EXHAUST SHAFT DATA REPORT: 72-HOUR PUMPING TEST ON C-2506 AND 24-HOUR PUMPING TEST ON C-2505

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ABSTRACT

A 72-hour pumping test was conducted on well C-2506 followed by a 24-hour pumping test on well C-2505 at the Waste Isolation Pilot Plant (WIPP) Site, located near Carlsbad, New Mexico. Activities took place between February 25 and March 7, 1997. Test activities were part of a characterization program designed to determine the source(s) of fluid leaking into the Exhaust Shaft liner from a horizon located 50-80 feet below land surface (bls) at the WIPP. The pumping tests were performed in an attempt to define hydrologic boundaries and to determine if the existing wells surrounding the Exhaust Shaft would be sufficient as dewatering/interception wells to prevent leakage of fluid into the shaft. Results of those tests indicate that boundary conditions could not be clearly defined, that the existing wells would not be sufficient to dewater the area surrounding the Exhaust Shaft, and that the total head in water-bearing unit (lower Santa Rosa/Upper Dewey Lake Formations) has increased by an average of over 1.5 feet between November 1996 and March 1997 indicating that there is signifficant recharge from some artificial source.

During the pumping tests fluid samples were collected from wells C-2506 and C-2505. Analysis of the samples indicate a decrease in total dissolved solids and most major ions relative to samples collected in the fall of 1996. A decrease in these parameters is attributed to significant differences in the sampling protocols. Fall 1996 samples were collected during drilling and bailing exercises in which less than 100 gallons of fluid had been removed from each well prior to sampling. Whereas the winter 1997 samples were collected after pumping over 3000 gallons from well C-2506 and 1000 gallons from C-2505. An ongoing monitoring program is presently in place to sample wells C-2505, C-2506, and C-2507 on a monthly basis to establish baseline chemical conditions of the perched groundwater.

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1.0 INTRODUCTION

This report presents data collected during a 72-hour pumping test in well C-2506 and a 24-hour pumping test in well C-2505 located near the Exhaust Shaft at the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico. The pumping tests were implemented to characterize the areal extent, water quality, and potential source(s) of fluid leaking into parts of the upper 80 feet of the Exhaust Shaft at the WIPP. The testing activities were performed between February 25, 1997 and March 7, 1997. The WIPP is a US Department of Energy (DOE) site designed to develop methods for safe long-term disposal of transuranic (TRU) wastes generated by US defense programs.

1.1 Background

Surface geophysical investigations mapped conductive zones possibly related to water leaking into the upper Exhaust Shaft in August and September 1996 as part of the Exhaust Shaft: Hydraulic Assessment Program at WIPP (DOE, 1997). Based on these geophysical investigations, five boreholes were drilled in September and October 1996 to depths of up to 100 feet below ground surface (bgs) to evaluate the near surface formations as potential ground water sources of the fluid seeping into the shaft. Four boreholes; C-2505, C-2506, and C-2507, and ES-001 (Figure 1.1) penetrated water bearing horizons between 48 and 63 feet bgs, located in sandstone's of the lower Santa Rosa Formation and mudstones of the upper Dewey Lake Red Beds Formation. Three boreholes; C-2505, C-2506, and C-2507 were drilled and selectively cored to determine the stratigraphic horizons producing fluid. These boreholes were then completed as monitor wells and future test wells.

Slug tests were conducted on wells C-2505, C-2506, and C-2507 from October 1, 1996 to October 4, 1996 to characterize the water bearing zones, to attempt to identify the lateral extent of fluid leaking through the shaft liner, to evaluate possible corrective action measures to eliminate or control leakage, and to identify the need (or not) for dewatering the horizon(s). In addition, a six-hour step-drawdown pumping test was performed on C-2506 to provide data with which to estimate the formations hydraulic parameters (hydraulic conductivity, specific storage, and/or specific yield).

Slug-test and pumping-test data provided estimates of hydraulic conductivity ranging from 5.48e-5 to 1.56e-6 m/sec, with storativity values ranging from 1.10 e-2 to 9.38 e-3. In addition, water level data was used to calculate a hydraulic gradient of 0.0245 ft/ft in a south/southeasterly direction (10/14/96). Test data indicated that the wells nearest the Exhaust Shaft were capable of sustaining water production in the range of 0.3 to 0.6 gallons per minute (gpm) for a period of 24 hours or longer. In addition, the step-drawdown pumping test indicated that the drawdown cone-of-depression encountered a no-flow boundary toward the end of the third (highest rate), pumping period of the step-drawdown test. Water-quality data indicated that total dissolved solids (TDS) are

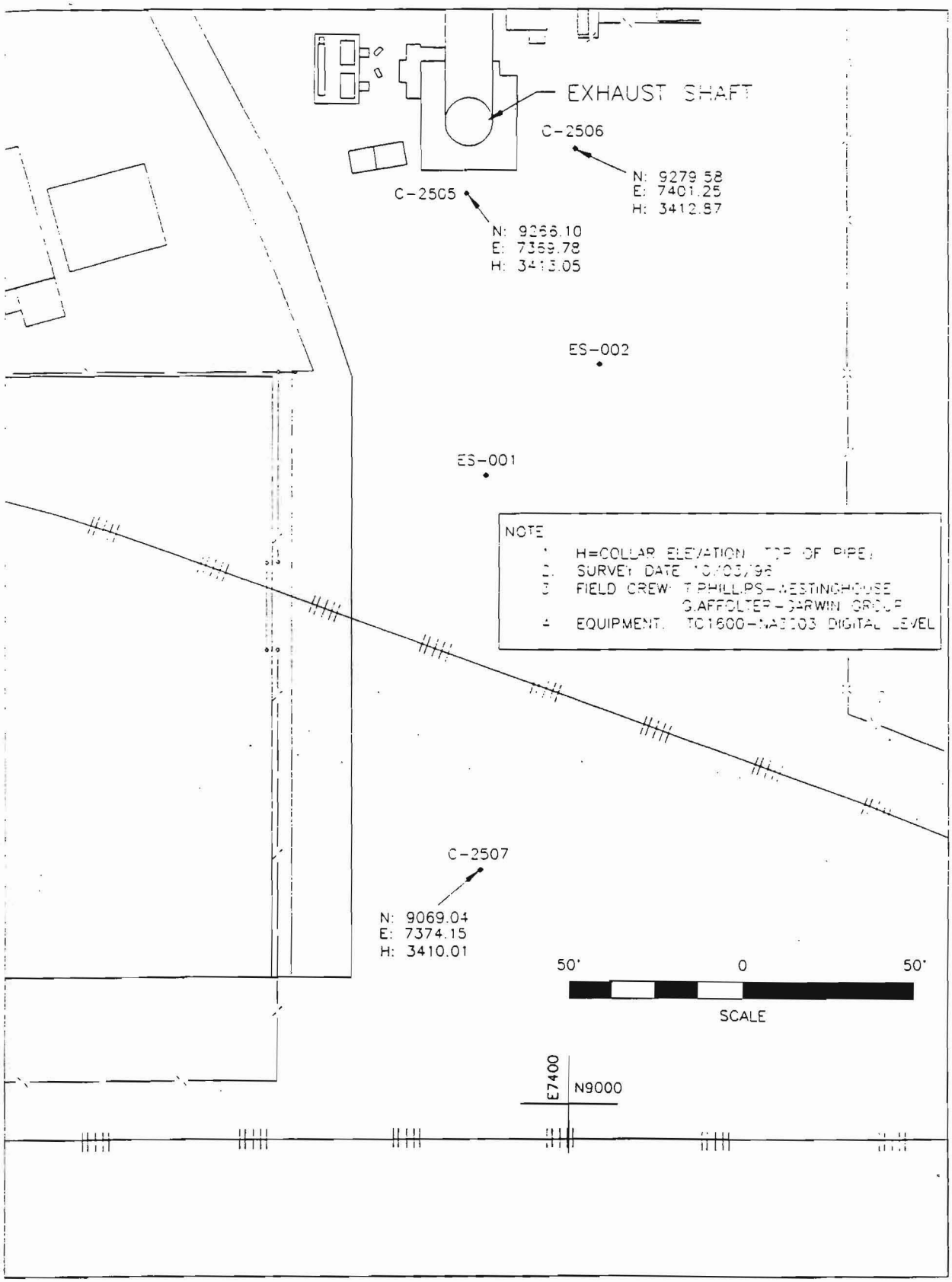

Figure 1.1. Location of boreholes C-2505, C-2506, and C-2507.

greatest near the Exhaust Shaft ranging from 11,500 mg/L (C-2506) and east of the Exhaust Shaft to 8500 mg/L (C-2505), decreasing to 4500 mg/L (ES-001) and 4000mg/L (C-2507) to the south, respectively. Higher TDS values near the shaft appear to correspond to an increase in chloride and sodium concentrations.

1.2 Test Objectives

Following evaluation of the October hydraulic testing as described in Exhaust Shaft: Hydraulic Assessment Program Study (DOE, 1997) a 72-hour step-drawdown pumping test was conducted from February 25, 1997 to February 28, 1997 in well C-2506, later followed by a 24-hour step-drawdown pumping test in well C-2505 on March 6, 1997. The objectives of the testing in C-2505 and C-2506 were to:

- determine if the water-bearing horizons within the lower Santa Rosa/upper Dewey Lake Formations are limited in areal extent or are a part of a regional groundwater zone;
- define local boundary conditions;
- determine if existing wells C-2505 and C-2506 are sufficient to dewater the area around the Exhaust Shaft;
- determine if additional wells are required to characterize source(s); and to
- collect additional water-quality samples.

1.3 Scope of Work

Water from an unknown source has been leaking through the Exhaust Shaft liner at a horizon located 50-to-80 feet bgs since as early as May 1995. Two pumping tests were performed in an effort to characterize the areal extent of the fluid within the lower Santa Rosa/upper Dewey Lake Red Bed Formations. The first test was a 72-hour step-drawdown pumping test on well C-2506 followed by three days of recovery monitoring in which the fluid-pressure response was monitored in the pumping well C-2506 as well as in observation wells C-2505 and C-2507. A step-drawdown pumping test was then performed on well C-2505 and the fluid-pressure response was monitored in pumping well C-2505 and in observation wells C-2506 and C-2507. In addition, fluid samples of the water produced during these tests were collected during the pumping tests to determine if there were any changes in the chemistry of the fluid as compared to the October 1996 samples. The water quality data was collected in order to provide additional information as to the source(s) of the fluid.

2.0 CONSTRUCTION AND TESTING HISTORY OF WELLS C-2505, C-2506 AND C-2507

2.1 Well Construction

2.1.1 Borehole C-2505

Borehole C-2505 was drilled between September 23-24, 1996 to a total depth of 97.0 feet bgs. C-2505 was drilled to a depth of 64.0 feet with a hollow-stem auger and from 64.0 to 97.0 feet using air-rotary methods. Core samples were collected from both drilling methods, beginning at a depth of about 9 feet bgs to describe the geologic materials in the formations encountered. C-2505 was sealed with a bentonite clay from 69.0 to 97.0 feet and reamed to a diameter of 7-7/8 inches from ground surface to about 65.0 feet bgs in order to set 4-inch PVC casing and well screen. The well was screened from about 45.0 feet to 64.9 feet bgs then gravel packed from 44.0 to 69.0 feet bgs, then sealed with bentonite from 41.5 to 43.9 feet bgs, and grouted to surface (Figure 2.1).

2.1.2 Borehole C-2506

Borehole C-2506 was drilled on September 25, 1996, to a total depth of 69.0 feet bgs using a hollow-stem auger and a rotary-cone reaming bit. Core samples were collected from 41.0 to 64.3 feet bgs and these samples were used to describe the geologic formations encountered. C-2506 was reamed to a diameter of 7-7/8 inches from land surface to 69 feet bgs in order to set 4-inch PVC casing and well screen. The well was screened from about 45.0 feet to 65.4 feet bgs, and gravel packed from 44.5 to 69.0 feet bgs. The well was then sealed with bentonite clay from 41.5 to 44.5 feet bgs and grouted to surface (Figure 2.2).

2.1.3 Borehole C-2507

Borehole C-2507 was drilled on October 1, 1996, to a total depth of 73.0 feet bgs using a hollow-stem auger and a rotary-cone reaming bit. Core samples were collected from 39.0 to 63.0 feet bgs and these samples were used to describe the geologic formations encountered. C-2507 was reamed to a diameter of 7-7/8 inches from land surface to 73.0 feet bgs in order to set 4-inch PVC casing and well screen. The well was screened from about 44.0 feet to 69.0 feet bgs and gravel packed from 43.0 to 73.0 feet bgs. The well was then sealed with bentonite clay from 39.0 to 42.9 feet bgs and grouted to surface (Figure 2.3).

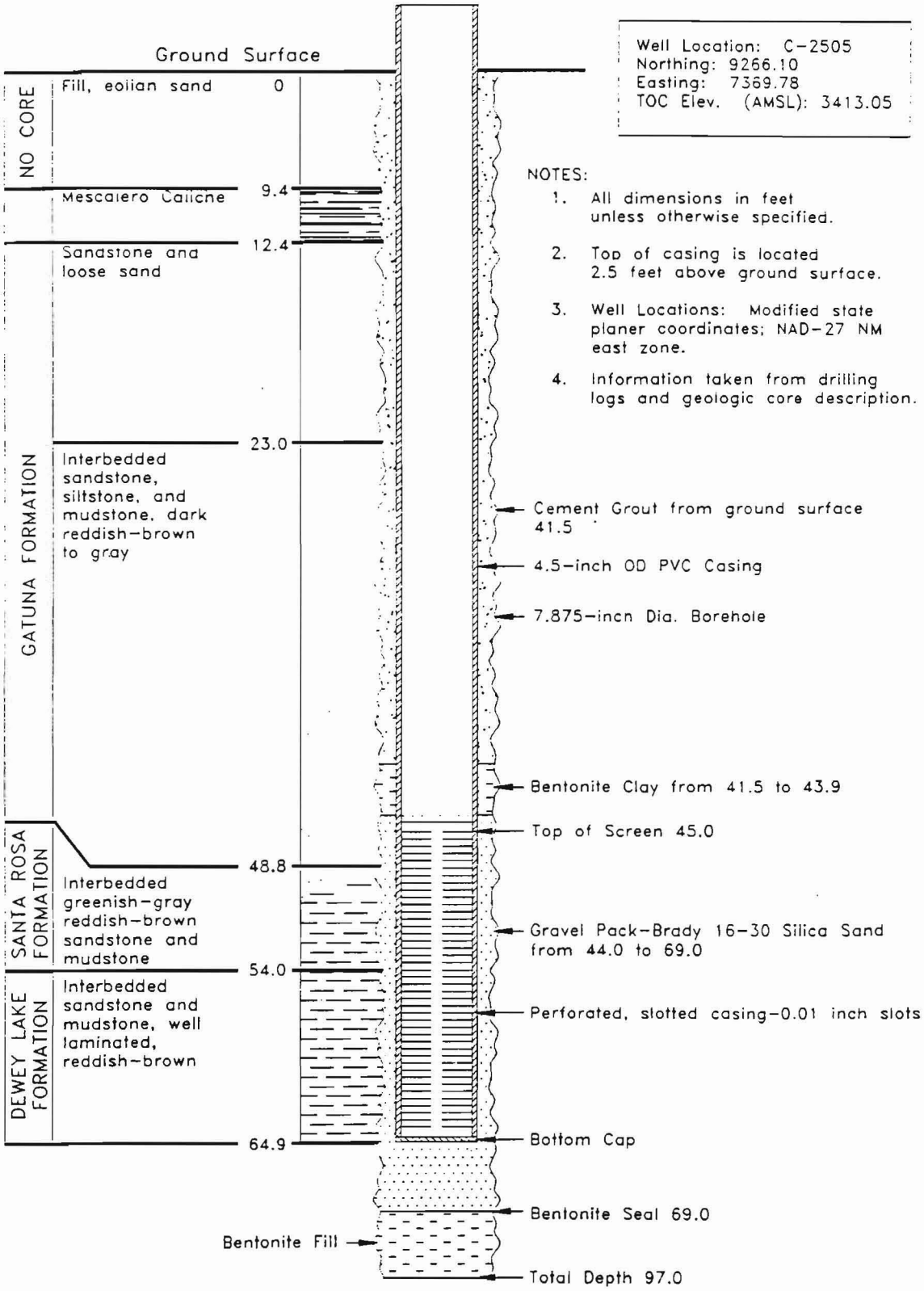

Figure 2.1. C-2505 well completion diagram.

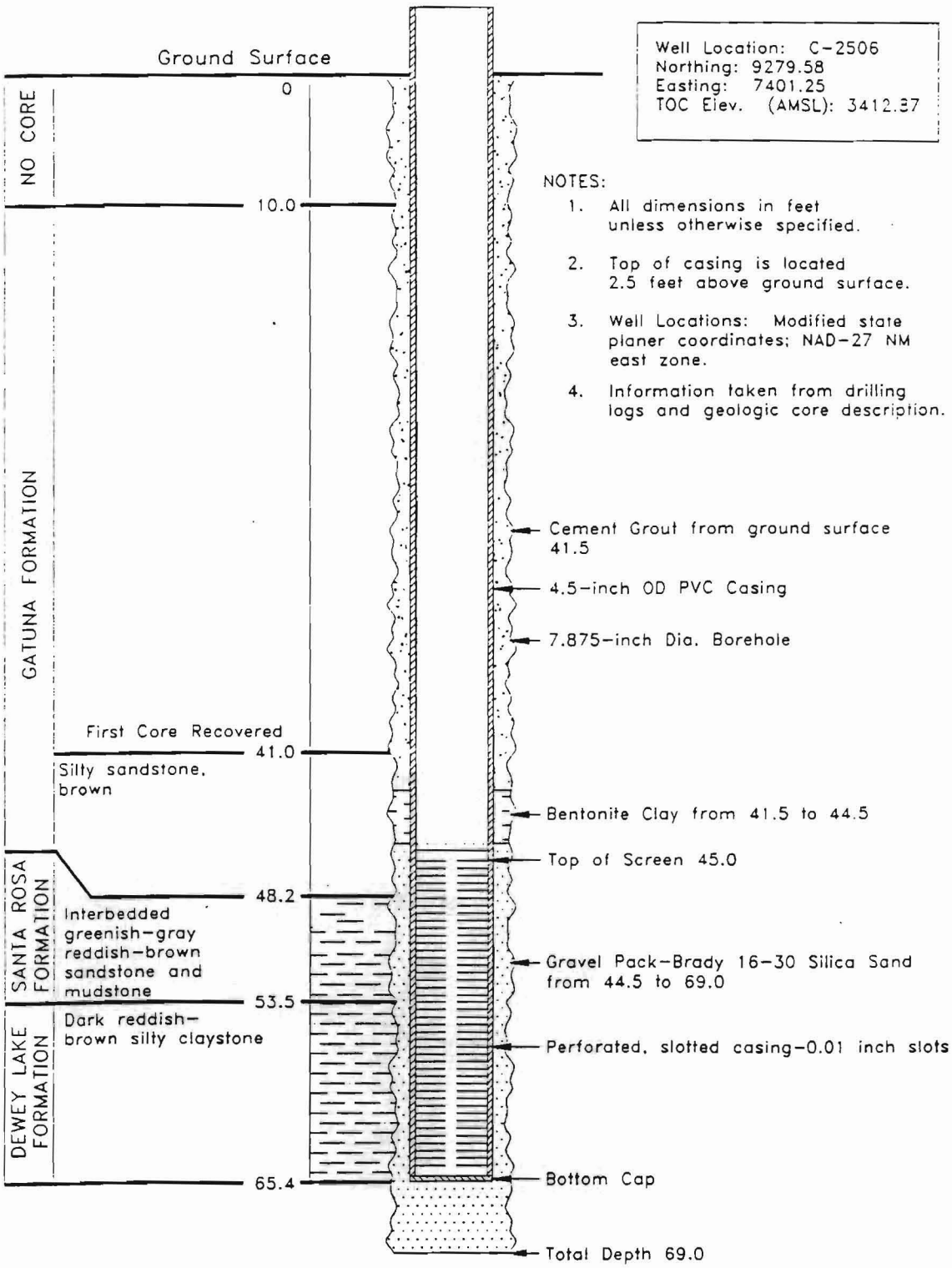

Figure 2.2. C-2506 well completion diagram.

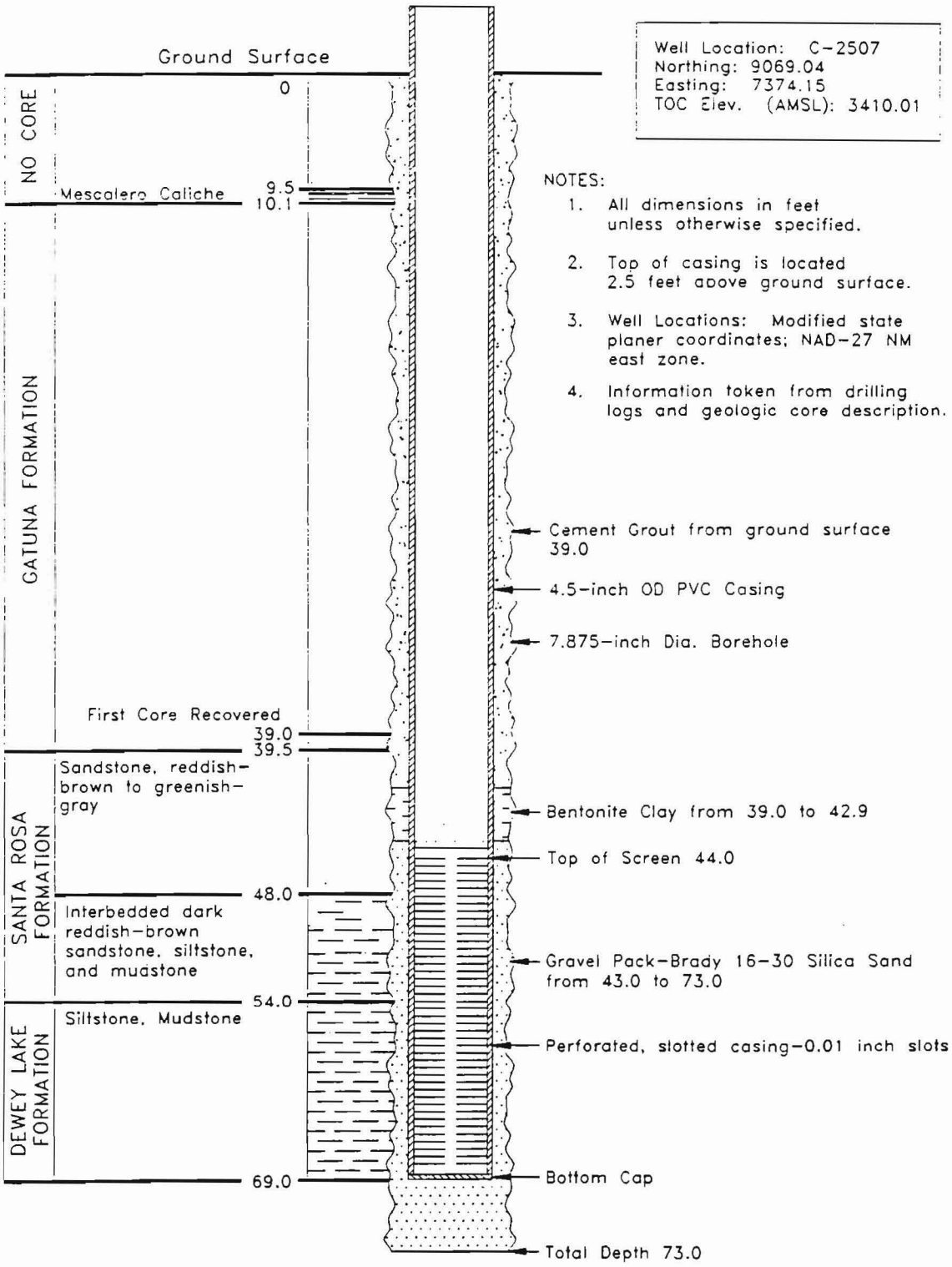

Figure 2.3. C-2507 well completion diagram.

2.2 Testing History of Wells C-2505, C-2506, and C-2507

Two slug-injection tests, approximately 4.5 gallons each, were conducted in wells C-2505, C-2506, and C-2507 between October 1-3, 1996 (DOE, 1997). The additional fluid-pressure associated with all of the slug injections was absorbed within approximately 10 minutes. Evaluation of the test data indicated that the tests were dominated by well-bore skin effects, indicating that the applied slug-injection pressures were not great enough to fully evaluate the formations. The slug tests did however indicate that the wells do respond to applied pressures in a relatively rapid manner and have sufficient hydraulic conductivity to sustain some level of pumping.

On October 17, 1996 a step-drawdown pumping test was conducted in well C-2506, consisting of three two-hour, consecutive pumping periods followed by a single recovery period after all pumping was complete. Pressure responses were monitored in the pumping well C-2506 as well as in observation wells C-2505 and C-2507. The pumping rates used in the C-2506 step-drawdown pumping test were approximately 0.28 gpm, 0.60 gpm, and 0.78 gpm.

Evaluation of the data collected during the Step-Drawdown Pumping Test indicated that:

- approximately 200 gallons of water were removed from C-2506 during the test;
- all three observation wells, C-2505, C-2506, and C-2507, responded to the test;
- the C-2506 fluid-pressure responses for each pumping period indicate that the test influence moved beyond wellbore storage and affected the formation;
- the drawdown cone encountered a no-flow boundary toward the end of the third step-pumping period;
- test data indicate a hydraulic conductivity range of 5.48 e-5 to 1.56 e-6 m/sec, and a storativity range of 1.11 e-2 to 9.38 e-3; and
- the water-bearing horizons behave as an unconfined system.

In addition, water-level measurements from C-2505, C-2506, and C-2507 indicated a hydraulic gradient of 0.0245 ft/ft to the south/southeast.

2.3 Water Level Monitoring in Wells C-2505, C-2506, and C-2507

Static water-level measurements were initiated on the wells upon completion of drilling All measurements were taken from a common reference point (top of PVC casing) and correlated to a standard elevation (feet above mean sea level). Water-level measurements were first made in September 1996 and continued through April 1997. These measurements are made with a Solinst brand water level meter. The frequency with which water-level measurements are made is variable dependent upon other Exhaust Shaft testing activities. When other activities are being conducted (slug and/or

pumping tests) the frequency is high. In the absence of other testing activities, the water levels are measured monthly.

3.0 HYDRAULIC TESTING

Based on the results obtained from hydraulic tests performed in each of the three wells associated with the Exhaust Shaft Assessment Program (C-2505, C-2506, and C-2507) in October 1996, pumping tests were performed to provide additional information regarding the area in the vicinity of the Exhaust Shaft. This additional information was used to :

1) better characterize the boundary conditions of the system that were identified during the initial series of hydraulic tests;
2) assess the areal extent of the water bearing system;
3) better identify the source of the water seeping into the Exhaust Shaft;
4) quantify any changes that are occurring within the system as a function of time; and
5) assess the adequacy of the existing wells as a potential dewatering system.

A 72-hour step-drawdown pumping test was conducted in well C-2506 with pumping rates of 0.5 gpm for 48 hours, 1.0 gpm for 12 hours, and 0.5 gpm for 12 hours followed by 72 hours of recovery monitoring. The fluid-pressure responses were monitored in the pumping well C-2506 and in observation wells C-2505 and C-2507.

A 24-hour step-drawdown pumping test was conducted in well C-2505 with pumping rates of 0.4 gpm for 5 hours and 0.7 gpm for 19 hours, followed by 24 hours of recovery monitoring. The fluid-pressure responses were monitored in the pumping wells C-2505 and in observation wells C-2506 and C-2507.

3.1 Well C-2506

3.1.1 Pumping Rate Information

The 72-hour step-drawdown pumping test was initiated in well C-2506 on Tuesday, February 25, 1996. The initial pumping rate for the first 48 hours of testing was 0.5 gpm based on test data collected from the series of hydraulic tests performed in October 1996. During that test, the pressure response in pumping well C-2506 and observation wells C-2505 and C-2507 was monitored. Due to the fact that no observable response was detected in wells C-2505 and C-2507, the pumping rate was then increased to 1.0 gpm and sustained at that rate for a period of 12 hours. It should be noted that in order to effectively characterize boundary conditions and/or the areal extent of the system, the fluid-pressure response to pumping must be observed in at least two observation wells. After increasing the pumping rate to 1.0 gpm, the system encountered multiple no-flow hydraulic boundaries resulting in periods of abrupt increases in drawdown in pumping well C-2506. After 12 hours of pumping at 1.0 gpm the pumping rate was then decreased to 0.5 gpm due to the decline in the fluid level in

C-2506, which had dropped to near the top of the pump intake. The pumping test was continued at a pumping rate of 0.5 gpm for 12 hours before the pump was shut off on Friday, February 28, 1996. The recovery phase was monitored for a period of 72 hours at which time the test was terminated. Figure 3.1 is a plot of the pumping rate data versus time.

3.1.2 Fluid Pressure Responses

Figures 3.2 - 3.4 are plots of the fluid-pressure response verses time in pumping well C-2506. Analysis of the fluid pressure response in C-2506 provided the following:

1) Analysis of the diagnostic derivative plots from the final pumping period, Figure 3.2, and analysis of the recovery period, Figure 3.3, confirm the order of magnitude of the parameter estimates reported from the initial tests performed in October 1996 during the Exhaust Shaft: Hydraulic Assessment Program. Analysis of the data from the 72-hour step-drawdown pumping in C-2506 indicates parameter estimates of:

   K= 1.99 e-5 m/s
   S= 1.00 e-2 1/m

   Both values fall within the ranges that were previously reported (DOE, 1997).

   Diagnostic derivative-plot analysis was not attempted on the first and second pumping periods due to the level of noise encountered during the first pumping period, and the boundary conditions experienced during the second pumping period.

2) Examination of the pressure response in pumping well C-2506, during the second pumping period, suggests that the water-bearing system is closed or finite in areal extent. This is indicated by the linear pressure responses in Figure 3.4. A linear response is characteristic of a closed system. Although the pressure response in well C-2506 suggests that the system has a no-flow boundary at some radial distance, the observation wells do not indicate any type of boundary condition being encountered (because of minimal pressure response). Therefore the distance to the no-flow (closed) boundary cannot be directly calculated.

   Examination of the fluid-pressure response during the initial pumping period also suggests that other, linear, no-flow boundary conditions may have been encountered during pumping (Figure 3.4).

3) The shapes of the drawdown curves and recovery curves associated with well C-2506 suggests that C-2506 may be getting recharge from some other source. The shapes of the drawdown and recovery curves in well C-2506 are sharp and abrupt (Figure 3.4) which can sometimes be explained by a high positive skin value. A positive skin value indicates that the hydraulic conductivity immediately around the borehole is lower than that of the overall formation. However, information obtained

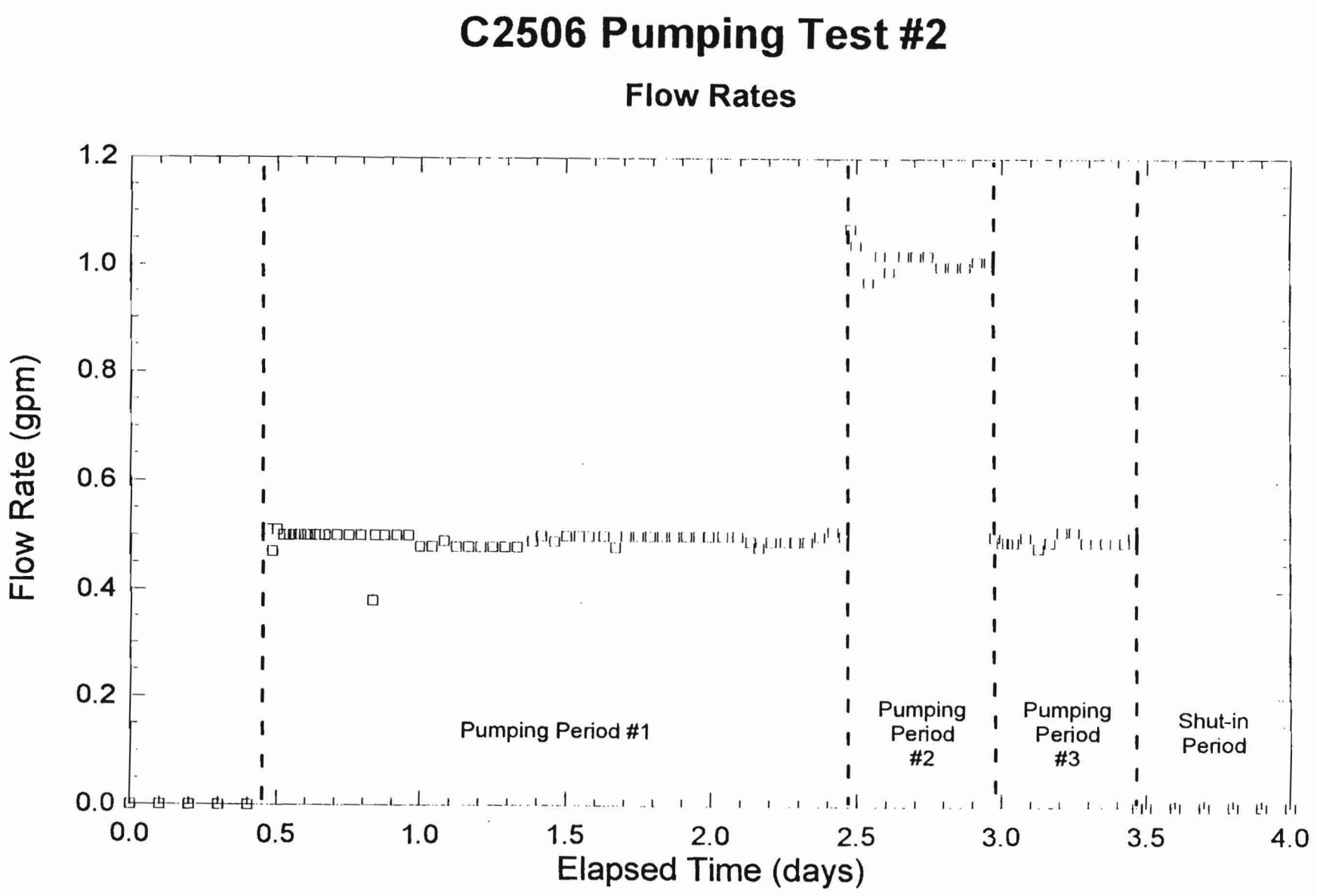

Figure 3.1. C-2506 Pumping Test #2: Flow Rate Versus Time.

C-2506 Pumping Test #2

Diagnostic Derivative Plot
(Pumping Period #3)

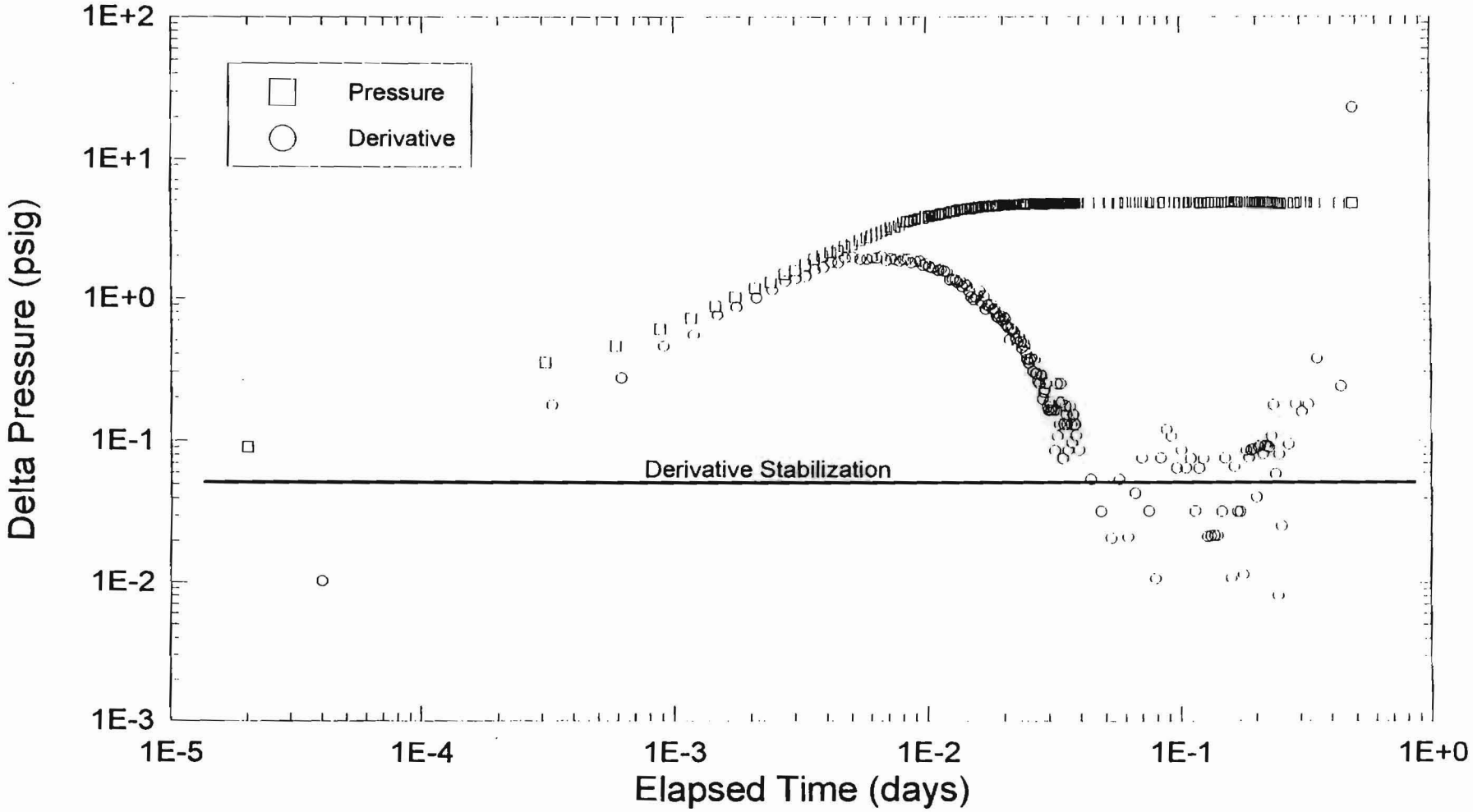

Figure 3.2. C-2506 pumping test #2: diagnostic derivative plot (pumping period #3).

C-2506 Pumping Test #2

Diagnostic Derivative Plot
(Recovery Period)

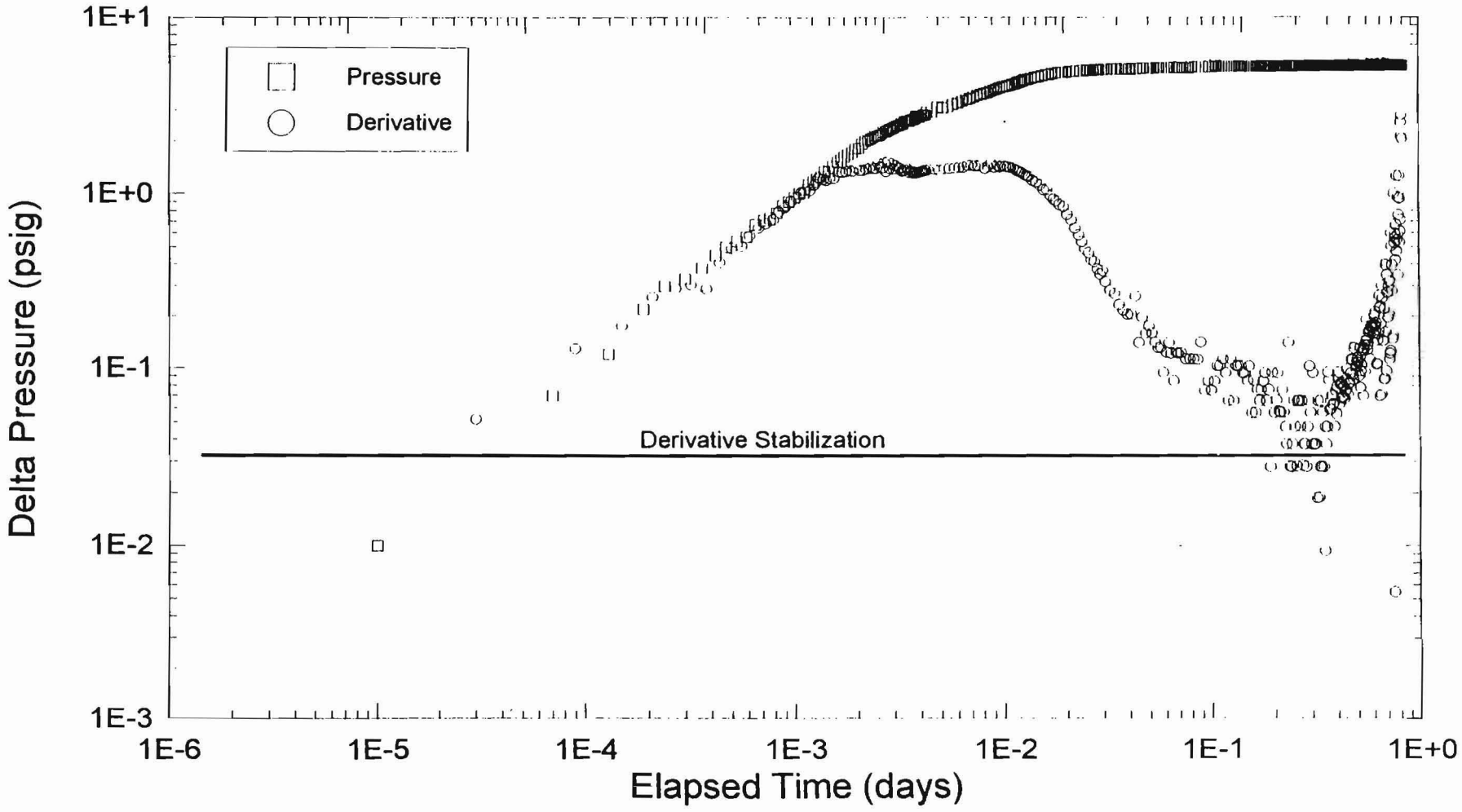

Figure 3.3. C-2506 pumping test #2: diagnostic derivative plot (recovery period).

C2506 Pumping Test #2

Pressure Response

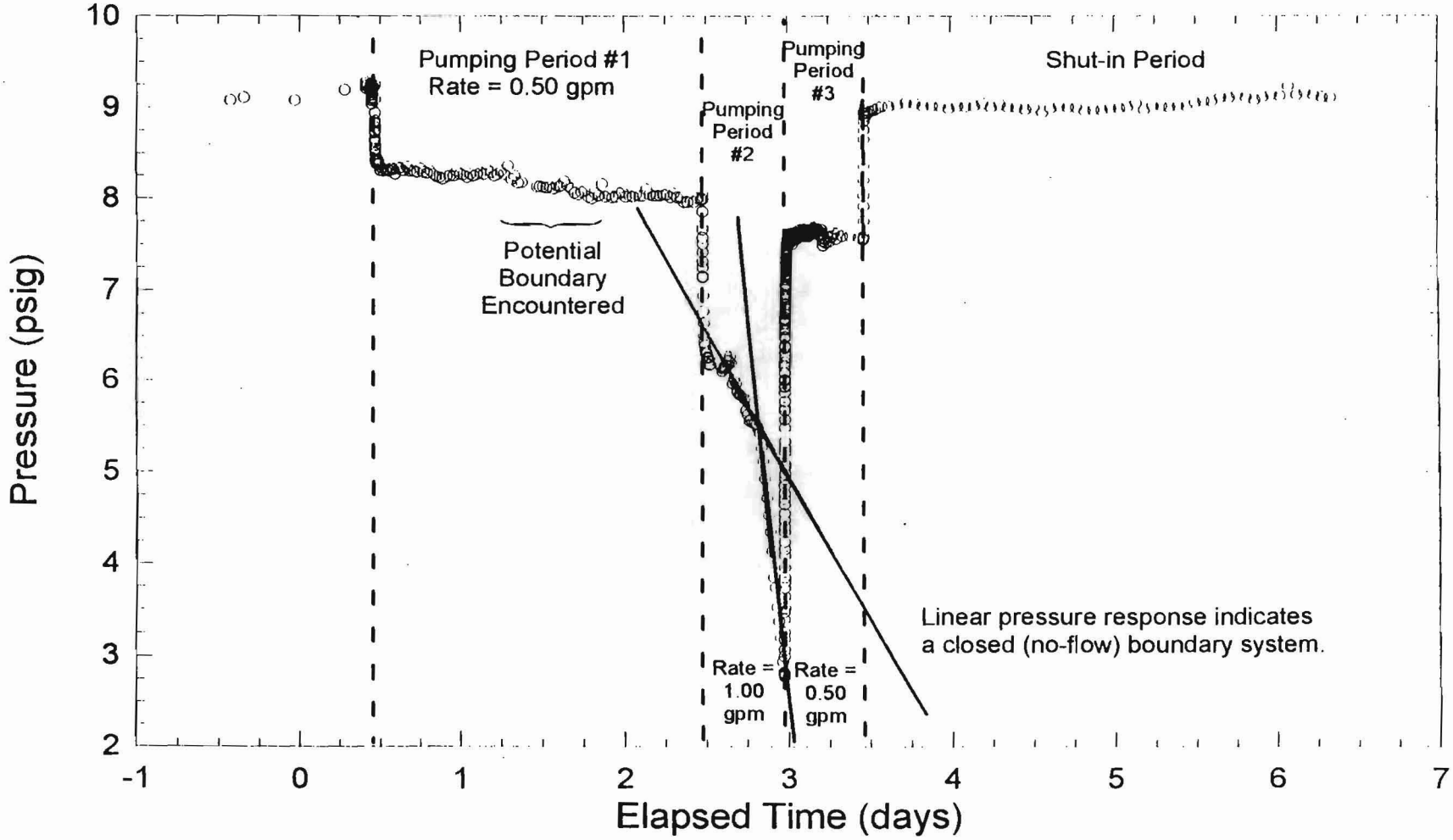

Figure 3.4. C-2506 pumping test #2: pressure versus time (C-2506).

during the initial slug tests conducted in C-2505, C-2506, and C-2507 in October 1996 (Figures 3.5 - 3.7) indicates that the near borehole formation is dominated by a negative skin value. A negative skin value indicates that the hydraulic conductivity immediately around the borehole is higher than that of the overall formation. The latter scenario would be expected considering the gravel pack that was installed as part of each well completion.

Another explanation as to the shape of the drawdown and recovery curves may be that well C-2506 is receiving recharge from an unknown source. In this scenario, an initial drawdown is established to initiate water flowing to the well followed by relative pressure stabilization. This scenario would explain the sharp, abrupt drawdown and recovery pressure responses in C-2506, as well as the relatively stable pressure following the initial drawdown during the first pumping period and when the purnping rate was decreased after the second pumping period. These pressure stabilizations could be attributed to the influence of the proposed recharge source. Under these conditions (0.5 gpm pumping rate) the recharge source rate was greater than or equal to the pumping rate, thereby, creating an artificial steady-state condition (stable pressure while pumping).

4) The data from the 72-hour pumping test in C-2506 indicates that significant changes have occurred within the water bearing system (lower Santa Rosa/upper Dewey Lake Formations) since the October 1996, step-drawdown pumping test. Figure 3.8 shows the pressure response and the respective pumping rates associated with the October test. Figure 3.9 presents data associated with the step-drawdown pumping test conducted in February 1997. Examination of the figures, reveal noticeable changes in the observation well responses. Figure 3.8 shows that both observation wells (C-2505 and C-2507) responded significantly at low pumping rates (0.3 to 0.8 gpm) during the October, 6-hour step-drawdown pumping test. However, in February, minimal response was observed in C-2505, while no response was observed in C-2507 though sustaining higher pumping rates (0.5 to 1.1 gpm) for a period of 72 hours.

Due to the limited radius of influence of a slug test of this magnitude, the no-flow boundary that is indicated by the derivativ suggests that the formation is acting as a boundary to the gravel pack.

C2505 Slug Test #1
Equivalent Diagnostic Derivative Plot

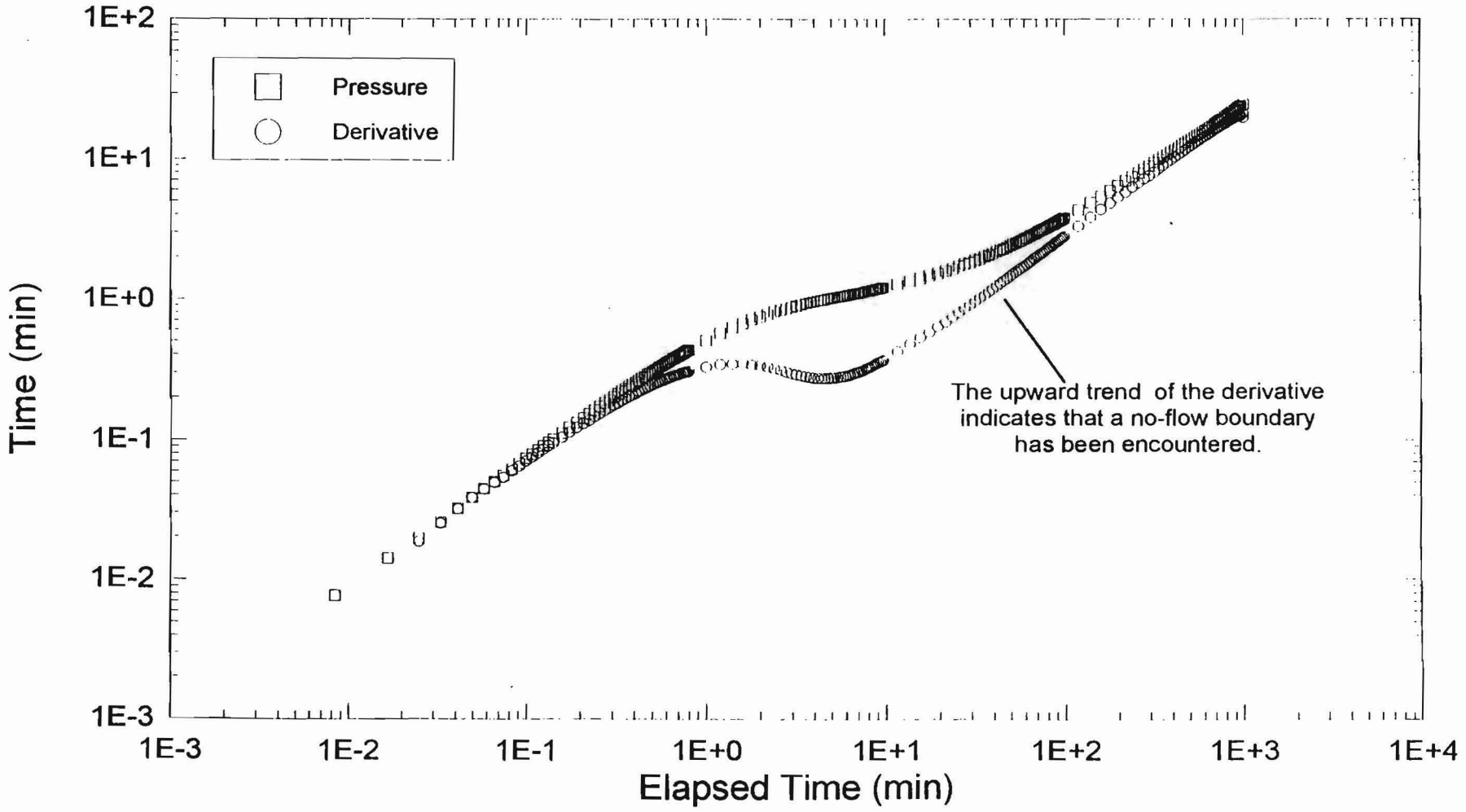

Figure 3.5. C-2505 slug test #1: equivalent diagnostic derivative plot.

Due to the limited radius of influence of a slug test of this magnitude, the no-flow boundary that is indicated by the derivativ suggests that the formation is acting as a boundary to the gravel pack.

C2506 Slug Test #2
Equivalent Diagnostic Derivative Plot

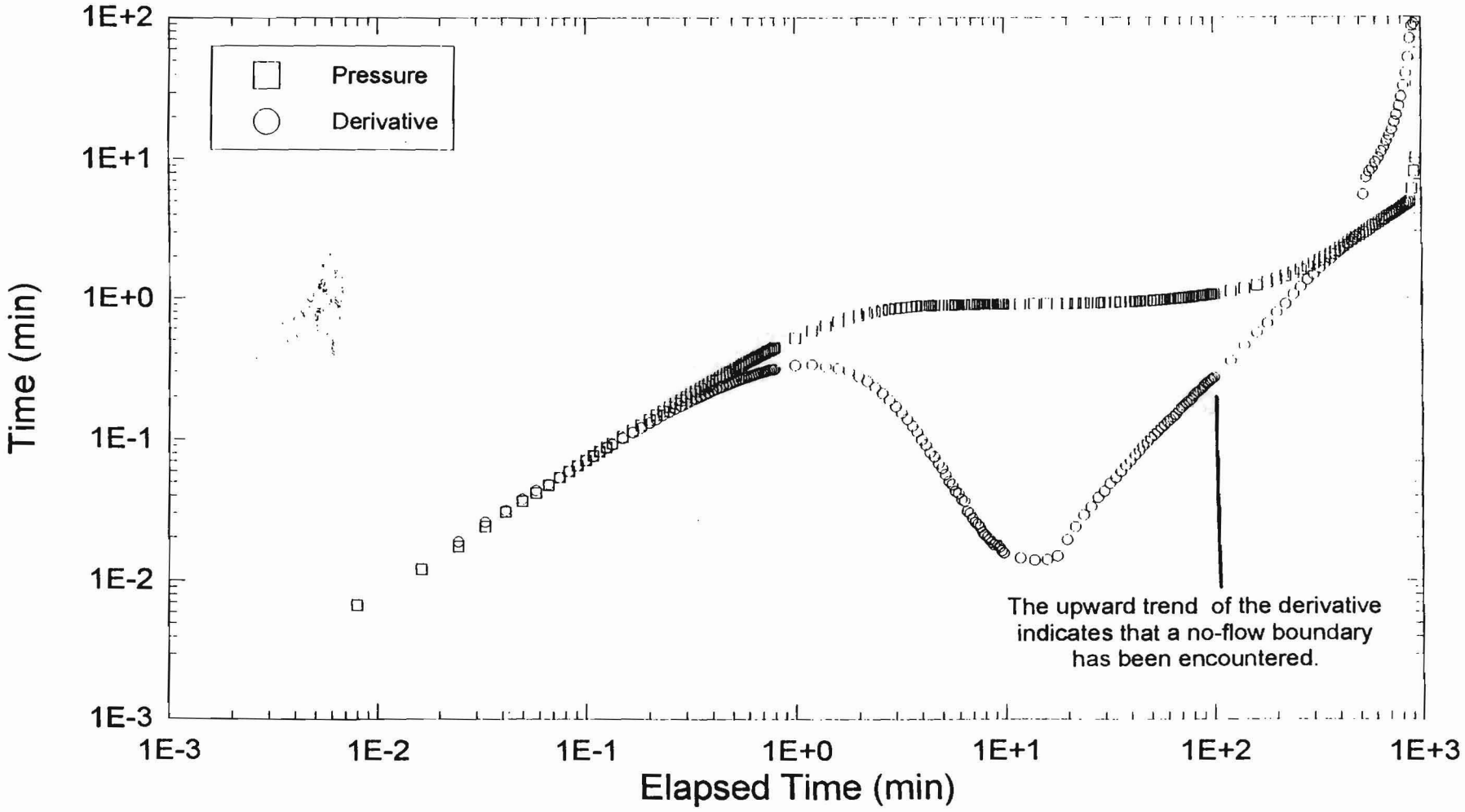

Figure 3.6. C-2506 slug test #2: equivalent diagnostic derivative plot.

slug test of this magnitude, the no-flow boundary that is indicated by the derivativ suggests that the formation is acting as a boundary to the gravel pack.

C2507 Slug Test #2
Equivalent Diagnostic Derivative Plot

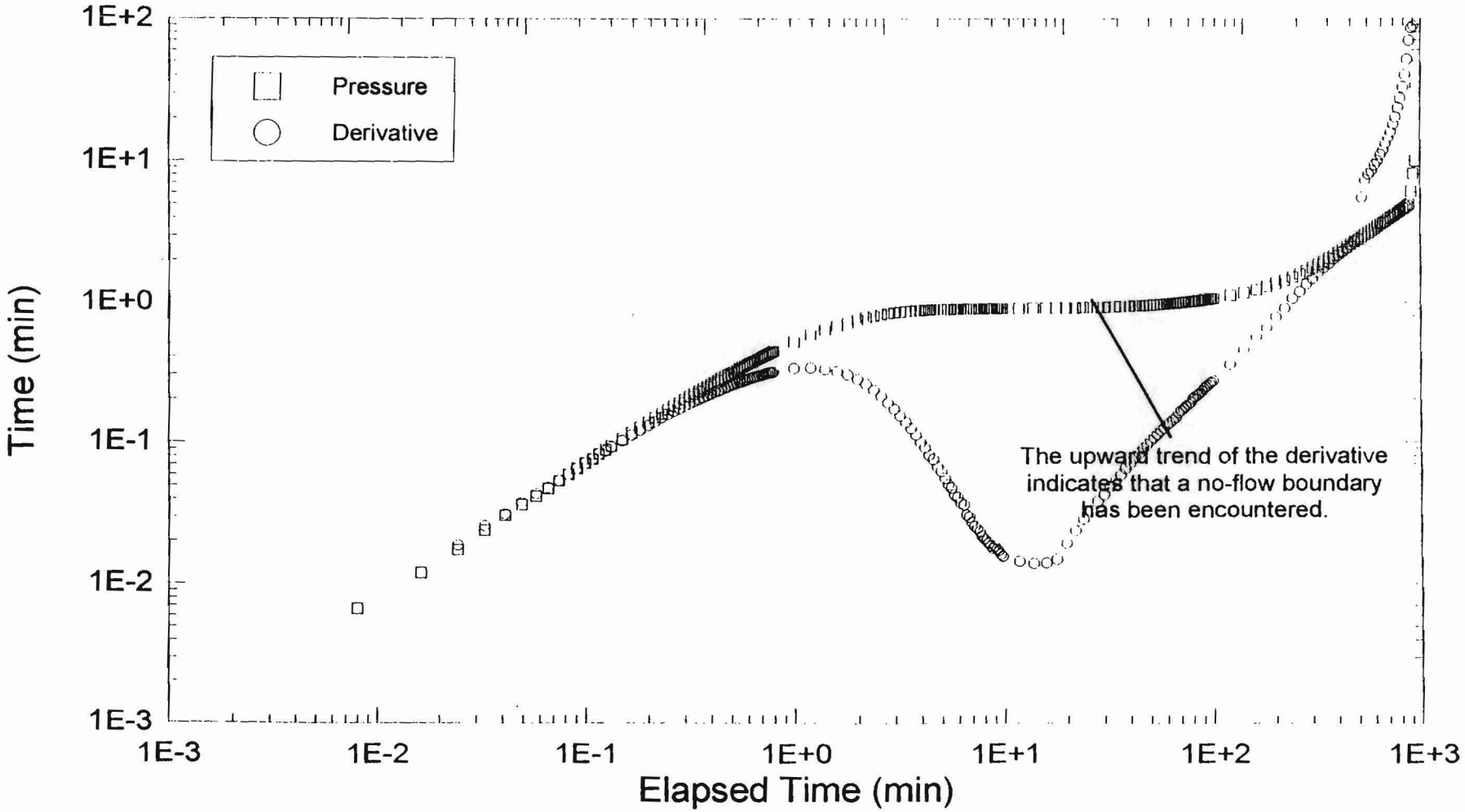

Figure 3.7. C-2507 slug test #2: equivalent diagnostic derivative plot.

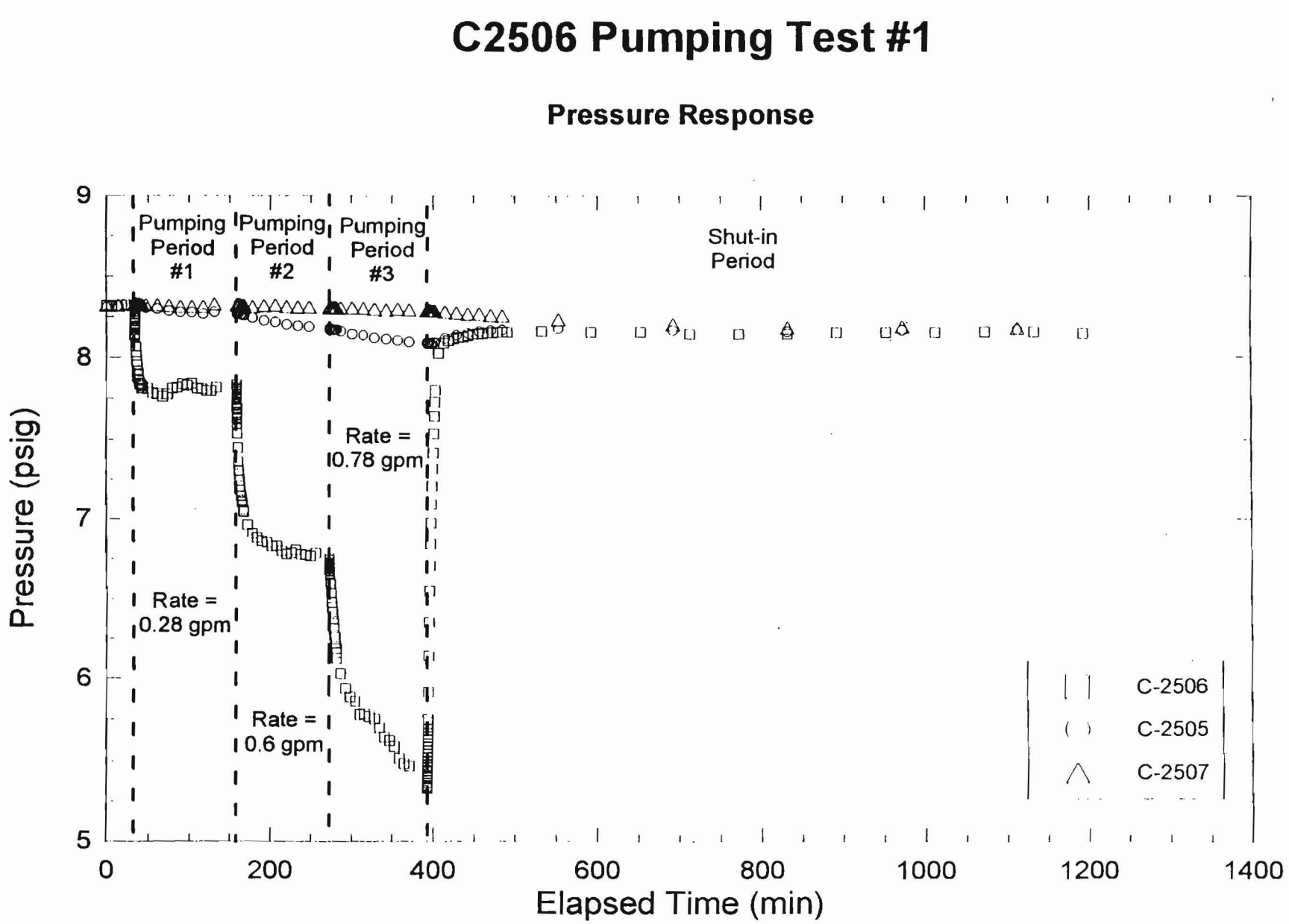

Figure 3.8. C-2506 pumping test #1: pressure versus time (C-2505, C-2506, and C-2507).

C2506 Pumping Test #2

Pressure Response

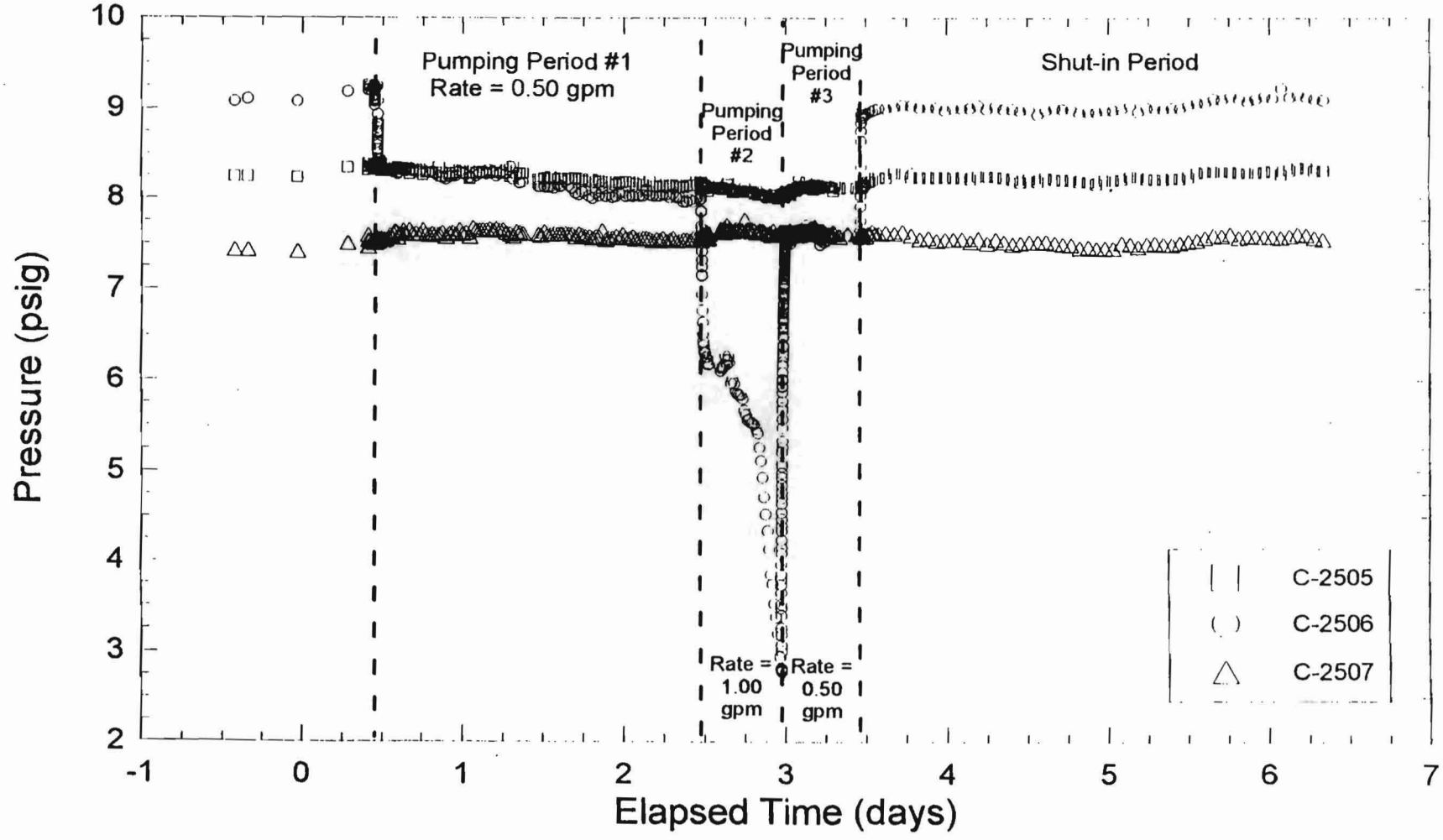

Figure 3.9. C-2506 pumping test #2: pressure versus time (C-2505, C-2506, and C-2507).

3.2 Well C-2505

3.2.1 Pumping Rate Information

A 24-hour step-drawdown pumping test was initiated in well C-2505 on Tuesday, March 6, 1997. The initial pumping rate for the test was 0.4 gpm. After 5 hours, the pumping rate was increased to 0.7 gpm due to a lack of any observable fluid-pressure response in observation wells C-2506 or C-2507. After increasing the pumping rate to 0.7 gpm, the fluid-pressure response in the pumping well indicated boundary conditions as seen in periods of increased drawdown relative to previous conditions. However, these responses were significantly different from those observed during the C-2506 pumping test conducted in February in that there were no linear pressure decreases in the C-2505 pressure response. Figure 3.10 is a plot of the pumping rate versus time for the C-2505 step-drawdown pumping test.

3.2.2 Fluid Pressure Responses

Figures 3.11 - 3.13 are plots of the fluid pressure response versus time in pumping well C-2505. Analysis of the fluid pressure response in C-2505 provided the following:

1) Analysis of the diagnostic derivative plots from the initial pumping period, Figure 3-11, and the recovery period, Figure 3.12, confirm the order of magnitude of the parameter estimates that were reported in the Exhaust Shaft: Hydraulic Assessment Data Report (DOE, 1997). Analysis of the data from the C-2505 step-drawdown test indicates parameter estimates of:

   K = 7.80 e-6 m/s
   S = 1.00 e-2 1/m

   Even though the value of hydraulic conductivity is lower than that reported for C-2506 above, both values are consistent with the ranges previously reported. Diagnostic derivative plot analysis was not attempted on the second pumping period due to the boundaries encountered during that phase of testing.

2) Examination of the pressure response in pumping well C-2505, during the second pumping period, suggests that the water-bearing system encounters at least two linear, no-flow boundaries as the cone of depression extends away from the pumping well (Figure 3.13). Although the pressure response in well C-2505 suggests that there are no-flow boundaries at some radial distance, the observation well responses in C-2506 and C-2507 do not indicate any boundaries (Figure 3.14). Therefore, the distance to the no-flow boundaries could not be directly determined.

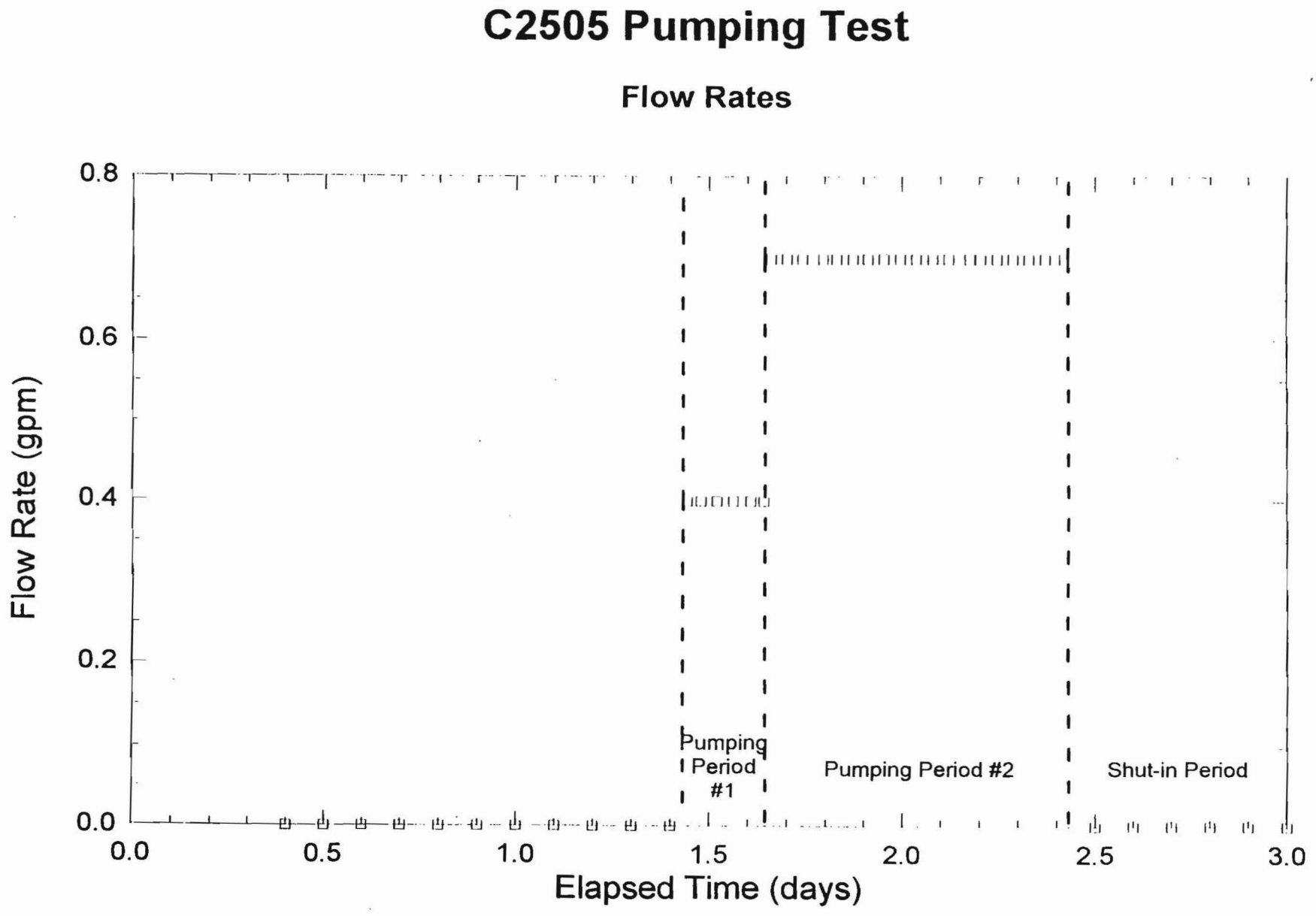

Figure 3.10. C-2505 pumping test: flow rate versus time.

C-2505 Pumping Test

Diagnostic Derivative Plot
(Pumping Period #1)

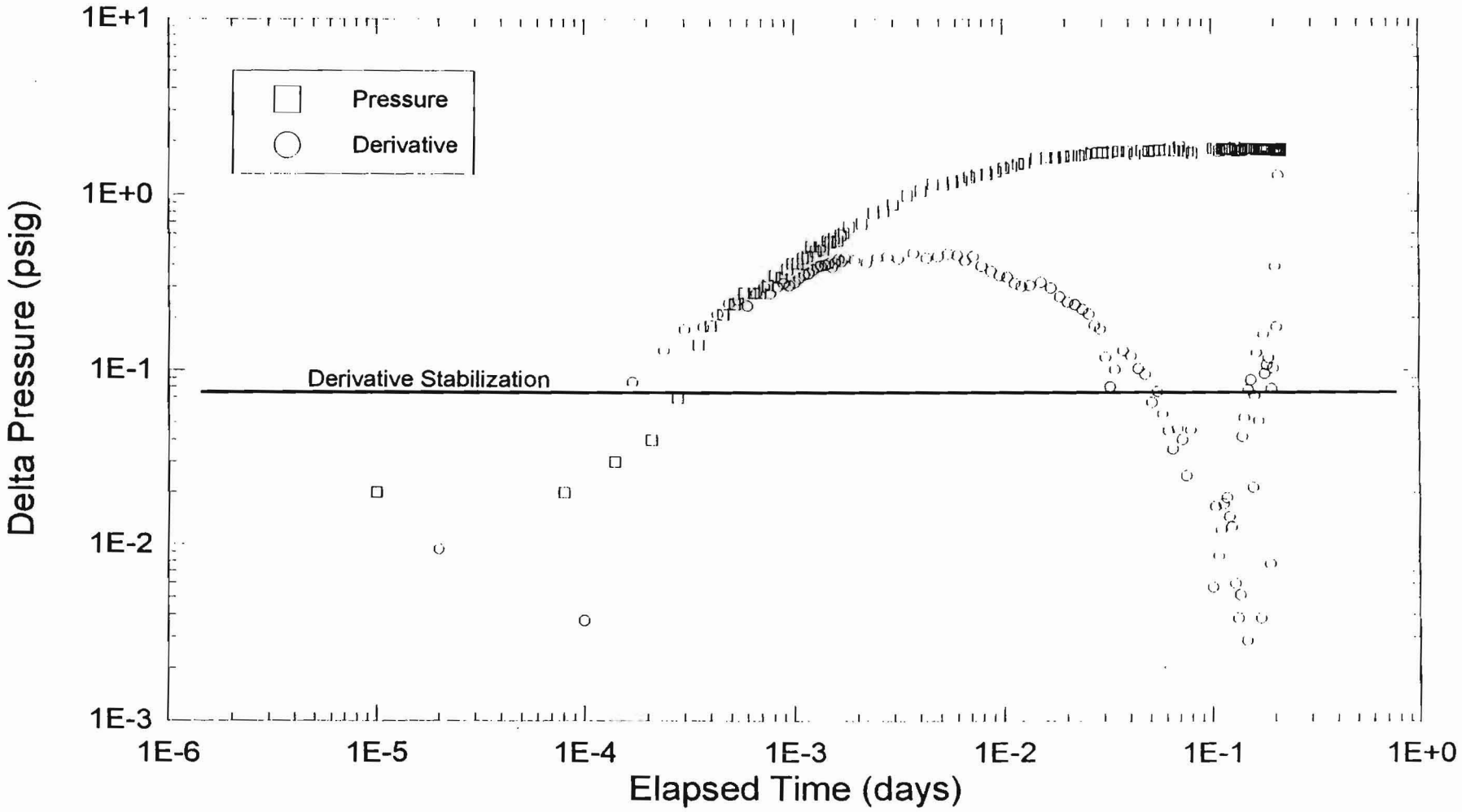

Figure 3.11. C-2505 pumping test: diagnostic derivative plot (pumping period #1).

C-2505 Pumping Test

Diagnostic Derivative Plot
(Recovery Period)

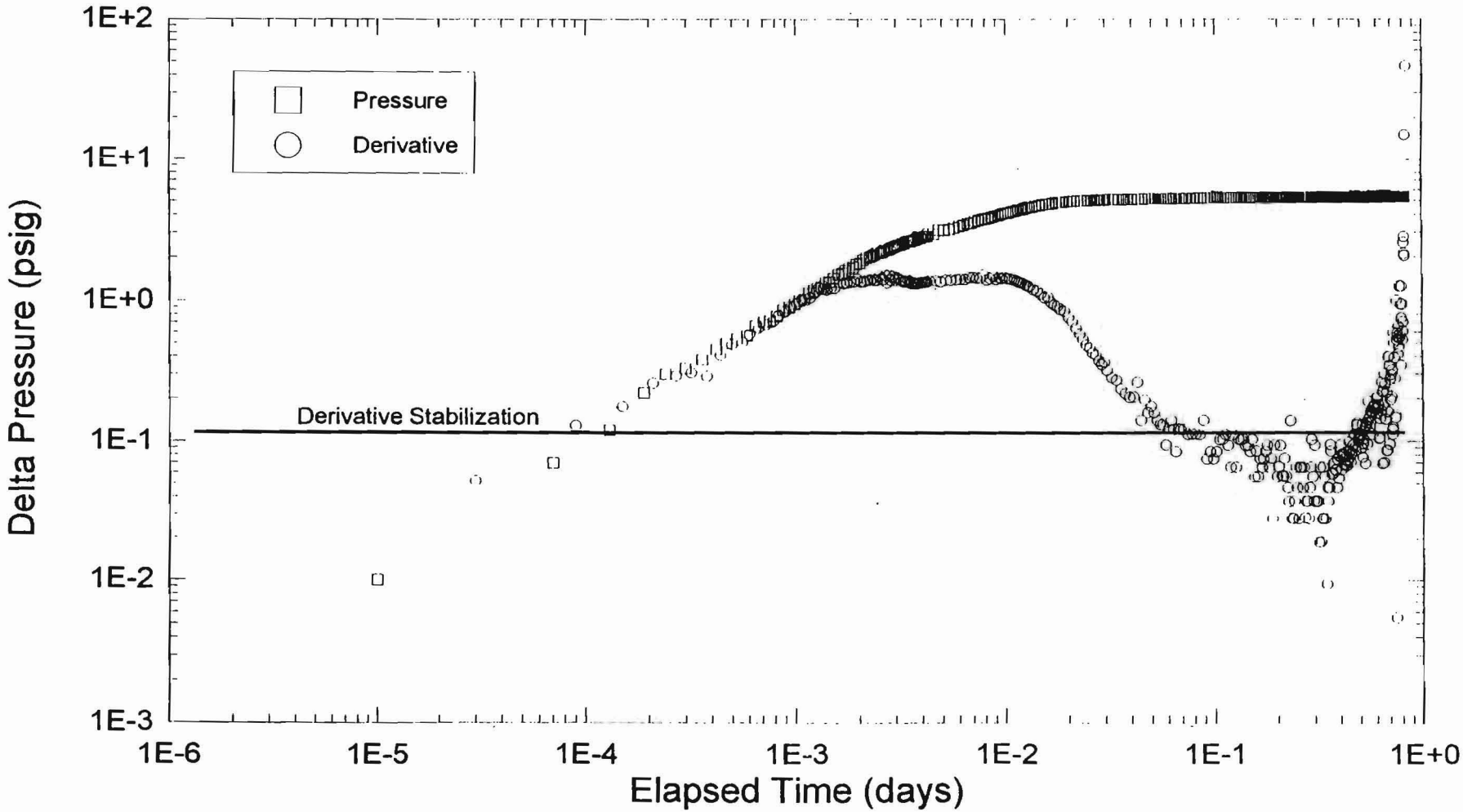

Figure 3.12. C-2505 pumping test: diagnostic derivative plot (recovery period).

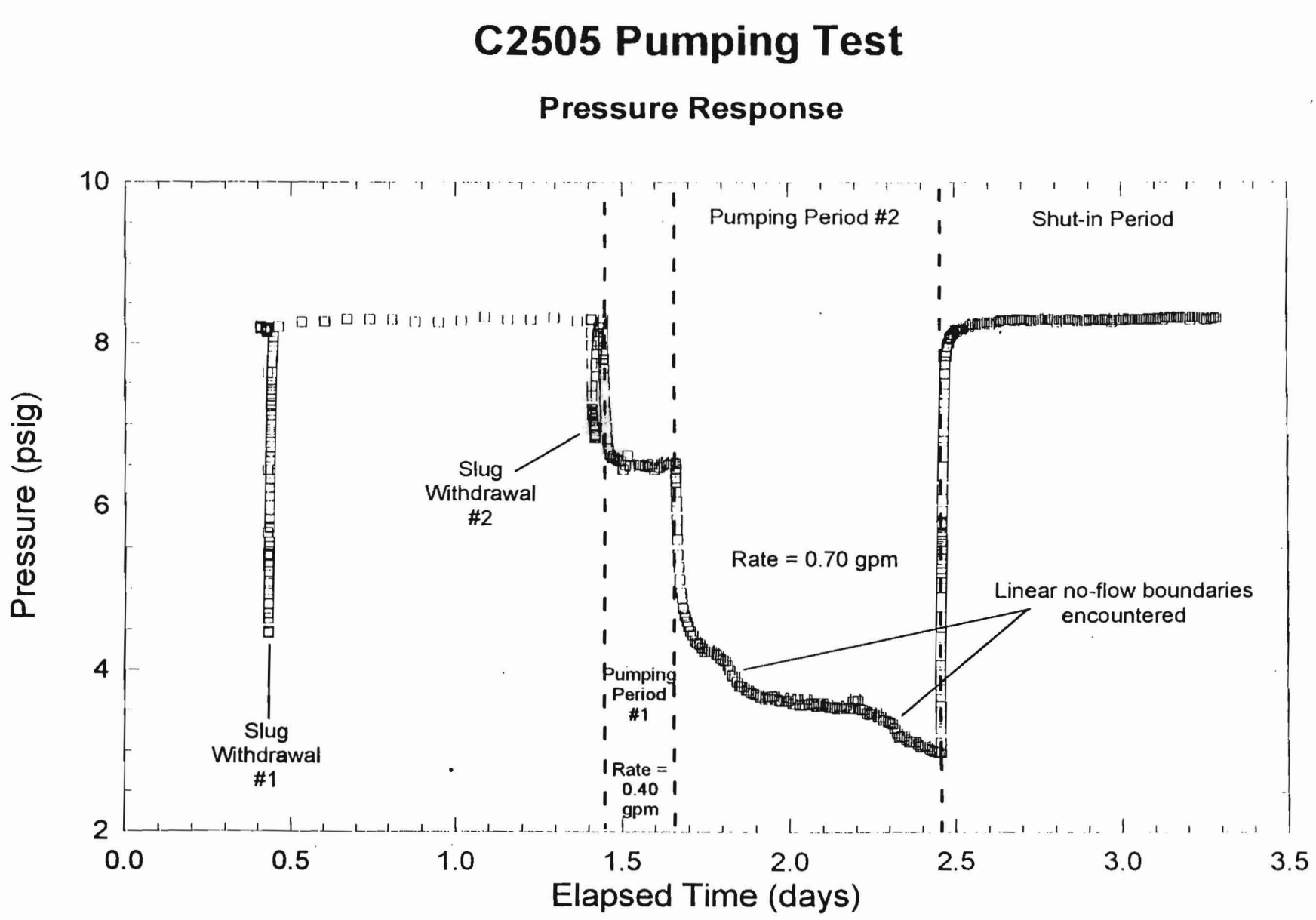

Figure 3.13. C-2505 pumping test: pressure versus time (C-2505).

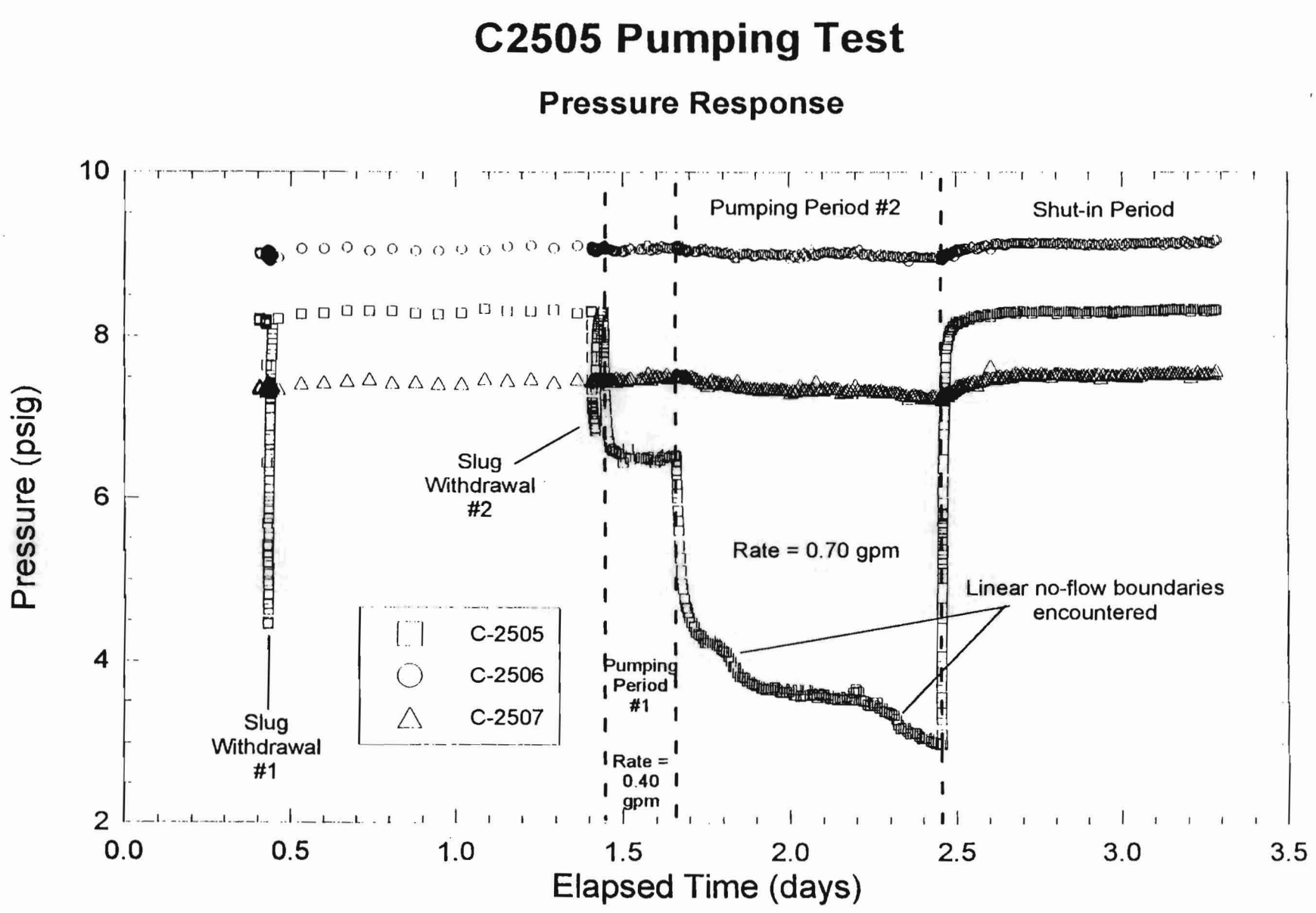

Figure 3.14. C-2505 pumping test: pressure versus time (C-2505, C-2506, and C-2507).

3) Comparing fluid-pressure response in observation wells C-2506 and C-2507 (Figure 3.14) in response to pumping in C-2505 with fluid-pressure response in observation wells C-2505 and C-2507 in response to pumping in C-2506 (Figure 3.9) supports the hypothesis that well C-2506 may be receiving recharge from some source close to C-2506. During the C-2506 pumping test, there was only minimal pressure response in observation well C-2505 (34 ft distance) and no measurable response in observation well C-2507 (212 ft distance). During the C-2505 pumping test, there was a measurable response in both observation wells as seen in Figure 3.14. There was approximately 5 inches of drawdown in well C-2506 (34 ft distance) while over 8 inches of drawdown in well C-2507 (197 ft distance). Under normal conditions, drawdown decreases as a function of distance from the pumping well. Therefore, the drawdown in well C-2506 suggests that a source(s) of recharge is present.

3.3 Water-Level Observations

Figures 3.15 - 3.17 are plots of the water-level measurements for wells C-2505, C-2506, and C-2507, respectively, collected between September 25, 1996 and May 6, 1997. Those water level plots reveal the following:

1) Between October 14, 1996 (prior to any pumping activities) and March 24, 1997 (18 days after the latest pumping activities) the water level in well C-2505 has increased by 2.59 ft (Figure 3.15). Between October 14, 1996 (prior to any pumping activities) and March 24, 1997 (18 days after the latest pumping activities) the water level in well C-2506 has increased by 2.49 ft. (Figure 3.16). Between October 14, 1996 (prior to any pumping activities) and March 24, 1997 (18 days after the latest pumping activities) the water level in well C-2507 has increased by 1.64 ft. (Figure 3.17).

   Figures 3.15 - 3.17 show that the water levels in C-2505, C-2506, and C-2507 have increased at a relatively constant rate (linear) over the months between October and March. This trend is more consistent with a continuous local recharge source(s) than with any natural water table response.

2) Figure 3.18 illustrates the rate (slope of linear trend) of increase in the water level for each of the three wells. This figure shows that the water level in C-2505 and C-2506 are increasing at a faster rate than the water level in well C-2507. The fact that the water level in wells C-2505 and C-2506 are increasing faster than in C-2507 also suggests that the unknown recharge source(s) is located closer to wells C-2505 and C-2506, possibly north/northeast of the Exhaust Shaft.

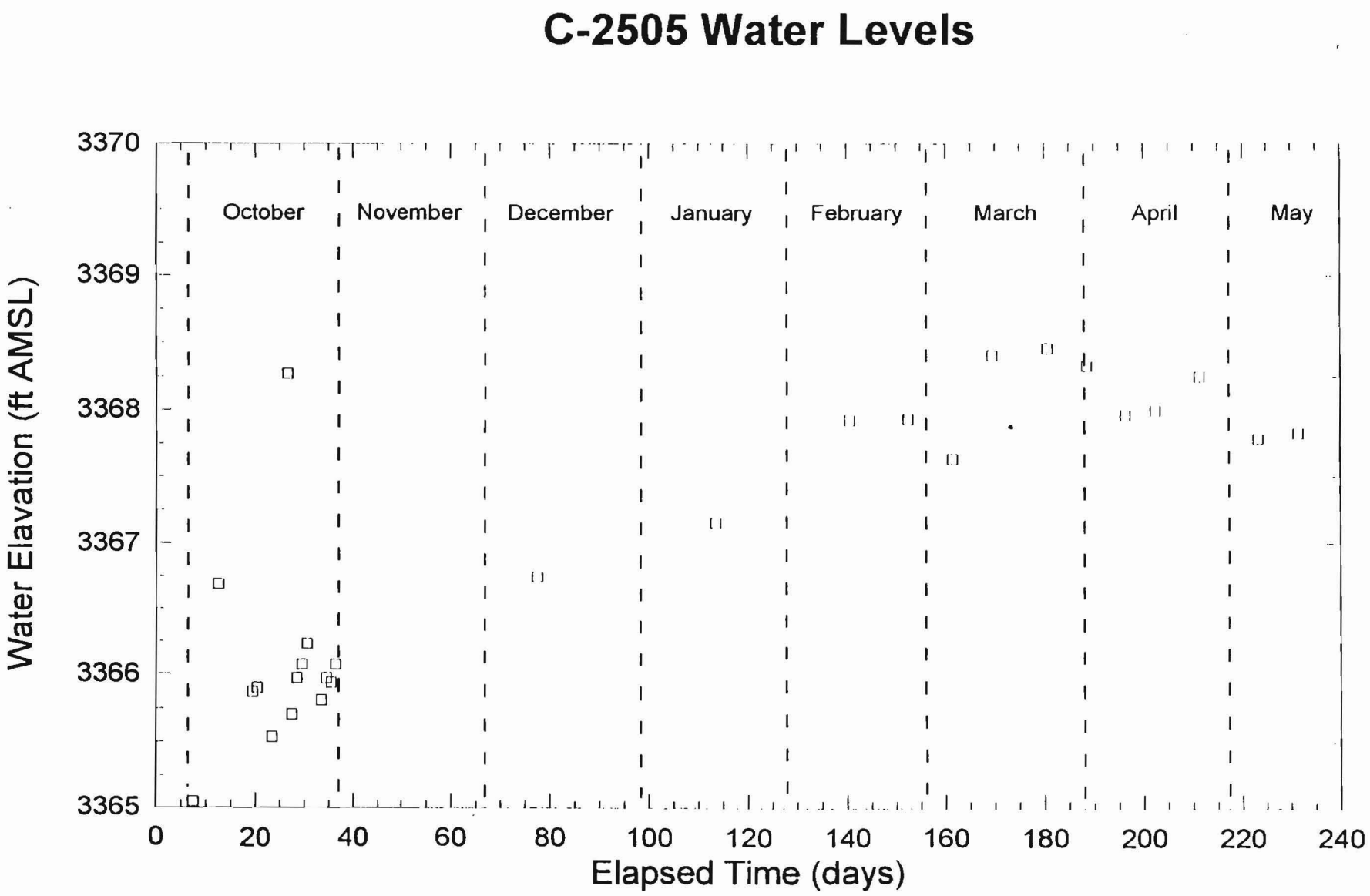

Figure 3.15. C-2505: water level versus time.

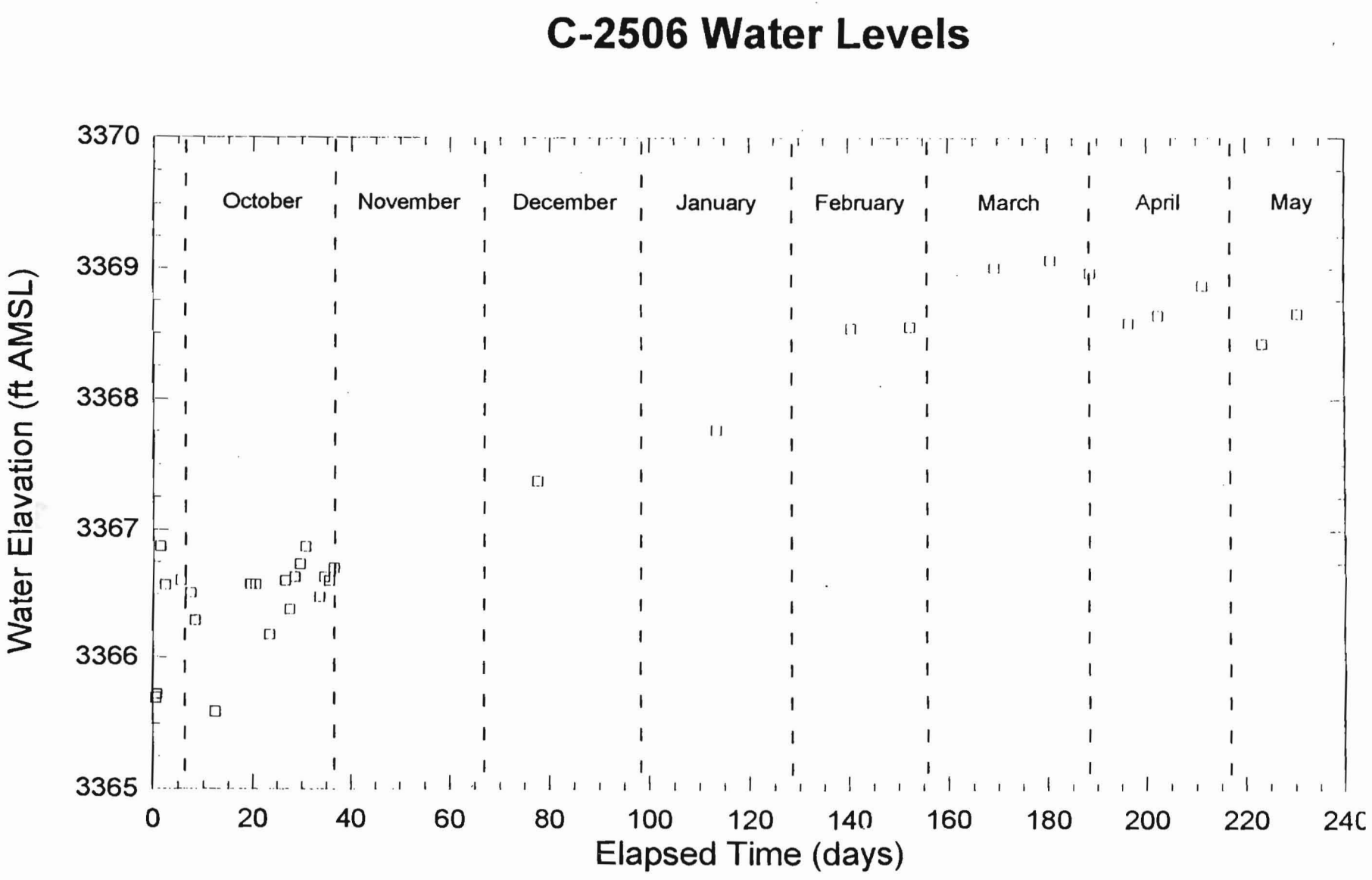

Figure 3.16. C-2506: water level versus time.

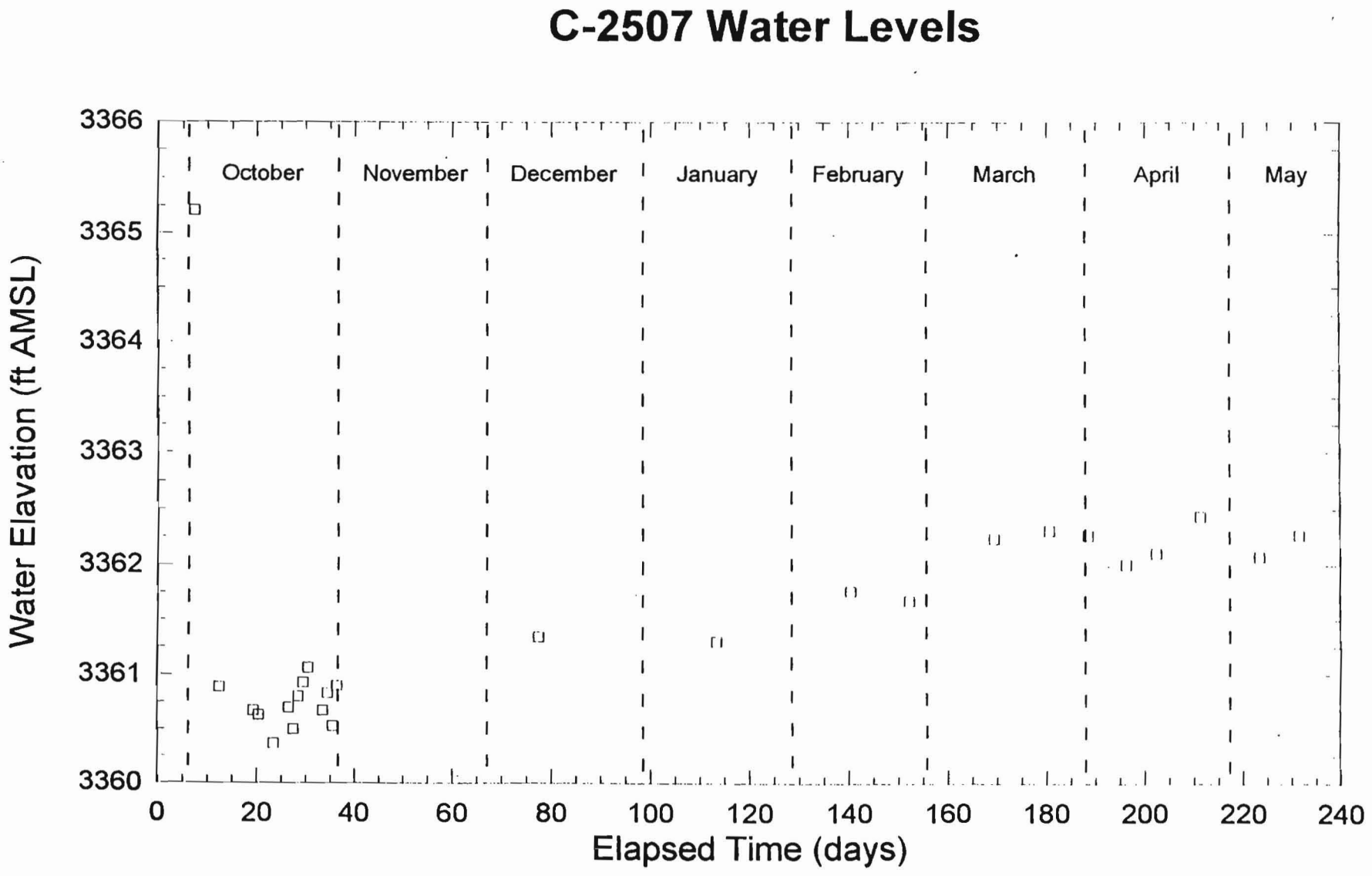

Figure 3.17. C-2507: water level versus time.

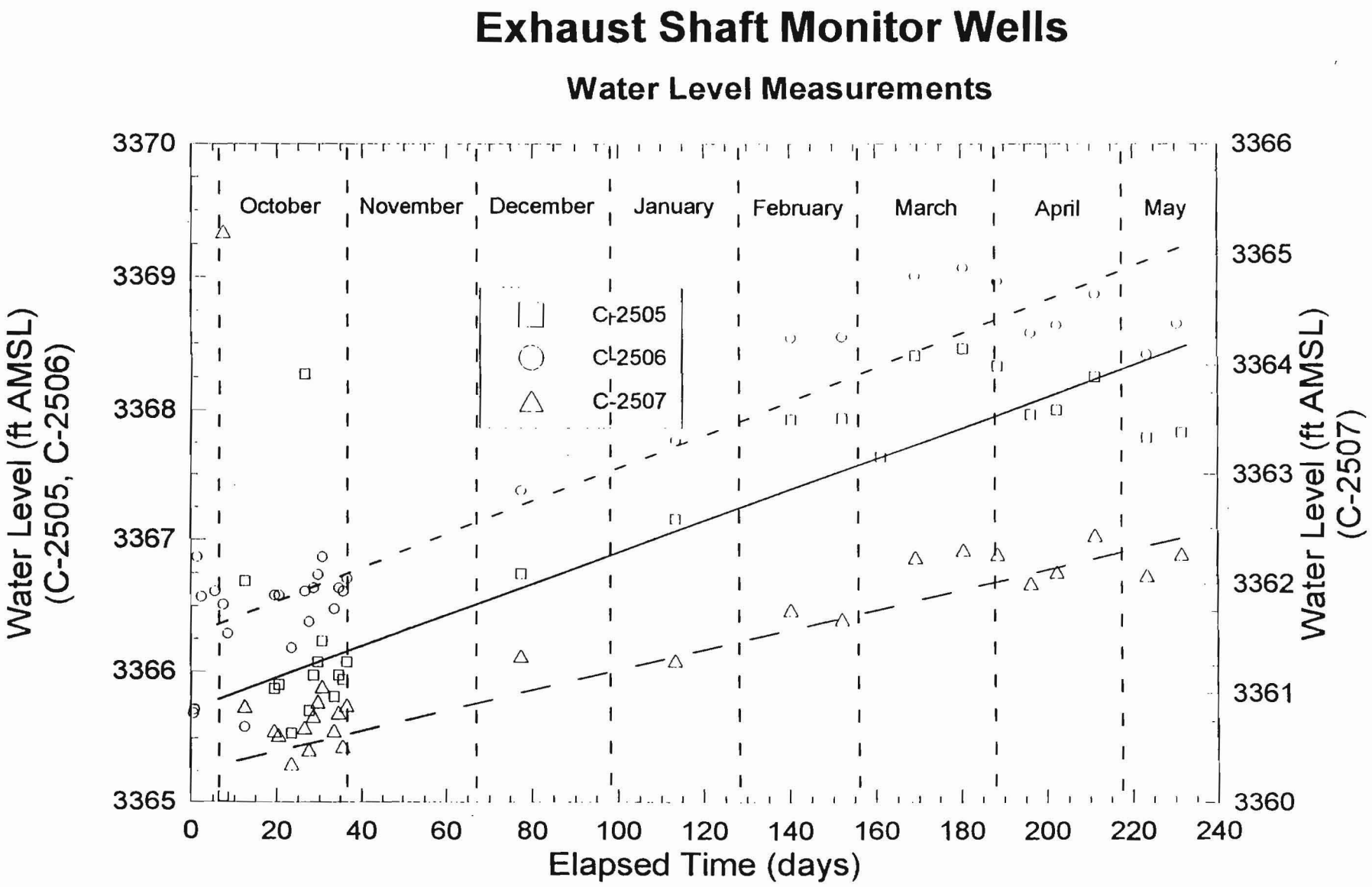

Figure 3.18. C-2505, C-2506, and C-2507: water levels versus time.

3) The magnitude of the hydraulic gradient from C-2505 and C-2506 to C-2507 has increased from 2.45 e-2 ft/ft in October 1996 to 3.19e-2 ft/ft in March 1997. This is a 30% increase in the hydraulic gradient over this time period. During the same time frame, the direction of the hydraulic gradient has remained essentially the same. By plotting the water-level measurements for each well relative to mean sea level, potentiometric contour maps can be generated to determine lines of equipotential and the direction of groundwater flow. Figures 3.19 and 3.20 illustrate the equipotential lines and flow direction south of the Exhaust Shaft as determined in October 1996 and March 1997, respectively. The change in flow direction amounts to about 13° to the south.

4) The increase in water levels in the vicinity of the Exhaust shaft was used to calculate a conservative estimate as to the volume of water that would be required to cause such an increase. The following simplifying assumptions were made;

   a) A uniform system porosity (n) equal to 0.1 based upon values reported in the literature (Freeze and Cherry, 1979).
   b) A uniform water level increase (h) equal to the smallest of the three observed values (1.64 ft. in C-2507).
   c) A 200 ft radius of influence (r) with the Exhaust Shaft as the center point (distance to well C-2507).
   d) An elapsed time from the initial to the final water level measurement equal to 161 days (October 14, 1996 to March 24, 1997).
   e) The water-bearing unit behaves as an unconfined system.

   Using these values, the volume is calculated by:

$$V = \pi r^2 H(n) = 20609 \text{ ft}^3$$

   This converts to 154,154 gallons added to the system over a period of 161 days which translates to a recharge rate (q):

$$q = V/\text{time} = 0.67 \text{ gpm}$$

Based upon the calculations that were carried out above and considering the maximum sustainable rate at which any one of the existing wells can be pumped, the existing wells pumped individually will not serve adequately as dewatering wells. Assuming the calculated recharge rate from above, pumping one well would only serve to remove water that is being added to the system, and not even address the preexisting volume in the vicinity of the Exhaust Shaft. Also, the location and proximity of wells C-2505 and C-2506 relative to the Exhaust Shaft are such that it would most probably act to move water toward the shaft more directly than moving water away from the shaft.

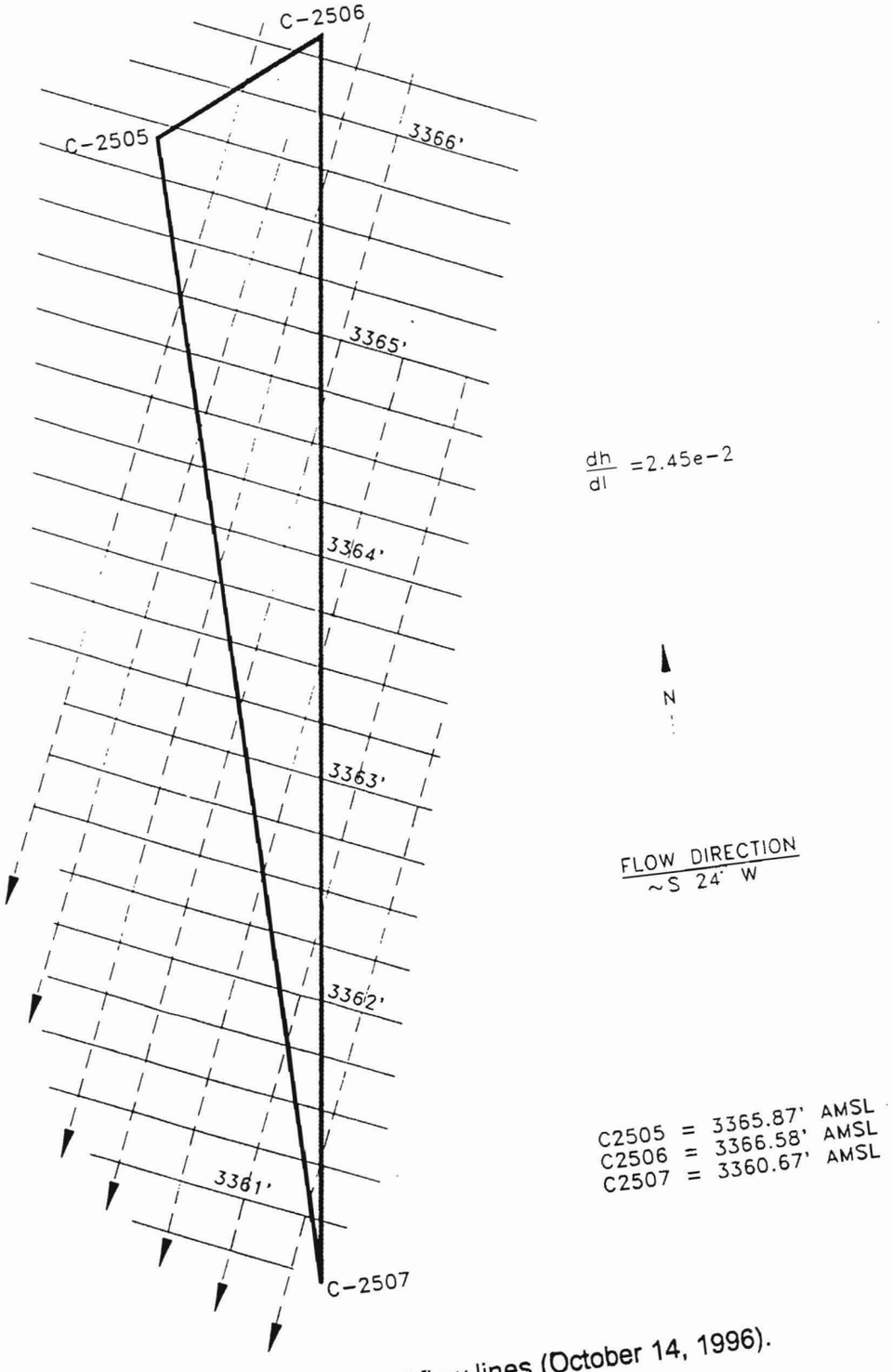

Figure 3.19. Equipotential and flow lines (October 14, 1996).

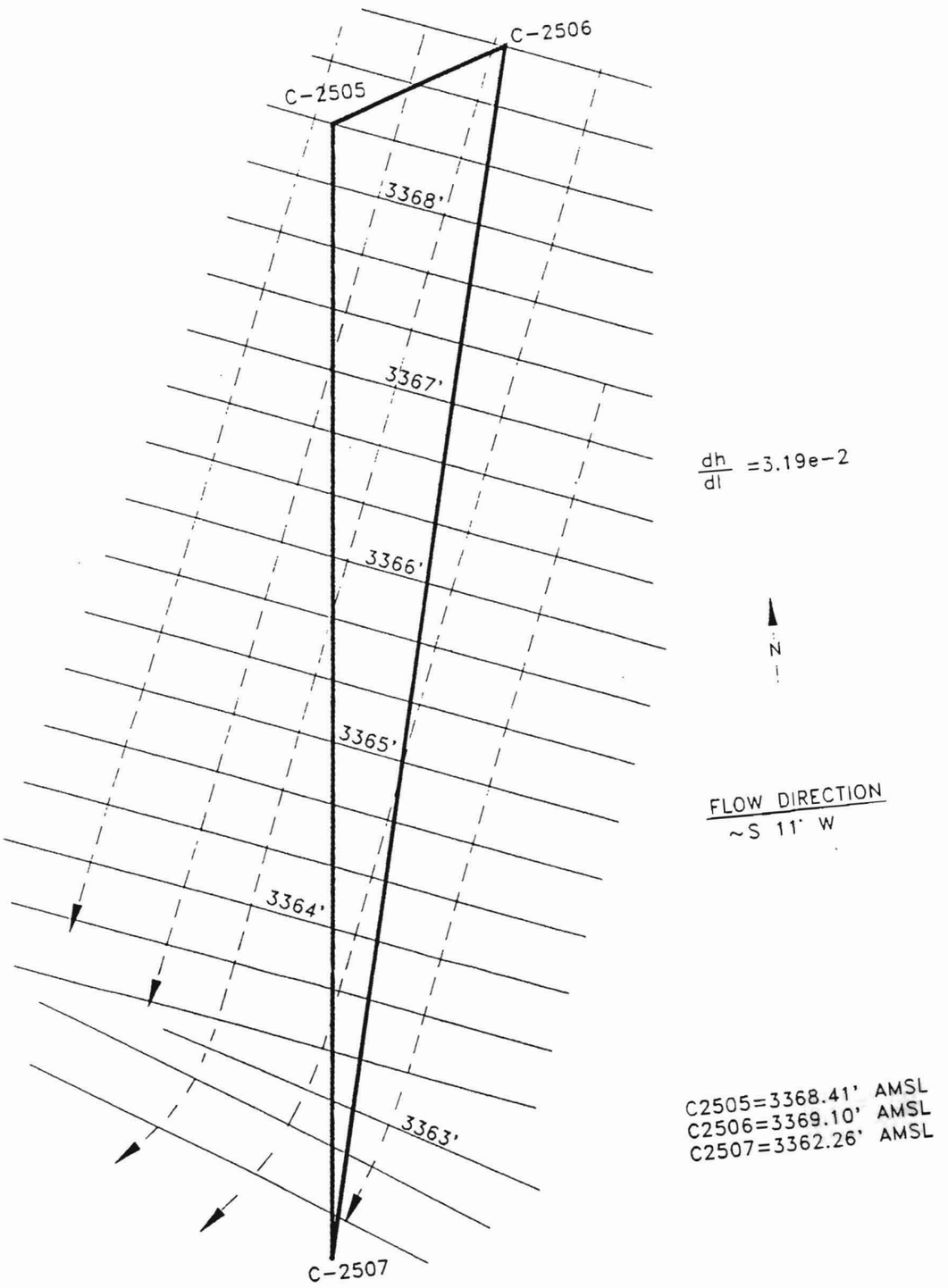

Figure 3.20. Equipotential and flow lines (March 13, 1997).

4.0 WATER-QUALITY SAMPLING AND ANALYSIS

Groundwater samples and associated duplicates were collected from Exhaust Shaft Borings (ESB) C-2505 and C-2506 after a 24-hour pumping test was perfromed on C-2505 and a 72-hour pump test was performed on C-2506. The samples and duplicates were analyzed for pH, specific gravity, total dissolved solids, and major, minor, and trace ions. A list of the analytes and analytical results are given in Appendix A. Samples from ESB C-2507 were not obtained during these pump tests. However, beginning in May 1997, all three ESB will be sampled on a monthly basis to establish a representative baseline composition for the perched groundwater.

The summary presented here builds on the initial interpretation presented in the "Exhaust Shaft Hydraulic Assessment Data Report" (DOE, 1997), which summarized the initial development and sampling of the ESB. Based on a comparison of the analytical results obtained from ESB C-2505 and C-2506 in the fall of 1996 and winter of 1997, a significant decrease in most major analyte concentrations is observed in the winter 1997 results. This may be attributed to differences in the sampling protocols. Fall 1996 samples were collected during drillling and bailing activities in which less than 100 gallons of fluid was removed from each well prior to sampling. On the other hand, the winter 1997 samples were collected after pumping over 3000 gallons from well C-2506 and 1000 gallons from well C-2505, respectively. Therefore, it is believed that the winter 1997 analytical results are more representative of the dissolved chemistry of the groundwater. A detailed geochemical report will be developed after a sufficient number of analyses have been obtained to establish the baseline composition.

4.1 pH and Total Dissolved Solids

The pH values recorded by the analytical laboratory vary from 7.1 to 7.5 (Appendix A); there were no field pH measurements recorded. These pH measurements are approximately 0.1 to 0.3 pH units greater than pH measurements reported for samples obtained in fall 1996 (DOE, 1997). As noted for the fall 1996 pH values (DOE, 1997), the laboratory measurements tend to be greater than field measurements due to degassing of carbon dioxide. This has been confirmed with recent field pH measurements of 6.8 to 6.9 at ESB C-2505, C-2506, and C-2507.

Total dissolved solids (TDS) measured in winter 1997 samples varied from 4,440 to 6,050 milligrams per liter (mg/L), values that are about one-half the values reported for fall 1996 samples (Figure 4.1). The decrease in TDS is attributed to a decrease in all major ion concentrations except total inorganic carbon (TIC). As noted above, this decrease is attributed to differences in sampling techniques and protocol. That is, bailing water with suspended sediment versus pumping visibly clear groundwater after a pump test. All TDS values recorded for the winter 1997 samples exceed the New

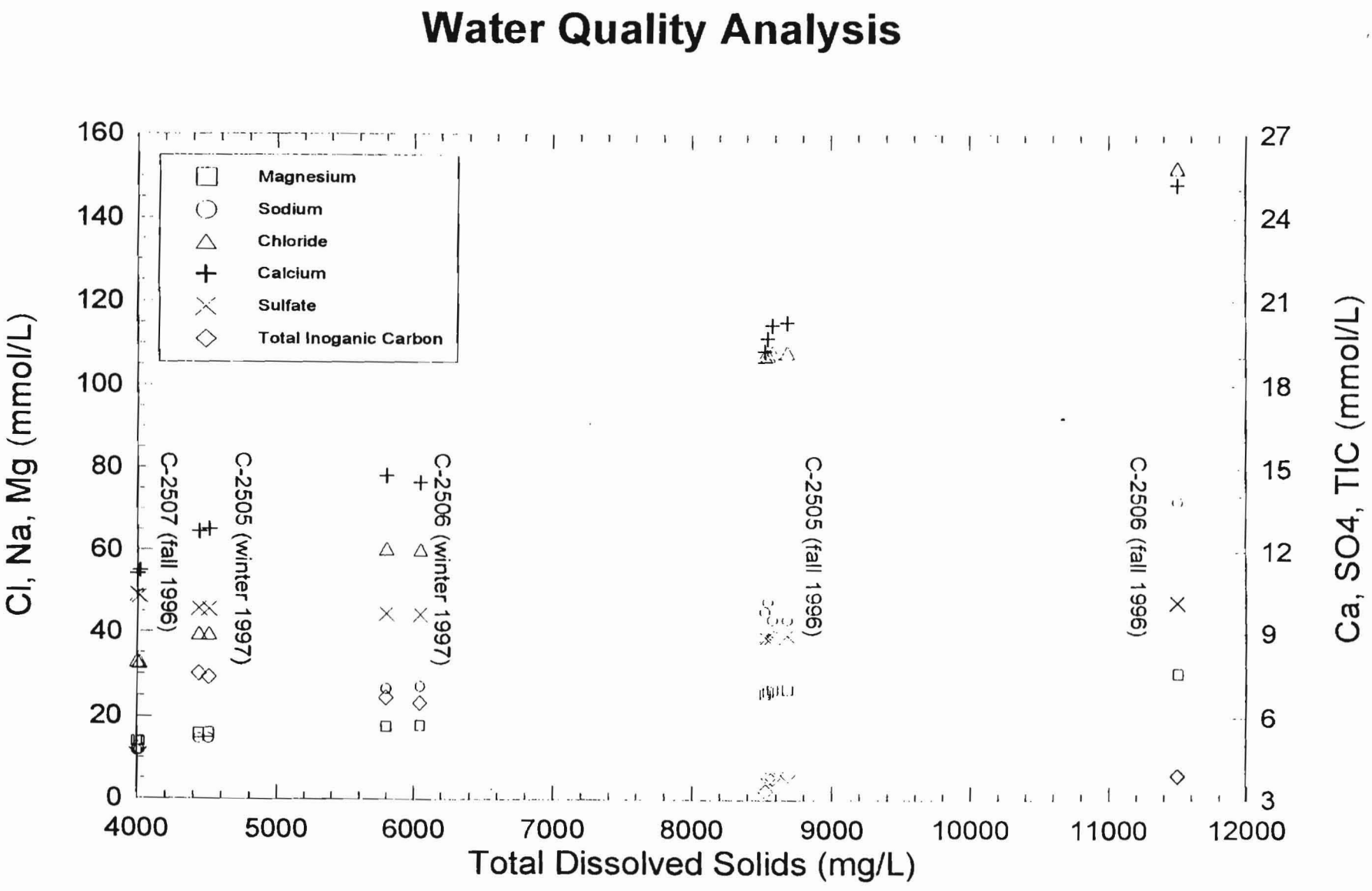

Figure 4.1. Major-ion concentrations versus total dissolved solids.

Mexico Water Quality Control Commission (NMWQCC) groundwater standard of 1,000 mg/L.

4.2 Major Ions

The major ions (i.e., > 100 mg/L) in recovered groundwater samples are chloride (Cl), sulfate (SO_4), bicarbonate (HCO_3), sodium (Na), calcium (Ca), and magnesium (Mg). Bicarbonate concentration is calculated from the reported value for TIC as follows;

$$HCO_3 \text{ (mg/L)} = \text{TIC (mg/L)} * 5.08$$

Figure 4.1 shows that all major ions, principally Na and Cl, have decreased since the initial sampling event with the exception of the increase in TIC values. As noted above, the basis for this change is believed to be due to differences in sampling protocol and borehole conditions. An ongoing monitoring program will establish the baseline composition of the groundwater with monthly sampling events scheduled through the summer of 1997.

A substantial decrease in the Na/Cl molar ratio for the samples obtained from ESB C-2505 between the fall and winter sampling events is enigmatic (Figure 4.2). However, based on the relative ranking of cation abundance in fall samples and the winter sample from ESB C-2506 (i.e., Na > Mg > Ca), it appears that the recently reported Na concentration for ESB C-2505 is low (Figure 4.2). The apparent low Na concentration would account for the decrease in the Na/Cl molar ratio for ESB C-2505. Verification of these anomalies must await receipt of results from the May 1997 sampling event. It is also noted that all samples obtained in the winter 1997 sampling event have Cl concentrations that exceed the NMWQCC groundwater standard of 250 mg/L (7.05 mmol/L).

Figure 4.3 compares the variation of Ca, Mg and the Ca/SO_4 molar ratio with SO_4 for fall 1996 and winter 1997 samples. Solubility calculations with the EQ3NR geochemical code (Wolery, 1992) indicate all Ca and SO_4 concentrations are below the saturation concentration for gypsum and/or anhydrite, indicating the water is capable of dissolving additional gypsum or anhydrite. Sulfate concentrations in samples from ESB C-2505 increased between fall 1996 and winter 1997, while they decreased over this same period for ESB C-2506. The Ca/SO_4 molar ratio and Mg and Ca concentrations decreased at both locations. The clustering of the winter 1997 results for both locations is expected, given that the separation between these borings is less than 15 meters. The larger spread in SO_4 concentration for the fall 1996 sampling event is attributed to sampling during well development. All samples obtained from the winter 1997 sampling event have SO_4 concentrations that exceed the NMWQCC groundwater standard of 600 mg/L (6.25 mmol/L).

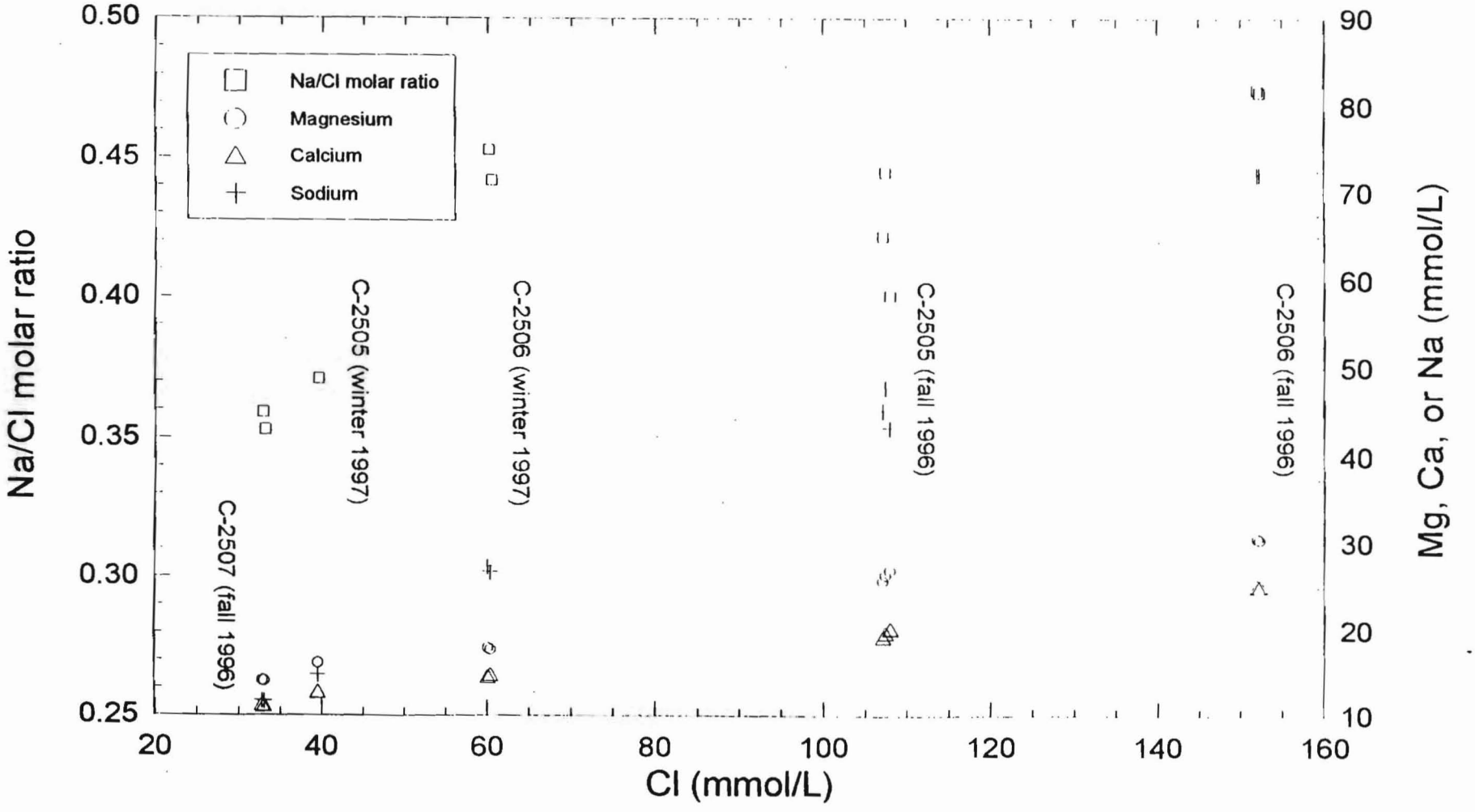

Figure 4.2. Variation of Na/Cl molar ratio and magnesium, calcium, and sodium concentrations with chloride concentration.

Water Quality Analysis

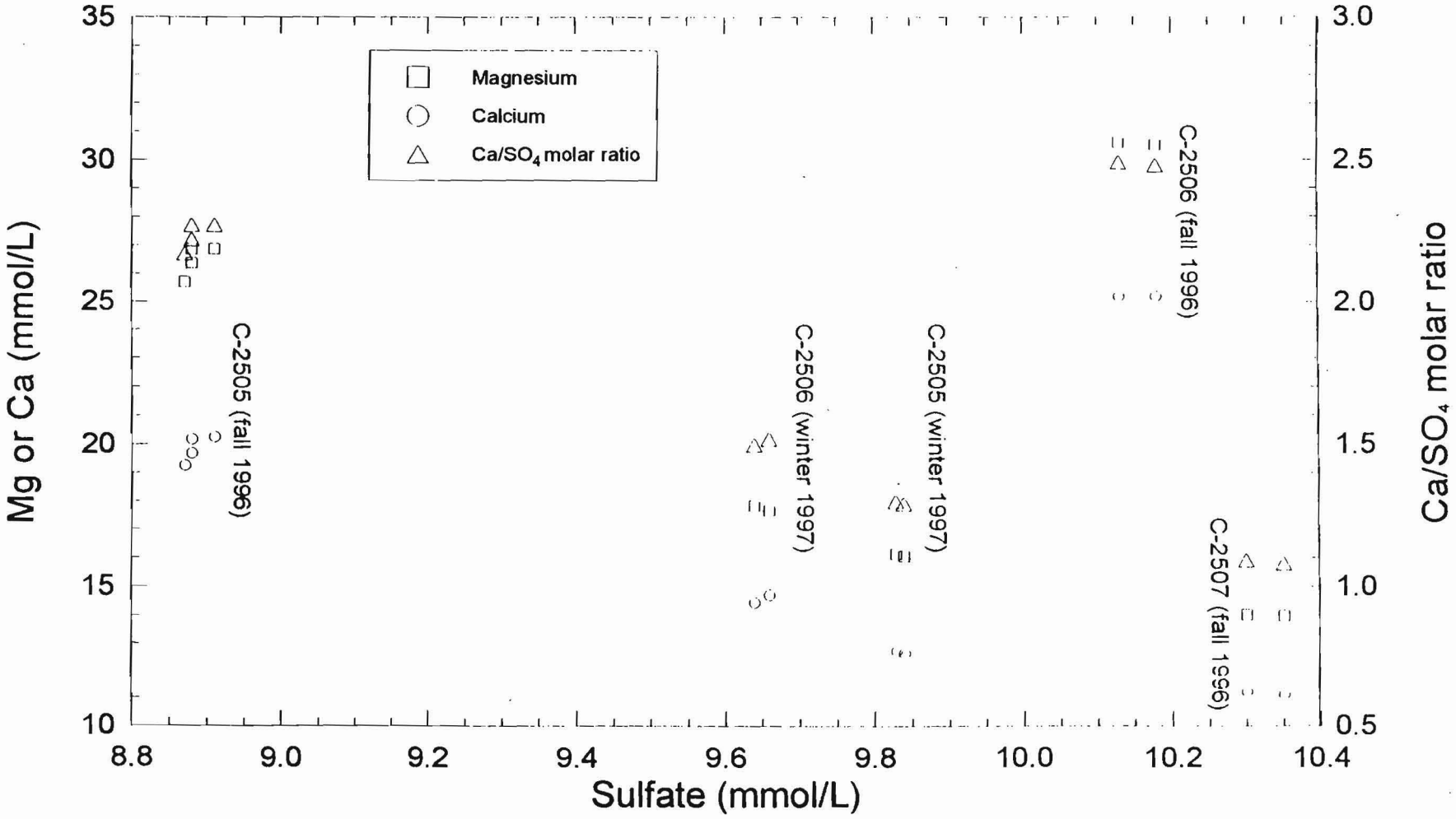

Figure 4.3. Variation of Ca/SO_4 molar ratio and magnesium and calcium concentrations with sulfate concentration.

The carbonate system for the groundwater samples collected from ESB C-2505 and ESB C-2506 is summarized on Figure 4.4. Values for TIC range from 39.9 mg/L (3.32 mmol/L) to 90.2 mg/L (7.51 mmol/L). Note that a millimole of TIC is equal to a millimole of CO_3 or HCO_3, and TIC has been plotted to coincide with TIC values listed in Appendix A. In general, Figure 4.4 shows that the concentrations of Ca and Mg ions decrease as TIC increases, which suggests carbonate mineral equilibria (i.e., calcite and dolomite) controls the concentrations of TIC, Ca, and Mg. This statement is supported by solubility calculations carried out with the EQ3NR geochemical code, which predicts all groundwaters to be supersaturated with calcite and dolomite at the reported pH values.

As noted in the pH discussion, laboratory pH measurements probably overestimate the pH of the samples by approximately one-half pH unit. This is a commonly observed phenomenon in samples containing carbonate that undergo CO_2 degassing, and is suggested further by solubility calculations that indicate the calcite supersaturation state is reduced to saturation as the pH is dropped to 6.9 (i.e., the recently measured field pH of ESB C-2505 and C-2506). The plotted calcite solubility curve at a pH of 6.9 (Figure 4.4) passes through or near all Ca concentrations except those from ESB C-2506, indicating suspended carbonate minerals may have been present in the bailed sample obtianed from this well in the fall of 1996.

The dolomite solubility curve is not plotted because dolomite formation is a diagenetic process, probably due to kinetic inhibition of nucleation sites needed for chemical precipitation to occur (Berner, 1971). However, dissolution of dolomite is hypothesized to play an important role in the observed Ca/Mg molar ratios. Dissolution of dolomite in deionized water produces a Ca/Mg molar ratio of one. The Ca/Mg molar ratio of the samples on Figure 4.4 varies between 0.72 and 0.82, which suggests Ca ion is being provided and/or removed by calcite dissolution and/or precipitation to lower the Ca/Mg molar ratio. This is supported by the position of the solubility curve on Figure 4.4.

4.3 Minor Ions

Minor ions (i.e., 1 - 100 mg/L) in the samples include bromide (Br), nitrate (NO_3), total organic carbon (TOC), potassium (K) and iron (Fe). All results for K are flagged with the B qualifier Appendix A), indicating the reported result is an estimate that lies

Water Quality Analysis

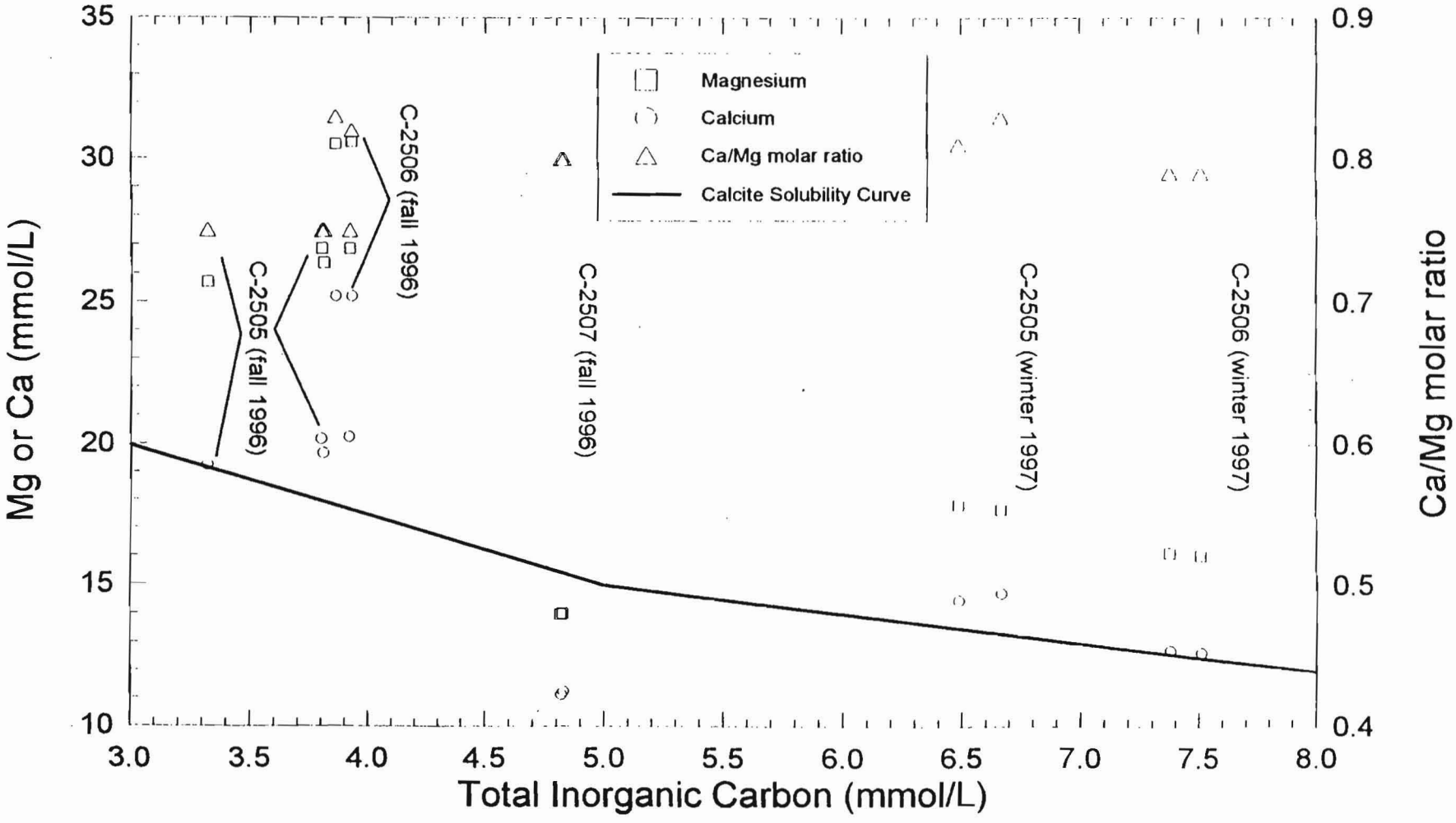

Figure 4.4. Variation of Ca/Mg molar ratio amd magnesium and calcium concentrations with total inorganic carbon (TIC).

between the practical quantitation limit (PQL) and the instrument detection limit (IDL).

Bromide (Br) concentrations vary from 6.6 to 6.8 mg/L (Appendix A), a slight decrease realtive to fall 1996 values. This decrease agrees with a decrease in Cl concentration and indicates Br is also derived from the dissolution of halite.

Nitrate (NO_3) values are reported as NO_3, and indicate a range of 26.2 to 26.6 mg/L. The reported NO_3 values may indicate some animal or human source for the nitrogen, but they are below the NMWQCC groundwater standard of 44 mg/L (as NO_3) and well below the NO_3 concentrations of 440 to 530 mg/L reported for groundwater from the Dewey Lake Redbeds at the Ranch Well (southern border of DOE withdrawn land) (DOE, 1992).

Values for TOC range from 2.0 to 8.0 mg/L (Appendix A). These values exceed TOC values reported for groundwater from the Dewey Lake Redbeds (<3 to 5 mg/L; DOE, 1992), and the slightly higher values may reflect infiltration of surface water runoff from the asphalt parking lots and roads at WIPP.

Estimates of K concentration range from 4.7 to 6.0 mg/L, with all reported values falling between the PQL and the IDL (Appendix A). Potassium exhibits limited substitution for Na in the halite structure, implying K concentrations should increase with Na as halite is dissolved. Therefore, lower K concentrations in winter 1997 samples follow the decrease in Na concentrations

Iron concentrations range from 2.96 to 3.98 mg/L, values which exceed the NMWQCC groundwater standard of 1 mg/L. This range of Fe concentrations is significantly greater than the fall 1996 results. However, the fall 1996 results had reported QA problems with matrix recovery for Fe. Therefore, additional sampling rounds in the summer of 1997 will establish the baseline level for Fe in the groundwater.

4.4 Trace Metals

Analytical results for the metals boron (B) and zinc (Zn) and the RCRA metals arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), selenium (Se), and silver (Ag) are given in Appendix A. All reported trace-metal concentrations are below the NMWQCC groundwater standards, except for several Se results and a single B result. Individual trace metals are discussed below, with the exception of

results for B, Ag, Hg, Cd, and Pb. All B, Ag, Hg, Cd and Pb results are below their respective IDLs of 1.0, 0.0011, 0.0002, 0.0011, and 0.0011 mg/L.

Reported Zn results are approximately three to four orders of magnitude lower than the NMWQCC standard of 10 mg/L. One result is at the IDL of 0.02 mg/L, and others are considered estimated quantities because the reported values are near the IDL.

Arsenic results (Appendix A) are at or near the IDL of 0.0011 mg/L which is approximately two orders of magnitude below the NMWQCC groundwater standard of 0.1 mg/L. All results for As that lie between the PQL and IDL and are considered estimated values.

Results for Ba are approximately one order of magnitude below the NMWQCC groundwater standard of 1 mg/L. Most samples have Ba concentrations that lie between the PQL and IDL, which indicates they are estimated values. The similar Ba concentrations at all locations agrees with observations of similar SO_4 concentrations across the sampling sites, and suggests that Ba concentrations are controlled by barite ($BaSO_4$) solubility. This observation agrees with solubility calculations that indicate all groundwater samples are saturated with barite.

Chromium concentrations are an order of magnitude lower than the NMWQCC standard of 0.05 mg/L. Most Cr results lie between the PQL and IDL, indicating the results are considered estimates of Cr concentration.

Selenium results range from 0.0807 to 0.08883 mg/L, which exceed the NMWQCC groundwater standard of 0.05 mg/L. Additional sampling events will be used to determine if the elevated Se values indicate an elevated regional background level for Se.

5.0 DISCUSSION

5.1 Water-Level Measurements

Water-levels have risen linearly between 1.6 and 2.6 feet in wells C-2505, C-2506, and C-2507 during the five-month period extending from October 14, 1996 through March 24, 1997. (Figure 3.18). Water levels in C-2505 and C-2506, located nearest the shaft, have risen at a rate of about 0.016 ft/day, while the water level in well C-2507 has risen at a rate of 0.097 ft/day. Comparison of fresh-water total-head values, indicates a 6-foot difference in the fresh water heads between wells C-2506 located near the Exhaust Shaft and well C-2507 located approximately 200 feet to the south.

5.2 Hydraulic Gradient

Water-level measurements collected on October 14, 1996 prior to the 6-hour step-drawdown pumping test indicated a flow direction of south/southeast and a hydraulic gradient of 2.45 e-2 ft/ft. Water-level measurements collected on March 24, 1997 also indicate a flow direction of south/southeast but a gradient of 3.19 e-2 ft/ft. Since October 14, the hydraulic gradient has increased significantly suggesting that some type of recharge is occurring north of the Exhaust Shaft.

Potentiometric contour maps, Figures 3-19 and 3-20 clearly indicate that fluid is flowing to the south/southeast, but without additional hydraulic information north of the Exhaust Shaft it is not possible at this time to isolate or determine the source(s) of the fluid present in the lower Santa Rosa/upper Dewey Lakes Formations.

5.3 Well C-2506 72-Hour and Well C-2505 24-Hour Step-Drawdown Pumping Tests

Comparison of the October 1996 and February 1997 step-drawdown pumping tests performed in well C-2506 indicates that the hydrologic characteristics of the system have changed over the 5 month period. Both pumping and observation well fluid-pressure responses suggest that there is active recharge from some unknown source(s). This is illustrated by two distinct phenomena:

1) the relative pressure stabilization after initiating pumping; and
2) the lack of measurable pressure response in observation well C-2507.

During the October 1996 test, the water levels in both observation and pumping wells continued to decrease as a function of time (during constant withdrawal periods). This was not the case for the February 1997 test. Also, during the October, 1996 test, there were measurable pressure responses in both of the observation wells in a relatively

short period of time. Again, this was not the case for the February, 1997 test. In this test, only minimal response was observed in well C-2505, and there was no observed response in well C-2507. Both of these phenomena can be explained by a source of recharge occurring to the north/northeast of the Exhaust Shaft.

The 24-hour C-2505 step-drawdown, pumping test produced interesting observation well responses. During this test a measurable fluid-pressure response was observed in both of the observation wells. However, the magnitude of the response in observation well C-2507, 197 feet away was almost twice the magnitude of the response in observation well C-2506, 34 feet away. These observations also suggest that there is a local recharge source(s), probably located to the north or northeast of well C-2506. This is because, under normal conditions, the drawdown should decrease as a function of distance from the pumping well. However, if the recharge is originating north/northeast of the Exhaust Shaft, the pressure response in well C-2506 when pumping well C-2506 would be minimal because of the influence of the recharge.

5.4 Water-Quality Data

Analytical results for 4 groundwater samples from 2 locations (ESB C-2505 and C-2506) indicate TDS and major-ion concentrations have decreased significantly between the fall 1996 and winter 1997 sampling events. However, reported concentrations for TDS, Cl, and SO_4 still exceed the NMWQCC groundwater standards. The decrease in concentration is attributed to differences in samples obtained from bailing during developing activities (fall 1996) and samples obtained after pump tests (winter 1997). An ongoing monitoring program will establish the baseline composition of the groundwater by sampling the groundwater monthly through the summer of 1997. A detailed geochemical report will be issued to discuss the baseline groundwater composition after a sufficient number of analyses have been obtained.

The principal minor ions in the groundwater samples are Br, Fe, NO_3, K and TOC. Nitrate concentrations are below the NMWQCC standard of 44 mg/L (as NO_3), and the reported levels of approximately 26 mg/L may reflect past livestock grazing in the area. Local ranch wells within the Dewey Lake Redbeds have NO_3 concentrations of 20 to 530 mg/L. Results for TOC are slightly above concentrations reported for Dewey Lake Redbeds, which may indicate a component of surface runoff from asphalt parking lots and roads. Iron concentrations are approximately 3 mg/L and exceed the NMWQCC standard of 1.0 mg/L. Future sampling events will be used to establish if elevated baseline levels for Fe reflect reducing conditions in the groundwater.

All trace metals are below NMWQCC standards except for Se results. The results from additional sampling events will be used to establish if Se concentrations are naturally elevated in the area groundwaters.

6.0 RECOMMENDATIONS

The pumping tests in wells C-2505 and C-2506 and the hydraulic gradient calculated from water-level measurements suggest that there is recharge from some unknown source(s) located north of the Exhaust Shaft. In addition, there have also been several reported leaks in water and fire lines at the WIPP in the past several months suggesting that the WIPP water-supply system north of the Exhaust Shaft could be a potential source of recharge for fluid leaking into the shaft. Future investigations in the vicinity of the Exhaust Shaft should focus on:

- defining and eliminating the source(s) of recharge in the vicinity of the shaft by better characterizing the water table in the vicinity of the Exhaust Shaft;
- intercepting fluid flowing to the Exhaust Shaft; and
- minimizing the potential of future occurrences of similar nature.

In order to achieve the objectives noted above the following recommendations are suggested:

1) Hand auger a series of 10 - 20 boreholes, 2-inches in diameter to the top of the Mescalero caliche (8 - 13 feet bgs) in order to:

    - identify any near-surface, fluid-saturated zones;
    - identify potential locations for additional piezometers and/or pumping wells.

    The locations of these hand-augered boreholes are indicated in Figure 6.1.

2) If a near-surface, fluid-saturated zone is detected in any of the hand augured boreholes, appropriate steps will be taken to:

    - identify and elirninate potential sources; and
    - begin corrective action measures to facilitate the removal of water from the system.

3) Considering the information obtained from the hand augured boreholes, a series of up to eight, 2-inch piezometer approximately 70-ft deep are recommended in order to better characterize the near-surface potentiometric surface. Figure 6.1 indicates preliminary locations of the eight piezometer. However, the locations that are indicated are only tentative and the final locations will be determined as additional information becomes available. The information from these piezometers will provide for a more detailed characterization of the system to be made (identify source(s) of recharge), will allow for a determination of the scale of the fluid-saturated formations, will provide additional water quality samples to be obtained, and will provide a mechanism by which future occurrences can be detected and evaluated real time. It is recommended that the piezometer be installed under the following conditions in order minimize cost and maximize information generated.

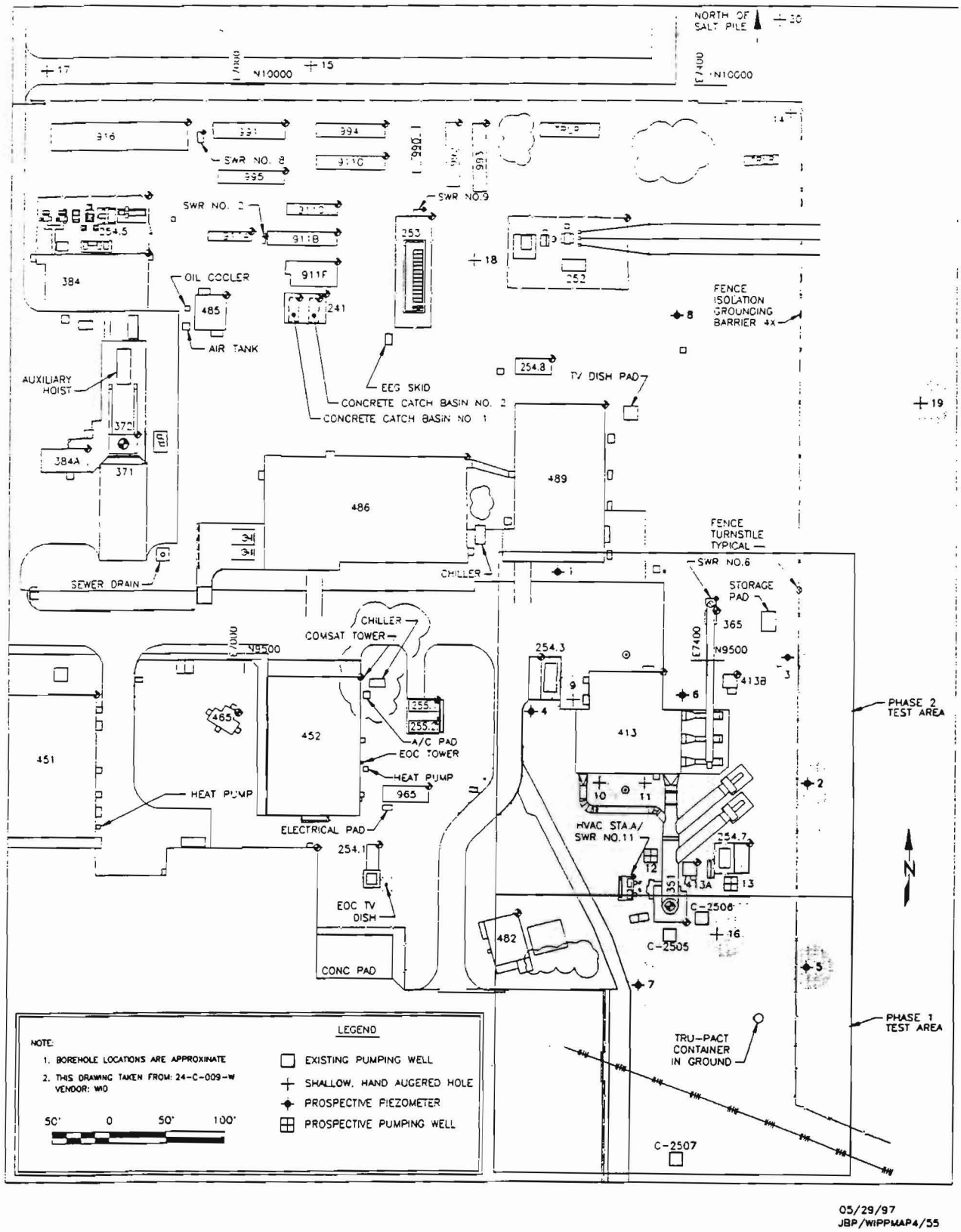

Figure 6.1. WIPP site map indicating shallow, hand augured boreholes, piezometers, and pumping wells associated with the Exhaust Shaft Assessment Program.

- complete piezometer #1 (Figure 6.1) in the near-surface, fluid saturated zone;
- survey the top of casing to elevation above mean sea level;
- make static water level measurement;
- evaluate potentiometric surface of the entire system; and
- determine the location of the next piezometer based upon all available information.

This process should be repeated as each piezometer is completed, thereby, obtaining information where it is necessary and eliminating unnecessary information. Core samples should be considered in some of these boreholes in horizons where water has been observed previously.

4) Based upon information obtained from water level measurements collected from the eight piezometer and subsequent potentiometric surface mapping, one to two 4-inch pumping wells approximately 100 feet deep completed in the vicinity of the Exhaust Shaft are recommended. Figure 6.1 indicates preliminary locations of the two additional pumping wells. However, the locations that are indicated are only tentative and the final locations will be determined as additional information regarding the potentiometric surface becomes available. These pumping wells will be completed in relatively close proximity to the Exhaust Shaft with the primary function of dewatering the fluid-saturated formations. Core samples should be considered in both of these boreholes in order to obtain additional, comparative geologic information in the vicinity of the Exhaust Shaft.

5) An additional 72-hour pumping test is recommended in order to better evaluate the fluid-saturated formations. A pumping test would serve to:

    - remove water from the fluid-saturated formations in the vicinity of the Exhaust Shaft;
    - assess the effectiveness of the new pumping wells as components of a dewatering system;
    - evaluate the hydraulic parameters at different locations in the vicinity of the Exhaust Shaft, thereby assessing the homogeneity/heterogeneity of the system; and
    - confirm local boundary conditions that have been identified in previous pumping tests and better determine distances to these boundaries.

In order to evaluate the adequacy of the two additional pumping wells, pumping tests in both of these wells should be considered. This information will allow for a qualitative determination as to how each of the four wells in close proximity to the exhaust shaft affects the others while pumping. This information will be necessary in the design of a multi-well dewatering system.

7.0 REFERENCES

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Freeze, R.A. and J.A. Cherry, 1979. Groundwater. Prentice Hall, Inc., Englewood, New Jersey.

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U.S. DOE, 1997. Exhaust Shaft: Hydraulic Assessment Data Report: Waste isolation Pilot Plant, Carlsbad, New Mexico. DOE/WIPP 97-2219

Wolery, T.J., 1992. EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0), Lawrence Livermore National Laboratory, UCRL-MA-110662 PT III. September 1992.

Grand Junction Office Analytical Laboratory

V1.05

ANALYTICAL RESULTS

Customer ID: WST-97-047
Ticket ID:

Date: April 1, 1997
Lab ID: 242777

Requestor: WIPP (02054)
Sample Matrix: BRINE
Project Number: L30A90000

Case: 15334
Date Received: Mar 10, 199
Date Collected: Mar 6, 19

Exploratory Borehole C2505

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHOD ANALYSI
Silver	<10.0	U	ug/L	03/21/97	AS-6 R0
Arsenic	<4.0	U	ug/L	03/21/97	AS-4 R0
Boron	<1.0	U	mg/L	03/21/97	AS-5 R0
Barium	75.7	B	ug/L	03/21/97	AS-6 R0
Bromide	6.6		mg/L	03/24/97	D-3 R13
Calcium	508		mg/L	03/21/97	AS-5 R0
Cadmium	<10.0	U	ug/L	03/21/97	AS-6 R0
Chloride	1400		mg/L	03/24/97	D-3 R13
Chromium	<10.0	U	ug/L	03/21/97	AS-6 R0
Iron	2960		ug/L	03/21/97	AS-5 R0
Mercury	<1.0	U	ug/L	03/21/97	AS-3 R0
Potassium	6.0	B	mg/L	03/21/97	AS-1 R0
Magnesium	390		mg/L	03/21/97	AS-5 R0
Sodium	337		mg/L	03/21/97	AS-5 R0
Lead	<10.0	U	ug/L	03/21/97	AS-6 R0
pH	7.24			03/11/97	H-4 R04
Selenium	89.0	B	ug/L	03/21/97	AS-4 R0
Specific Gravity	1.01		mg/L	03/12/97	K-4 R01
Sulfate	945		mg/L	03/24/97	D-3 R13
Total Dissolved Solids	4440		mg/L	03/12/97	K-3 R06
Total Inorganic Carbon	90.2		mg/L	03/26/97	K-5 R05
Total Suspended Solids	14.0	B	mg/L	03/12/97	K-3 R06
Zinc	<20.0	U	ug/L	03/21/97	AS-5 R0

Grand Junction Office Analytical Laboratory

V1.05

ANALYTICAL RESULTS

Customer ID: WST-97-048
Ticket ID:

Date: April 1, 1997
Lab ID: 242775

Requestor: WIPP (02054)
Sample Matrix: BRINE
Project Number: L30A90000

Case: 15334
Date Received: Mar 10, 199
Date Collected: Mar 6, 19

Exploratory Borehole C2505

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHOD ANALYS
Ammonium	1.0		mg/L	03/25/97	F-6 R0
Nitrite	<0.10	U	mg/L	03/20/97	D-3 R1
Nitrate	26.2		mg/L	03/20/97	D-3 R1
Total Organic Carbon	8.0		mg/L	03/26/97	K-5 R0

Grand Junction Office Analytical Laboratory

V1.03

ANALYTICAL RESULTS

Customer ID: WST-97-049
Ticket ID:

Date: April 1, 1997
Lab ID: 242778

Requestor: WIPP (02054)
Sample Matrix: BRINE
Project Number: L30A90000

Case: 15334
Date Received: Mar 10, 199
Date Collected: Mar 6, 19

Exploratory Borehole C-2505

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHOD ANALYS
Silver	<10.0	U	ug/L	03/21/97	AS-6 RC
Arsenic	<4.0	U	ug/L	03/21/97	AS-4 RC
Boron	<1.0	U	mg/L	03/21/97	AS-5 RC
Barium	~86.1	B	ug/L	03/21/97	AS-6 RC
Bromide	6.6		mg/L	03/24/97	D-3 R1
Calcium	511		mg/L	03/21/97	AS-5 RC
Cadmium	<10.0	U	ug/L	03/21/97	AS-6 RC
Chloride	1400		mg/L	03/24/97	D-3 R1
Chromium	<10.0	U	ug/L	03/21/97	AS-6 RC
Iron	3980		ug/L	03/21/97	AS-5 RC
Mercury	<1.0	U	ug/L	03/21/97	AS-3 RC
Potassium	~6.0	B	mg/L	03/21/97	AS-1 RC
Magnesium	392		mg/L	03/21/97	AS-5 RC
Sodium	337		mg/L	03/21/97	AS-5 RC
Lead	<10.0	U	ug/L	03/21/97	AS-6 RC
pH	7.46			03/11/97	H-4 R04
Selenium	~92.2	B	ug/L	03/21/97	AS-4 RC
Specific Gravity	1.00		mg/L	03/12/97	K-4 R01
Sulfate	944		mg/L	03/24/97	D-3 R1
Total Dissolved Solids	4510		mg/L	03/12/97	K-3 R06
Total Inorganic Carbon	88.7		mg/L	03/26/97	K-5 R05
Total Suspended Solids	~15.0	B	mg/L	03/12/97	K-3 R06
Zinc	~26.2	B	ug/L	03/21/97	AS-5 RC

Grand Junction Office Analytical Laboratory

V1.05

ANALYTICAL RESULTS

Customer ID: WST-97-050
Ticket ID:

Date: April 1, 1997
Lab ID: 242776

Requestor: WIPP (02054)
Sample Matrix: BRINE
Project Number: L30A90000

Case: 15334
Date Received: Mar 10, 19
Date Collected: Mar 6, 1

Exploratory Borehole C-2505

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHO ANALY
Ammonium	1.0		mg/L	03/25/97	F-6 R
Nitrite	<0.10	U	mg/L	03/20/97	D-3 R
Nitrate	26.6		mg/L	03/20/97	D-3 R
Total Organic Carbon	2.0		mg/L	03/26/97	K-5 R

Grand Junction Office Analytical Laboratory

ANALYTICAL RESULTS

Customer ID: WST-97-029
Ticket ID:

Requestor: WIPP
Sample Matrix: BRINE
Project Number: L30A90000

Date: March 18, 1997
Lab ID: 242663

Case: 15325
Date Received: Mar 3, 1997
Date Collected: Feb 28, 1997

Exploratory Borehole C2506

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHOD OF ANALYSIS
Silver	<10.0	U	ug/L	03/04/97	AS-6 R06
Arsenic	<4.0	U	ug/L	03/06/97	AS-4 R02
Boron	<1.0	U	MG/L	03/05/97	AS-5 R05
Barium	~69.5	B	ug/L	03/04/97	AS-6 R06
Bromide	6.8		MG/L	03/05/97	D-3 R13
Calcium	580		MG/L	03/05/97	AS-5 R05
Cadmium	<10.0	U	ug/L	03/04/97	AS-6 R06
Chloride	2130		MG/L	03/05/97	D-3 R13
Chromium	<10.0	U	ug/L	03/04/97	AS-6 R06
Iron	3110		ug/L	03/05/97	AS-5 R05
Mercury	<1.0	U	ug/L	03/04/97	AS-3 R04
Potassium	~4.7	B	MG/L	03/05/97	AS-1 R05
Magnesium	~434	B	MG/L	03/05/97	AS-5 R05
Sodium	626		MG/L	03/05/97	AS-5 R05
Lead	<10.0	U	ug/L	03/04/97	AS-6 R06
pH	7.08			03/03/97	H-4 R04
Selenium	~91.0	B	ug/L	03/04/97	AS-4 R02
Specific Gravity	1.02		G/ML	03/04/97	K-4 R01
Sulfate	926		MG/L	03/05/97	D-3 R13
Total Dissolved Solids	6050		MG/L	03/04/97	K-3 R06
Total Inorganic Carbon	78.0		MG/L	03/06/97	K-5 R05
Total Suspended Solids	~11.0	B	MG/L	03/04/97	K-3 R06
Zinc	~65.5	B	ug/L	03/05/97	AS-5 R05

Grand Junction Office Analytical Laboratory

ANALYTICAL RESULTS

ustomer ID: WST-97-030
Ticket ID:

Date: March 18, 1997
Lab ID: 242661

Requestor: WIPP
Sample Matrix: BRINE
Project Number: L30A90000

Case: 15325
Date Received: Mar 3, 1997
Date Collected: Feb 28, 1997

Supplementary Borehole SH C2506

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHOD OF ANALYSIS
mmonium	1.0		MG/L	03/04/97	F-6 R07
itrite	<0.10	U	MG/L	03/05/97	D-3 R13
Nitrate	23.9		MG/L	03/05/97	D-3 R13
Total Organic Carbon	7.2		MG/L	03/06/97	K-5 R05

Grand Junction Office Analytical Laboratory

.05 ANALYTICAL RESULTS

Customer ID: WST-97-032
Ticket ID:

Date: March 18, 1997
Lab ID: 242662

Requestor: WIPP
Sample Matrix: BRINE
Project Number: L30A90000

Case: 15325
Date Received: Mar 3, 1997
Date Collected: Feb 28, 1997

Duplicate Exploratory Borehole C2506

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHOD OF ANALYSIS
Ammonium	~0.50	B	MG/L	03/04/97	F-6 R07
Nitrite	<0.10	U	MG/L	03/05/97	D-3 R13
Nitrate	~0.80	B	MG/L	03/05/97	D-3 R13
Total Organic Carbon	8.0		MG/L	03/06/97	K-5 R05

Grand Junction Office Analytical Laboratory

ANALYTICAL RESULTS

Customer ID: WST-97-031
Ticket ID:

Date: March 18, 1997
Lab ID: 242664

Requestor: WIPP
Sample Matrix: BRINE
Project Number: L30A90000

Case: 15325
Date Received: Mar 3, 1997
Date Collected: Feb 28, 1997

Duplicate Exploratory Borehole C-2506

ANALYSIS REQUESTED	RESULTS	RESULT QUALI's	UNITS	DATE ANALYZED	METHOD OF ANALYSIS
Silver	<10.0	U	ug/L	03/04/97	AS-6 R06
Arsenic	<4.0	U	ug/L	03/06/97	AS-4 R02
Boron	<1.0	U	MG/L	03/05/97	AS-5 R05
Barium	~78.5	B	ug/L	03/04/97	AS-6 R06
Bromide	6.8		MG/L	03/05/97	D-3 R13
Calcium	590		MG/L	03/05/97	AS-5 R05
Cadmium	<10.0	U	ug/L	03/04/97	AS-6 R06
Chloride	2140		MG/L	03/05/97	D-3 R13
Chromium	~11.3	B	ug/L	03/04/97	AS-6 R06
Iron	3160		ug/L	03/05/97	AS-5 R05
Mercury	<1.0	U	ug/L	03/04/97	AS-3 R04
Potassium	~5.2	B	MG/L	03/05/97	AS-1 R05
Magnesium	~430	B	MG/L	03/05/97	AS-5 R05
Sodium	613		MG/L	03/05/97	AS-5 R05
Lead	<10.0	U	ug/L	03/04/97	AS-6 R06
pH	7.16			03/03/97	H-4 R04
Selenium	~87.8	B	ug/L	03/04/97	AS-4 R02
Specific Gravity	1.02		G/ML	03/04/97	K-4 R01
Sulfate	928		MG/L	03/05/97	D-3 R13
Total Dissolved Solids	5800		MG/L	03/04/97	K-3 R06
Total Inorganic Carbon	80.1		MG/L	03/06/97	K-5 R05
Total Suspended Solids	~6.0	B	MG/L	03/04/97	K-3 R06
Zinc	~83.7	B	ug/L	03/05/97	AS-5 R05

1.0 INTRODUCTION

This report presents data collected during hydraulic assessment activities near the Exhaust Shaft at the Waste Isolation Pilot Plant (WIPP) located in southeastern New Mexico. Assessment activities were implemented to determine the amount and source(s) of fluid leaking into the upper 80 feet of the Exhaust Shaft at the WIPP. This activity was performed between August 15 and October 31, 1996. The WIPP is a US Department of Energy (DOE) site designed to develop methods for safe long-term disposal of trasuranic (TRU) wastes generated by US defense programs.

Fluid migrating into the Exhaust Shaft at the WIPP site was first documented during a May 1995 shaft video inspection. A stream of fluid was observed from cracks in the Exhaust Shaft concrete liner at depths of 50 to 80 feet bgs. Analysis of a sample of the fluid collected in August 1995 indicated that the salinity of the inflowing water was similar to that of sea water (Appendix A). Fluid leakage continued to be observed in 1996. Other than the 1995 in-shaft sample, direct observations of water quality at the source of the leak have not been made.

This report describes geophysical survey activities performed, boreholes drilled and/or cored, cores, well completions, hydraulic testing, and the results of water-quality sampling and analysis from boreholes sampled in compliance with the scope of work defined in the Test Plan for this activity. Work for this activity was performed by INTERA, IT Corporation, and Ph. D. Dennis Powers under contract to the Westinghouse Waste Isolation Division (Table 1.1).

1.1 Test Objectives

The Exhaust Shaft Hydraulic Assessment Program consisted of three phases. During the first phase, boreholes were hand augered to the top of the caliche or approximately 9 feet bgs to verify the absence or presence of subsurface utilities indicated by the geophysical surveys prior to drilling. The second phase, involved drilling and hydrogeologic characterization of a single pilot borehole to a depth of 97 feet bgs. The third phase, included drilling and hydrogeologic characterization of additional boreholes based on information from phases 1 and 2.

The Exhaust Shaft Hydraulic Assessment Program has the following objectives:

- To identify the lateral extent of fluid leaking through the concrete shaft liner and into the Exhaust Shaft between 50-80 feet bgs
- To evaluate corrective-action measures to eliminate or control leakage; and
- To identify the need (or not) for de-watering the horizon(s).

Table 1.1 Division of responsibilities for the Exhaust Shaft: Hydraulic Assessment Program

Organization	Responsibilities
Core Descriptions	Dennis Powers, IT Corporation, Westinghouse
Drilling, Coring, and Well Completions	INTERA
Geophysical Surveys	IT Corporation
Hydraulic Testing	INTERA
Water-Quality Analysis	IT Corporation
Water-Quality Sampling	Westinghouse

1.2 Scope of Work

Water from an unknown source has been leaking through the Exhaust Shaft liner since at least May 1995 from a horizon located 50-to-80 feet bgs along the shaft liner. In an effort to characterize the fluid, a series of five boreholes were drilled. Boreholes were located radially within 215 feet of the Exhaust Shaft (Figure 1.1). The locations of the boreholes were based on an evaluation of the WIPP-site Exhaust Shaft history, and a series of EM-31 and EM-34 frequency-domain and EM-47 time-domain geophysical surveys that were conducted to identify the location of conductance zones (i.e. possible water-bearing horizons) down to depths of 100 feet. Based on that data, three boreholes were drilled and cored to determine if and at what stratigraphic horizon(s) water was present. Where fluid was encountered, samples were collected, analyzed, and water-quality charts generated to determine potential fluid sources. Three boreholes (C-2505, C-2506, and C-2507) were completed to evaluate hydrologic parameters such as hydraulic conductivity, storativity, and the hydraulic gradient; to identify potential water source(s); and to determine the need for additional wells. Two additional boreholes (ES-001 and ES-002) were drilled to examine the development of the near-surface Mescalero caliche and to evaluate its effectiveness as an infiltration barrier.

2.0 GEOPHYSICAL SURVEY

The IT Corporation conducted an integrated geophysical survey across the Exhaust Shaft area to investigate whether or not there were water-saturated horizons from 50 to 80 feet bgs. The presence of water-saturated horizons would be indicated by changes in subsurface conductivities, provided they cannot be explained by known variations in site geology, subsurface utilities. or surface cultural features (i.e. metallic structures,

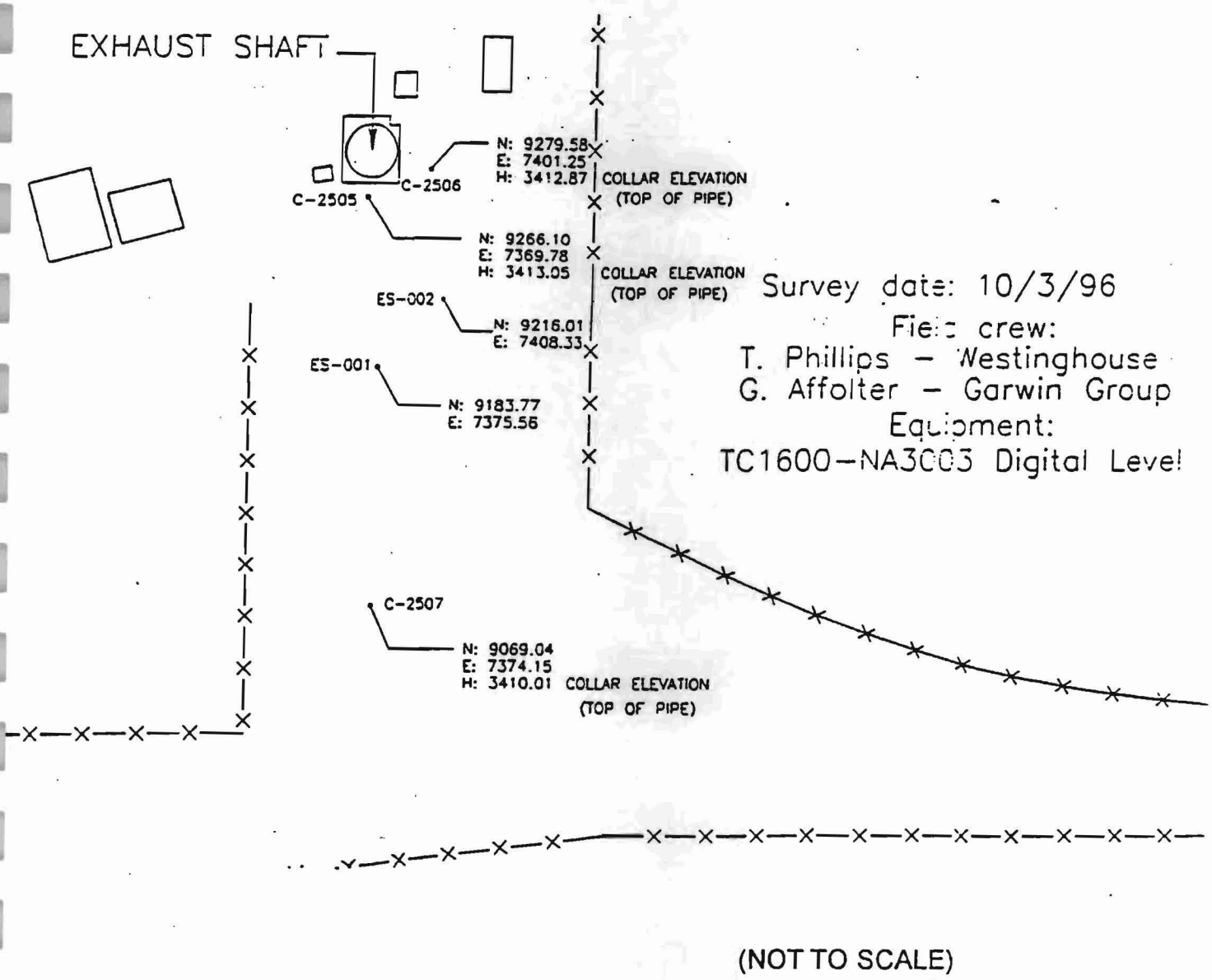

Figure 1.1. Location of boreholes C-2505, C-2506, and C-2507

ventilation ducts, and chain link fences). The results of the geophysical surveys conducted with the EM-31 and EM-34 terrain-conductivity meters and the EM-47 time-domain soundings indicated that a higher-conductivity layer could exist at depths up to 100-ft below land surface in the Exhaust Shaft area. IT Corporation personnel prepared a report summarizing the results of the geophysical survey. This report is included in Appendix B.

3.0 DRILLING, CORING, AND WELL COMPLETIONS

Exploratory drilling was conducted in the Exhaust Shaft area to investigate the geologic horizons up to about 100 feet bgs. After selecting the locations of the exploratory boreholes, the sites were augered to about 9 feet bgs by hand. After the hand-auger investigations determined the holes were clear of surface utilities, the boreholes were drilled and completed as observation wells. Core samples, photographs of core, and water-quality samples were taken from these boreholes during drilling. After completion, hydrologic testing was conducted to determine the hydraulic parameters of any water-saturated horizons and to investigate the productive potential of such horizons.

3.1 Hand Augering

Five hand-auger holes were completed to approximately 9 feet bgs in the area south and southeast of the Exhaust shaft. The hand-auger holes were used as pilot holes to ensure that the drilled boreholes would not encounter subsurface utilities; to estimate the top of caliche; and any interval of water saturation above the caliche.

Five hand-auger holes were completed. Three of the locations were used as drillhole pilot holes for wells C-2505, C-2506, and C-2507. The hand auger was easily turned in each of the holes and refusal was not encountered except at the top of the Mescalero caliche in borehole C-2507.

The results of the hand-auger holes indicate that the Mescalero caliche is poorly developed in the Exhaust Shaft area and is not uniformly distributed across the area of investigation. The calcite of the caliche is present as soft nodules of varying size and does not fill all soil interstices. A true petrocalcic horizon was not observed in these holes. None of the hand-auger holes encountered water saturation above the caliche. The hand-auger investigation appears to indicate that the Mescalero caliche is neither channeling water into the Exhaust Shaft nor acting as a significant barrier to infiltration.

3.2 Drilling and Coring

Boreholes C-2505, C-2506, and C-2507 were installed using hollow-stem auger and air-rotary methods. Both methods of sample collection achieved good to excellent core-sample recovery and core-samples exceeded 90% through cored intervals. Detailed descriptions of the core samples were provided by Ph. D. Dennis Powers, Liane Terril and Merrie Martin (Appendix D).

Core samples and groundwater samples were collected from C-2505, C-2506, and C-2507. C-2505 was cored from the surface to total depth. Based on core from C-2505, C-2506 and C-2507 were only cored from the lower Gatuña through the Santa Rosa and the upper Dewey Lake formations. In addition, two additional hollow-stem auger holes, ES-001 and ES-002 were used to further characterize the geology in the Exhaust Shaft area. Boreholes ES-001 and ES-002 were drilled for investigative purposes, geologic, and water-sample collection. These two boreholes were sealed immediately after they were drilled and sampled. Geochemical analysis of groundwater samples were performed focusing on major- and minor-ion chemistry to evaluate the origin of the groundwater. A list of the major and minor ions analyzed are provided in Table 3.1. A detailed water-analysis report provided by Rick Abitz, Ph. D., of the IT Corporation is presented in Appendix C.

3.2.1 Borehole C-2505

Borehole C-2505 was begun on September 23 and drilled to a total depth of 97 feet bgs on September 24, 1996. C-2505 was drilled to a depth of 64 feet with a hollow-stem auger and from 64 to 97 feet using air-rotary methods. Core samples were collected from both drilling methods, beginning at a depth of about 9 feet bgs, to describe the geologic materials in the formations encountered (Appendix D). Core-sample recovery averaged 90.6% using the hollow-stem auger and 97% using the air-rotary method. C-2505 was sealed with bentonite from 66 to 97 feet and reamed to a diameter of approximately 8 inches from ground surface to 65 feet bgs and 4-inch PVC casing and well screen was set in place.

A saturated formation was encountered during the recovery of the core samples from 49.0 to 51.5 feet bgs. The rocks at this level are greenish gray sandstone and reddish brown siltstone and mudstone of the upper Santa Rosa Formation. After the presence of groundwater was confirmed, a water level of 44.8 feet bgs was measured in the borehole with a water-level sounder. After letting the water-level recover to 44.2 feet bgs, a water-sample was collected from C-2505 using a disposable bailer. The sample was sent to the laboratory for geochemical analysis (Appendix C). Field analysis indicated that the specific conductivity of the water recovered from C-2505 was from 11,638 to 11,844 µmhos/cm @25°C (Table 3.1). A second sample was collected on September 24 before deepening C-2505 with air-rotary methods. As of October 31, 1996, the water level in C-2505 was 44.48 feet below ground surface (bgs).

Table 3.1 Summary of drilling and water-quality conductance measurements for the Exhaust Shaft: Hydraulic Assessment Program

Borehole	Total Depth (feet)	Cored Interval (feet)	Saturate Interval Formation	Specific Conductance umhos/cm @25° C
C-2505	97	49.0 - 51.1	upper Santa Rosa	11,638 to 11,844
C-2506	69	41.0 - 64.3	upper Santa Rosa	15,772
C-2507	72	39.0 - 63.0	upper Dewey Lake	5,050
ES-001	54	NA	NA	5,890
ES-002	19	NA	NA	NA

3.2.2 Borehole C-2506

Borehole C-2506 was drilled on September 25, 1996, to a total depth of 69 feet bgs using a hollow-stem auger and a rotary-cone reaming bit. Core samples were collectec from 41 to 64.3 feet bgs and these samples were used to describe the geologic formations encountered. Core-sample recovery averaged 97.8%. C-2506 was reamed to a diameter of approximately 8 inches from land surface to 69 feet bgs in order to set a 4-inch PVC casing and well screen.

A saturated formation was demonstrated with the recovery of the core samples from 44.0 to 48.5 feet bgs. The presence of groundwater appeared to coincide with a greenish-grey fine-grained sandstone in the upper Santa Rosa Formation (Appendix D). In addition, the core sample for the 49- to 49.8-foot bgs depth interval displayed an arcuate, high-angle, clean fracture. After the presence of groundwater was confirmed, a water level of 44.7 feet bgs was measured in the borehole with a water-level sounder. A water-sample was collected from C-2506 using a disposable bailer. The sample was sent to the laboratory for geochemical analysis. Field analysis indicated that the specific conductivity of the water recovered from C-2506 was 15,772 µmhos/cm @25°C (Table 3.1). After completing the borehole, the water level in C-2506 was 44.65 feet bgs on the evening of September 25 and 43.5 feet bgs on the morning of September 26, 1996. An additional water sample for laboratory analysis was collected from C-2506 on September 26 (Appendix C). As of October 31, 1996 the water level in C-2506 was 43.66 feet bgs.