Well No. Ø Date 12-17-01 – 12-18-01

Observation Well No. RW-1 Recorded by GARVEY / MARCILLAC

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12:00	1:45:00	20.263		0.5		
12:15	2:00:00	20.231		0.5		
12:30	2:15:00	20.234		0.5 → 0.8	ΔQ	STEPED UP @ 12:31
12:45	2:30:0	18.487		0.8		
13:00	2:45:00	17.713		0.8		
13:15	3:00:00	17.402		0.8		
13:38	3:23:00	17.203		0.8		
13:45	3:30:00	17.063		0.8		
14:00	3:45:00	16.868		0.8		
14:20	4:05	16.782		0.8		
14:30	4:15	16.763		0.8		
14:35				1.0	59.4 Hz	ΔQ
14:45	4:30	15.639		1.0		
15:00	4:45	15.200		1.0		
15:18	5:03	14.842		1.0		
15:30	5:15	14.713		1.0		
15:45	5:30	14.578		1.0		
16:00	5:45	14.549		1.0		
16:15	6:00	14.483		1.0		
16:45	6:30	14.467		1.0		
12-18-01 = 11:00	24:45	13.241		1.0		
13:15	27:00	13.238		1.0		
12-20-01 AF[illegible] 08:15		25.288		Ø		

Hi-Flo Test

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well: 0   Bearing: —   Page 1 of 1

Pumped Well No. RW-1   Date 12-20-01

Observation Well No. RW-1   Recorded by MARCILLAC

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to ~~Water Below Land~~ (feet) Head	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
10:05	0	26.134		0-1.5		
10:10	5	21.088		1.5		72.8 Hz
10:16	11	17.277		|		
10:20	15	15.448		|		
10:25	20	14.046		|		
10:31	26	12.857		|		74 Hz
10-35	30	12.152		|		
10:40	35	11.378		|		
10:45	40	10.386	—	H_2O beginning to cloud		
10:50	45	9.536		|		
10:55	50	8.831		|		
11:00	55	8.134		|		
11:05	60	7.399	— H_2O clearing up			
11:10	65	6.758	— H_2O clear again			
11:15	70	6.270		|		
11:21	76	5.732	— H_2O clouding up again			
1125	80	5.390		1.2-1.3		Hz turned
11:32	87	4.742		1.5 cloudy		up to 76.6 Flow was @
11:35	90	4.361		|		1.2 due to filter clogging
11:40	95	4.106		1.3		Back up to 1.5
11:45	100	3.552		1.5	same clogging problem	
1150	105	3.192		1.5→0		

pump shut off @ 1148

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

- (a) date
- (b) temperature
- (c) discharge rate
- (d) weather
- (e) well location
- (f) well number
- (g) owner of the well
- (h) type of test (drawdown or recovery)
- (i) description of measuring point
- (j) elevation of measuring point
- (k) type of measuring equipment
- (l) radial distance from center of pumped well to the center of the observation well
- (m) static depth to water
- (n) person recording the data
- (o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

- (a) the elapsed time since pumping started, shown as the value (t)
- (b) the elapsed time since pumping stopped, shown as (t')
- (c) the depth in feet to the water level
- (d) drawdown or recovery of the water level in feet
- (e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
- (f) the discharge rate in gallons per minute
- (g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-01 Date 12/17/01

Observation Well No. MW-2 Weather SUNNY, COLD

Owner U.S. EPA Location FEMACO

Observers: Jacques Marcillac, Tim Garvey

D.L.-B CH.-1

Measuring Point is — which is — feet above/below surface.

Static Water Level 65.59 feet below land surface.

Distance to pumped well 71' 4" feet. Type of Test STEP → CONSTANT → REC

Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).

Total number of observation wells 15.

Water Measurement Technique Data Logger.

Recorded by GARVEY. Temperature during test ~60°F.

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	~~Depth to Water Below Land (feet)~~ TDBwl	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	11.712		0.0		
	12:50		11.514		0.5		
	13:50	3:35:00	11.448		0.8		
	14:55	4:40	11.419		1.0		
	16:10	5:55	11.377		1.0		
12/18							
	11:20	25:05	11.271		1.0		
	1530		11.288				
12-20-01 After recharge	0815		11.649				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-1 Date 12-17-01
Observation Well No. MW-3 Weather Sunny
Owner EPA Location ON SITE
Observers: Jacques Marcillac, Tim Garvey
D.L.-T CH-4
Measuring Point is — which is — feet above/below surface.
Static Water Level 62.94 feet below land surface.
Distance to pumped well 81' feet. Type of Test Step → Constant → Rech.
Discharge rate of pumped well 0.5 → 1 gpm (gallons per minute).
Total number of observation wells 15.
Water Measurement Technique Troll Data Logger.
Recorded by MARCILLAC. Temperature during test ~60° F.

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water ~~Below Land (feet)~~ H₂O level above Troll	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	1510		10.021				
↓	1625		9.979				
12/18							
	11:45	25:30	9.902				
12/19	10:24		9.902				
12/20 After Recharge	0815		10.327				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 2

Pumped Well No. RW-01 Date 12/17/01
Observation Well No. MW-14-S (80) Weather SUNNY -
Owner U.S. EPA Location PEMACO
Observers: GARVEY/MARCILLAC
DATA LOGGER - A CHANNEL - 1
Measuring Point is — which is — feet above/below surface.
Static Water Level 68.36 feet below land surface.
Distance to pumped well 111' 2" feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 to 1.0 gpm (gallons per minute).
Total number of observation wells 15 .
Water Measurement Technique DL .
Recorded by GARVEY / MARCILLAC . Temperature during test ~60°F .

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	~~Depth to Water Below Land (feet)~~ TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	9.029		0.0		
					0.5		
	1345	3:30	9.129		0.8		
	14 50	4:35	9.135		1.0		
	16 05	5:50	9.125		1.0		
12/18	1105	24:50	9.046		1.0		

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well 111' 2"　　Bearing -　　Page 2 of 2

Pumped Well No. RW-1　　Date 12-18-01

Observation Well No. MW-14-S　　Recorded by JM

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
13:15	27:00	9.112				
08:15		9.104				

12-20-01 After Recharge

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 2

Pumped Well No. RW-01 Date 12-18-01

Observation Well No. MW-14D (90) Weather SUNNY

Owner U.S. EPA Location Pemaco

Observers: GARVEY/MARCILLAC

D.L.-A CH.-6

Measuring Point is — which is — feet above/below surface.

Static Water Level 72.74 feet below land surface.

Distance to pumped well 111' 2" feet. Type of Test STEP → CONSTANT → REC

Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).

Total number of observation wells 15 .

Water Measurement Technique Data Logger .

Recorded by GARVEY — . Temperature during test ~60° F .

12/17

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	~~Depth to Water Below Land (feet)~~ TOBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
9:50	0	12.548		0.0		
12:43	2:15:00	12.299		0.5		
13:45	3:30:00	12.192		0.8		
14:50	4:35	12.148		1.0		
16:05	5:50	12.071		1.0		

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well 111' 2" Bearing — Page 2 of 2

Pumped Well No. RW-1 Date 12-18-01

Observation Well No. MW-14D Recorded by SM

12/18

[illegible]

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth ~~to Water~~ ~~Below~~ Land (feet) TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
1110	24:50	11.984		1.0		
1355	27:40	12.043				
0815		12.675				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 2

Pumped Well No. RW-01 Date 12/17/01
Observation Well No. MW-15-70 Weather ☼
Owner U.S. EPA Location PEMACO
Observers: GARVEY/MARCILLAC
DATA LOGGER - A CHANNEL - 3
Measuring Point is — which is — feet above/below surface.
Static Water Level 64.76 feet below land surface.
Distance to pumped well 14' 9" feet. Type of Test STEP → CONSTANT → REC.
Discharge rate of pumped well 0.5 → gpm (gallons per minute).
Total number of observation wells 15 .
Water Measurement Technique D.L. .
Recorded by GARVEY — . Temperature during test ~60°F .

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	~~Depth to Water Below Land (feet)~~ TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	4.474		0.0		
					0.5		
	13:45	3:30	4.485		0.8		
	14:50	4:35	4.461		1.0		
	16:05	5:50	4.418		1.0		
12/18	11:05	24:50	4.269		1.0		

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well 14' 9"   Bearing -   Page 2 of 2

Pumped Well No. RW-1   Date 12/17/01

Observation Well No. MW-15-70   Recorded by GARVEY / MARCILLAC

12-20-01

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
1340	27:55	4.333				
0815		4.507				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-01 Date 12/17 - 12/18
Observation Well No. MW-15-85 Weather SUNNY
Owner U.S. EPA Location PEMACO
Observers: GARVEY/MARCILLAC
D.L. - B CH. 5
Measuring Point is — which is — feet above/below surface.
Static Water Level 68.68 feet below land surface.
Distance to pumped well 18' 2" feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15 .
Water Measurement Technique DATA LOGGER .
Recorded by GARVEY — . Temperature during test ~60°F .

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to ~~Water Below~~ Land (feet) TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	10.895		0.0		
	12:50	2:35:00	9.425		0.5		
	13:50	3:35:00	9.164		0.8		
	14:55	4:40	8.904		1.0		
	16:10	5:55	8.747		1.0		
12/18	11:20	25:05	8.625		1.0		
	15:30		8.678				

0815 10.995

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 2

Pumped Well No. RW-1 Date 12/17
Observation Well No. MW-16-70 Weather SUNNY
Owner U.S. EPA Location PEMACO
Observers: GARVEY/MARCILLAC
D.L. - A CH. - 4
Measuring Point is — which is — feet above/below surface.
Static Water Level 62.91 feet below land surface.
Distance to pumped well 10' 4'' feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15.
Water Measurement Technique DATA LOGGER.
Recorded by GARVEY - . Temperature during test ~60°F.

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water ~~Below Land (feet)~~ TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	5.3		0.0		
					0.5		
	13:45	3:30	5.237		0.8		
	14:50	4:35:00	5.200		1.0		
	16:05	5:50	5.138		1.0		
12/18	11:05	24:50	4.990		1.0		

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well 10' 4"　　Bearing –　　Page 2 of 2

______ Pumped Well No. RW-1　　Date 12-18-01

______ Observation Well No. MW-16-70　　Recorded by GARVEY/MARCILLAC

12-20-01

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
1345	27:30	5.051				
0815		5.336				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-01 Date 12/17/01
Observation Well No. MW-16-85 Weather SUNNY
Owner U.S. EPA Location PEMACO
Observers: GARVEY/MARCILLAC
D.L. B CH. 3
Measuring Point is — which is — feet above/below surface.
Static Water Level 66.95 feet below land surface.
Distance to pumped well 10' 4" feet. Type of Test STEP → CONSTANT → REC.
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15 .
Water Measurement Technique DATA LOGGER .
Recorded by GARVEY – . Temperature during test ~60°F .

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below ~~Land~~ (feet) TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	9.256		0.0		
	12:50	2:35:00	7.457		0.5		
	13:50	3:35:00	7.061		0.8		
	14:55	4:40:00	6.752		1.0		
	16:10	5:55	6.523		1.0		
12/18	11:20	25:05	6.352		1.0		
	1530		6.404				
12-20-01 After Recharge	0815		9.331				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Pumped Well No. RW-01
Observation Well No. MW-17-70
Owner U.S. EPA
Observers: GARVEY/MARCILLAC
Date 12/17/01
Weather SUNNY
Location PEMACO
Page 1 of 1

D.L. - B CH. 8

Measuring Point is — which is — feet above/below surface.
Static Water Level 63.38 feet below land surface.
Distance to pumped well 14' 9" feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15
Water Measurement Technique DATA LOGGER
Recorded by GARVEY –
Temperature during test ~60° F

Date	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water ~~Below Land~~ (feet) TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	00	4.661				
	12:50	2:35:00	4.645		0.0		
	13:50	3:35:00	4.597		0.5		
	14:55	4:40:00	4.565		0.8		
	16:10	5:55	4.511		1.0		
12/18					1.0		
	11:30	25:15	4.391				
					1.0		
	15:30		4.430				
2-20-01 After pulldown	08:15		4.702				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

_______ Pumped Well No. RW-01
_______ Observation Well No. MW-17-85 Date 12/17/01 Page 1 of 1
Owner U.S. EPA Weather SUNNY
Observers: GARVEY/MARCILLAC Location PEMACO
D.L.-B CH. 6
Measuring Point is — which is — feet above/below surface.
Static Water Level 66.43 feet below land surface.
Distance to pumped well 18' 0" feet. Type of Test STEP -> CONSTANT -> RECOV
Discharge rate of pumped well 0.5->1.0 gpm (gallons per minute).
Total number of observation wells 15
Water Measurement Technique Data Logger
Recorded by GARVEY - Temperature during test ~60°F

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below ~~Land~~ (feet) TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	9.853				
	12:50	2:35:00	8.960		0.0		
	13:50	3:35:00	8.679		0.5		
	14:55	4:40:00	8.527		0.8		
	16:10	5:55	8.346		1.0		
					1.0		
12/18	11:25	25:10	8.229				
					1.0		
	1530		8.286				

12-01 After Recharge 0815 9.964

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-01 Date 12/17/01
Observation Well No. MW-17-95 Weather SUNNY
Owner U.S. EPA Location PEMACO
Observers: GARVEY/MARCILLAC
D.L.-B CH. 7
Measuring Point is — which is — feet above/below surface.
Static Water Level 83.24 feet below land surface.
Distance to pumped well 16' 9" feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15 .
Water Measurement Technique Data Logger .
Recorded by GARVEY - . Temperature during test ~60°F .

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to ~~Water Below Land~~ (feet) TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	9.742		0.0		
	12:50	2:35:00	9.657		0.5		
	13:50	3:35:00	9.553		0.8		
	14:55	4:40	9.437		1.0		
	16:10	5:55	9.282		1.0		
12/18							
	11:25	25:10	7.695		1.0		
	1530		7.615				
12-20-01 After Recharge	0815		8.857				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

- (a) date
- (b) temperature
- (c) discharge rate
- (d) weather
- (e) well location
- (f) well number
- (g) owner of the well
- (h) type of test (drawdown or recovery)
- (i) description of measuring point
- (j) elevation of measuring point
- (k) type of measuring equipment
- (l) radial distance from center of pumped well to the center of the observation well
- (m) static depth to water
- (n) person recording the data
- (o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

- (a) the elapsed time since pumping started, shown as the value (t)
- (b) the elapsed time since pumping stopped, shown as (t')
- (c) the depth in feet to the water level
- (d) drawdown or recovery of the water level in feet
- (e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
- (f) the discharge rate in gallons per minute
- (g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 2

______ Pumped Well No. RW-01 Date 12/17/01

______ Observation Well No. MW-18-70 Weather SUNNY

Owner U.S. EPA Location Pemaco

Observers: GARVEY/MARCILLAC

D.L. - A CH. 5

Measuring Point is — which is — feet above/below surface.

Static Water Level 61.49 feet below land surface.

Distance to pumped well 15' 9" feet. Type of Test STEP → CONSTANT → REC.

Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).

Total number of observation wells 15.

Water Measurement Technique Data Logger.

Recorded by GARVEY. Temperature during test ~60°F.

Date	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	~~Depth to Water Below Land (feet)~~ TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17	9:50	0	5.409		0.0		
					0.5		
	13:45	3:30	5.444		0.8		
	14:50	4:35	5.417		1.0		
	16:05	5:50	5.376		1.0		
12/18	11:10	24:45	5.172		1.0		

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well 15'9" Bearing – Page 2 of 2

Pumped Well No. RW-1 Date 12-18-01

Observation Well No. MW-18-70 Recorded by GARVEY/MARCILLAC

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
1355	2740	5.227				
0815		5.417				

12-20-01 After recharge

1355
1015
340
2.4

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-01 Date 12-17-01
Observation Well No. MW-18-85 Weather SUNNY
Owner U.S. EPA Location PEMACO
Observers: GARVEY/MARCILLAC
D.L. - B CH. 2
Measuring Point is – which is – feet above/below surface.
Static Water Level 65.17 feet below land surface.
Distance to pumped well 15'9" feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15.
Water Measurement Technique D.L..
Recorded by GARVEY –. Temperature during test ~60°F.

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet) TDBW	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17 9:50	0	9.907		0.0		
12:50	2:35	8.475		0.5		
13:50	3:35	8.167		0.8		
14:55	4:40	7.916		1.0		
16:10	5:55	7.740		1.0		
12/18 11:20	25:05	7.608		1.0		
15:30		7.665				

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-1
Date 12-17-01
Observation Well No. MW-19-70
Weather Sunny
Owner USEPA
Location Pemaco
Observers: JM, TG, + JE

Measuring Point is — which is — feet above/below surface.
Static Water Level 61.47 feet below land surface.
Distance to pumped well 31'6" feet. Type of Test Step DD → constant → Rech
Discharge rate of pumped well 0.5→1 GPM gpm (gallons per minute).
Total number of observation wells 15.
Water Measurement Technique Troll T2.
Recorded by JM. Temperature during test ~60°F.

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17							
	1513		5.611				
	1630		5.572				
12/18	1205	25:50	5.506				
12/19	10:28		5.931				
12/20 After Recharge	08:15		6.466				

12/18 - 12:16 Am
0.4' increase
instaneous

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page 1 of 1

Pumped Well No. RW-1 Date 12-17-01
Observation Well No. MW-19-85 Weather Sunny - Cold
Owner USRDA Location Onsite
Observers: JM, TG, + JE

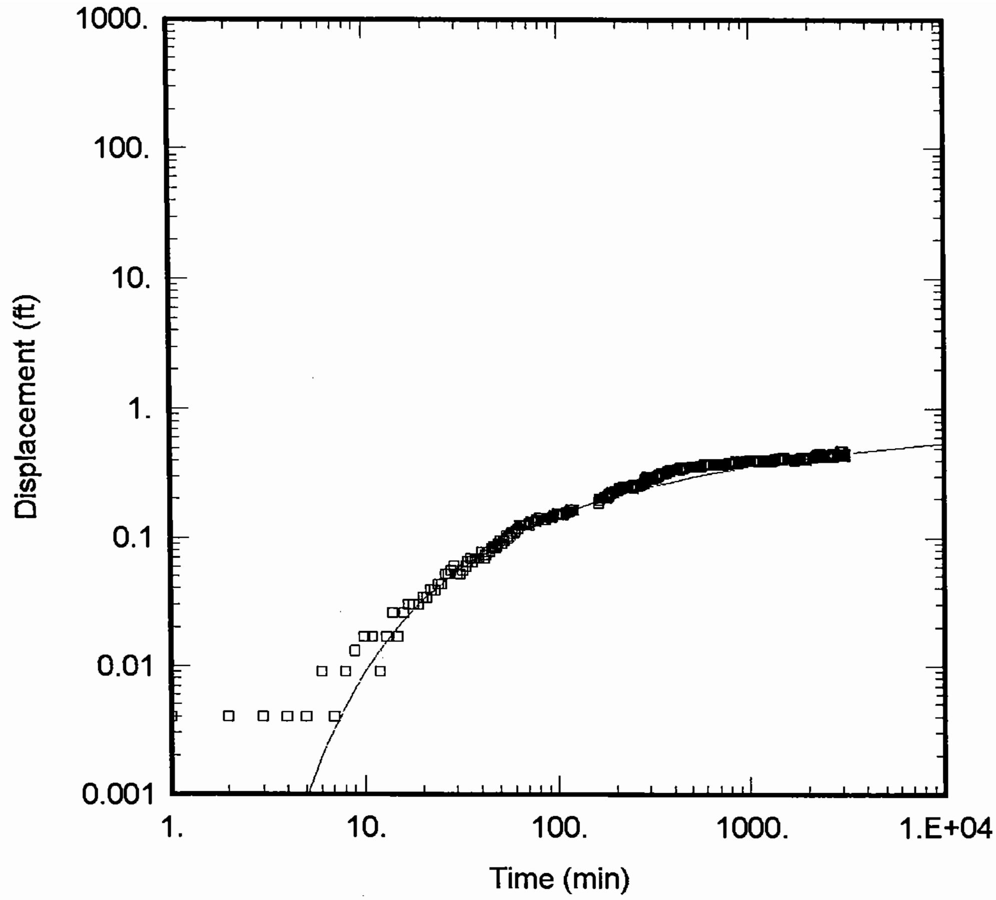
Measuring Point is – which is – feet above/below surface.
Static Water Level 65.20 feet below land surface.
Distance to pumped well 31'6" feet. Type of Test STEP → CONSTANT → REC
Discharge rate of pumped well 0.5 → 1.0 gpm (gallons per minute).
Total number of observation wells 15.
Water Measurement Technique Data Logger T3.
Recorded by MARCILLAC. Temperature during test ~60°F.

	Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments
12/17							
	1511		8.157				
	1628		8.015				
12/18	1215	26:00	7.905				
12/19							
	10:31		7.939				
12/20 After Recharge	08:15		9.643				

ATTACHMENT C

Graphical Output of Aquifer Test Data (Curves), B Zone Wells

PUMPING TEST CURVES



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-2 DD (H).aqt
Date: 12/30/02 Time: 10:36:58

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

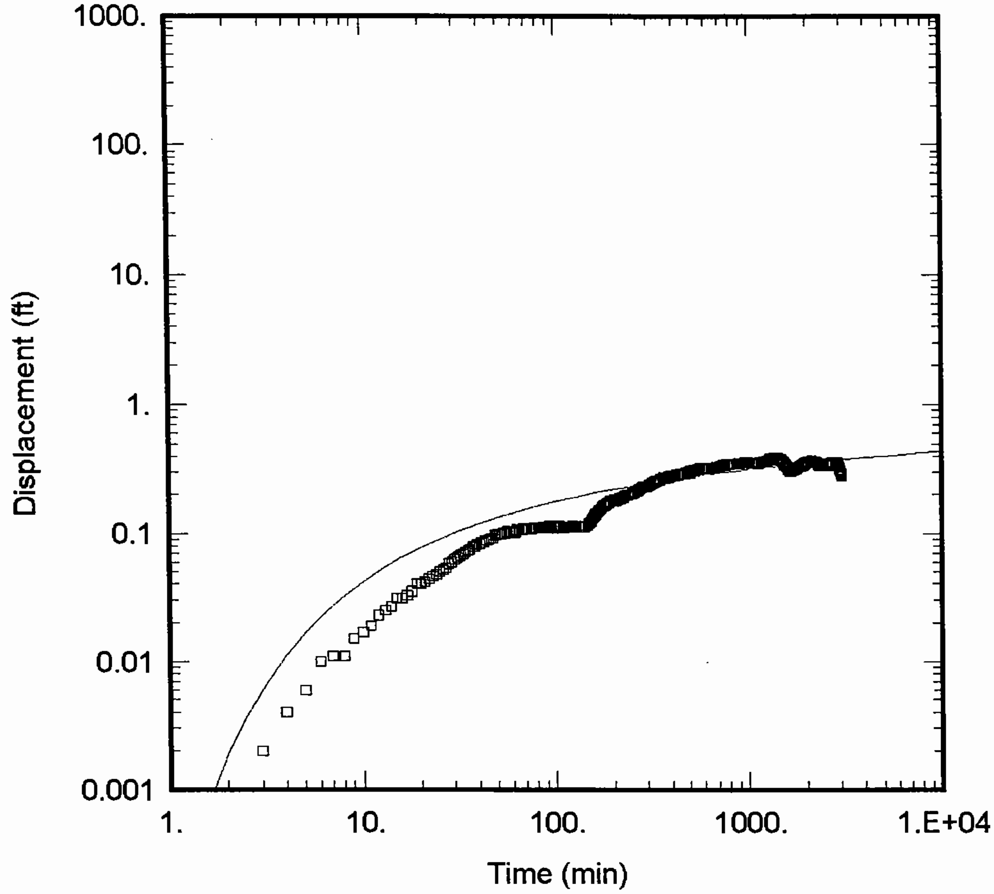
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-2	-8	70

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 0.0969 ft^2/min
S = 0.001294
ß = 0.05644



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-3 DD (H).aqt
Date: 12/30/02 Time: 10:38:31

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 4.5 ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

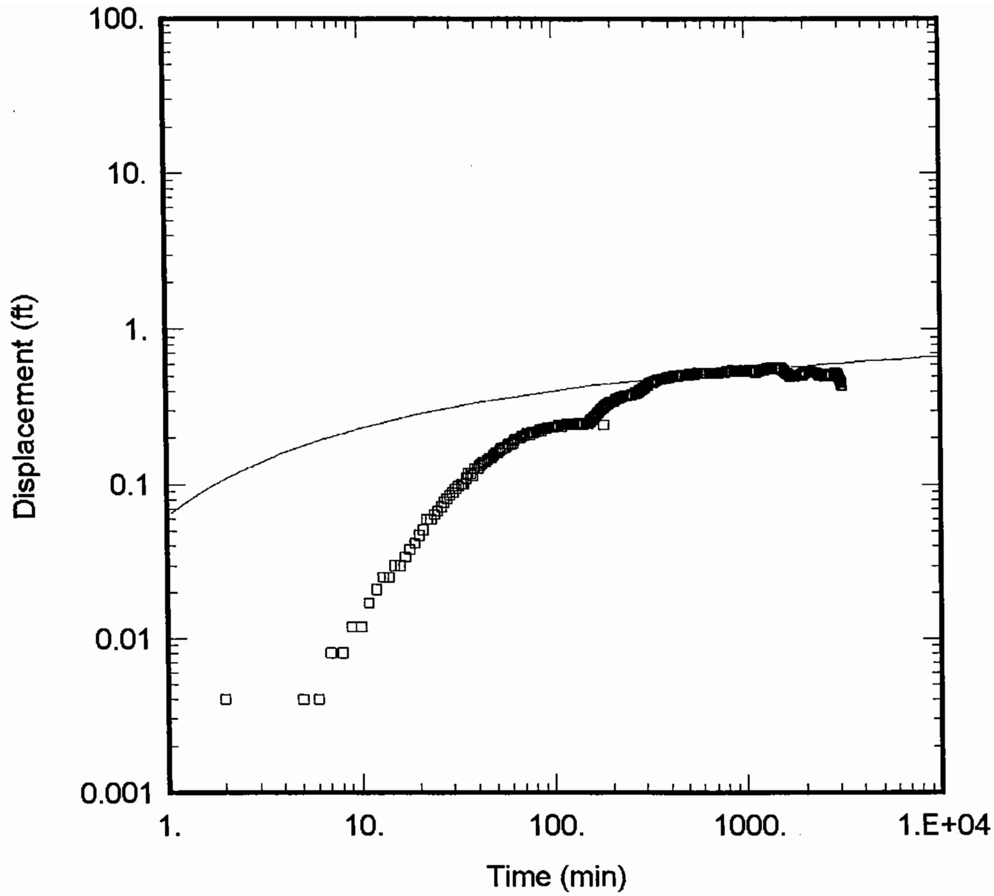
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-3	-36	-71

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.1466 ft^2/min S = 0.0004609
ß = 0.04302



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-14-90 DD (H).aqt
Date: 12/30/02 Time: 10:53:48

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

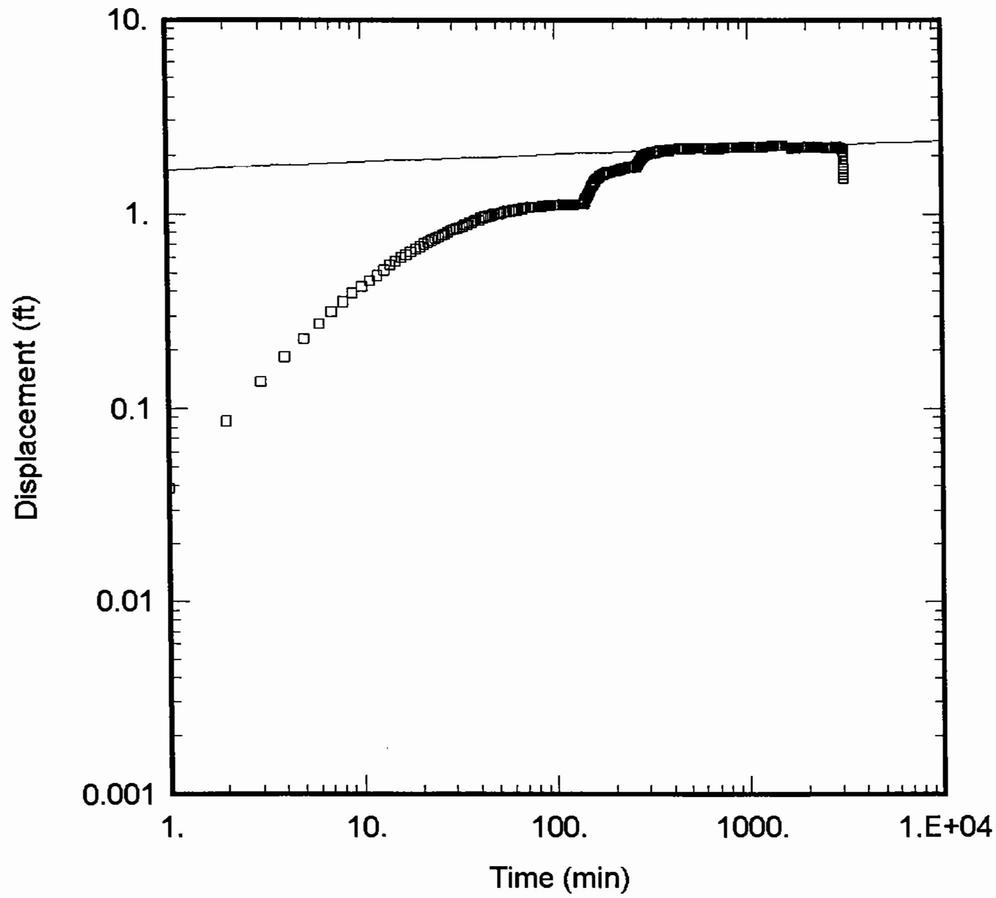
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-14-90	81	74

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.1276 ft^2/min S = 1.707E-05
ß = 0.02618



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-15-85 DD (H).aqt
Date: 12/30/02 Time: 10:41:00

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

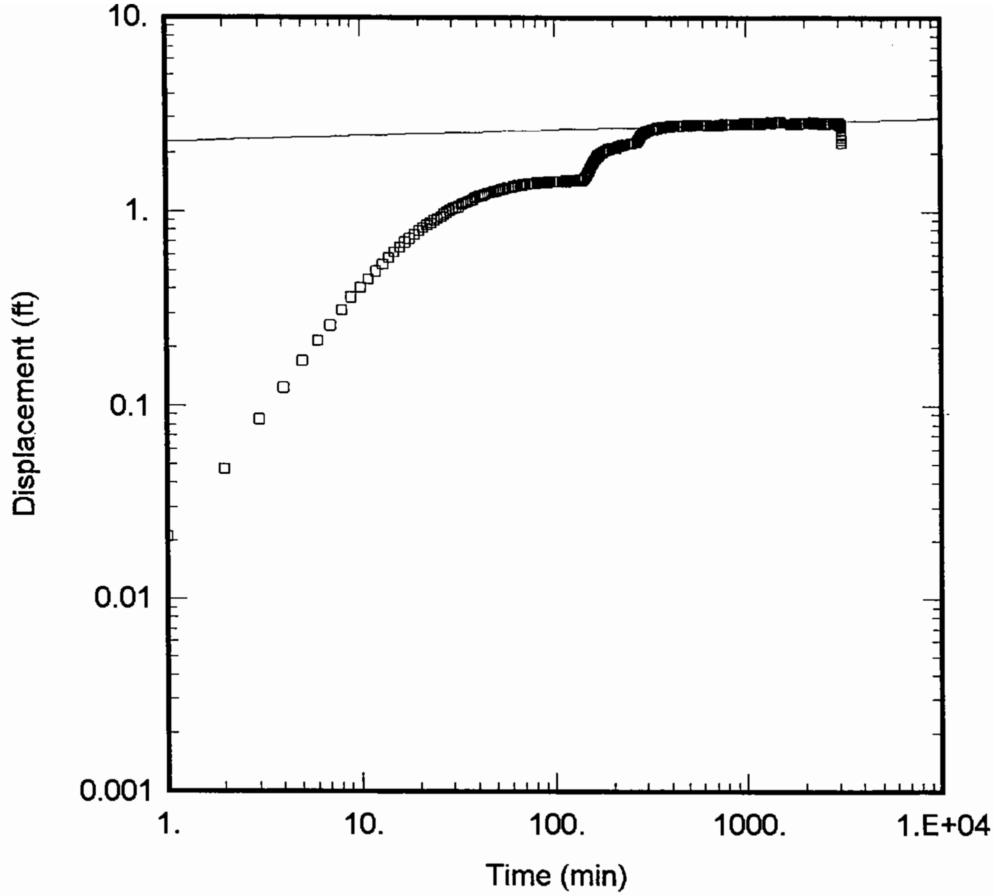
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-15-85	19	0

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.0809 ft^2/min S = 1.114E-14
ß = 0.8414



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-16-85 DD (H).aqt
Date: 12/30/02 Time: 10:43:23

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

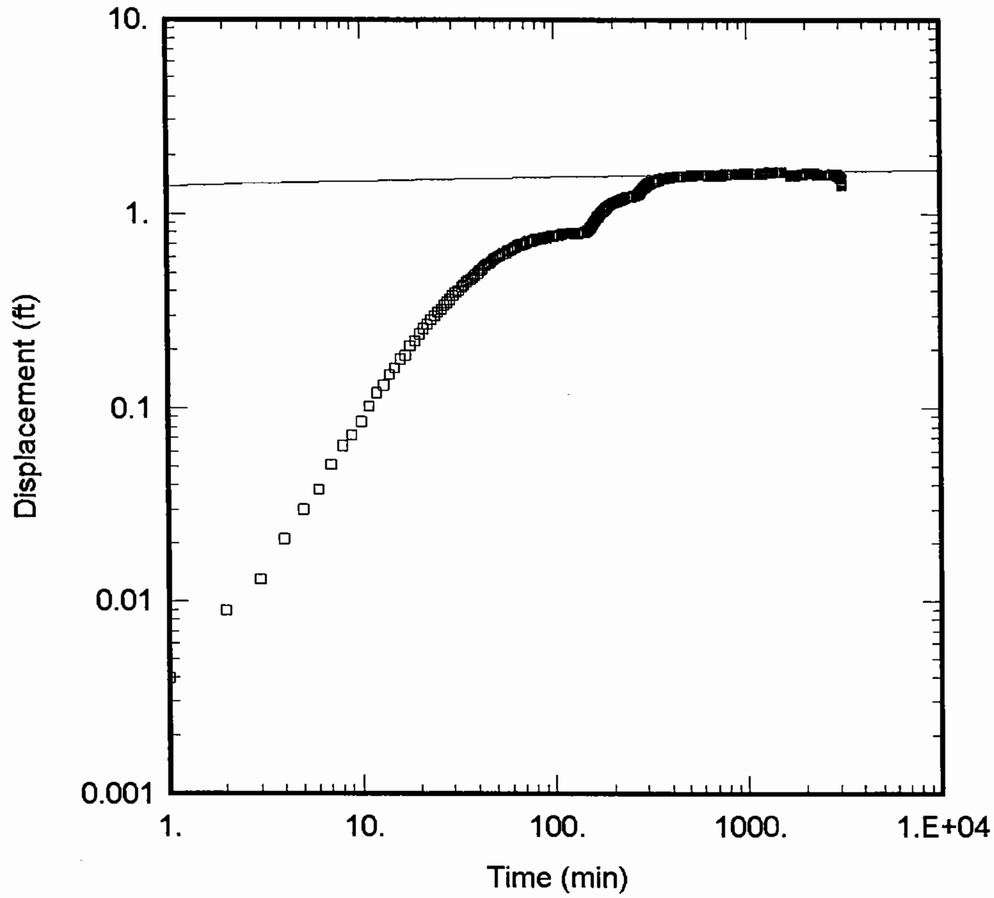
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-16-85	0	10

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.07628 ft^2/min S = 1.449E-12
ß = 0.006307



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-17-85 DD (H).aqt
Date: 12/30/02 Time: 10:45:27

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 2.5 ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

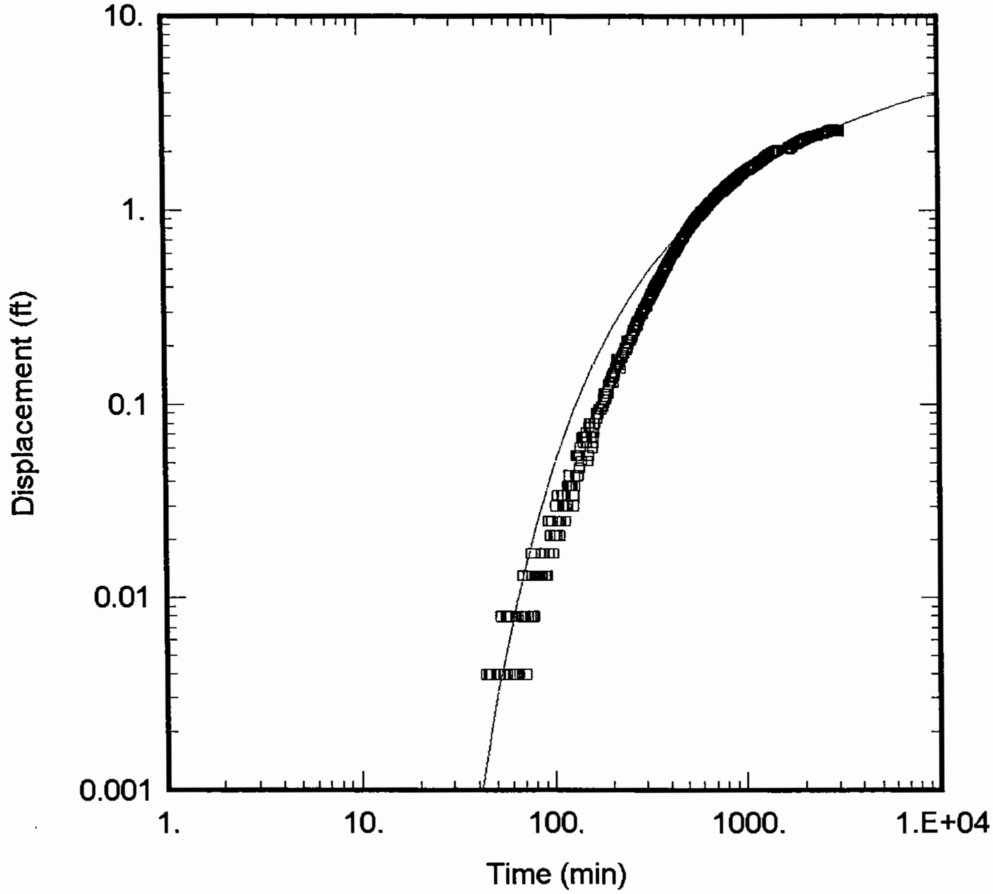
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-17-85	0	-18

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.1938 ft^2/min S = 2.554E-18
ß = 0.001454



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-17-95 DD (H).aqt
Date: 12/30/02 Time: 10:56:11

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 1. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

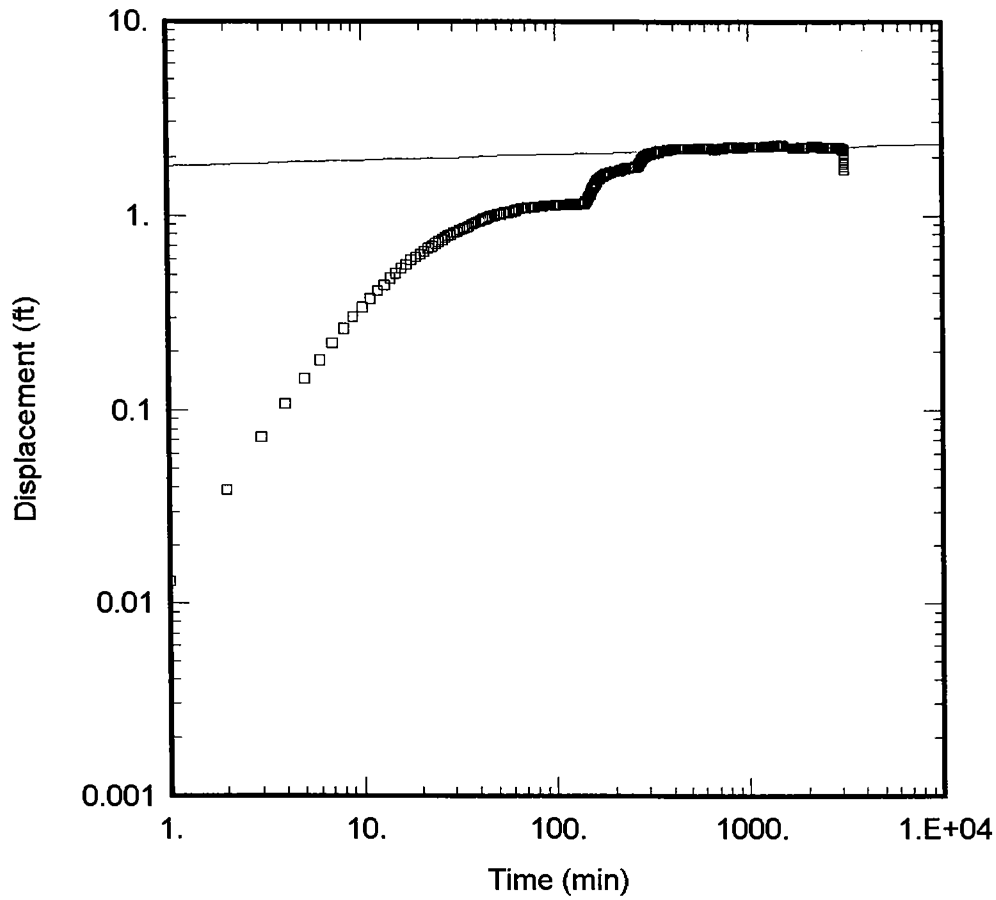
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-17-95	0	-17

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.006691 ft^2/min S = 0.02056
ß = 0.1306



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-18-85 DD (H).aqt
Date: 12/30/02 Time: 10:49:26

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 1. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-18-85	0	-18

SOLUTION

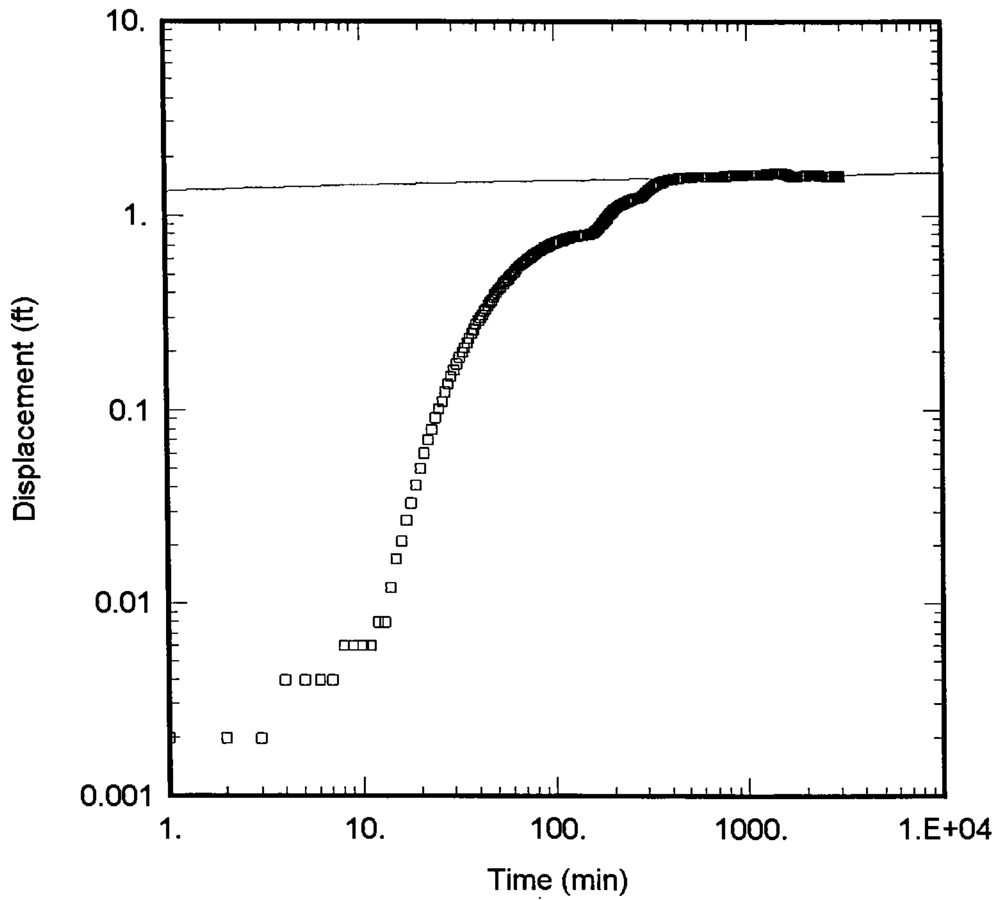
Aquifer Model: Leaky

Solution Method: Hantush

T = 0.1046 ft^2/min

S = 6.635E-15

ß = 0.01856



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\DD\MW-19-85 DD (H).aqt
Date: 12/30/02 Time: 10:51:11

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 4.5 ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

Observation Wells

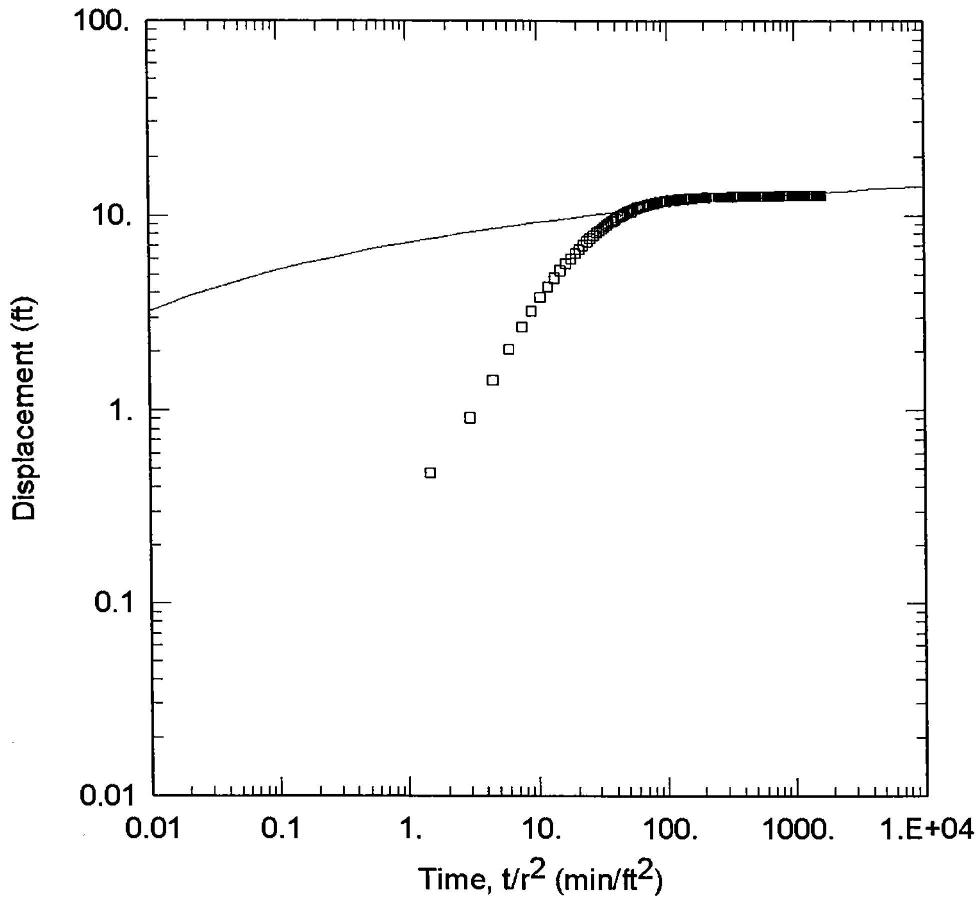
Well Name	X (ft)	Y (ft)
□ MW-19-85	-32	0

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.1884 ft^2/min S = 1.43E-13
ß = 1.E-05

RECOVERY TEST CURVES



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\RW-1 Recovery (H).aqt
Date: 12/30/02 Time: 13:15:54

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 9. ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

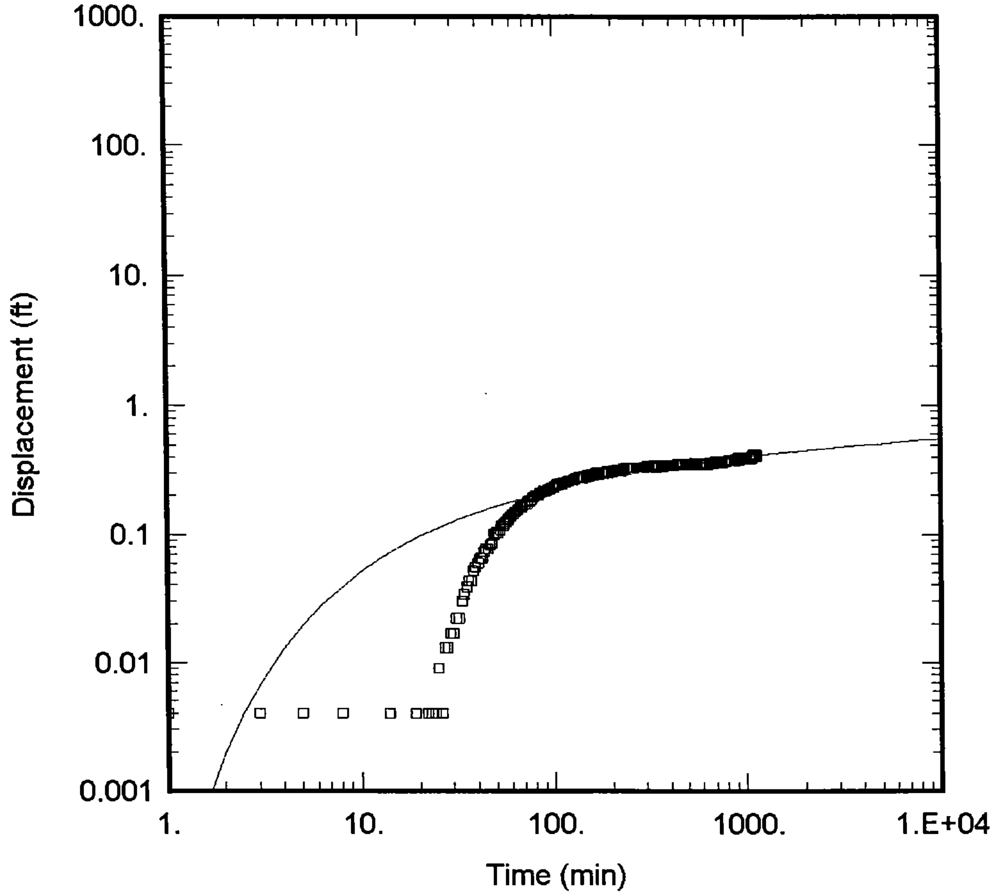
Observation Wells

Well Name	X (ft)	Y (ft)
□ RW-1	0.58	0.58

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.01383 ft^2/min S = 7.931E-06
ß = 0.0001414



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-2 Recovery (H).aqt
Date: 12/30/02 Time: 13:13:23

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

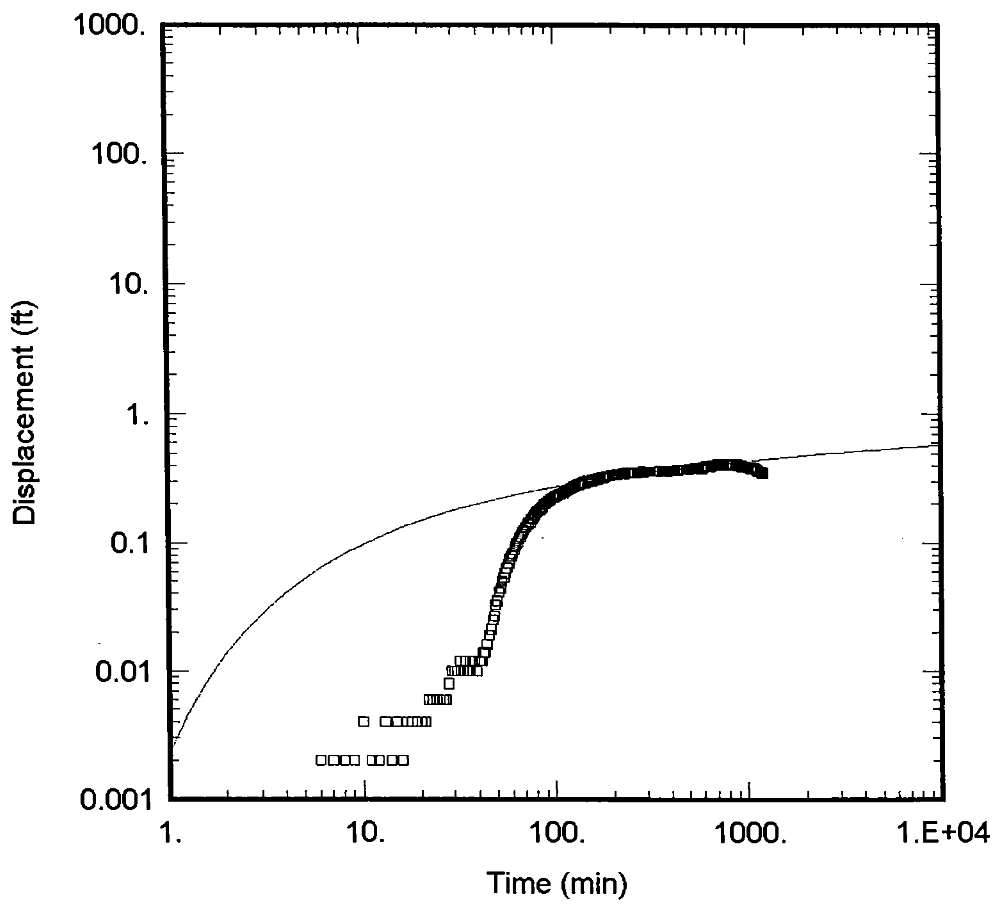
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-2	-8	70

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.1053 ft^2/min S = 0.0004527
ß = 0.06966



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-3 Recovery (H).aqt
Date: 12/30/02 Time: 13:13:09

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 4.5 ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

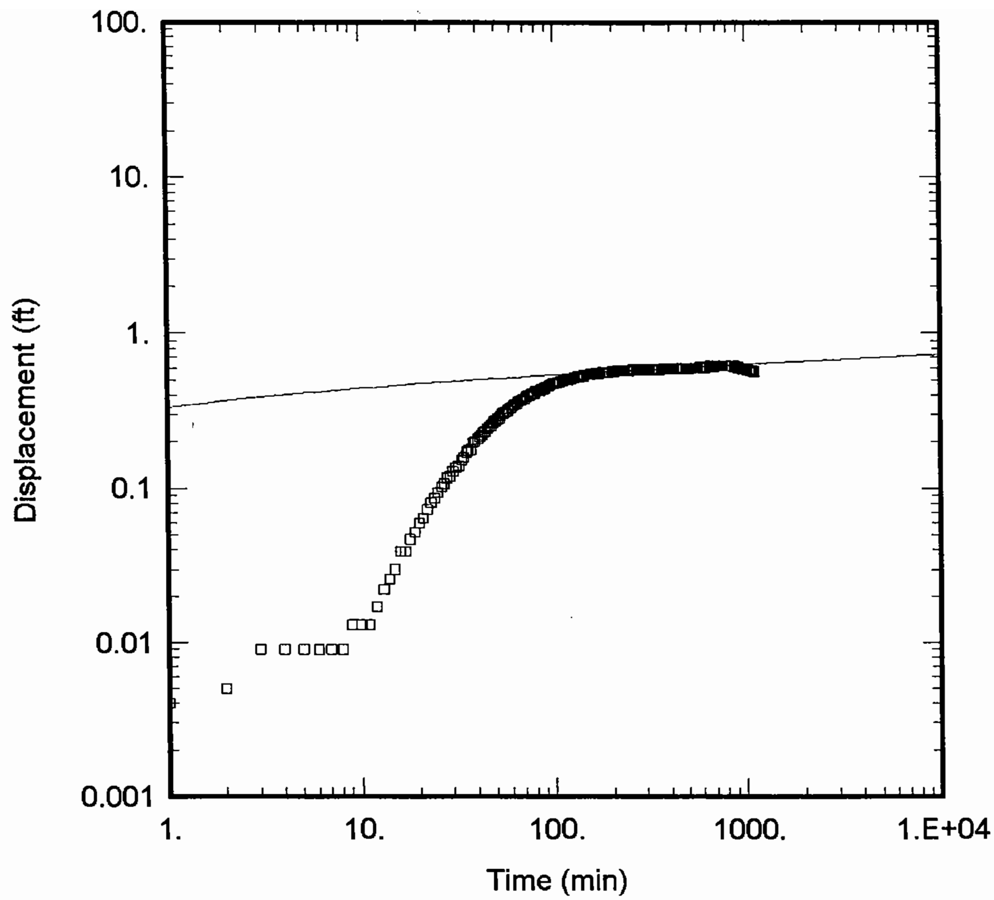
Observation Wells

Well Name	X (ft)	Y (ft)
▫ MW-3	-36	-72

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.1104 ft^2/min S = 0.0001713
ß = 0.06605



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-14-90 Recovery (H).aqt
Date: 12/30/02 Time: 13:14:27

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

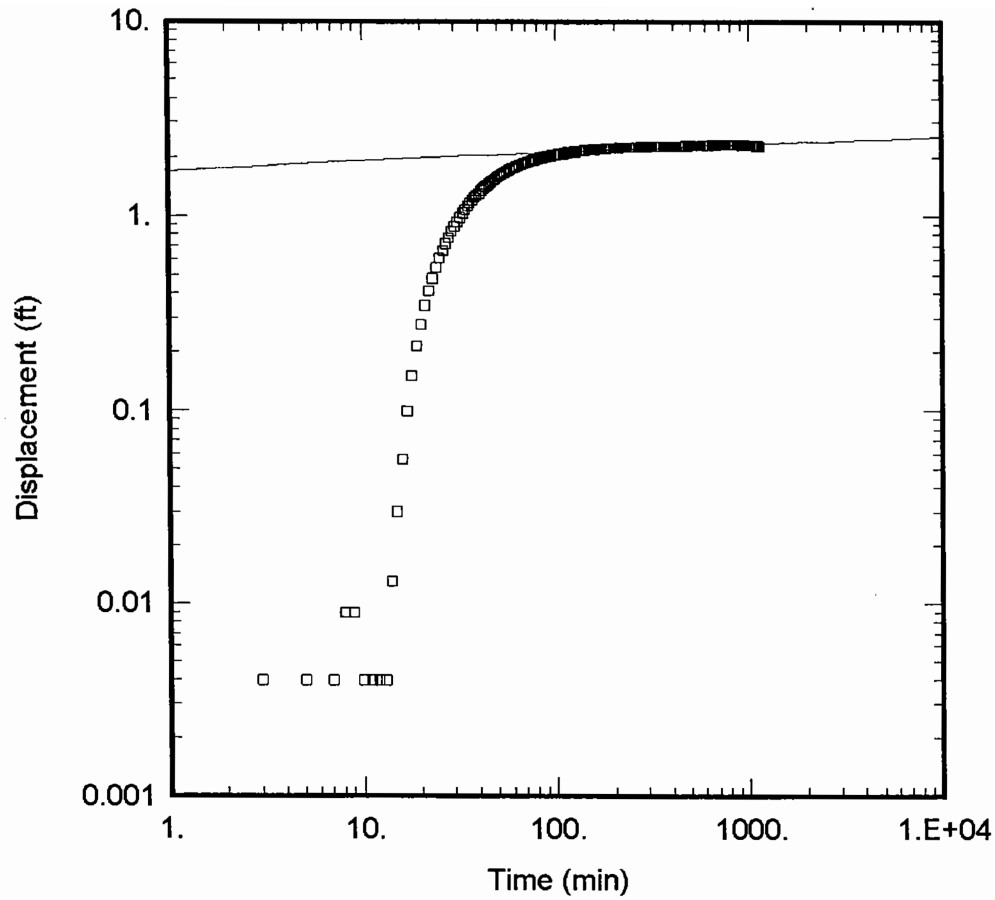
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-14-90	81	74

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.1489 ft^2/min S = 1.634E-07
ß = 0.04396



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-15-85 Recovery (H).aqt
Date: 12/30/02 Time: 13:13:36

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

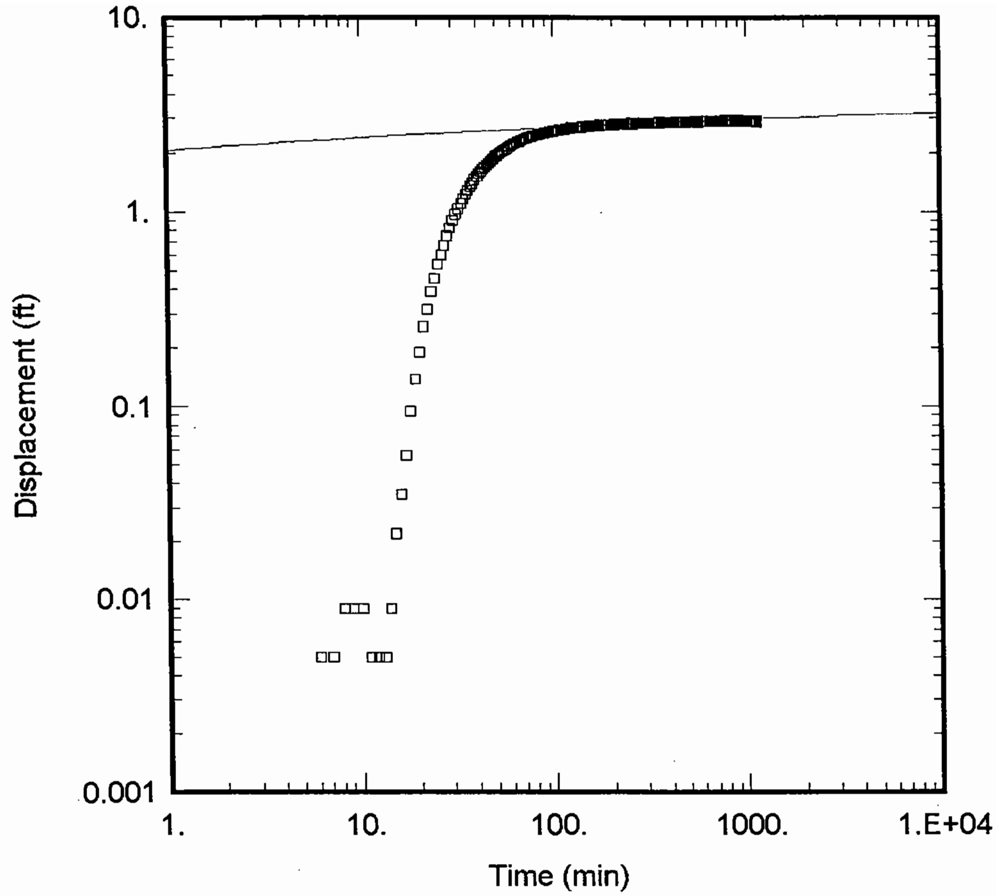
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-15-85	19	0

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.06819 ft^2/min S = 7.366E-09
ß = 0.0044



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-16-85 Recovery (H).aqt
Date: 12/30/02 Time: 13:54:01

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 5. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

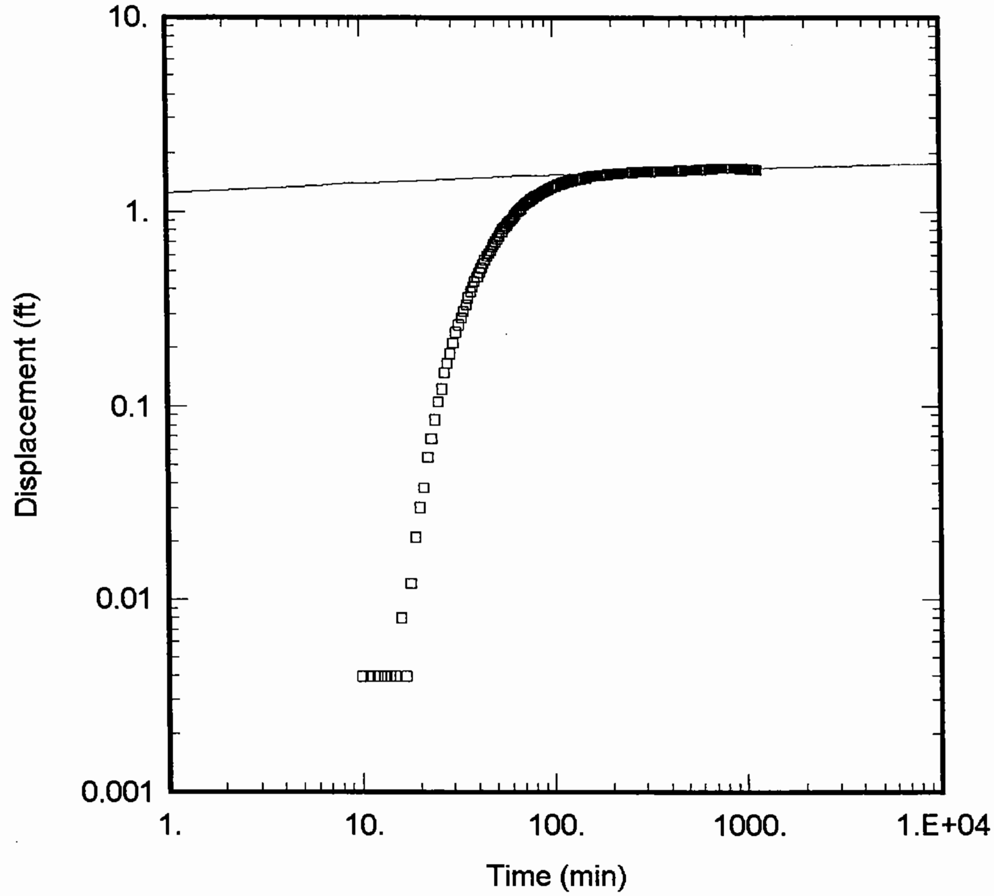
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-16-85	0	10

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.08145 ft^2/min S = 1.773E-09
ß = 1.E-05



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-17-85 Recovery (H).aqt
Date: 12/30/02 Time: 13:13:53

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 2.5 ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

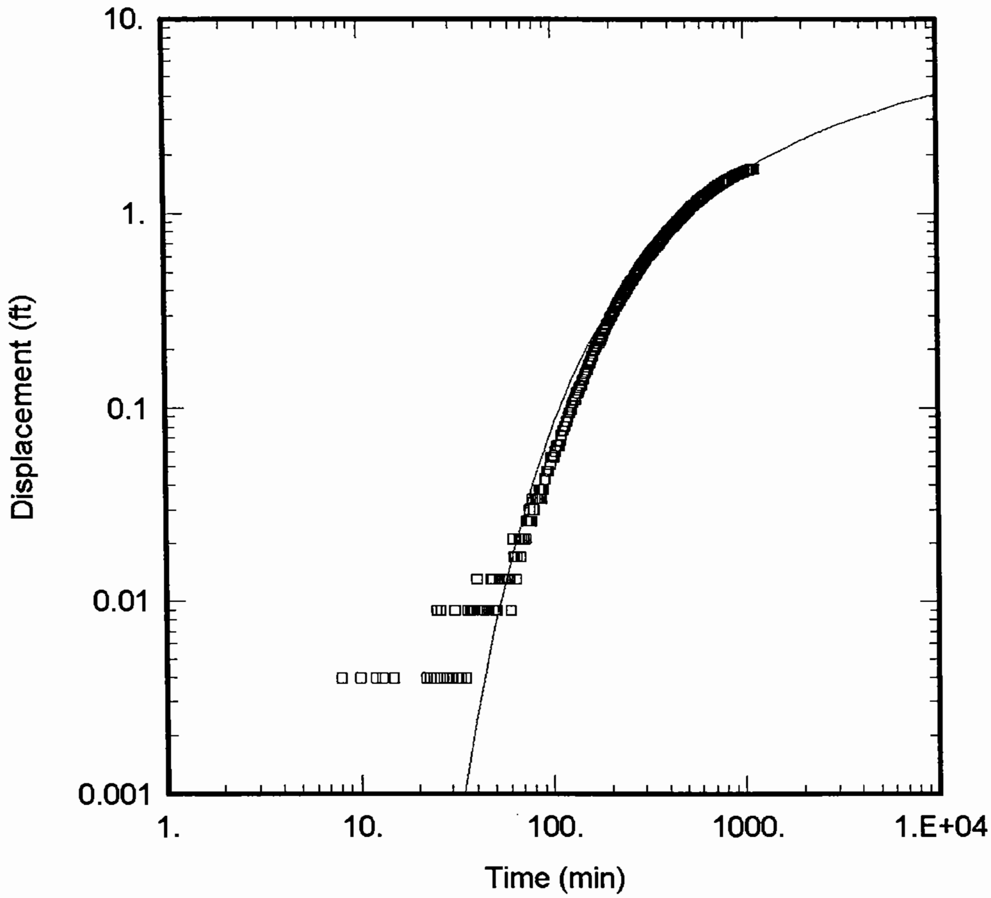
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-17-85	0	-18

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.157 ft^2/min S = 1.133E-10
ß = 1.E-05



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-17-95 Recovery (H).aqt
Date: 12/30/02 Time: 13:41:35

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 1. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

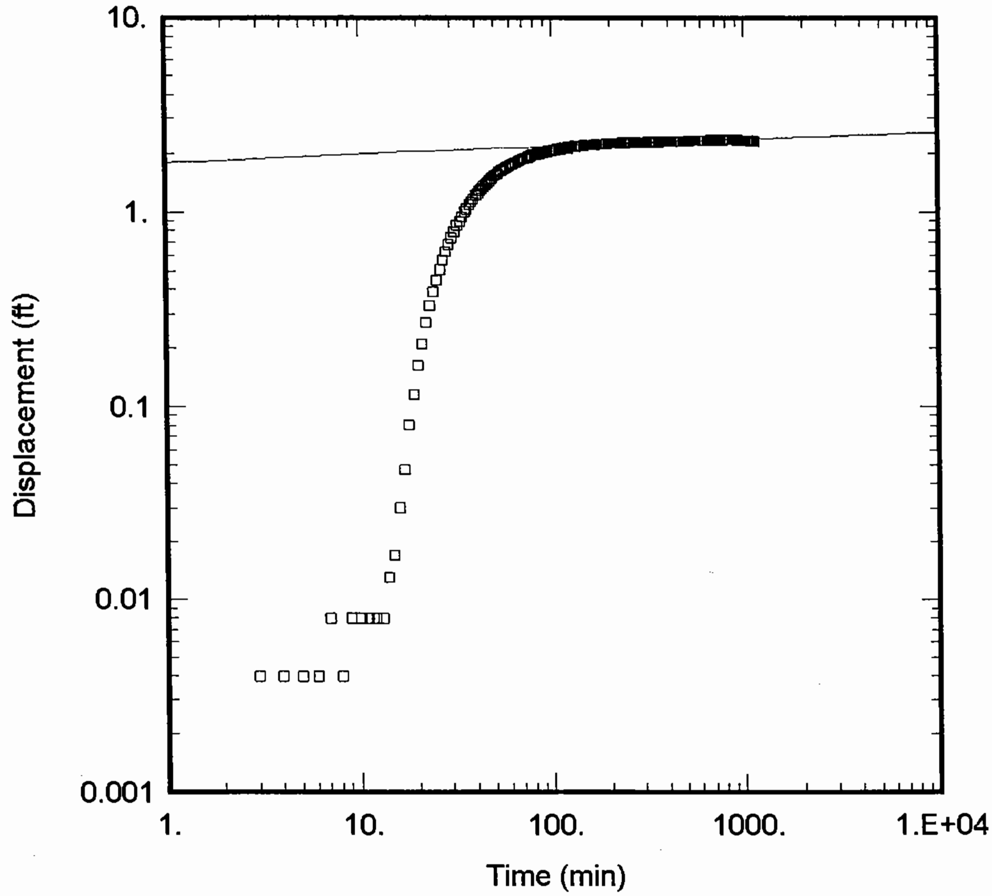
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-17-95	0	-17

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.00656 ft^2/min S = 0.01666
ß = 0.1519



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-18-85 Recovery (H).aqt
Date: 12/30/02 Time: 13:55:52

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 1. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

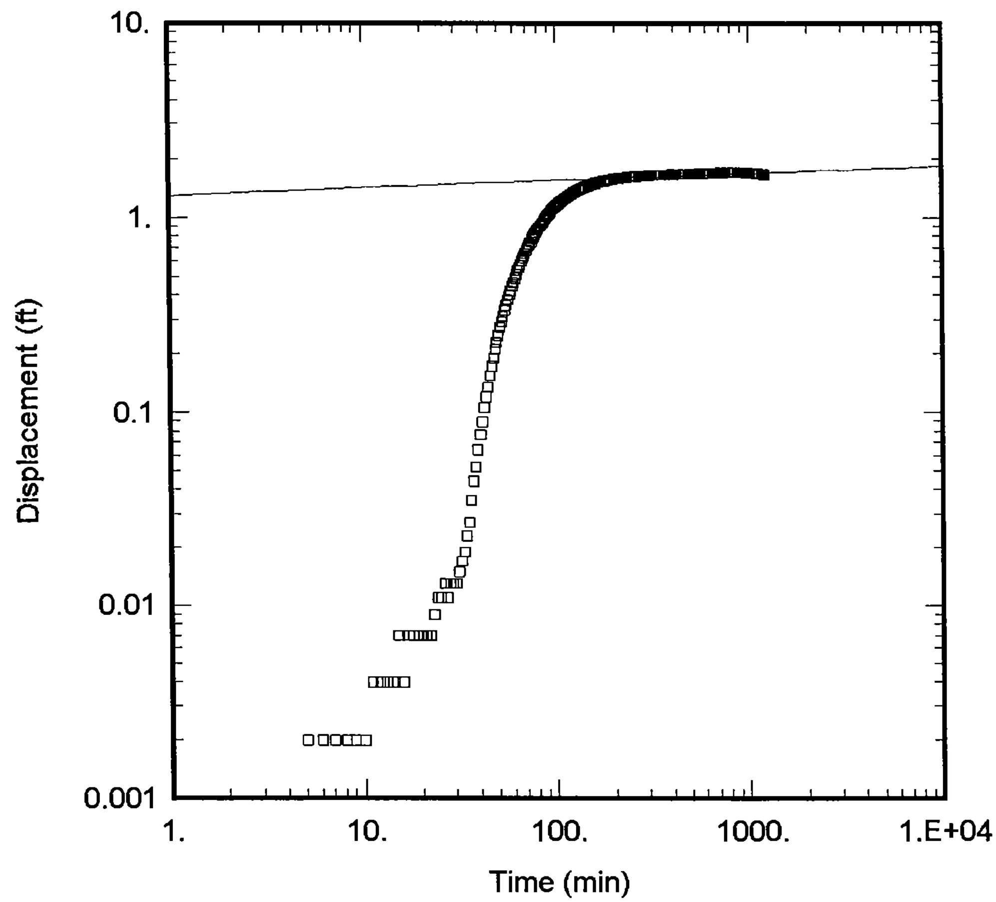
Observation Wells

Well Name	X (ft)	Y (ft)
□ MW-18-85	0	-17

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.07197 ft^2/min S = 5.168E-10
ß = 0.007454



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\REC\MW-19-85 Recovery (H).aqt
Date: 12/30/02 Time: 14:38:41

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: RW-1
Test Date: 12-17-01

AQUIFER DATA

Saturated Thickness: 4.5 ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
RW-1	0	0

Observation Wells

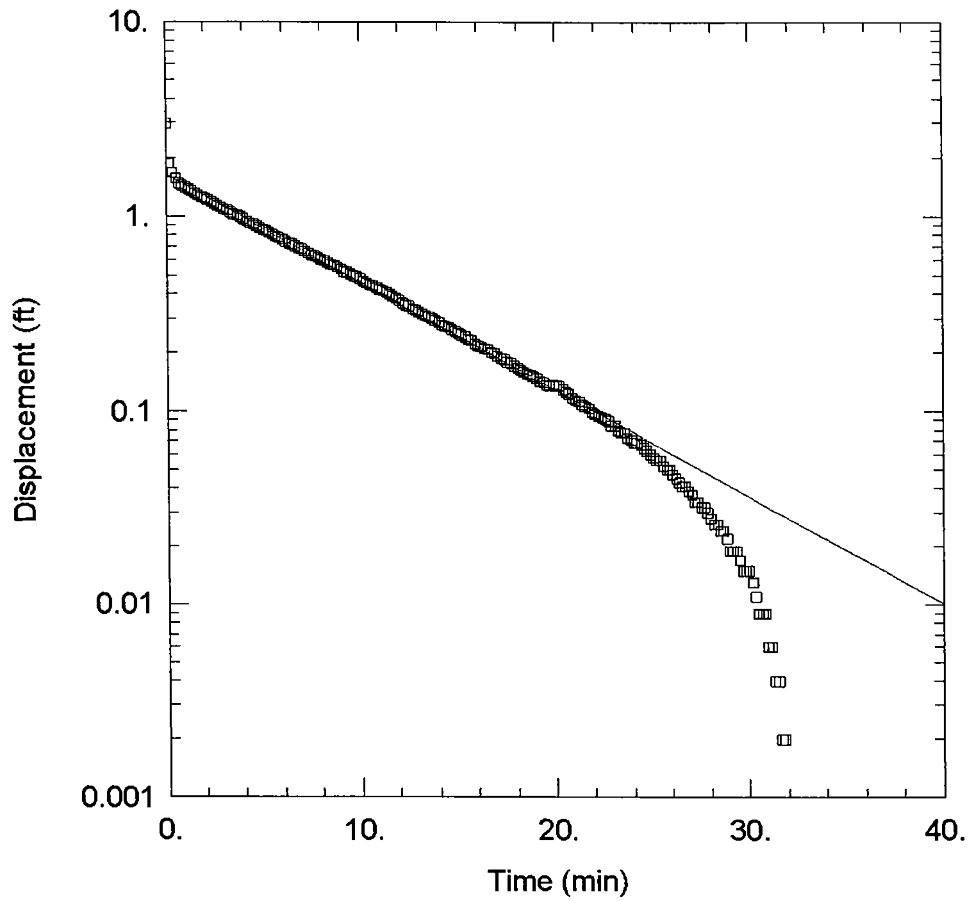
Well Name	X (ft)	Y (ft)
□ MW-19-85	-32	0

SOLUTION

Aquifer Model: Leaky Solution Method: Hantush

T = 0.105 ft^2/min S = 1.151E-12
ß = 0.05787

SLUG TEST CURVES



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\Slug\MW-14-80 Slug.aqt
Date: 12/30/02 Time: 14:59:20

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: MW-14-80
Test Date: 12-13-01

AQUIFER DATA

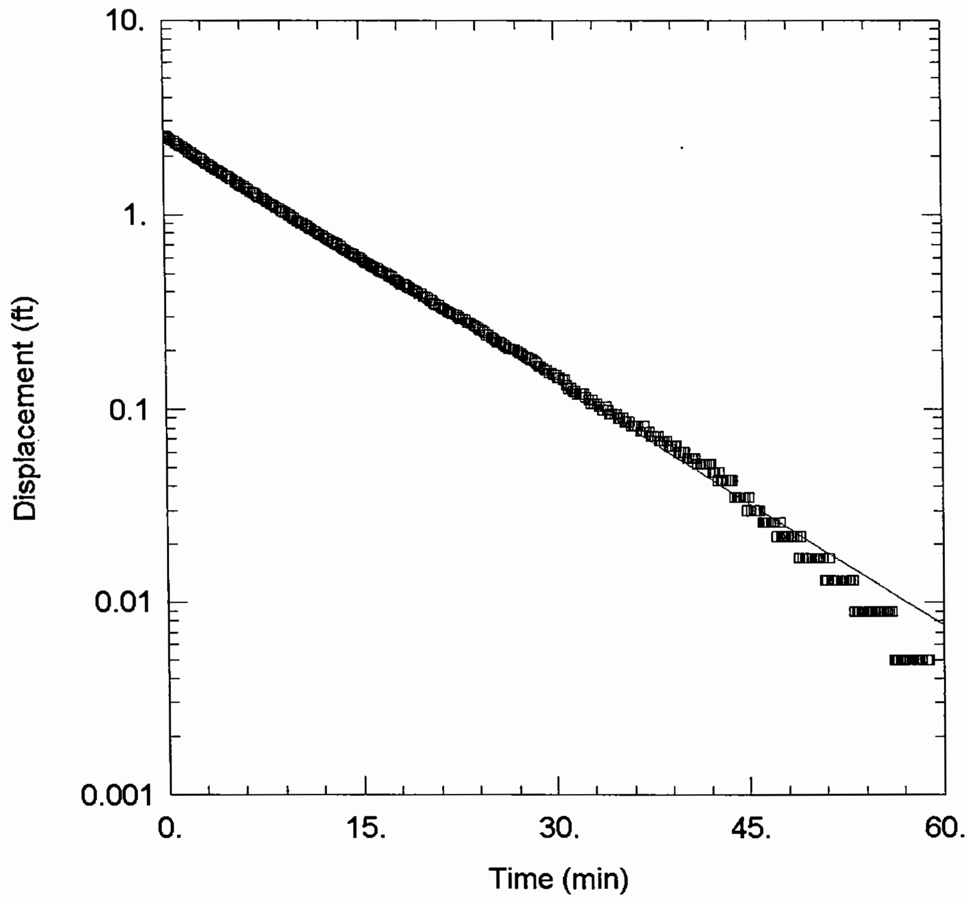
Saturated Thickness: 1. ft
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (MW-14-80)

Initial Displacement: 2.988 ft
Water Column Height: 12.64 ft
Casing Radius: 0.08333 ft
Wellbore Radius: 0.3333 ft
Screen Length: 5. ft
Gravel Pack Porosity: 0.33

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.001303 ft/min
y0 = 1.63 ft



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\Slug\MW-14-90 Slug.aqt
Date: 12/30/02 Time: 14:59:37

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: MW-14-90
Test Date: 12-13-01

AQUIFER DATA

Saturated Thickness: 5. ft
Anisotropy Ratio (Kz/Kr): 0.1

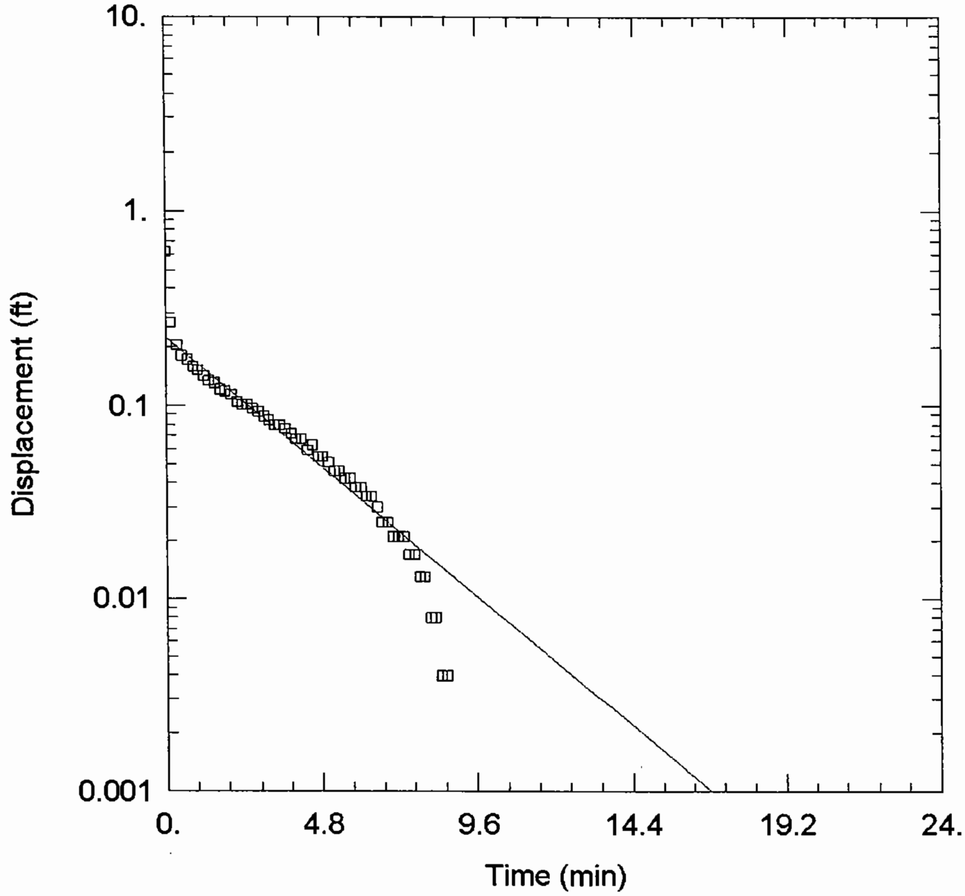
WELL DATA (MW-14-90)

Initial Displacement: 2.48 ft
Casing Radius: 0.08333 ft
Screen Length: 5. ft
Water Column Height: 19.26 ft
Wellbore Radius: 0.3333 ft
Gravel Pack Porosity: 0.33

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.001078 ft/min
y0 = 2.537 ft



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\Slug\MW-15-70 Slug.aqt
Date: 12/30/02 Time: 14:58:14

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: MW-15-70
Test Date: 12-13-01

AQUIFER DATA

Saturated Thickness: 3. ft
Anisotropy Ratio (Kz/Kr): 0.1

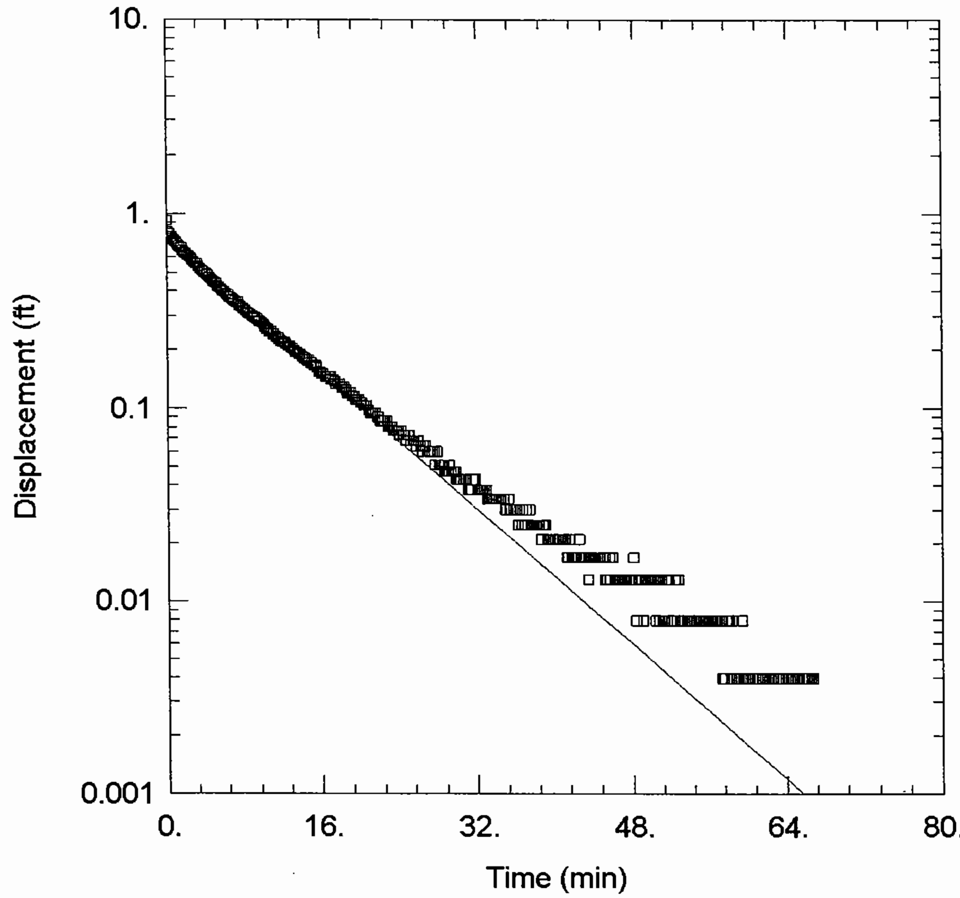
WELL DATA (MW-15-70)

Initial Displacement: 0.615 ft
Casing Radius: 0.08333 ft
Screen Length: 5. ft
Water Column Height: 3.24 ft
Wellbore Radius: 0.3333 ft
Gravel Pack Porosity: 0.33

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.002277 ft/min
y0 = 0.2255 ft



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\Slug\MW-16-70 Slug.aqt
Date: 12/30/02 Time: 14:58:38

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: MW-16-70
Test Date: 12-13-01

AQUIFER DATA

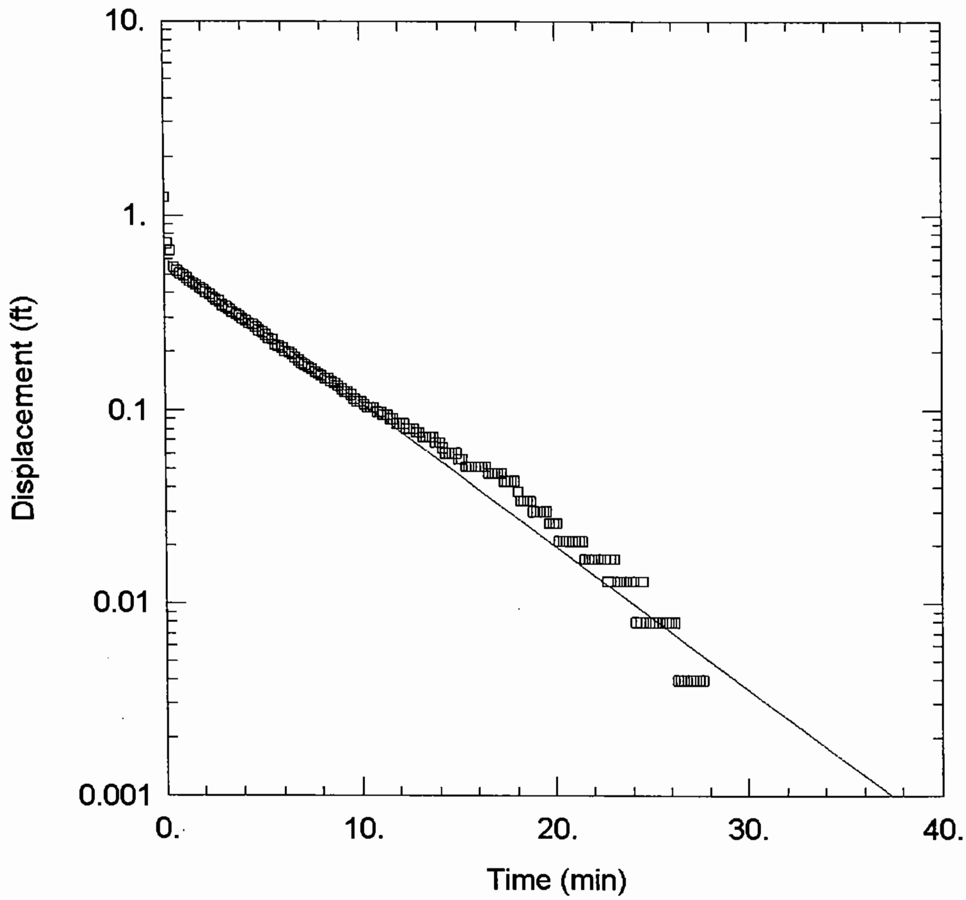
Saturated Thickness: 1. ft
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (MW-16-70)

Initial Displacement: 0.92 ft
Casing Radius: 0.08333 ft
Screen Length: 5. ft
Water Column Height: 5.09 ft
Wellbore Radius: 0.3333 ft
Gravel Pack Porosity: 0.33

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.0008281 ft/min
y0 = 0.7593 ft



WELL TEST ANALYSIS

Data Set: C:\TSG\Projects\Pemaco\Aquifer Test\Analysis\Slug\MW-18-70 Slug.aqt
Date: 12/30/02 Time: 14:58:58

PROJECT INFORMATION

Company: T N & Associates
Client: Pemaco
Test Location: Maywood
Test Well: MW-18-70
Test Date: 12-13-01

AQUIFER DATA

Saturated Thickness: 1. ft
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (MW-18-70)

Initial Displacement: 1.237 ft
Casing Radius: 0.08333 ft
Screen Length: 5. ft
Water Column Height: 5.51 ft
Wellbore Radius: 0.3333 ft
Gravel Pack Porosity: 0.33

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.001435 ft/min
y0 = 0.602 ft