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Pilot Test Report for Evaluating Soil-Vapor Extraction at Material Disposal Area G at Technical Area 54, Revision 1

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EXECUTIVE SUMMARY

This investigation report presents the results from the implementation of a pilot study to evaluate soil-vapor extraction (SVE) as a technology for treating volatile organic compound (VOC) vapor plumes at Material Disposal Area (MDA) G, Technical Area 54, at Los Alamos National Laboratory.

The results of the MDA G SVE pilot study indicate that SVE is an effective means for extracting vapor-phase VOC contamination from higher permeability geologic units in the vadose zone beneath MDA G. The pilot study was performed in five phases: baseline monitoring, a shallow active extraction test, a shallow rebound period, a deep active extraction test, and a passive monitoring test. Approximately 278 lb of VOCs was removed from the Tshirege Member of the Bandelier Tuff during a 30-d shallow active extraction test. Low airflow conditions were observed in the Otowi Member of the Bandelier Tuff during a subsequent 30-d deep active extraction test. As a result of the low airflow conditions and the historically lower vapor-phase VOC concentrations, approximately 15 lb of VOCs was removed from this unit.

Passive airflow monitoring in the shallow-extraction borehole was conducted after the active extraction periods. The passive monitoring indicates that changes in barometric pressure result in airflow out of the Tshirege Member. Concentrations of vapor-phase VOCs were observed in the exhaled air, indicating that passive venting is capable of removing VOCs from the subsurface. Passive airflow out of the Otowi Member was not observed. Approximately 0.7 lb of VOCs is estimated to have been removed during the 14-d passive phase of the SVE study.

Two-dimensional modeling of the radii of influence for both the active shallow and the active deep extraction tests estimated the radii of influence to be approximately 100 ft in the shallow-extraction interval and approximately 25 ft in the deep extraction interval.

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1.0 INTRODUCTION

This report presents the results of the in situ soil-vapor extraction (SVE) pilot study conducted at Material Disposal Area (MDA) G in Technical Area 54 (TA-54) at the Los Alamos National Laboratory (LANL or the Laboratory) (Figure 1.0-1). The New Mexico Environment Department (NMED) requested that tests be conducted to evaluate SVE technology in treating the subsurface volatile organic compound (VOC) vapor plumes beneath MDA G (NMED 2007, 098446, p. I-1). The MDA G SVE pilot study was conducted between May 29 and October 10, 2008, in accordance with the NMED-approved work plan (LANL 2008, 102816; NMED 2008, 101884).

The data from the pilot test will be used to evaluate the potential of SVE as a treatment technology for remediating the MDA G vapor plumes and for controlling plume source areas at MDA G. SVE can be used to control plume source areas by minimizing diffusion into the vadose zone and by facilitating interphase mass transfer of the source term into the vapor phase. The Laboratory will use these data to simulate the movement of VOCs in the subsurface using the computer code Finite Element Heat and Mass (Zyvoloski et al. 1997, 070147) to replicate the venting tests, develop extraction rates over time, and estimate zones of influence for remediating the plumes. If SVE is a component of the remedy selected for MDA G, the modeling may be used as part of the design of an SVE system. The final design criteria for SVE will be included in the corrective measures implementation (CMI) plan. Design criteria include the number and placement of extraction and monitoring boreholes, extraction intervals, equipment sizing, effluent treatment technology, and operational parameters (e.g., flow rates, vacuum, and duration).

Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with U.S. Department of Energy (DOE) policy.

2.0 BACKGROUND

2.1 Site History

MDA G is located within Area G, a 63-acre fenced area located in the east-central portion of the Laboratory at TA-54 on Mesita del Buey (Figure 1.0-1). TA-54 has been the main waste storage and disposal facility for the Laboratory since the 1950s. MDA G consists of active and inactive disposal units and contains both surface and subsurface waste management units including 32 pits, 193 shafts, and 4 trenches (Figure 2.1-1) with depths ranging from 10 ft to 65 ft below the original ground surface. Historically, MDA G was used for the disposal of low-level radioactive waste (LLW) and transuranic (TRU) radioactive waste, certain radioactively contaminated infectious waste, asbestos-contaminated material, organic chemical waste, polychlorinated biphenyls (PCBs), and the retrievable storage of TRU waste. Disposal of LLW continues at MDA G. The operational history of MDA G is summarized in the Resource Conservation and Recovery Act facility investigation (RFI) work plan for Operable Unit 1148 (LANL 1992, 007669, pp. 5-179–5-200) and in the approved investigation work plan for MDA G (LANL 2004, 087833, Appendix B).

2.2 Site Description and Geologic Setting

The Laboratory lies between the Jemez Mountains and the Rio Grande on the Pajarito Plateau. The plateau is capped by the Bandelier Tuff, a thick sequence of ash-fall pyroclastics. Erosion of the tuff over time has created a series of canyons separating the narrow, finger-like mesas that comprise the Pajarito Plateau.

The pits, trenches, and shafts of MDA G are constructed in unit 2 (caprock) and unit 1 (subsurface) of the Tshirege Member of the Bandelier Tuff (consolidated tuff units). The regional aquifer is estimated to be at an average depth of approximately 930 ft below ground surface (bgs) at MDA G, based on data from wells in the vicinity and the predictions of the hydrogeologic conceptual model for the Pajarito Plateau (LANL 1998, 059599, Appendix H). The topography of Area G is relatively flat. Surface runoff from the site is controlled and discharges into drainages to the north towards Cañada del Buey and to the south towards Pajarito Canyon. Stormwater and sediment monitoring stations are distributed throughout the surface of Area G and in drainages leading to the canyons.

The strata below MDA G are composed of nonwelded to moderately welded rhyolitic ash-flow and ash-fall tuffs interbedded within pumice beds. The rhyolitic units overlie a thick basalt unit, which, in turn, overlies a conglomerate formation. Figure 2.2-1 provides a schematic of the tuff stratigraphy. The three upper units make up the Tshirege Member of the Bandelier Tuff. Unit 2 (Qbt 2) and the upper portion of unit 1v (Qbt 1v) are fractured, and the fractures are often filled with calcite and/or clay. The Cerro Toledo interval (Qct) is made up of volcanoclastic sediments interbedded with minor pyroclastic flows. The Otowi Member (Qbo) of the Bandelier Tuff, a nonwelded to poorly welded unit that is not fractured, lies beneath the Cerro Toledo interval, and consists of nonwelded to poorly welded tuff with little evidence of fracturing (Reneau and Raymond 1995, 054709). The Cerros del Rio basalt lies beneath the tuff and makes up roughly 35% of the vadose zone. Characteristics of this unit vary widely, ranging from extremely dense with no effective porosity to highly fractured to very vesicular so as to appear foamy (Turin 1995, 070225). The saturated zone extends from the lower Cerros del Rio basalt into the underlying Puye Formation basalt. A complete summary of the site geology and geologic properties of Area G is provided in the approved MDA G investigation work plan (LANL 2004, 087624).

Table 2.2-1 summarizes the geohydrologic and hydraulic properties for the stratigraphic layers and provides the bulk density, porosity, in situ permeability, moisture content by volume, percent saturation, saturated hydraulic conductivity, and an indication of the induration and fracturing of the various formations. Bulk permeability can be inferred from data collected in wells at the site (Lowry 1997, 087818). Anemometry measurements from the site provide information on the bulk flow. These data show that the Qbt and Qct stratigraphic layers produced three-quarters of the total airflow from the boreholes. Subsequent discrete point permeability measurements confirmed the Cerro Toledo interval has a higher permeability (3 to 10 Darcies) than the other stratigraphic layers (0.2 to 0.9 Darcies).

2.3 MDA G Vapor Plumes

Three VOC vapor plumes have been identified at MDA G (Figure 2.3-1). Pore-gas monitoring conducted at MDA G since 1985, and conclusions of the 2005 MDA G investigation report and the 2007 addendum (LANL 2005, 090513; LANL 2007, 096110) indicate the highest VOC concentrations are beneath the eastern portions of MDA G in the vicinity of the shaft field west of Pits 2 and 4. The dominant subsurface VOC vapor contaminant is 1,1,1-trichloroethane (TCA) in the eastern and central portion of MDA G; whereas, trichloroethene (TCE) is the most dominant VOC in the western portion of MDA G. The physical and chemical properties of the primary VOCs detected in the vapor-phase plumes at MDA G are shown in Table 2.3-1.

VOC concentrations are highest in the Tshirege Member of the Bandelier Tuff and decrease markedly in the underlying stratigraphic units. Concentrations of VOCs are lowest in the deepest unit sampled, the Cerros del Rio basalt. The MDA G investigation report (LANL 2005, 090513) and the addendum to the MDA G investigation report (LANL 2007, 096110) conclude that the nature and extent of the MDA G VOC plumes are defined. The most recent MDA G annual pore-gas monitoring report (LANL 2008, 104513) further indicates that VOCs demonstrate decreasing or stable trends in concentrations at all locations and depths sampled periodically since 1985.

The VOC plume treated during the MDA G SVE pilot test is comprised primarily of TCA. Lesser amounts of tetrachloroethene (PCE), TCE, and trichlorofluoromethane (Freon-11) are also present. TCA is the most consistent and prevalent VOC detected in pore-gas samples, and is the best indicator of the extent of the plume. The shallow-extraction phase of the MDA G pilot test targeted the shallower Tshirege Member, which has historically demonstrated the highest concentrations of TCA. The deep-extraction phase of the pilot test targeted the deeper Otowi Member, which historically has demonstrated lower concentrations of TCA than those observed in the Tshirege Member.

3.0 SVE PILOT TEST METHODOLOGY

The primary goal of the SVE pilot test was to evaluate the effectiveness and suitability of SVE as a treatment technology for remediating the MDA G vapor plumes.

3.1 SVE Pilot Test Scope

The MDA G SVE pilot test consisted of the following activities.

- Two boreholes were drilled and configured specifically to be used as vapor-extraction boreholes. The shallow- and deep-extraction boreholes were installed to extract vapor from the Tshirege and Otowi Members of the Bandelier Tuff, respectively.
- Existing borehole locations 54-01116, 54-01117, 54-24378, and 54-24388 were extended and instrumented with pore-gas monitoring ports located in each geologic unit to facilitate pore-gas and differential-pressure monitoring.
- Pretest pore-gas and differential-pressure monitoring were conducted to establish baseline conditions.
- Active extraction was performed on the shallow vapor-extraction borehole for 30 d, followed by a 2-wk rebound monitoring period.
- Active extraction was performed at the deep-extraction borehole for 30 d after the 2-wk shallow test rebound period.
- Passive extraction was evaluated at the shallow- and deep-extraction boreholes for 2 wk following the deep-extraction test. Pore-gas and airflow monitoring were conducted at the shallow-extraction borehole and airflow monitoring was conducted at the deep-extraction borehole.
- Discrete permeability testing was conducted in the extraction boreholes at 5-ft intervals to provide detailed permeability data for model calibration. Results of permeability testing are provided in Appendix C.

If SVE is selected as a component of the remedy selected for MDA G, analysis of the pilot study data can be used to determine the extraction rates necessary to meet cleanup objectives.

3.2 SVE Pilot Test Summary

One shallow- and one deep-extraction borehole were installed at MDA G in the vicinity of the shaft field in the north-central portion of the site (Figure 3.2-1). Both boreholes were installed using hollow-stem auger (HSA) drilling methodology. The characteristics of the extraction borehole are summarized in Table 3.2-1.

The shallow-extraction borehole was constructed to evaluate SVE in the Tshirege Member of the Bandelier Tuff. The borehole was cored and logged from the surface to a total depth (TD) of 182.5 ft bgs. The bottom of the shallow-extraction borehole was grouted up to a depth of 145 ft bgs to avoid short-circuiting of air-flow through the more permeable Tsankawi Pumice Bed. The top of the borehole was completed with a 10-in.-diameter steel casing from the ground surface to 63 ft bgs, approximately 3 ft into the top of Qbt 1v of the Tshirege Member, resulting in an 82-ft extraction interval within the Tshirege Member from 63 ft to145 ft bgs (Figure 3.2-2).

The deep-extraction borehole was constructed to evaluate SVE in the Otowi Member of the Bandelier Tuff. The borehole was drilled to a TD of 185 ft bgs. The bottom of the deep-extraction borehole was grouted up to a depth of 177 ft bgs to ensure the extraction interval would not be affected by the more permeable Guaje Pumice Bed. The top of the borehole was completed with a 10-in.-diameter steel casing from the ground surface to 161 ft bgs, approximately 10 ft into the top of the Otowi Member, resulting in a 16-ft extraction interval within the Otowi Member from 161 ft to 177 ft bgs (Figure 3.2-3).

Existing borehole locations 54-24878, 54-01116, 54-24388, and 54-01117 were extended and constructed for pore-gas monitoring. The port depths and corresponding stratigraphy are summarized in Table 3.2-2. The boreholes are located approximately 25 ft, 40 ft, 110 ft, and 125 ft, respectively, from the shallow-extraction borehole and approximately 27 ft, 50 ft, 115 ft, and 135 ft, respectively, from the deep-extraction borehole (Figure 3.2-4). Each existing borehole was extended using an HSA drilled to refusal and then air-rotary drilled approximately 15 ft into the Cerros del Rio basalt. Once drilled, each monitoring borehole was completed with nine stainless-steel vapor-monitoring ports installed in 5-ft intervals of sand (2.5 ft of sand above and below the port). Each vapor-monitoring interval was sealed with 2.5 ft of hydrated bentonite chips on the bottom and top of the interval. Ports were installed in each borehole within Qbt 2 at approximately 22.5 ft and 42.5 ft bgs; within Unit Qbt 1v–u at approximately 66.5 ft bgs; within Qbt 1v–c at approximately 82.5 ft bgs; within Qbt 1g at approximately 97.5 ft and 132.5 ft bgs; within Qct at approximately 151.5 ft bgs; within Qbo at approximately 167.5 ft bgs; and within Tb 4 at approximately 190 ft bgs (Table 3.2-2). Typical pore-gas monitoring well construction is shown in Figure 3.2-5.

The SVE pilot system consisted of a 12-ft-long × 3-ft-wide skid-mounted Model 100 standard cubic feet per minute (scfm) Blower Package system provided by Catalytic Combustion Corp. of Bloomer, WI. The system used a positive displacement blower driven by a 7.5-hp electric motor. Extracted vapor was first drawn through a 20-gal. vapor/liquid separator and then was passed through a heat-exchanger set to maintain a temperature range of approximately 95° to 105°F. Extracted effluent air was then discharged to two epoxy-lined steel canisters, plumbed in series, each containing 400 lb of granular active carbon (GAC). Effluent treated by the GAC canisters was then discharged from the second canister to the atmosphere through a 10-ft emission stack. Specifications of the SVE and monitoring equipment are presented in Appendix E.

Baseline monitoring was conducted for a period of 14 d before the shallow-extraction test began. Active SVE was performed in both the shallow- and the deep-extraction boreholes for a period of 30 d. Active extraction was first performed at the shallow-extraction borehole, followed by a 2-wk rebound monitoring period at the pore-gas monitoring wells. Active extraction was then performed at the deep-extraction borehole following shallow rebound monitoring. Passive monitoring was conducted for a period of 14 d following the deep extraction test. A summary of the test phases, parameters, monitoring activities, and waste managed is provided in Table 3.2-3.

During active extraction, a Brüel & Kjær (B&K) 1302 photoacoustic multigas analyzer was used to monitor TCA, TCE, Freon-11, PCE, carbon dioxide, and water-vapor concentrations in both the pore-gas monitoring boreholes and in the vapor-extraction boreholes. Differential pressure readings (the difference between surface and subsurface pressures, measured in kilopascals [kPa]) were collected from the four pore-gas monitoring boreholes using a Dwyer Series 475 Mark III digital manometer. B&K pore-gas parameters were measured once each day (generally in the morning) at each of the pore-gas monitoring boreholes and every 3 min at the extraction borehole. B&K values measured at the extraction boreholes were recorded using a Campbell Scientific CS-23X data logger. Differential pressure readings were collected from each pore-gas monitoring borehole once in the morning and once in the afternoon. Data collected during the MDA G SVE pilot study are provided in Appendix B.

During active extraction, total extraction airflow, vacuum, air temperature, and relative humidity were monitored at the extraction boreholes. Airflow was monitored using a Dwyer Series PE in-line orifice plate flow meter with a Dwyer Model 677-8 differential pressure transducer. The airflow rate was established by closing the SVE system's dilution valve to the differential pressure corresponding with the desired flow rate and calculated per equations provided by Dwyer (Appendix D). The calculations provided by Dwyer incorporate differential pressure measured at the orifice plate and vacuum measured at the extraction wellhead. Temperature and relative humidity were collected using a Viasala HMP45AC humidity and temperature probe. Vacuum pressure at the top of the extraction boreholes was monitored using a 0 to 20 in.-Hg vacuum gauge. Orifice plate differential pressure, temperature, and relative humidity were recorded using a data logger.

Pore-gas monitoring boreholes were monitored for VOCs and differential pressure after each extraction test to evaluate the near-field rebound of VOCs in those boreholes. Following the active deep-extraction test, both extraction boreholes were monitored for 2 wk to evaluate the effect of barometric pressure changes on passive airflow from the subsurface and the potential effectiveness of that airflow for removing VOCs from the subsurface vapor plumes. During passive airflow monitoring, a check valve was installed on each extraction borehole that allowed airflow out of the subsurface but prevented airflow into the subsurface. The check valves prevented airflow into the extraction wells that could potentially impact nearby vapor-phase VOC concentrations that might otherwise be observed in airflow out of the extraction wells. Because airflow into the subsurface was minimized during passive airflow monitoring and would not likely impact the rebound of VOC concentrations observed at the pore-gas monitoring wells, deep-extraction rebound monitoring was conducted concurrently with the passive airflow monitoring.

During passive airflow monitoring, the shallow-extraction borehole was monitored for VOCs, airflow, temperature, and relative humidity. Because low airflow conditions were observed in the deep-extraction borehole during active extraction (section 4.2), airflow out of the deeper formation (and associated VOCs) would be unlikely during the passive venting stage. Consequently, only airflow was monitored at the deep-extraction borehole during this same period.

Treated effluent discharged from the GAC canisters were monitored between the two treatment vessels and from the emission stack using the B&K to ensure maximum GAC was used while maintaining compliance with VOC emission standards. As part of site health and safety monitoring activities, treated effluent discharged from the GAC canisters was also monitored for beta activity at the emissions stack using a PTM Model 1812 air sampler. Beta activity monitoring was conducted approximately every 2 h during the first week of each active extraction test, then daily for the remainder of each active extraction test.

Based on pore-gas VOC analytical data collected during historical pore-gas monitoring activities at MDA G, PCE, TCA, and TCE on average account for approximately 85% of the mass of the VOCs detected at MDA G (Table 3.2-4). The VOCs 1-1,dichloroethane (DCA) and 1-1,dichloroethene (DCE) make up a large portion of the remaining VOCs present at MDA G but were not monitored as part of SVE pilot study activities. Because TCA on average accounts for 83% of the total mass of VOCs in the vapor plume, it is the primary VOC addressed in this document.

Different methods were used to calculate the mass of specific VOCs (Freon-11, PCE, TCA, and TCE) extracted for the active extraction and passive venting tests. The methods are described as follows.

Active Shallow- and Deep-Extraction Tests

The mass of VOCs extracted is a function of the concentrations measured in the extracted vapor during active extraction and the extracted airflow. Using the Dwyer calculation (Appendix D), average well head vacuum (measured in in.-Hg) and orifice plate differential pressure (measured in in.-H_2O) values measured during the duration of the extraction tests were first used to calculate airflow (in scfm). The shallow-extraction test airflow averaged 104.9 scfm and the deep-extraction test airflow averaged 16.9 scfm.

To obtain VOC concentrations suitable for determining corresponding mass, field-screening values of Freon-11, PCE, TCA, and TCE were converted from parts-per-million by volume (ppmv) concentrations into mg/m^3 using the ideal gas law. The ideal gas law incorporates the average temperature for the extracted gas at the point of measurement, the atmospheric pressure at the test elevation, the molecular weight, and volumetric concentration (ppmv) of the given VOC.

The representative time period was then determined for each field-screening concentration of each VOC. The VOC concentration, average extraction airflow rate, and representative time period were multiplied and converted to a mass (lb). The mass (lb) calculation was performed for each recorded VOC concentration and a running sum was then calculated to determine the total mass removed during the respective active-extraction tests. VOC removal during the shallow-extraction test and the deep-extraction test are discussed in sections 4.2 and 4.3, respectively.

Passive Venting Test

Similar to the active-extraction tests, cumulative VOC mass removed was calculated for the passive-extraction test. The shallow-extraction borehole was fitted with an orifice plate to measure and log the pressure differential between the borehole interior and the atmosphere. The passive airflow rate was then calculated based on the measured differential pressure. Similar to the active-extraction tests, the mass concentration and representative time period for the given VOC was determined. However, given the variability of the airflow rate as a function of diurnal barometric pressure changes, only airflow out of the borehole was considered. The VOC concentration and time period during which airflow out of the borehole were multiplied by the respective airflow rate to determine the mass (lb) of the VOC for the given time point. The mass (lb) calculation was performed for each recorded VOC concentration and a running sum was calculated to determine the total mass removed during the test. The removal of VOC during the passive venting test is discussed in section 4.4.

To evaluate whether tritium was present in the soil vapor extracted from the subsurface, two tritium samples were collected from the shallow-extraction borehole: one sample during active extraction and one sample following active extraction. One tritium sample was also collected from the deep-extraction borehole during active extraction. The results of tritium sampling are discussed in section 4.5.

Condensate was not observed in the SVE system's vapor/liquid separator at any time during either active extraction test. The lack of condensate corresponds with the historically low soil-moisture content values typically observed throughout MDA G.

4.0 SVE PILOT TEST RESULTS

Baseline monitoring of the extraction boreholes and the pore-gas monitoring boreholes occurred before active extraction, from May 29 to June 16, 2008. Active extraction in the shallow-extraction borehole occurred from July 8 to August 6, 2008. Shallow-extraction rebound was monitored from August 7 to August 24, 2008. Active extraction in the deep-extraction borehole took place from August 25 to September 23, 2008. Deep-extraction rebound was monitored from September 24 to October 8, 2008, concurrently with monitoring of passive airflow out of the subsurface (Table 3.2-3). The range of field-screening concentrations of Freon-11, PCE, TCA, and TCE for each port is presented in Table 4.0-1.

Following the completion of the SVE extraction and passive tests, permeability testing was conducted in each extraction borehole at 5-ft intervals to provide detailed permeability data for model calibration (Appendix C). However, results of the permeability testing were inconclusive in defining the permeability of specific stratigraphic units and probably underestimate the actual permeability as a result of the sampling system design. The method used to determine permeability assumed downhole instrumentation and did not allow for the effects of sample tubing (e.g., friction loss) on measured values. During this test, differential pressure readings were collected at the surface using a manometer when they should have been obtained from a pressure transducer located downhole. Because the permeability values obtained as part of the SVE pilot study are inconclusive, the values are not appropriate for modeling purposes.

Although the results of stratigraphic-specific permeability testing were inconclusive, bulk permeability values could be calculated for each extraction borehole based on the observed extraction airflow rates. Bulk permeability values and stratigraphic-specific permeability values previously determined at MDA L were used to numerically model the radii of influence for the active shallow and active deep extraction tests. The two-dimensional model conservatively estimates the radius of influence to be approximately 100 ft for the shallow extraction interval and approximately 25 ft for the deep extraction interval. Results of the modeling effort estimated the range of permeability values in the Tshirege Member to be approximately 3.95×10^{-12} m^2 to 7.61×10^{-12} m^2. Permeability in the Otowi Member was estimated to be approximately 1.31×10^{-12} m^2 (Laboratory report in preparation).

4.1 Baseline Monitoring

The VOCs and differential pressure were monitored in the pore-gas monitoring boreholes before and after active extraction tests to establish baseline VOC and differential-pressure conditions. Baseline monitoring was conducted before the shallow-extraction test from May 29 to June 16, 2008, in borehole locations 54-24388, 54-01116, and 54-23488; and from June 5 to June 12, 2008, in borehole location 54-01117. The average, minimum, and maximum baseline field-screening concentrations of Freon-11, PCE, TCA, and TCE are shown in Table 4.1-1. Following the shallow-extraction test and before the deep-extraction test, additional baseline differential-pressure monitoring was conducted in all pore-gas monitoring boreholes from August 7 to August 24, 2008. Following the deep-extraction test, baseline differential-pressure monitoring was conducted in all pore-gas monitoring borehole locations from September 24 to October 8, 2008.

4.2 Shallow-Extraction Pilot Test

Active extraction in the shallow-extraction borehole was conducted for 30 d between July 8 and August 6, 2008. The airflow rate for the test was set to approximately 104.9 scfm; the corresponding vacuum imparted on the extraction borehole was 1.7 in.-Hg. On August 3, 2008, after approximately 26 d of operation, the SVE system shut down because of a power interruption in Area G; extraction was restarted August 4, 2008, 27.15 d after the start of shallow extraction. The system shut down a second time because of a second interruption in power at 27.25 d; the system was restarted 27.26 d after the start of shallow extraction. At 27.37 d, a power outage shut the system down; the system was restarted 27.97 d after the start of shallow extraction and continued to operate uninterrupted until 30 d following the start of shallow extraction. B&K and manometer readings were collected from the four pore-gas monitoring boreholes to evaluate the radius of influence of the SVE system and to assess the overall impact of extraction on the VOC plume.

The average, minimum, and maximum shallow extraction field-screening concentrations of Freon-11, PCE, TCA, and TCE are shown in Table 4.2-1. During the shallow test, TCA concentrations peaked in the shallow-extraction well at approximately 315 ppmv shortly after the start of the test and decreased to approximately 140 ppmv by the end of the 30-d test. Based on VOC mass-removal calculations using the average airflow and B&K readings, approximately 278 lb of VOCs was removed during the shallow-extraction pilot test. Figure 4.2-1 shows Freon-11, PCE, TCA, and TCE concentrations in the shallow-extraction well over time during the test period, and Figure 4.2-2 shows both the calculated cumulative VOCs and individual VOCs removed during the shallow-extraction test.

Five drums of spent carbon were generated during the shallow-extraction test, characterized, and classified as LLW.

Borehole Location 54-24378

Borehole location 54-24378 is approximately 25 ft from the shallow-extraction borehole and was the closest monitoring point to the shallow-extraction borehole. Pore-gas monitoring ports are installed in borehole location 54-24378 at depths of 22.5 ft, 42.5 ft, 66.5 ft, 82.5 ft, 97.5 ft, 132.1 ft, 151.5 ft, 167.5 ft, and 190 ft. Box plots of baseline versus shallow test-period differential pressure readings for both morning and afternoon (Figure 4.2-3) indicate a pressure response from 66.5 ft to 167.5 ft bgs, with these port depths shifting to negative differential pressures during extraction. The strongest responses were observed in the ports at 66.5 ft, 82.5 ft, and 97.5 ft. A stronger negative shift was more apparent during morning hours in all ports that showed a pressure response. Manometer data for borehole location 54-24378 collected before, during, and after the shallow-extraction test are shown in Figure 4.2-4 and further illustrate the pressure responses. The strong pressure response to the test is evidenced by the rapid return to near 0 kPa pressure differential at the end of the test following system shutdown. Borehole location 54-24378 exhibited the greatest pressure response of the four pore-gas monitoring boreholes during the shallow-extraction test.

A scatter plot of TCA concentrations measured in borehole location 54-24378 before, during, and after the shallow-extraction test is shown in Figure 4.2-5. Borehole location 54-24378 generally exhibited the highest baseline TCA concentrations of the four pore-gas monitoring boreholes. The data indicate TCA concentrations decreased from 22.5 ft to 97.5 ft bgs during extraction. A slight decrease in TCA concentrations was observed in ports at 132.1 ft, 151.5 ft, and 167.5 ft. Little or no change in TCA concentrations was observed at the 190-ft port. A rebound in TCA concentrations at the 97.5-ft port was observed on August 5, 2008, which corresponds to the August 3, 2008, system shutdown. With the exception of the 97.5-ft port, a slight rebound of TCA concentrations was observed during the post study monitoring period from August 6 to August 22, 2008.

Borehole Location 54-01116

Borehole location 54-01116 is approximately 40 ft from the shallow-extraction borehole and was the second closest monitoring point to the shallow-extraction borehole. Pore-gas monitoring ports are installed in borehole location 54-01116 at depths of 22.5 ft, 42.5 ft, 66.5 ft, 82.5 ft, 97.5 ft, 132.1 ft, 151.5 ft, 167.5 ft, and 190 ft. Box plots of baseline versus shallow test-period differential pressure readings for both morning and afternoon (Figure 4.2-6) indicate a pressure response from 66.5 ft to 167.5 ft bgs, with these ports shifting to negative differential pressures during extraction. The strongest responses were observed in ports at 66.5 ft, 82.5 ft, 97.5 ft, and 132.1 ft. A stronger negative shift was more apparent during morning hours in all ports showing a pressure response. Manometer data for borehole location 54-01116 collected before, during, and after the shallow-extraction test are shown in Figure 4.2-7 and further illustrate the pressure responses. The strong pressure response to the test is evidenced by the rapid return to near 0 kPa pressure differential at the end of the test following system shutdown. The pressure response observed at borehole location 54-01116 was slightly lower than that observed at borehole location 54-24378.

A scatter plot of TCA concentrations measured in borehole location 54-01116 before, during, and after the shallow-extraction test is shown in Figure 4.2-8. Baseline TCA concentrations were of a similar magnitude as those observed in borehole location 54-24378 but were slightly lower. The data indicate that during extraction TCA concentrations decreased in all ports with initial measurable concentrations, with the greatest decrease in ports from 22.5 ft to 97.5 ft bgs. A rebound in TCA concentrations at the 97.5-ft port was observed on August 5, 2008, which corresponds to the August 3, 2008, system shutdown. A slight rebound of TCA concentrations was observed in all ports during the post study monitoring period, with the great rebound observed at the 97.5-ft port.

Borehole Location 54-24388

Borehole location 54-24388 is approximately 110 ft from the shallow-extraction borehole and was the third closest monitoring point to the shallow-extraction borehole. Pore-gas monitoring ports are installed in borehole location 54-24388 at depths of 22.5 ft, 42.5 ft, 67.5 ft, 82.5 ft, 97.5 ft, 132.5 ft, 151.5 ft, 167.5 ft, and 189.5 ft. Box plots of baseline versus shallow test-period differential pressure readings for both morning and afternoon (Figure 4.2-9) indicate a pressure response from 67.5 ft to 151.5 ft bgs, with these ports shifting to negative differential pressures during extraction. The strongest responses were observed in ports at 82.5 ft and 97.5 ft. A slightly stronger negative shift was again apparent during the morning hours in all ports showing a pressure response. Manometer data for borehole location 54-24388 collected before, during, and after the shallow-extraction test are shown in Figure 4.2-10 and further illustrate the pressure responses. Although the pressure response observed in borehole location 54-24388 was not as great as that observed in the two closer pore-gas monitoring boreholes, the pressure response to the test is evidenced by the rapid return to near 0 kPa pressure differential at the end of the test following system shutdown.

A scatter plot of TCA concentrations measured in borehole location 54-24388 before, during, and after the shallow-extraction test is shown in Figure 4.2-11. Baseline TCA concentrations were approximately an order of magnitude lower than those in borehole locations 54-24378 and 54-01116. The data indicate that during extraction TCA concentrations decreased in all ports, with the exception of ports at 167.5 ft and 189.5 ft. A slight rebound of TCA concentrations was observed in all ports during the post study monitoring period.

Borehole Location 54-01117

Borehole location 54-01117 is approximately 125 ft from the shallow-extraction borehole and was the farthest monitoring point from the shallow-extraction borehole. Pore-gas monitoring ports are installed in borehole location 54-01117 at depths of 20 ft, 42.5 ft, 67.5 ft, 82 ft, 97.5 ft, 132.5 ft, 150 ft, 159.5 ft, and 179.8 ft. Box plots of baseline versus shallow test-period differential pressure readings for both the morning and afternoon (Figure 4.2-12) indicate a pressure response in ports from 67.5 ft to 159.5 ft bgs, with all of these ports shifting to negative differential pressures during extraction. The strongest responses were observed in ports at the 67.5-ft to 132.5-ft interval. A slightly stronger negative shift was again apparent during morning hours in all ports showing a pressure response. Manometer data for borehole location 54-01117 collected before, during, and after the shallow-extraction test are shown in Figure 4.2-13 and further illustrate the pressure responses. Although morning baseline differential pressure measurements were not collected from borehole location 54-01117 before the shallow-extraction test, baseline measurements were collected following both the active shallow- and active deep-extraction tests. Although the pressure response observed in borehole location 54-01117 was not as great as that in the other three pore-gas monitoring boreholes, the pressure response to the test is evidenced by the rapid return to a range of 0 to -0.1 kPa pressure differential at the end of the test following system shutdown.

A scatter plot of TCA concentrations measured in borehole location 54-01117 before, during, and after the shallow-extraction test is shown in Figure 4.2-14. Baseline TCA concentrations were slightly lower than those observed at borehole location 54-24388. TCA concentrations decreased slightly in all ports during the extraction test and rebounded to near-baseline conditions following the test.

4.3 Deep-Extraction Pilot Test

Active extraction from the deep-extraction borehole was conducted for 30 d between August 25 and September 23, 2008. The airflow rate for the deep extraction test was set to approximately 16.9 scfm; the corresponding vacuum imparted on the extraction borehole was 4.97 in.-Hg. On September 15, 2008, 21.25 d into the extraction period, the SVE system shut down because of a power interruption in Area G. The system was restarted at 21.27 d. B&K and manometer readings were collected from the four pore-gas monitoring boreholes to evaluate the radius of influence of the SVE system and to assess the overall impact of extraction on the VOC plume.

The average, minimum, and maximum deep extraction field-screening concentrations of Freon-11, PCE, TCA, and TCE are shown in Table 4.3-1. During the deep test, TCA concentrations in the extraction borehole ranged between approximately 50 and 70 ppmv throughout the 30-d test, with the lowest concentrations in the morning and the highest concentrations in the afternoon. Based on VOC mass-removal calculations using the calculated average airflow and B&K readings, approximately 15 lb of VOCs was removed during the deep-extraction test period. Figure 4.3-1 shows Freon-11, PCE, TCA, and TCE concentrations measured in the extraction borehole during the deep-extraction test. Figure 4.3-2 shows both the estimated cumulative VOCs and the individual VOCs removed during the test. Two drums of spent carbon were generated during the deep-extraction test, characterized, and classified as LLW.

Borehole Location 54-24378

Box plots of baseline versus deep test-period differential pressure readings for both morning and afternoon (Figure 4.3-3) indicate a pressure response in ports at 132.1 ft, 151.5 ft, and 167.5 ft bgs, with these ports shifting to negative differential pressures during extraction. A stronger negative shift occurred during morning hours in all ports showing a pressure response. Baseline differential pressures also appeared to be higher during morning hours. Manometer data for borehole location 54-24378 collected before, during, and after the deep-extraction test are shown in Figure 4.3-4 and further illustrate the pressure responses. The pressure response to the deep-extraction test is evidenced by the return to baseline differential pressure conditions at the end of the test following system shutdown. Borehole location 54-24378 exhibited the greatest pressure response of the four pore-gas monitoring boreholes during the deep-extraction test.

A scatter plot of TCA concentrations measured in borehole location 54-24378 before, during, and after the deep-extraction test is shown in Figure 4.3-5. With the exception of TCA concentrations at the 167.5-ft port, TCA concentrations in borehole location 54-24378 did not appear to decrease during the deep-extraction test.

Borehole Location 54-01116

Box plots of baseline versus deep test-period differential pressure readings for both morning and afternoon (Figure 4.3-6) indicate a pressure response in ports from 132.1 ft to 167.5 ft bgs, with all of these ports shifting to negative differential pressures during extraction. During active deep extraction, a stronger negative shift was more apparent during morning hours in all ports showing a pressure response. Afternoon baseline differential pressure readings generally trended positive rather than near 0 kPa or negative observed for morning baseline readings. Manometer data for borehole location 54-01116 collected before, during, and after the deep-extraction test are shown in Figure 4.3-7 and further illustrate the pressure responses. The pressure response observed at borehole location 54-01116, was slightly lower than that at borehole location 54-24378.

A scatter plot of TCA concentrations measured in borehole location 54-01116 before, during, and after the deep-extraction test is shown in Figure 4.3-8. During extraction, TCA concentrations decreased slightly at 97.5 ft, 151.5 ft, and 167.5 ft; however, a slight increase in TCA concentrations was observed in the shallow ports (22.5 ft, 42.5 ft, and 66.5 ft). Based on this observation, it appears that the deep-extraction well had little effect on the airflow in the shallow depths of the Tshirege Member and that TCA concentrations at these depths were experiencing a rebound following the active shallow-extraction test.

Borehole Location 54-24388

Box plots of baseline versus deep test-period differential pressure readings for both morning and afternoon (Figure 4.3-9) indicate a slight pressure response in ports from 132.5 ft to 159.5 ft bgs, with these ports shifting to negative differential pressures during extraction. A slightly stronger negative shift occurred in these ports during morning hours. Greater variability was also observed in the morning pressure readings during extraction. Afternoon baseline differential pressure readings generally trended positive, rather than near 0 kPa or negative as observed for morning baseline readings. Manometer data for borehole location 54-24388 collected before, during, and after the deep-extraction test are shown in Figure 4.3-10 and further illustrate the pressure responses.

A scatter plot of TCA concentrations measured in borehole location 54-24388 before, during, and after the deep-extraction test is shown in Figure 4.3-11. TCA concentrations in borehole 54-24388 did not appear to decrease during the deep-extraction test.

Borehole Location 54-01117

Box plots of baseline versus deep test-period differential pressure readings in borehole 54-01117 for both morning and afternoon (Figure 4.3-12) indicate a pressure response in ports from 132.5 ft to 167.5 ft bgs, with these ports shifting to negative differential pressures during extraction. A slightly stronger negative shift occurred in these ports during morning hours. As with the other pore-gas monitoring wells monitored during the deep-extraction test, greater variability was observed in the morning pressure readings during extraction. Afternoon baseline differential pressure readings generally trended positive, rather than near 0 kPa or negative as observed for morning baseline readings. Manometer data for borehole location 54-01117 collected before, during, and after the deep-extraction test are shown in Figure 4.3-13 and further illustrate the pressure responses.

A scatter plot of TCA concentrations measured in borehole location 54-01117 before, during, and after the deep-extraction test is shown in Figure 4.3-14. TCA concentrations in borehole 54-24388 were highly variable during the deep-extraction test and did not appear to decrease.

4.4 Passive Venting

Monitoring of passive airflow out of the extraction boreholes was conducted to evaluate the effect of barometric pressure changes on airflow from the subsurface and the potential effectiveness of that airflow for removing vapor-phase VOCs from the subsurface. Passive airflow was monitored from the shallow-extraction borehole from September 24 to October 8, 2008, and from the deep-extraction borehole from September 26 to October 8, 2008. To evaluate the airflow out of the extraction boreholes, a mylar check valve was installed on the orifice plate at the wellhead of each extraction borehole that allowed airflow out of the subsurface but prevented airflow into the subsurface.

The average, minimum, and maximum field-screening concentrations of Freon-11, PCE, TCA, and TCE monitored during the passive-venting phase are shown in Table 4.4-1. No measurable airflow from the Otowi Member occurred at the orifice plate of the deep-extraction borehole during the passive venting stage of the pilot test. Airflow data for the shallow-extraction borehole, however, indicated the borehole was passively venting air to the atmosphere during late morning and early afternoon. Eight significant airflow events were observed from the shallow-extraction well with maximum airflow rates ranging from 4 to 10 scfm. Each event typically lasted less than 12 h. These passive venting events are shown as airflow (measured in scfm) from the shallow-extraction borehole (Figure 4.4-1). Figure 4.4-2 shows VOC concentrations measured at the shallow-extraction borehole during passive venting to the atmosphere. Based on VOC mass-removal calculations using the variable airflow and B&K readings, approximately 0.7 lb of VOCs was removed during the deep-extraction test period. Figure 4.4-3 shows both the estimated cumulative VOCs and individual VOCs removed during the passive venting. Elevated TCA concentrations appear to correlate with higher airflow rates observed on September 26, 2008, and from September 30 to October 5, 2008. The concentrations of TCA ranged from 100 ppmv to 160 ppmv.

4.5 Tritium Sampling

Tritium samples were collected from both the shallow- and the deep-extraction boreholes at the wellhead riser, upstream of the SVE system, during the active extraction phases of the pilot test to evaluate whether tritium was present in the extracted vapor. An additional tritium sample was collected from the shallow-extraction borehole following active shallow extraction. All samples were submitted to the Laboratory's Sample Management Office and analyzed at an off-site analytical laboratory. The analytical results for the tritium samples are presented in Table 4.5-1.

Tritium was detected in the pore-gas sample collected from the shallow-extraction borehole during active shallow extraction at a concentration of 432,600 pCi/L and in the sample collected following active extraction at a concentration of 656,900 pCi/L. Tritium was detected in the pore gas sample collected from the deep-extraction borehole during active deep extraction at a concentration of 42,360 pCi/L.

Stack emissions from the GAC canisters were monitored for beta activity approximately every 2 h during the first week of each active extraction test, then approximately once per day for the duration of the active extraction tests. Monitoring was conducted by drawing air through a Swagelok fitting installed at the base of the emission stack using a PTM Model 1812 air sampler calibrated for beta activity. Beta activity was not detected at the emission stack at any time during the pilot study.

5.0 RECOMMENDATIONS FOR DATA ANALYSIS

The data generated during the MDA G SVE pilot test are suitable for evaluating SVE as a treatment technology for remediating the VOC vapor plumes at MDA G. The data are also suitable for developing a site-scale numerical model based on the one developed for MDA L (Stauffer et al. 2000, 069794). This subsurface model can provide a better understanding of how active and passive SVE affects vapor-phase VOC plumes within the mesa below MDA G. Once the behavior of the plume is validated, the model can be used to design a full-scale SVE system to control future vapor plume growth and to remediate the plumes.

6.0 CONCLUSIONS

The results of the MDA G SVE pilot test indicate that SVE is an effective method for extracting vapor-phase VOC contamination from higher permeability geologic units in the vadose zone beneath MDA G. The mass of VOCs removed from the subsurface at MDA G during the different phases of the pilot study are summarized in Table 6.0-1. Approximately 278 lb of VOCs was removed from the shallow-extraction borehole during the 30-d active shallow-extraction phase of the pilot study. Lower airflow was observed in the deep-extraction borehole installed within the Otowi Member. Low airflow, combined with historically lower concentrations of VOCs at this depth, resulted in the removal of approximately 15 lb of VOCs from the deep-extraction borehole during the 30-d active deep-extraction phase of the pilot study. The SVE pilot test also provided data to validate the conceptual model for vapor transport at MDA G. The validated model can be used to aid in the development of a vapor plume treatment strategy for MDA G.

Passive airflow monitoring in the shallow-extraction borehole indicates that changes in barometric pressure can result in airflow out of the Tshirege Member, typically during late morning and early afternoon hours. Monitoring during these times also indicates that VOCs are present in the exhaled air. Approximately 0.7 lb of VOCs was removed during the 14-d passive monitoring period following the 30-d active deep-extraction phase of the pilot study. Passive airflow out of the shallow formation indicates that an SVE remediation strategy that uses both active and passive venting phases may increase the overall removal of vapor-phase VOCs from the subsurface. However, such a strategy requires further evaluation and is beyond the scope of this report.

Permeability testing was conducted in each extraction borehole at 5-ft intervals to provide detailed permeability data for model calibration (Appendix C). However, the results of the permeability testing were inconclusive in defining the permeability of specific stratigraphic units and probably underestimate the actual permeability as a result of the sampling system design. The method used to determine permeability assumed downhole instrumentation and did not allow for the effects of sample tubing (e.g., friction loss) on measured values. During this test, differential pressure readings were obtained at the surface using a manometer when they should have been obtained from a pressure transducer located downhole. Because the permeability values obtained as part of the MDA G SVE pilot study are inconclusive, the values are not appropriate for modeling purposes.

Although the results of stratigraphic-specific permeability testing were inconclusive, bulk permeability values could be calculated for each extraction borehole based on the observed extraction airflow rates. Bulk permeability values and stratigraphic-specific permeability values previously determined at MDA L were used to numerically model the radii of influence for the active shallow- and active deep-extraction tests. The two-dimensional model conservatively estimates the radii of influence to be approximately 100 ft for the shallow-extraction interval and approximately 25 ft for the deep extraction interval. Results of the modeling effort estimated the range of permeability values in the Tshirege Member to be approximately 3.95×10^{-12} m^2 to 7.61×10^{-12} m^2. Permeability in the Otowi Member was estimated to be approximately 1.31×10^{-12} m^2 (Laboratory report in preparation).

According to the U.S. Environmental Protection Agency's (EPA) guidance for evaluating alternative cleanup technologies for underground storage tank sites (EPA 2004, 104515), the key parameters for evaluating the suitability of SVE are based primarily on the intrinsic permeability of the contaminated soils and the volatility, or vapor pressure, of the chemicals of concern. Additional site-specific parameters, including soil structure and stratification, depth to groundwater, and soil moisture content, should also be considered. Additional chemical-specific parameters, including boiling point and Henry's law constants, are also considered.

The EPA states that intrinsic permeability of the contaminated soil is the single most important factor in determining the effectiveness of SVE and should be greater than 10^{-12} m^2. Permeability values estimated for the Tshirege Member ranged from approximately 3.95×10^{-12} to 7.61×10^{-12} m^2, which are higher than those recommended by EPA. The estimated permeability value for the Otowi Member was approximately 1.31×10^{-12} m^2, which is slightly higher than EPA's recommendation.

The EPA also states that vapor pressure is the single most important contaminant characteristic in evaluating the applicability and potential effectiveness of an SVE system. Contaminants with vapor pressures greater than 0.5 mm Hg, boiling points less than 250° C, and Henry's law constants greater than 100 atmospheres (atm) are generally considered amenable for SVE. Table 2.3-1 shows the vapor pressures and other important chemical and physical properties for chemicals of concern at MDA G. The vapor pressure, boiling point, and Henry's law constants for each VOC at MDA G indicate they are amenable to SVE.

Based on EPA guidance regarding site- and chemical-specific parameters for determining the suitability of SVE, conditions at MDA G meet or exceed the EPA recommendations.

Tritium is not expected to be amenable to SVE because it has a dimensionless Henry's law constant on the order of 1×10^{-5} (LANL 2003, 076039, p. I-1). This conclusion is consistent with the EPA directive on the use of SVE as a presumptive remedy for VOCs in soil (EPA 1996, 103427). The directive indicates that SVE is not effective with contaminants having a dimensionless Henry's law constant of less than 0.01. In addition, tritium is almost entirely present in the liquid phase rather than as a vapor at MDA G.

7.0 REFERENCES AND MAP DATA SOURCES

7.1 References

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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7.2 Map Data Sources

Legend Item	Data Source
Extraction borehole	Graphic layer depicting approximate location of the SVE extraction boreholes. Actual locations should be incorporated into the “locations” feature class at a future date (see “Pore gas monitoring borehole” for data source statement).
Fence	Security and Industrial Fences and Gates; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 October 2008.
Laboratory boundary	LANL Areas Used and Occupied; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning; 04 June 2008.
Material disposal area	Materials Disposal Areas; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; ER2004-0221; 1:2,500 Scale Data; 23 April 2004.
Pore gas monitoring borehole	Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2008-0555; 09 October 2008.
Primary paved road Secondary paved road	Road Centerlines for the County of Los Alamos; County of Los Alamos, Information Services; as published 03 December 2007.
Structure	Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 October 2008.
Technical Area boundary TA-54	Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning; 04 June 2008.
Waste disposal shaft Waste disposal pit	Waste Storage Features; Los Alamos National Laboratory, Environment and Remediation Support Services Division, GIS/Geotechnical Services Group, EP2007-0032; 1:2,500 Scale Data; 13 April 2007.

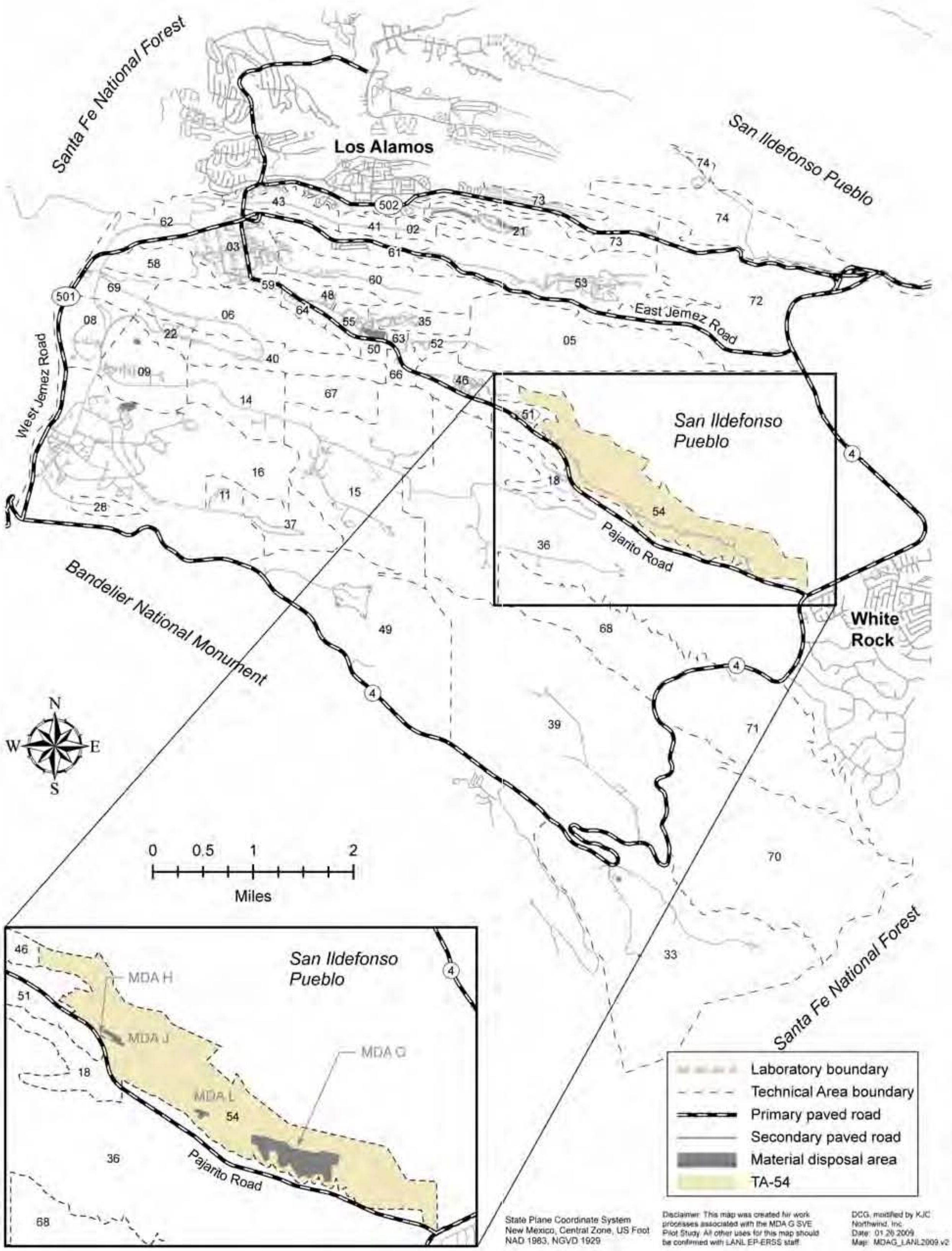

Figure 1.0-1 MDA G with respect to Laboratory TAs and surrounding land holdings

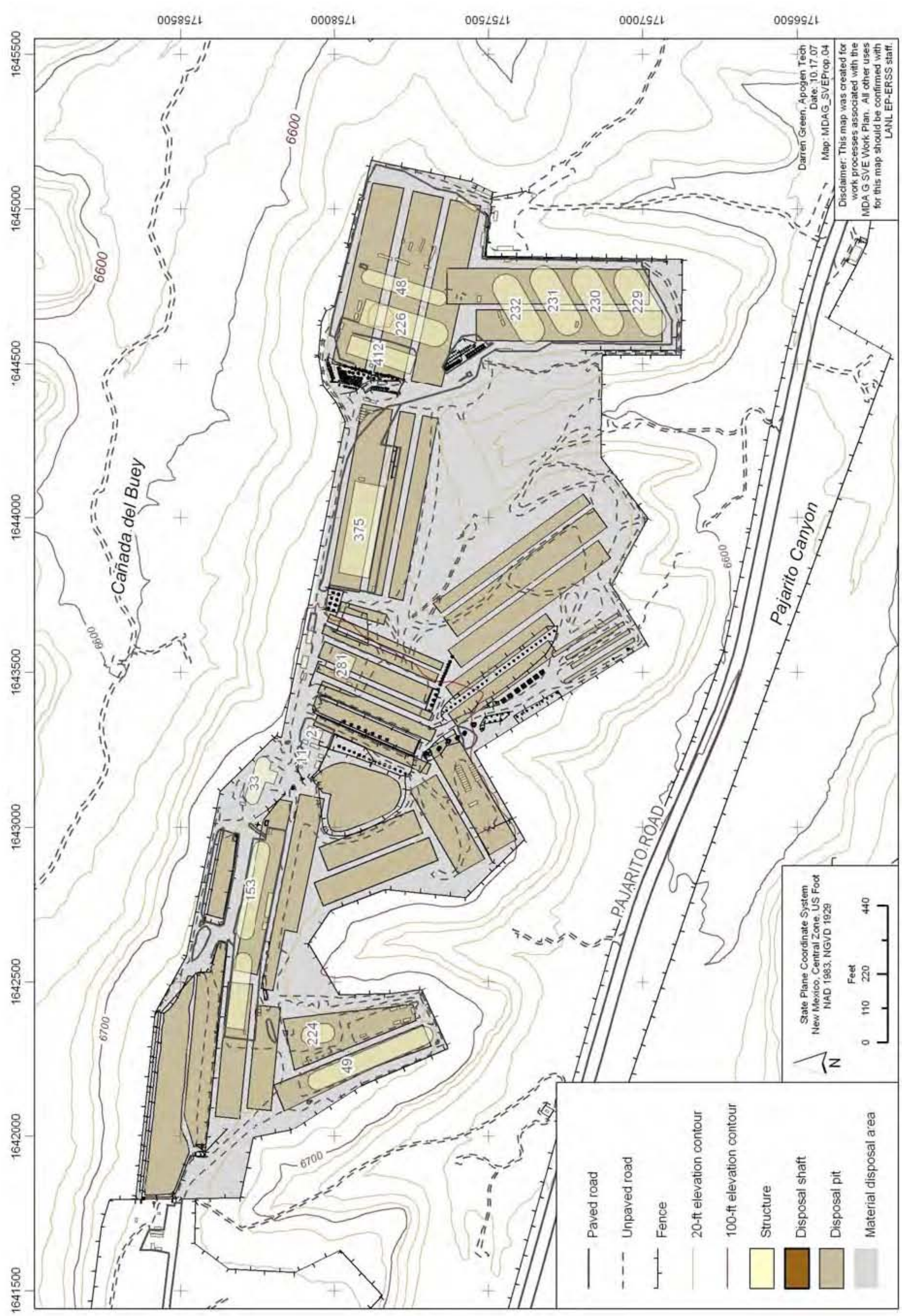

Figure 2.1-1 MDA G site map

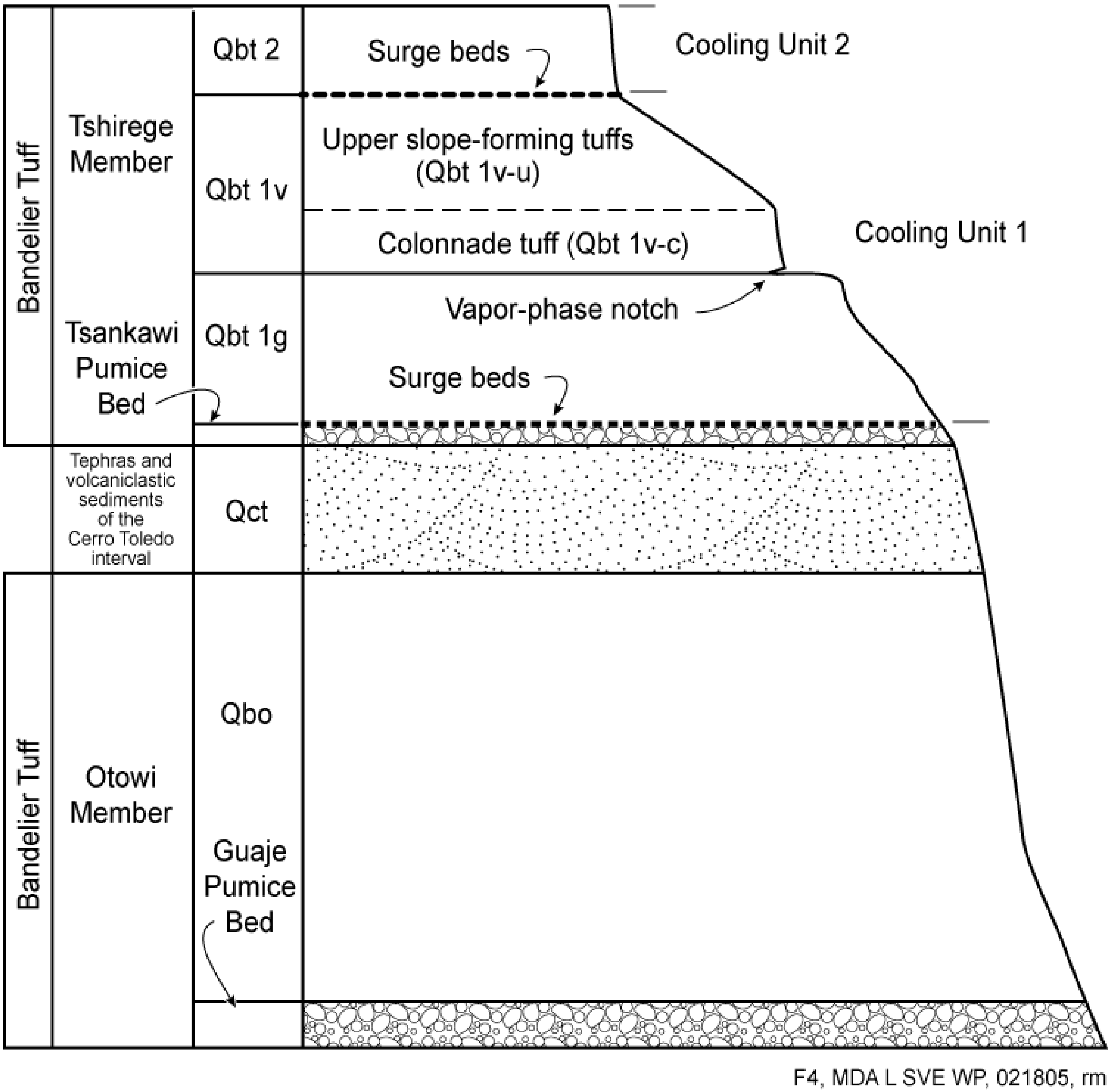

Figure 2.2-1 TA-54 site stratigraphy

Figure 2.3-1 VOC vapor plumes at MDA G

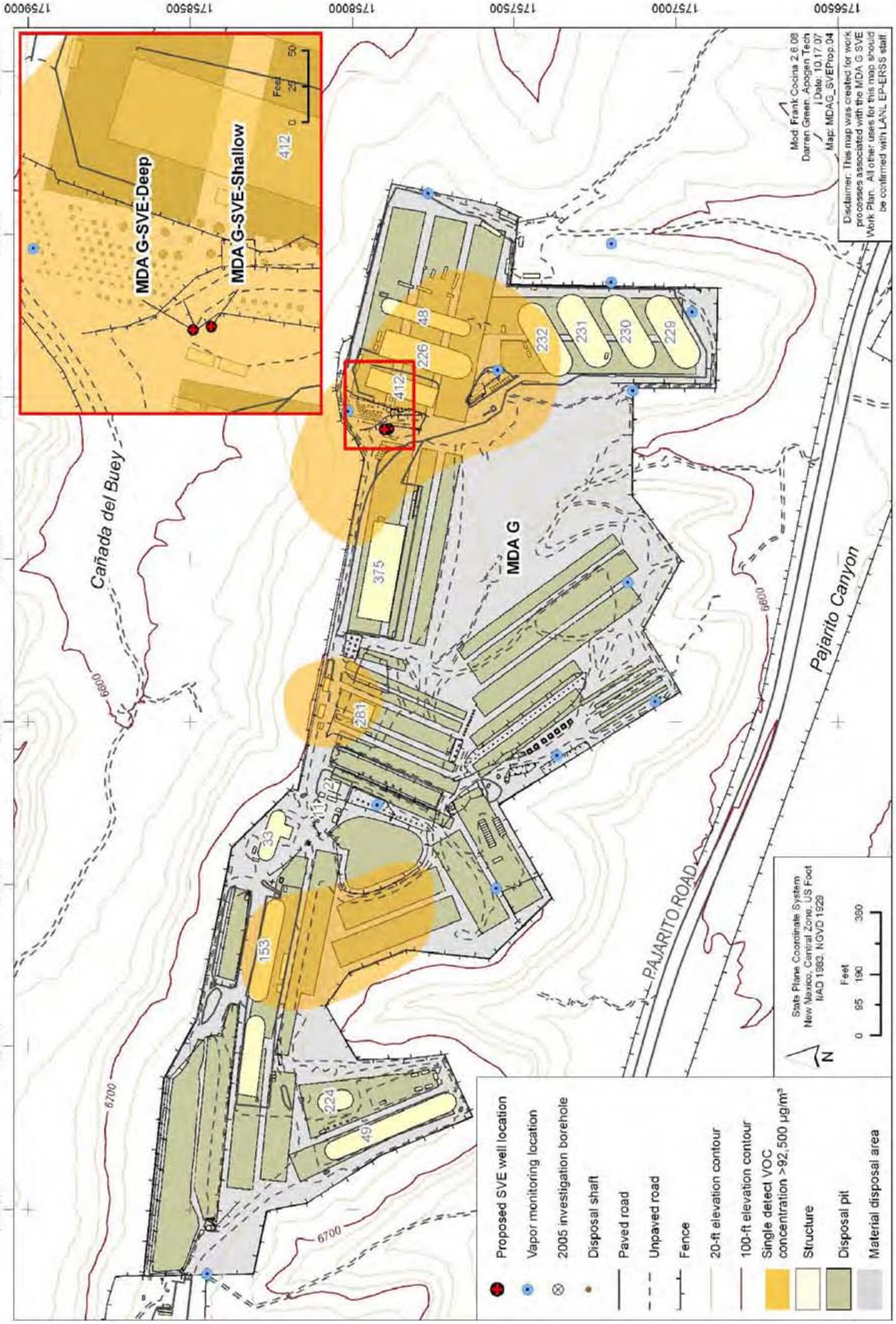

Figure 3.2-1 MDA G SVE pilot test location

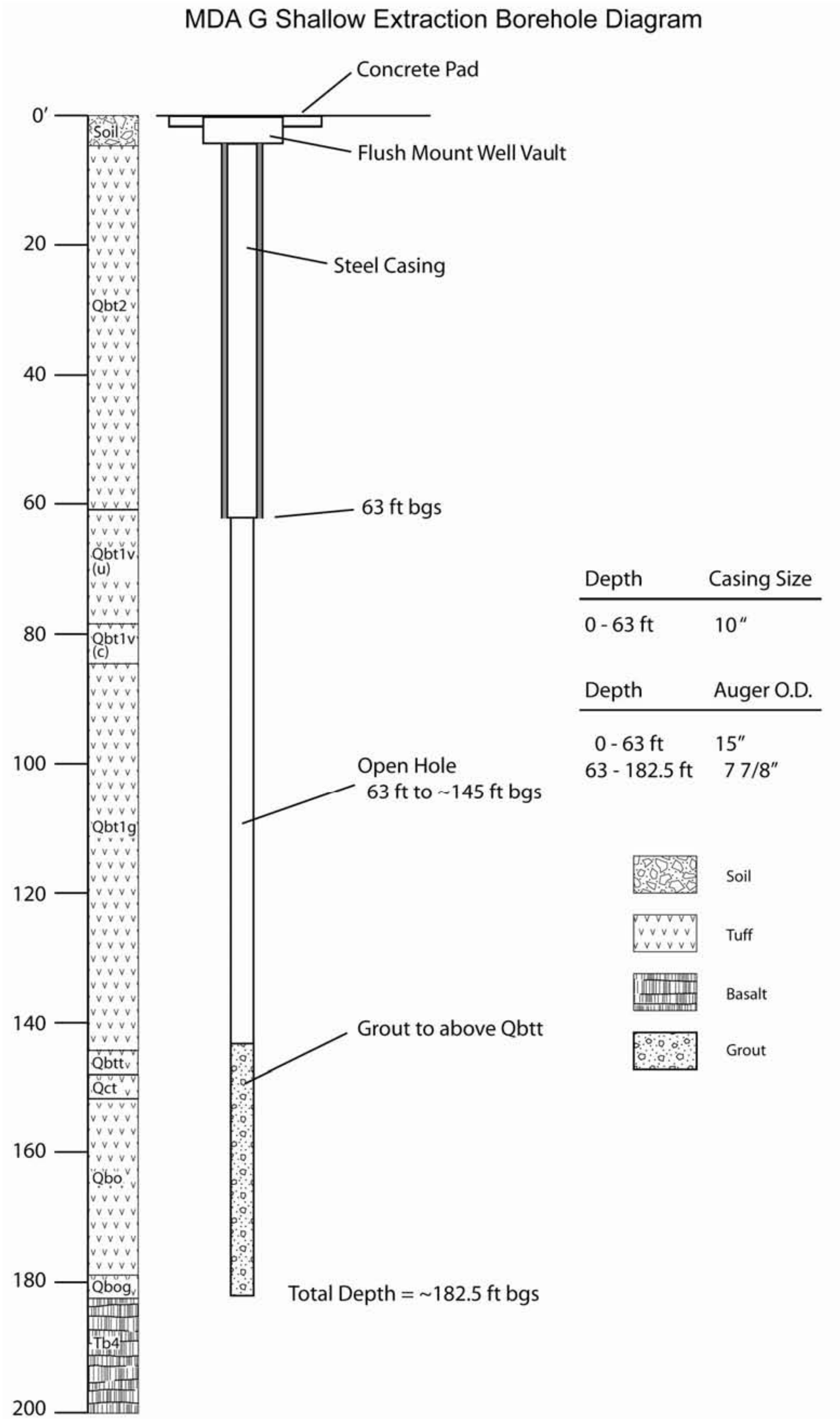

Figure 3.2-2 MDA G shallow extraction borehole completion diagram

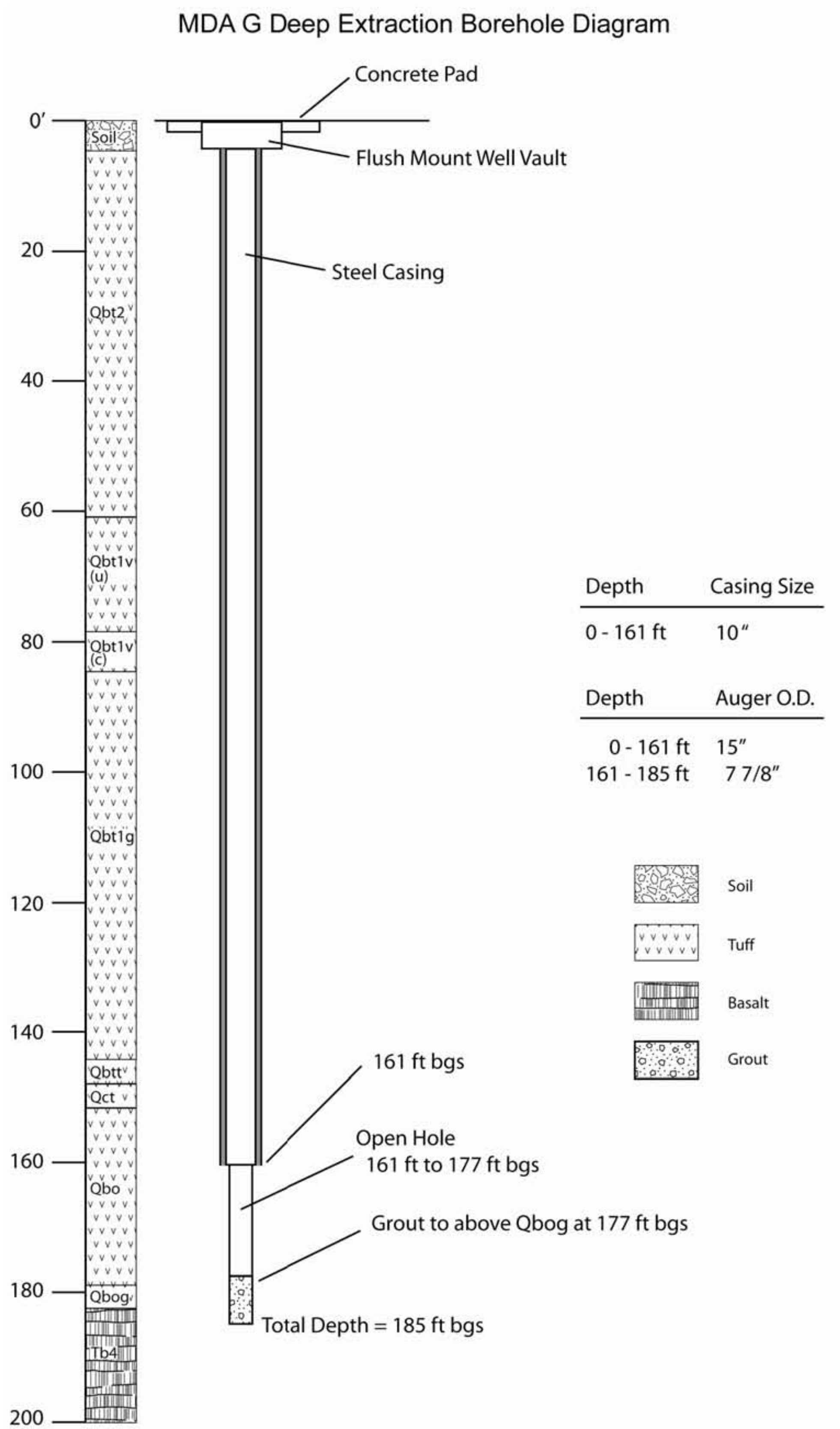

Figure 3.2-3 MDA G deep extraction borehole completion diagram

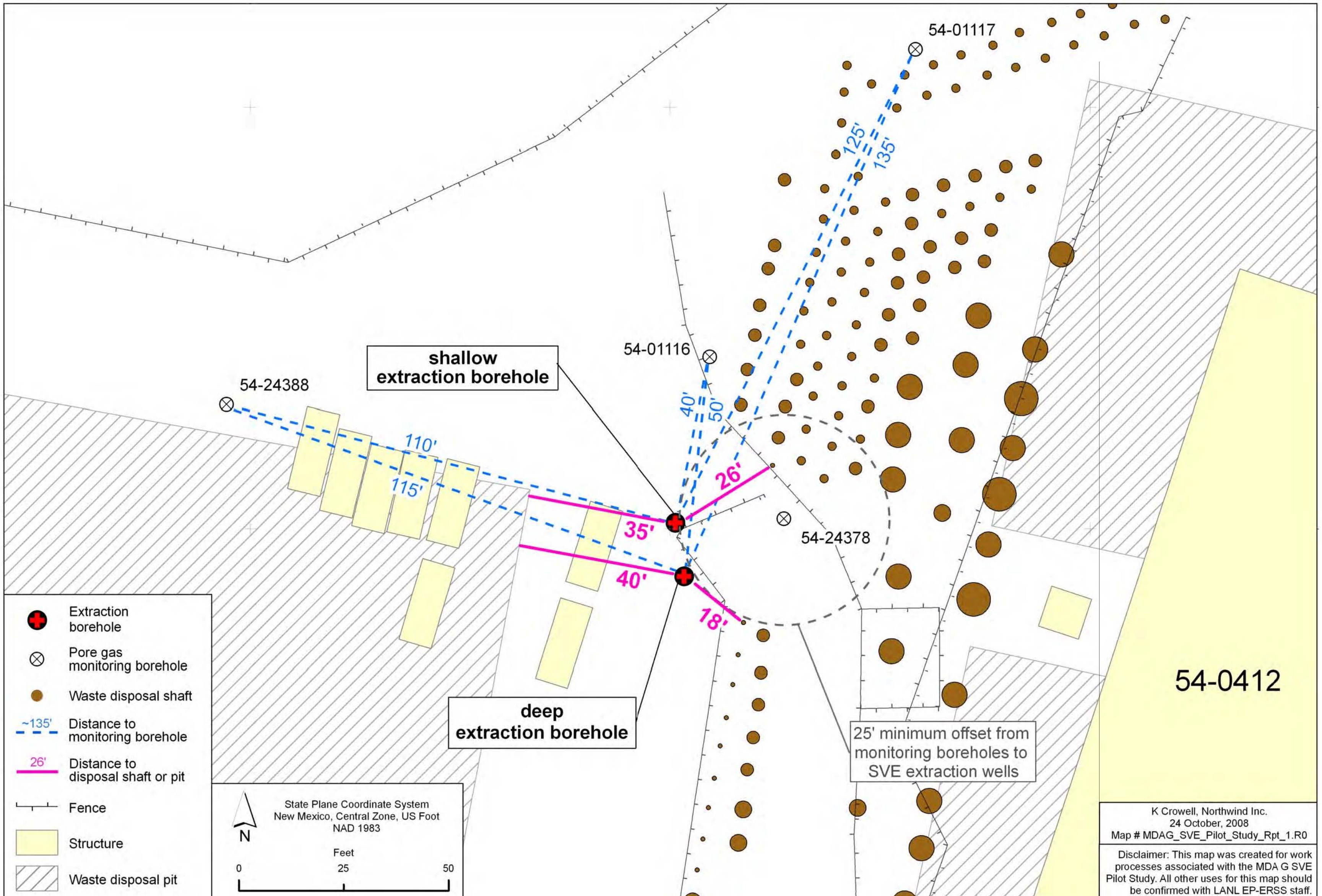

Figure 3.2-4 MDA G SVE pilot test site plan showing extraction and pore-gas monitoring boreholes

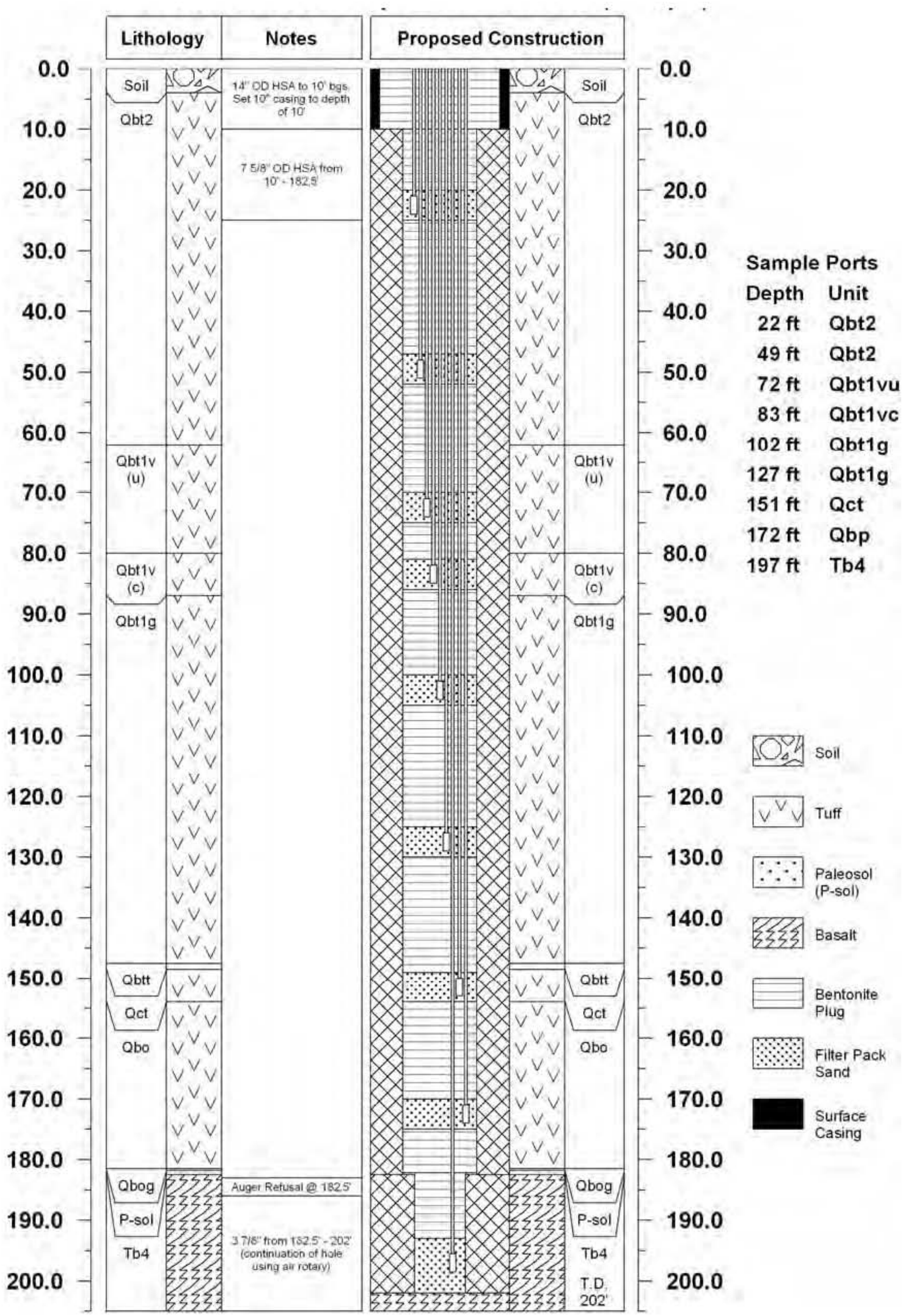

Figure 3.2-5 Typical MDA G SVE pore-gas monitoring well construction diagram

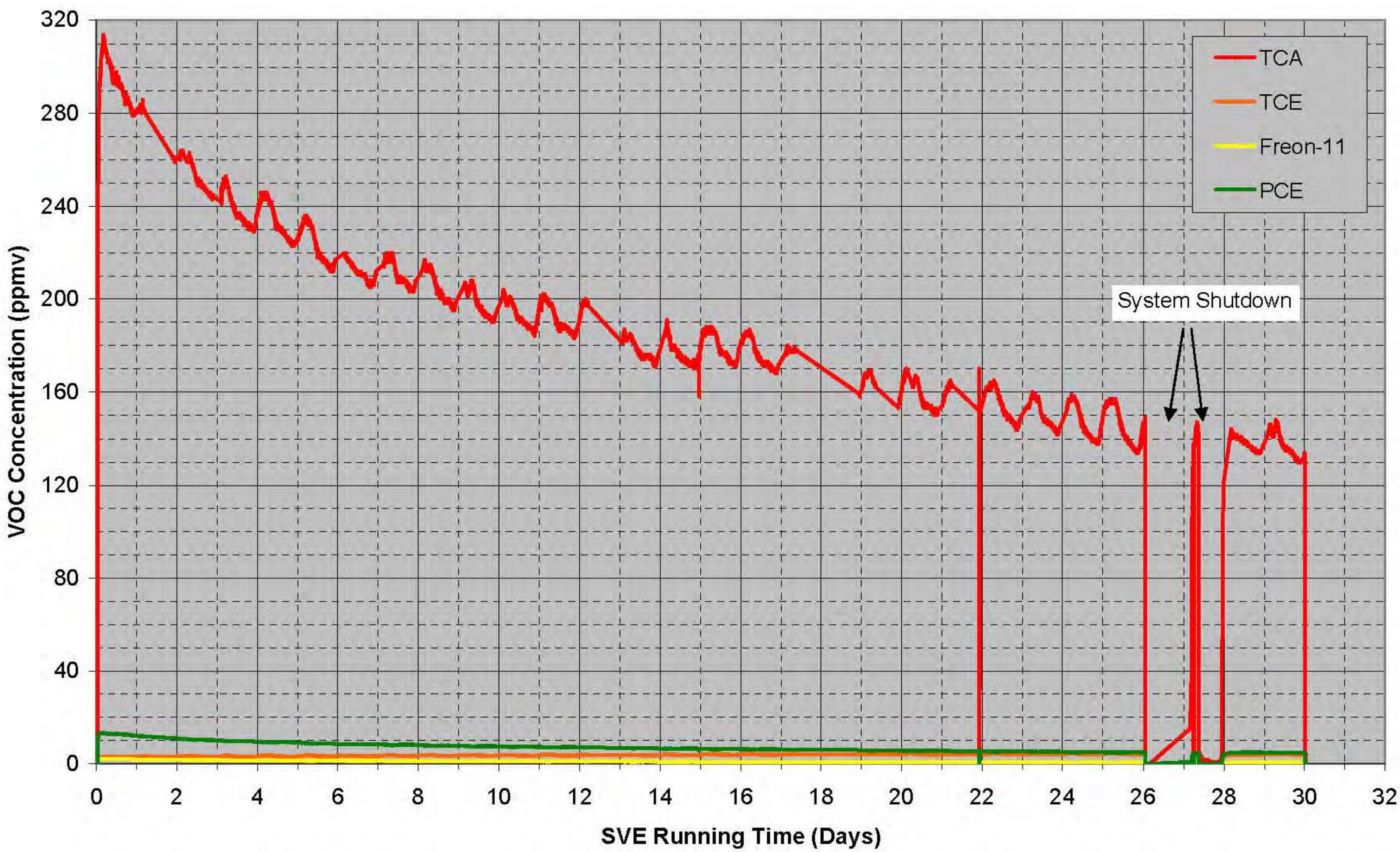

Figure 4.2-1 VOC concentrations measured during the shallow-extraction test

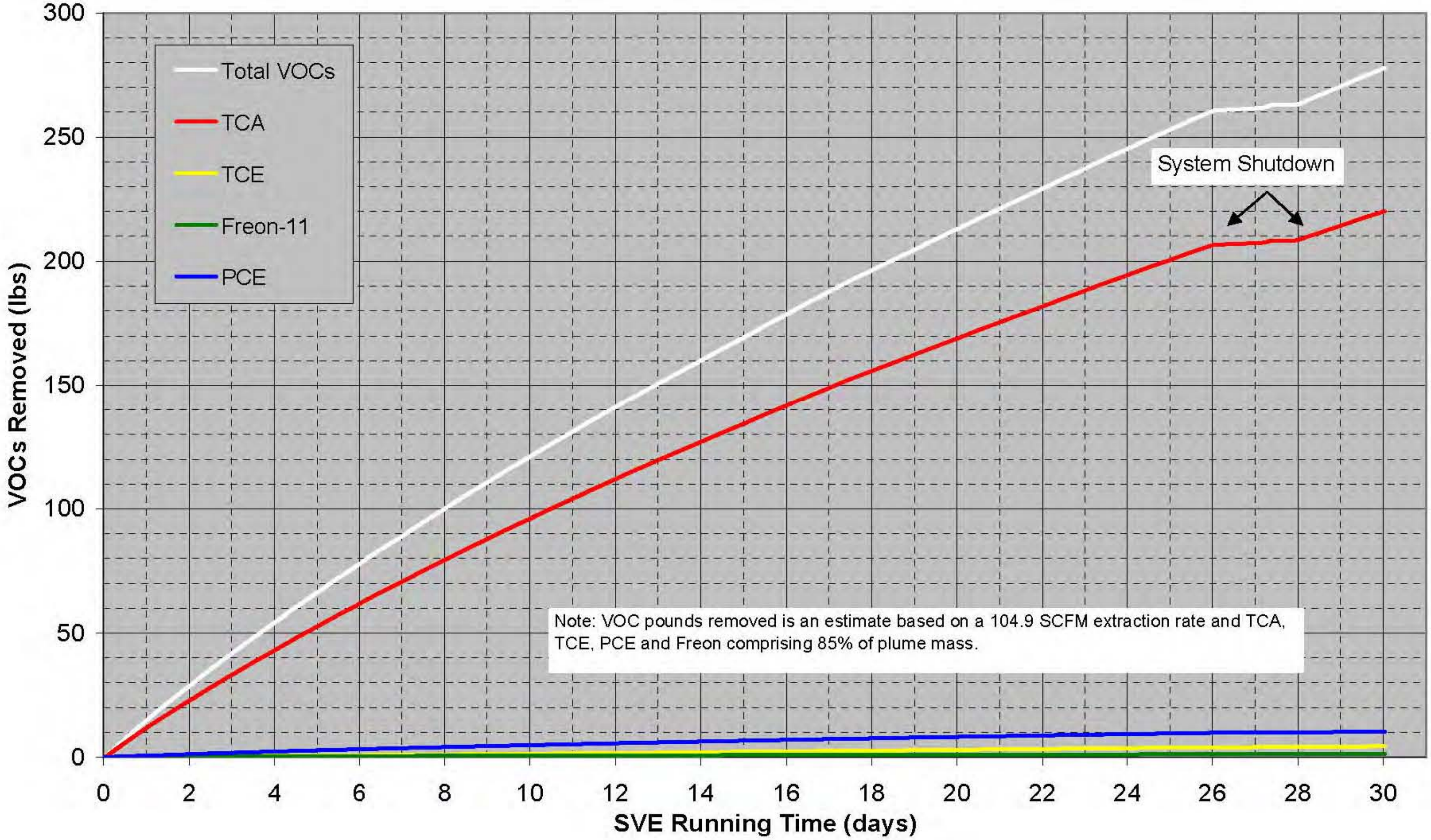

Figure 4.2-2 Estimated mass of VOCs extracted during the shallow-extraction test

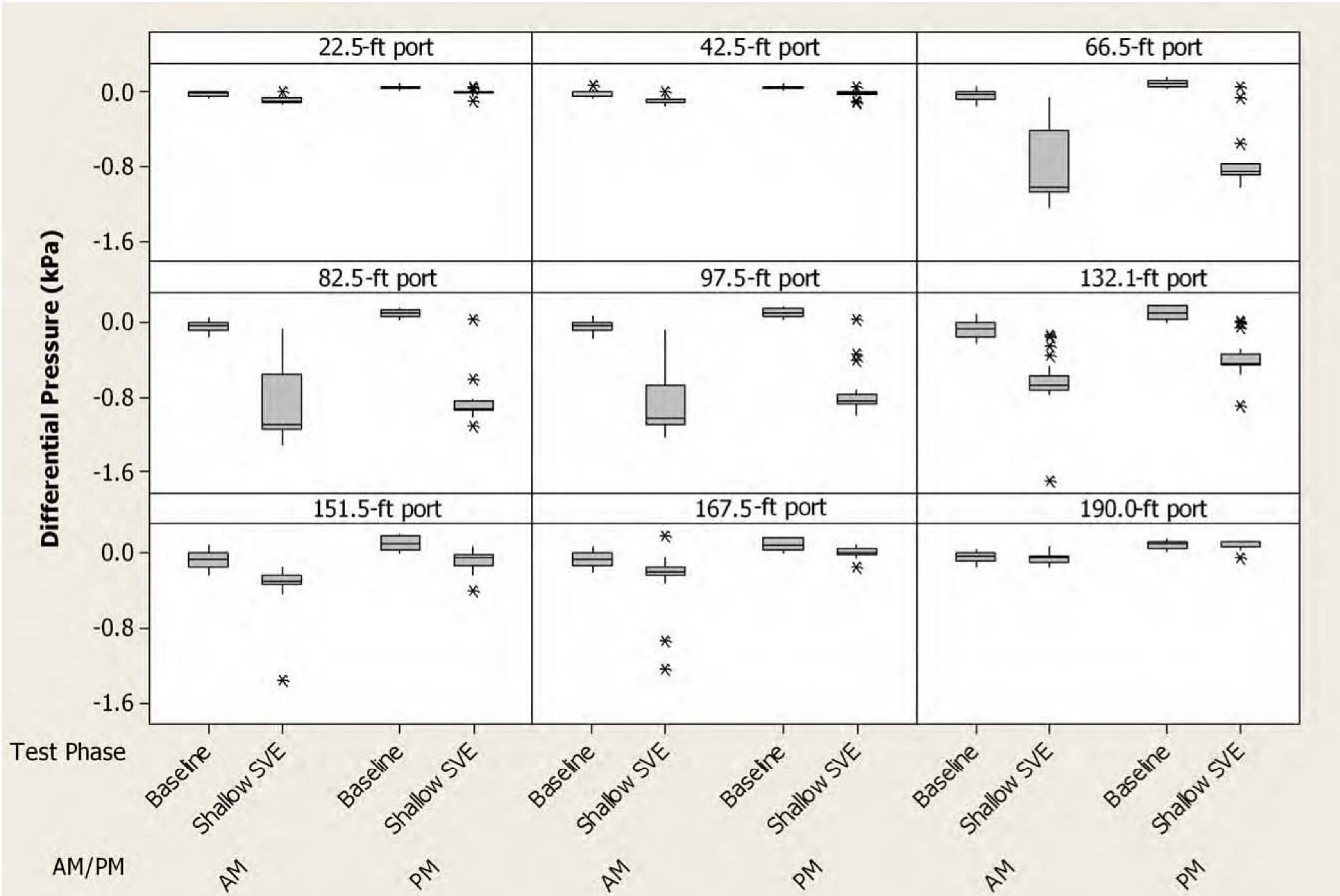

Figure 4.2-3 Comparison of baseline and shallow-extraction test differential pressure measured in borehole location 54-24378

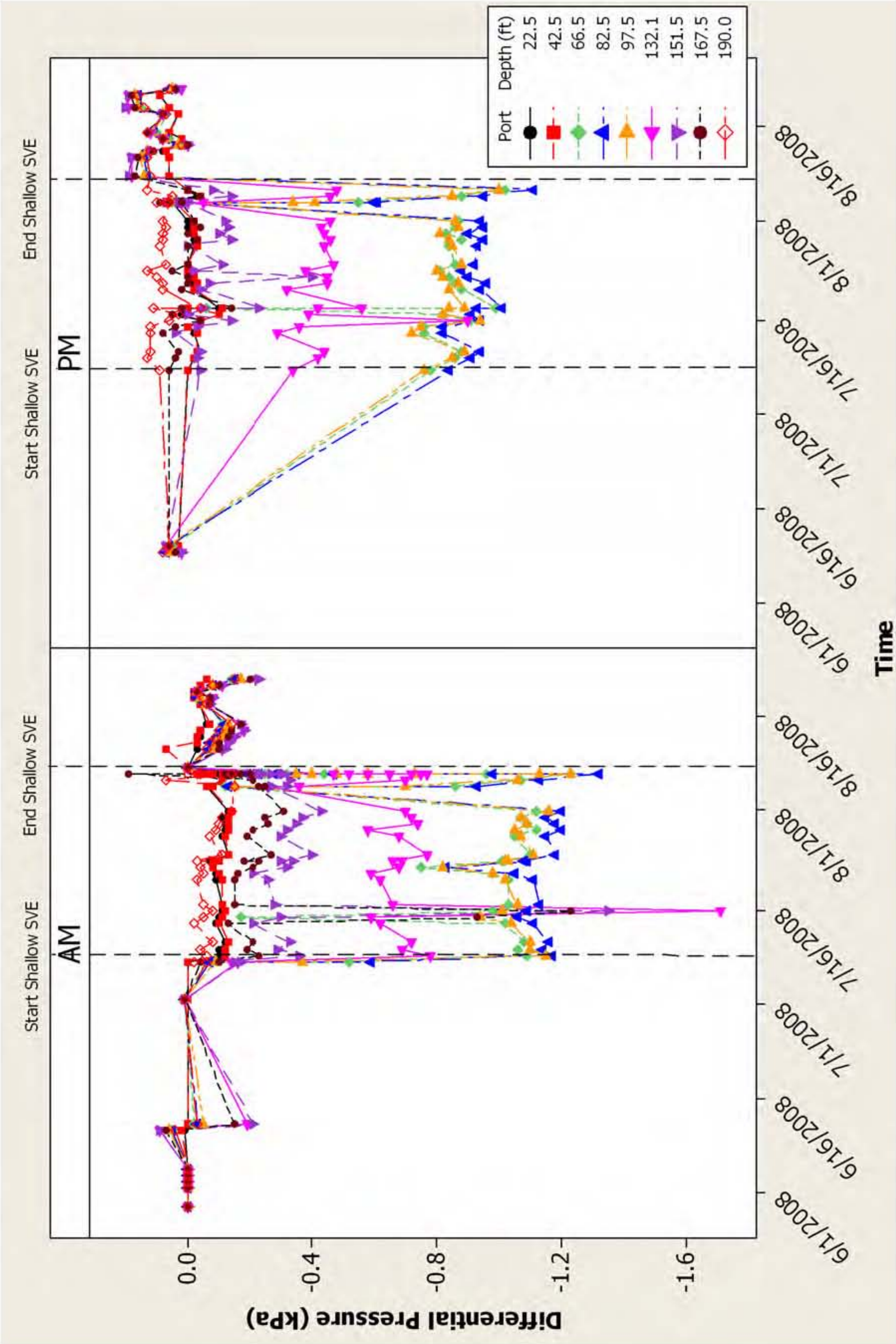

Figure 4.2-4 Differential pressure measured in borehole location 54-24378 during the shallow-extraction test

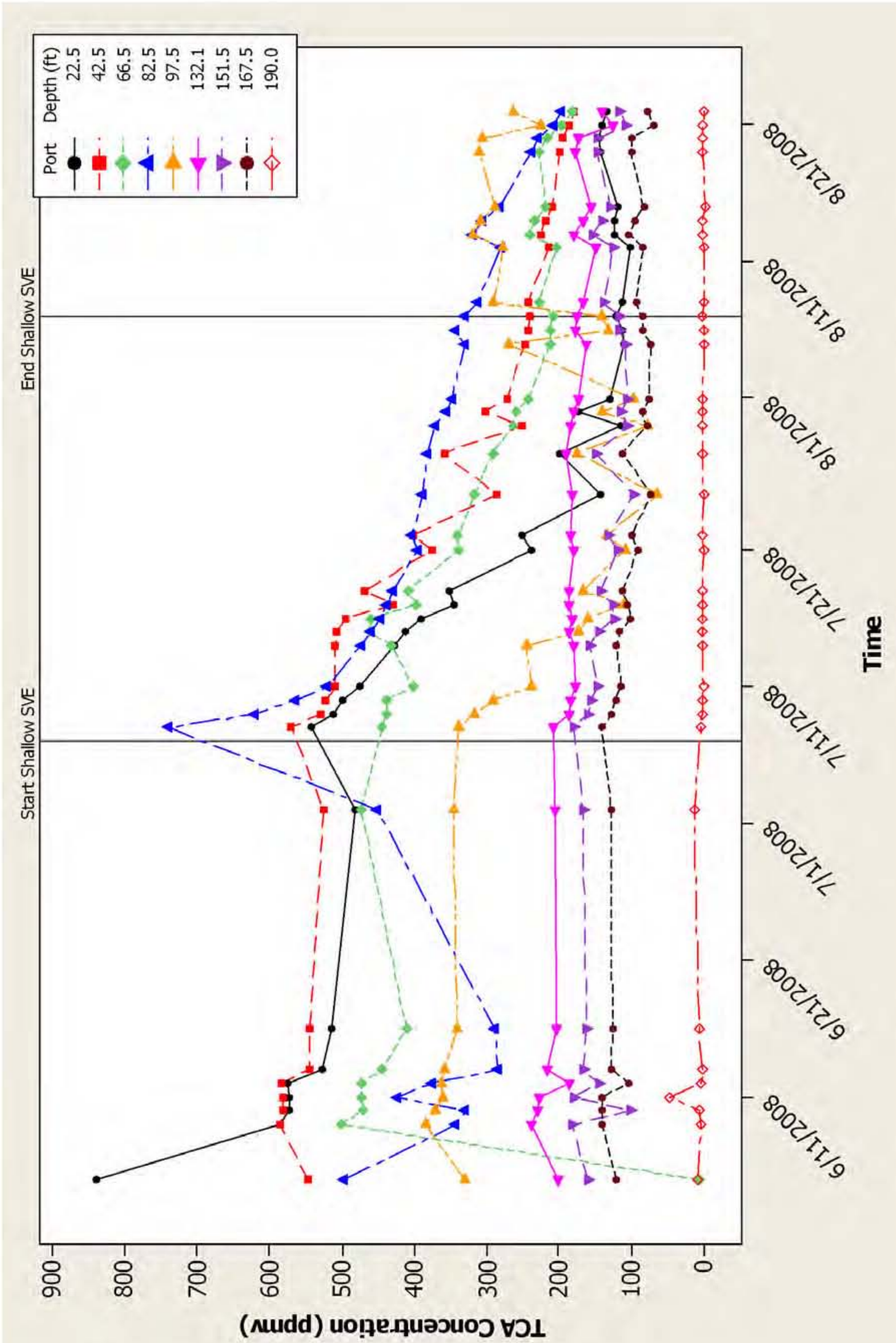

Figure 4.2-5 TCA concentrations measured in monitoring borehole location 54-24378 during the shallow-extraction test

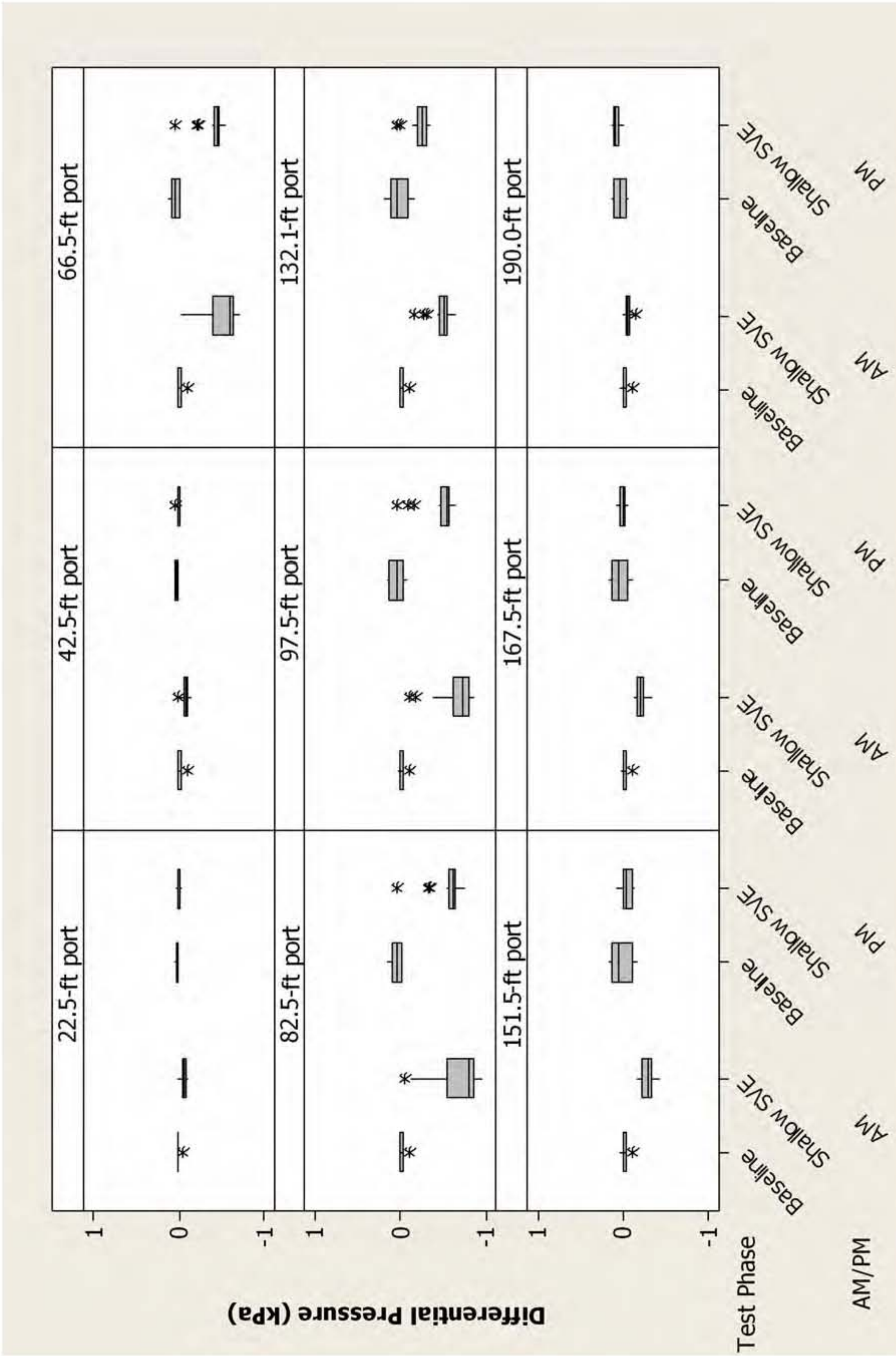

Figure 4.2-6 Comparison of baseline and shallow-extraction test differential pressure measured in monitoring borehole location 54-01116

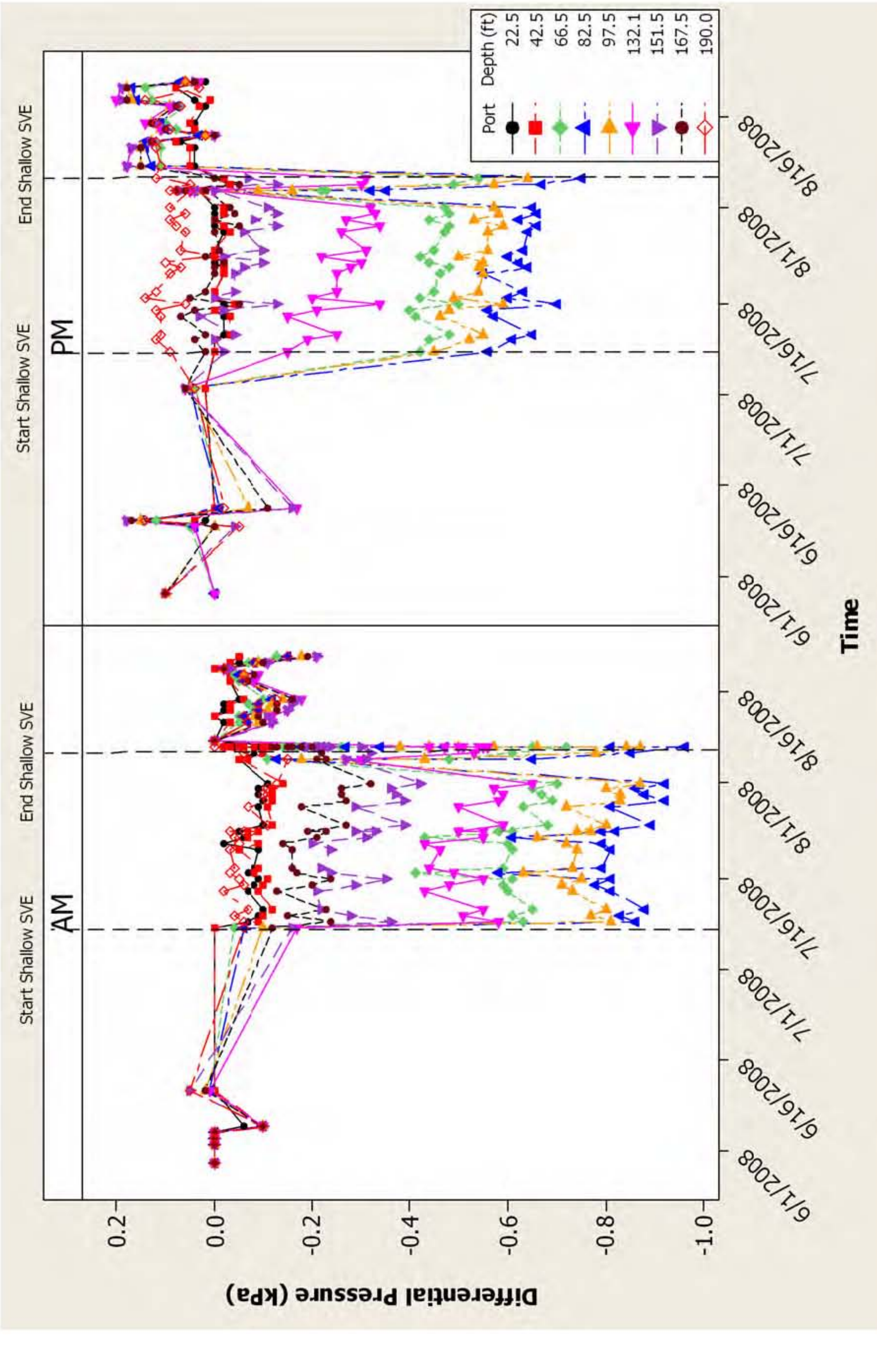

Figure 4.2-7 Differential pressure measured in monitoring borehole location 54-01116 during the shallow-extraction test

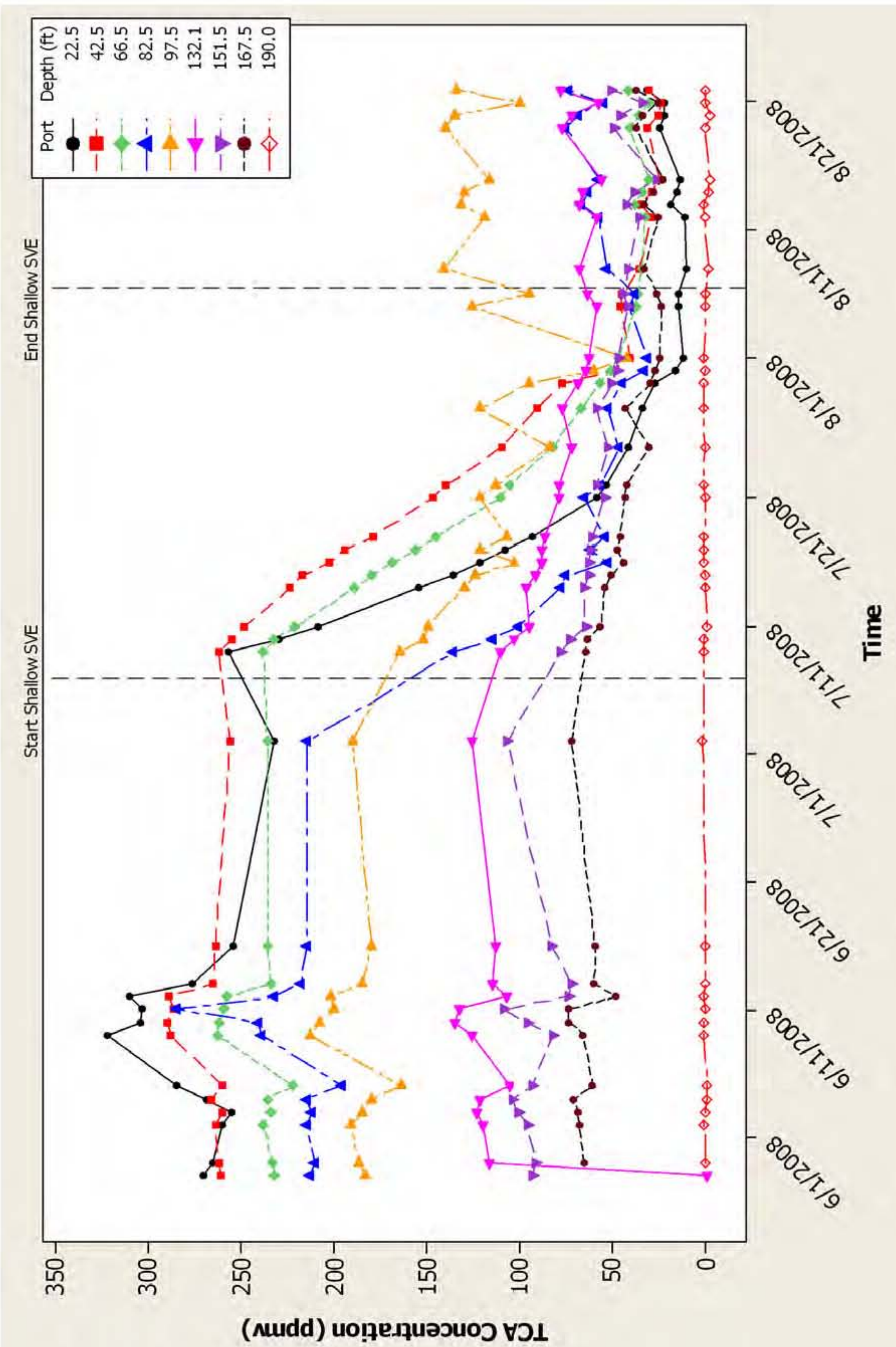

Figure 4.2-8 TCA concentrations measured in monitoring borehole location 54-01116 during the shallow-extraction test

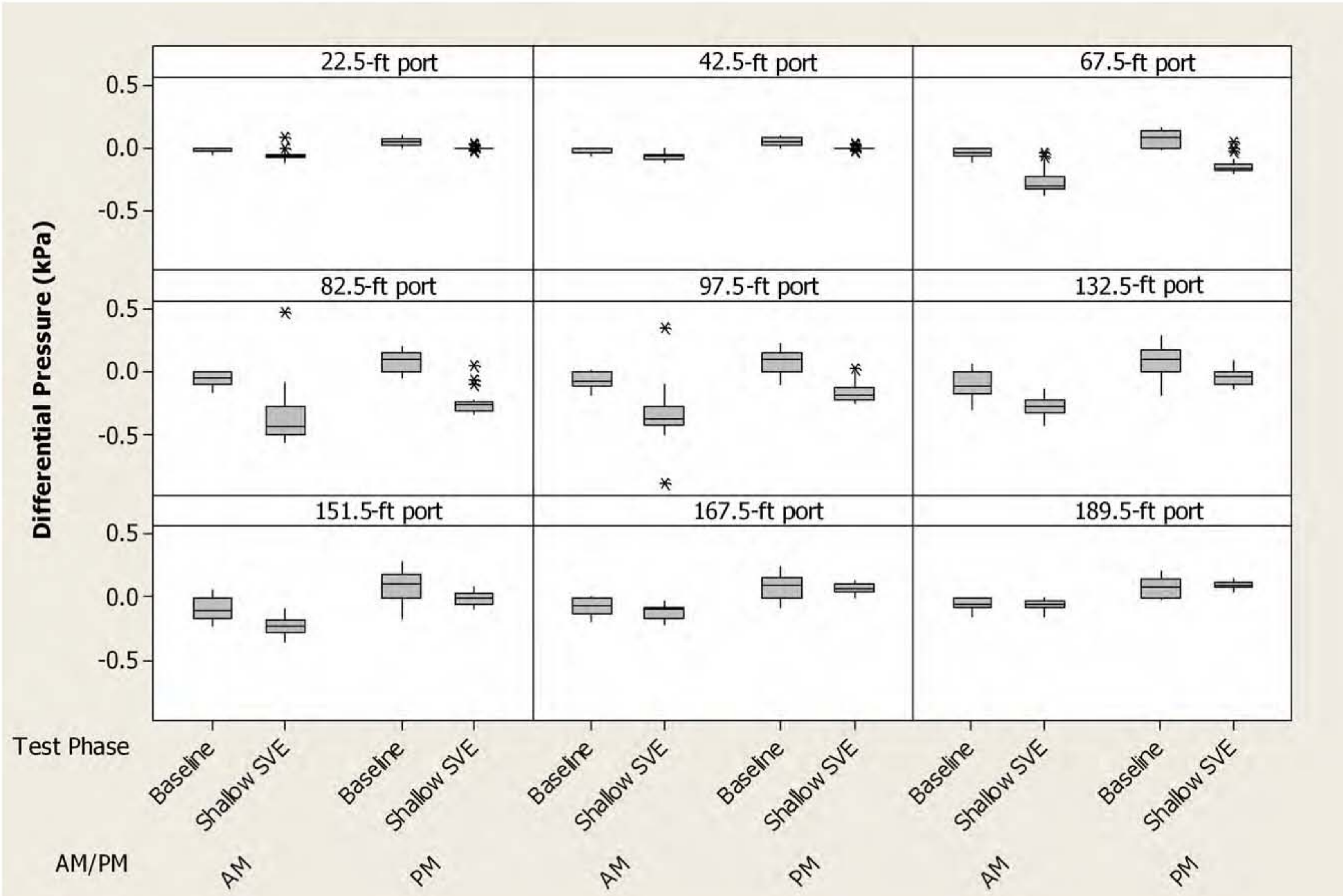

Figure 4.2-9 Comparison of baseline and shallow-extraction test differential pressure measured in monitoring borehole location 54-24388

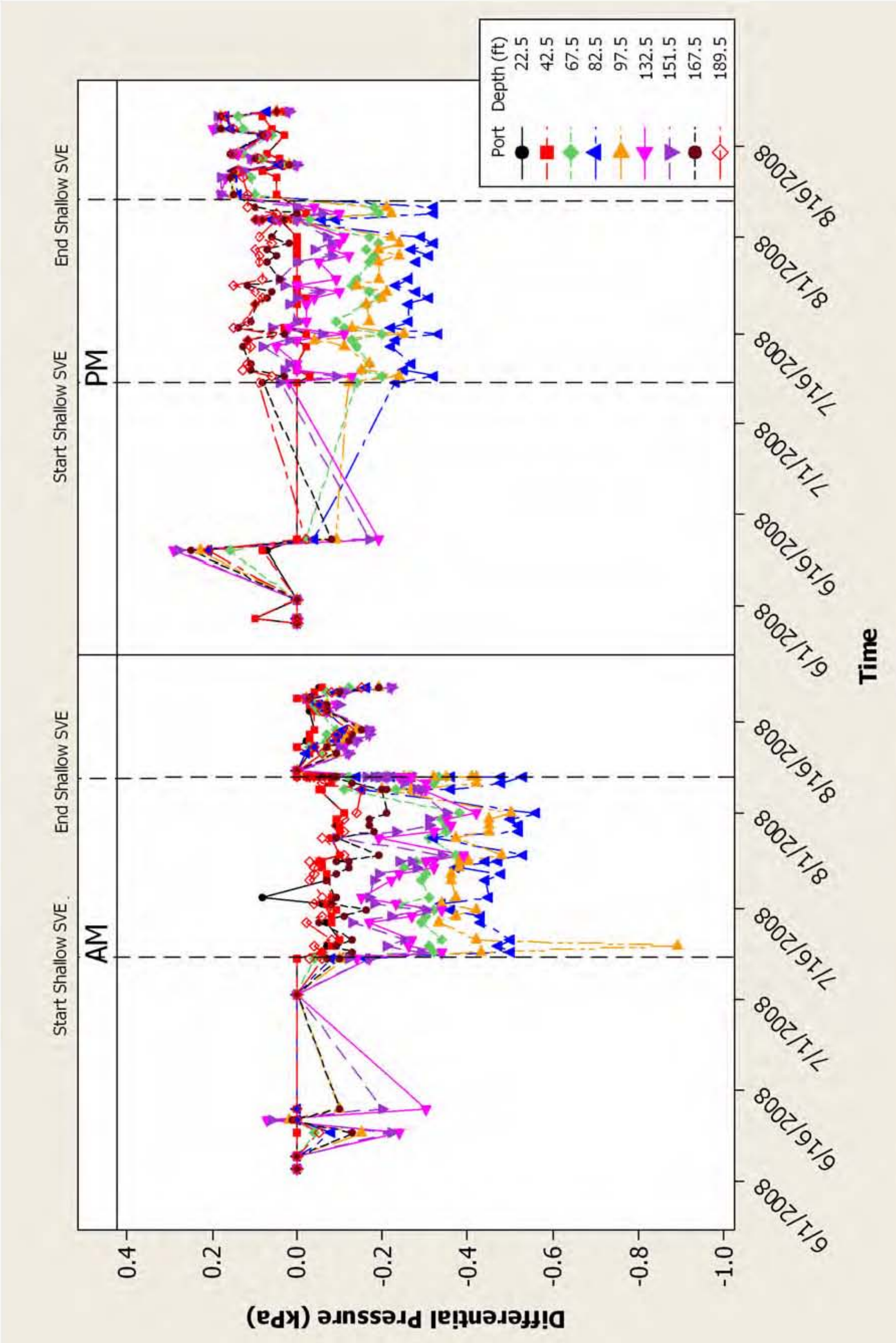

Figure 4.2-10 Differential pressure measured in monitoring borehole location 54-24388 during the shallow-extraction test

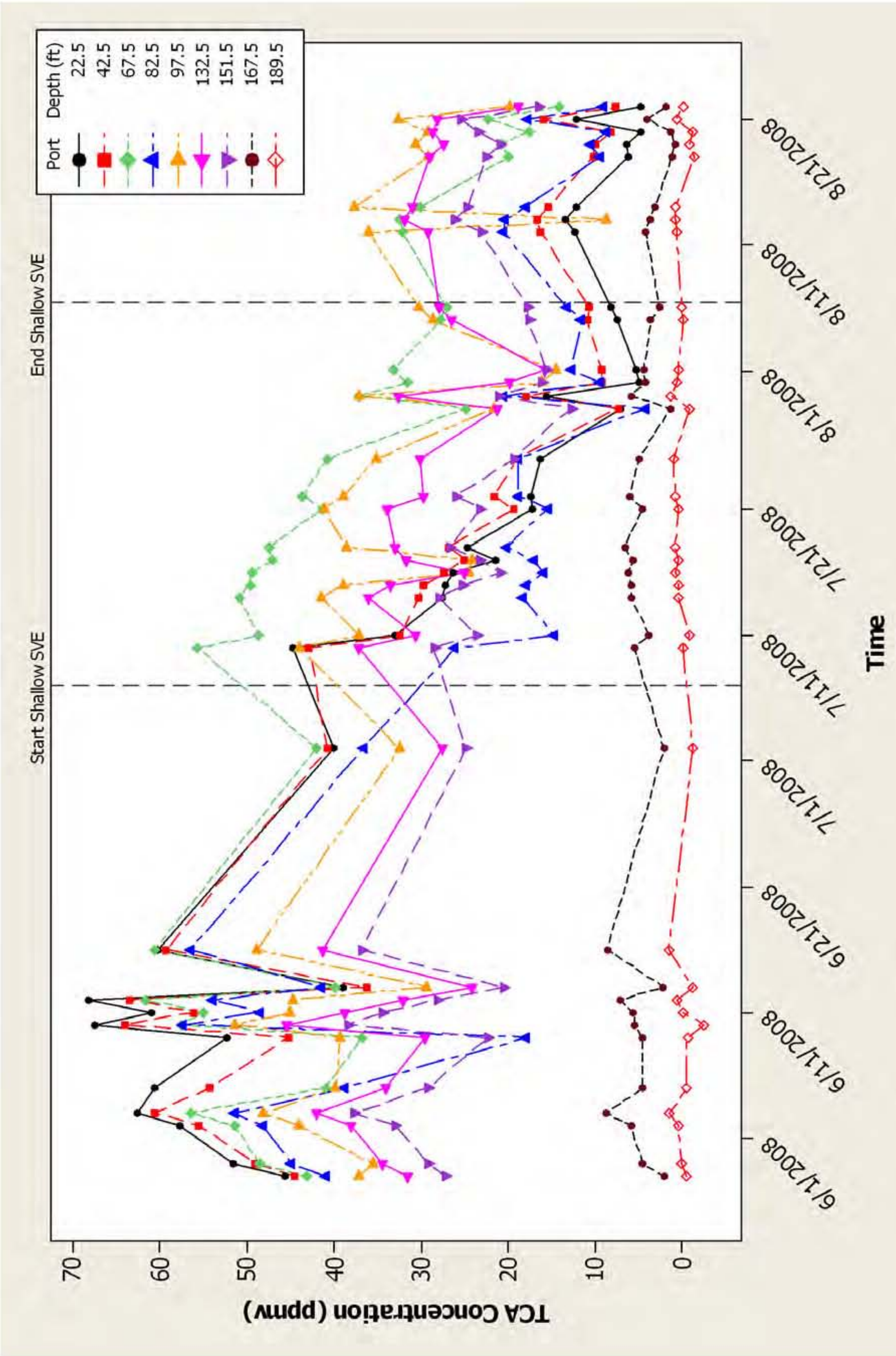

Figure 4.2-11 TCA concentrations measured in monitoring borehole location 54-24388 during the shallow-extraction test

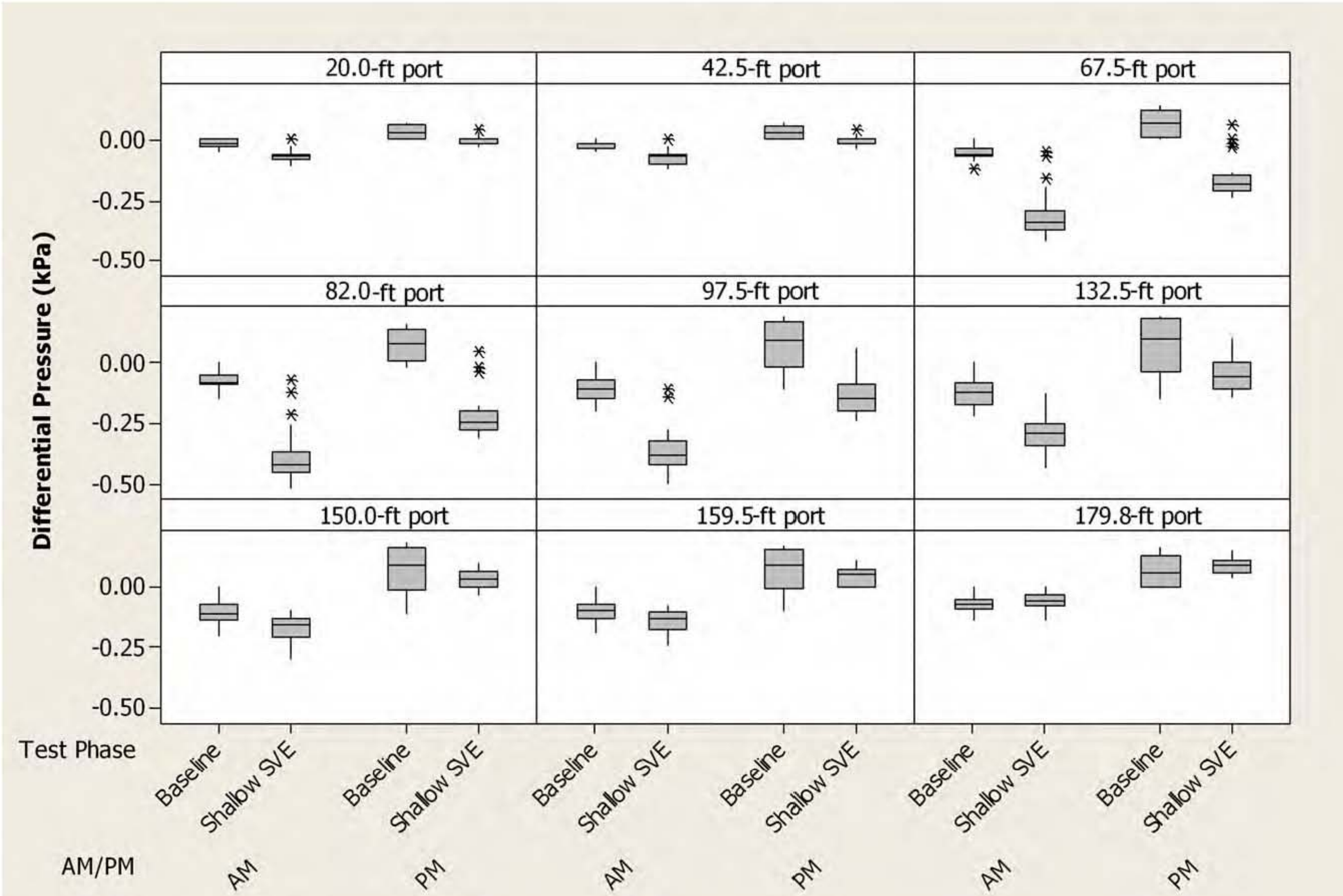

Figure 4.2-12 Comparison of baseline and shallow-extraction test differential pressure measured in monitoring borehole location 54-01117

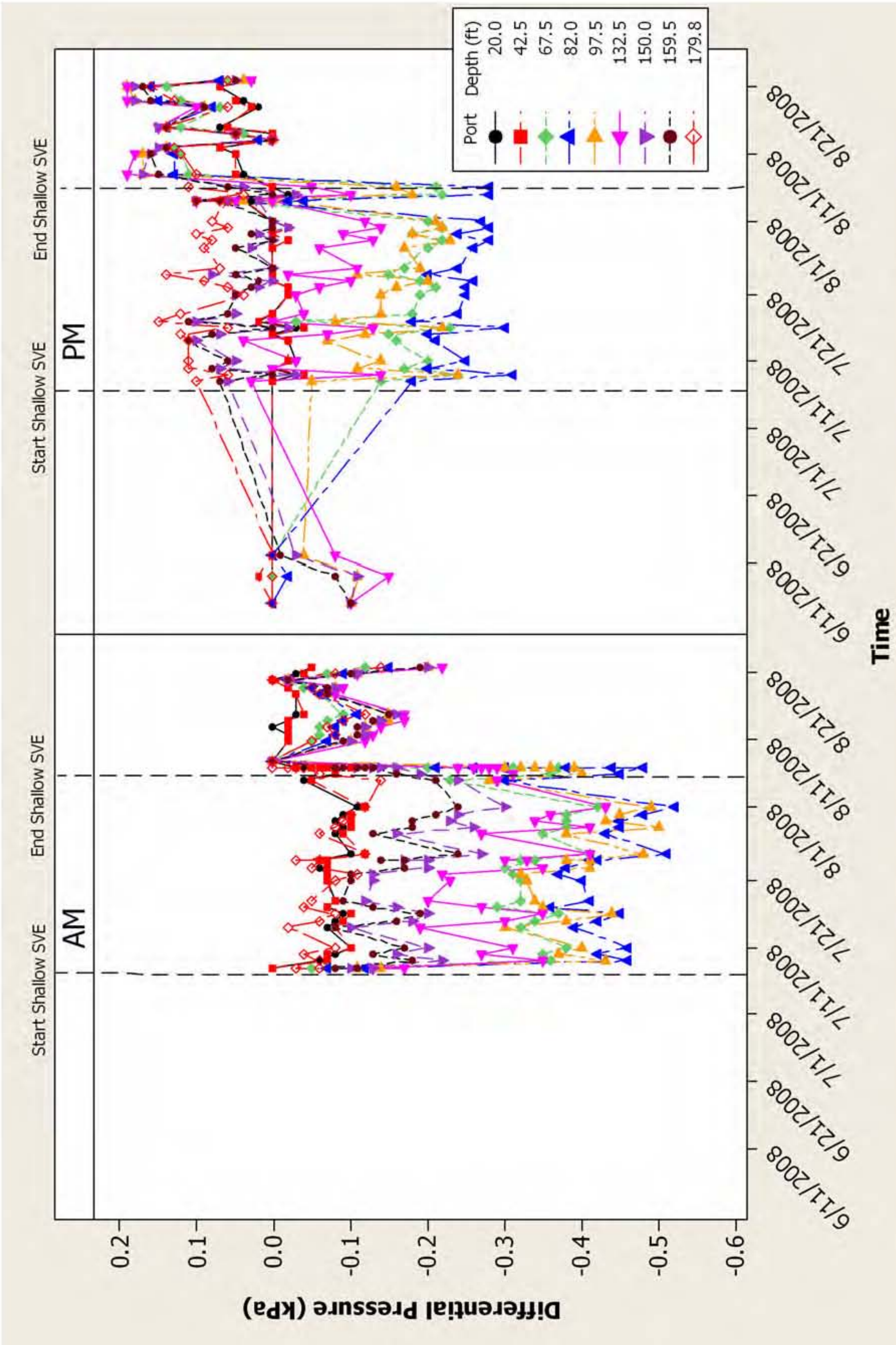

Figure 4.2-13 Differential pressure measured in monitoring borehole location 54-01117 during the shallow-extraction test

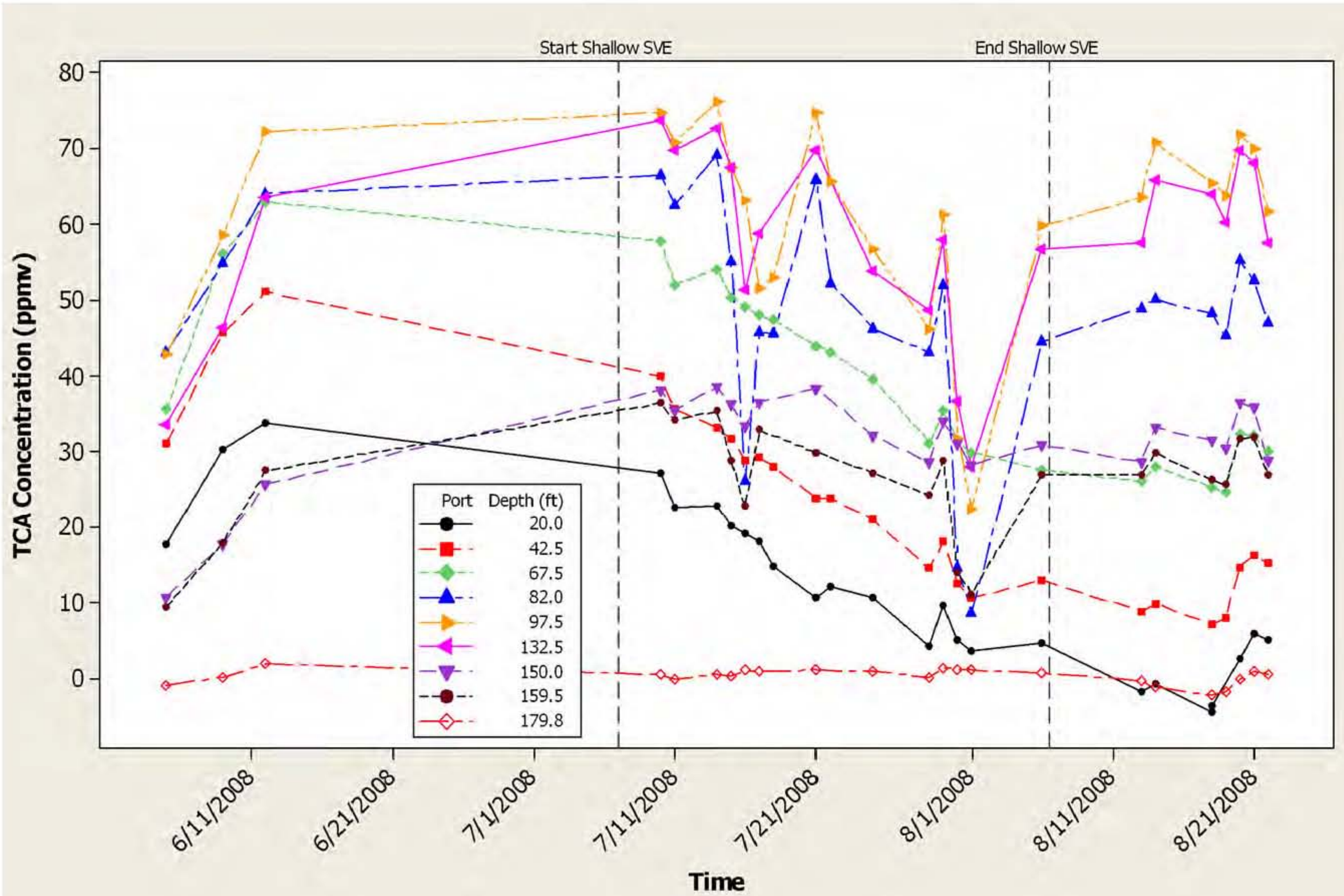

Figure 4.2-14 TCA concentrations measured in monitoring borehole location 54-01117 during the shallow-extraction test

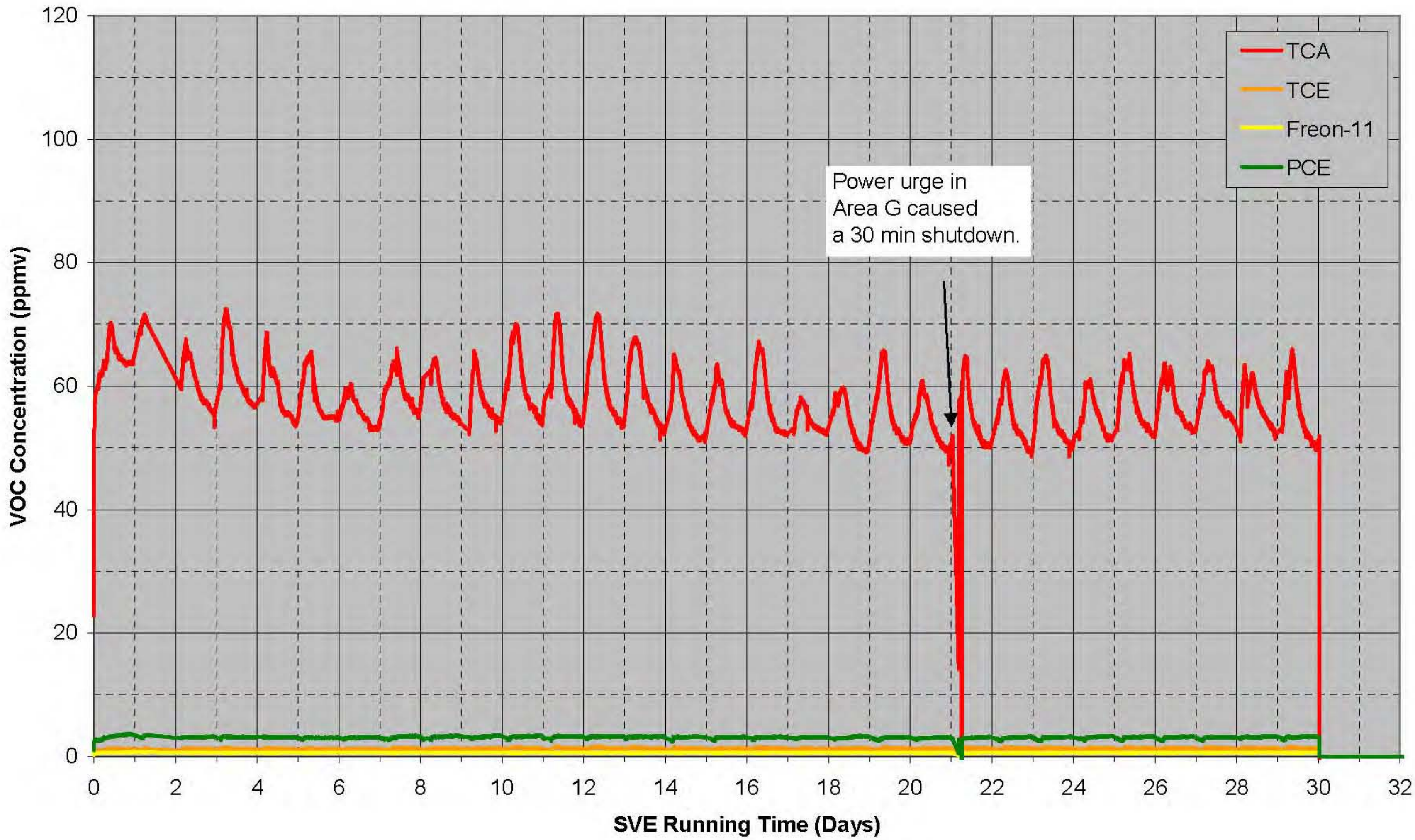

Figure 4.3-1 VOC concentrations measured during deep-extraction test

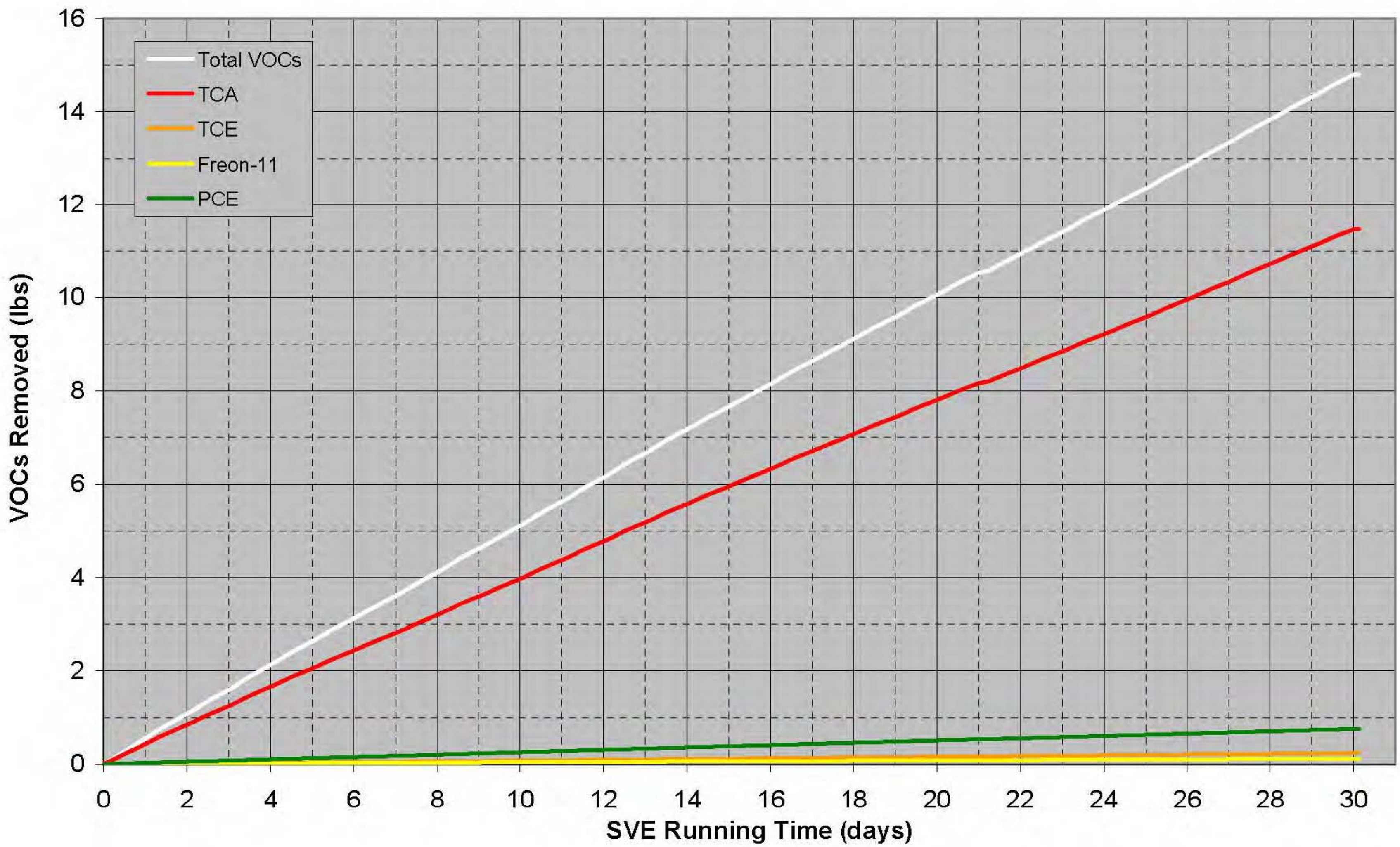

Figure 4.3-2 **Estimated mass of VOCs extracted during deep-extraction test**

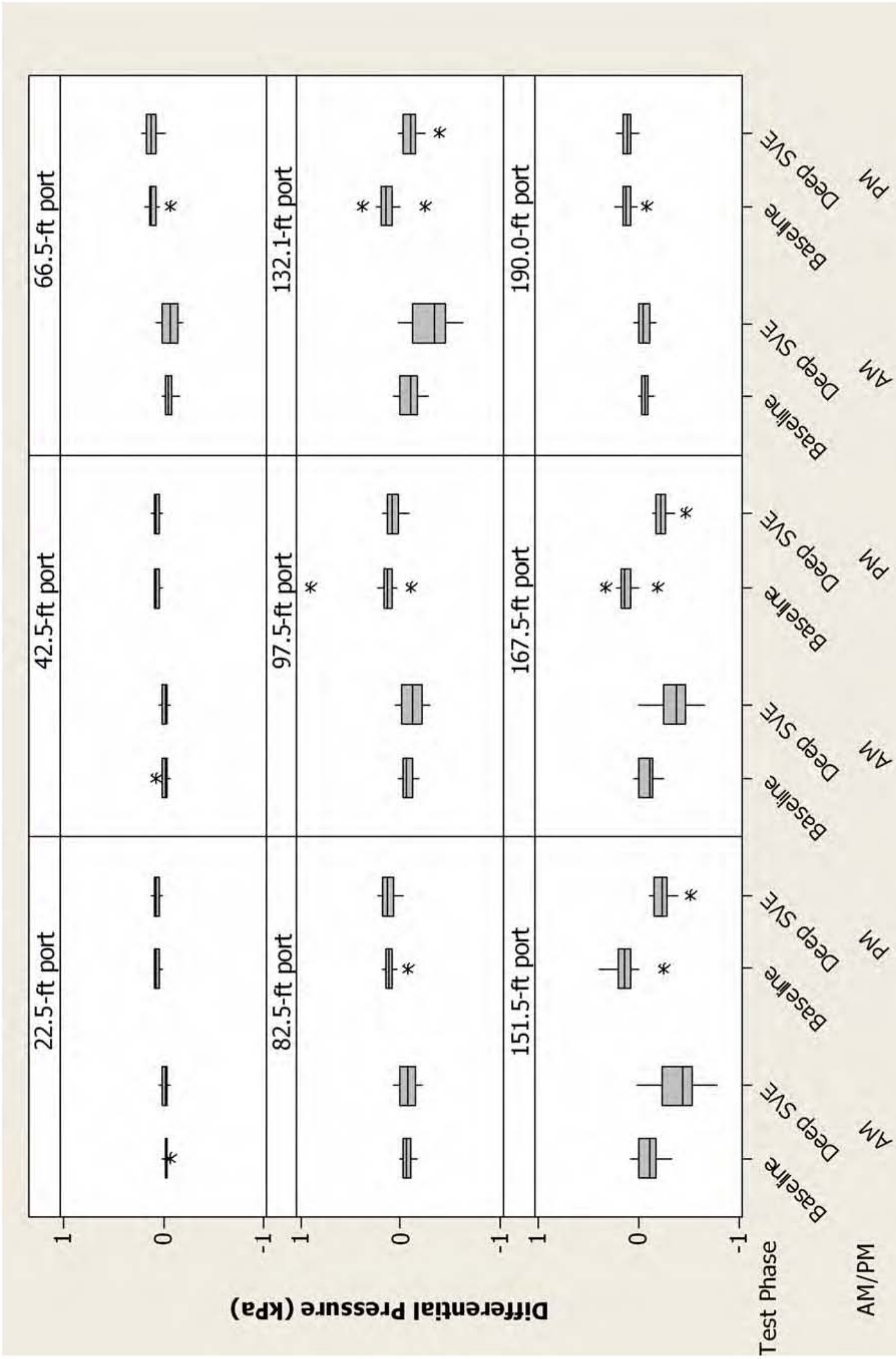

Figure 4.3-3 Comparison of baseline and deep-extraction test differential pressure measured in monitoring borehole location 54-24378.

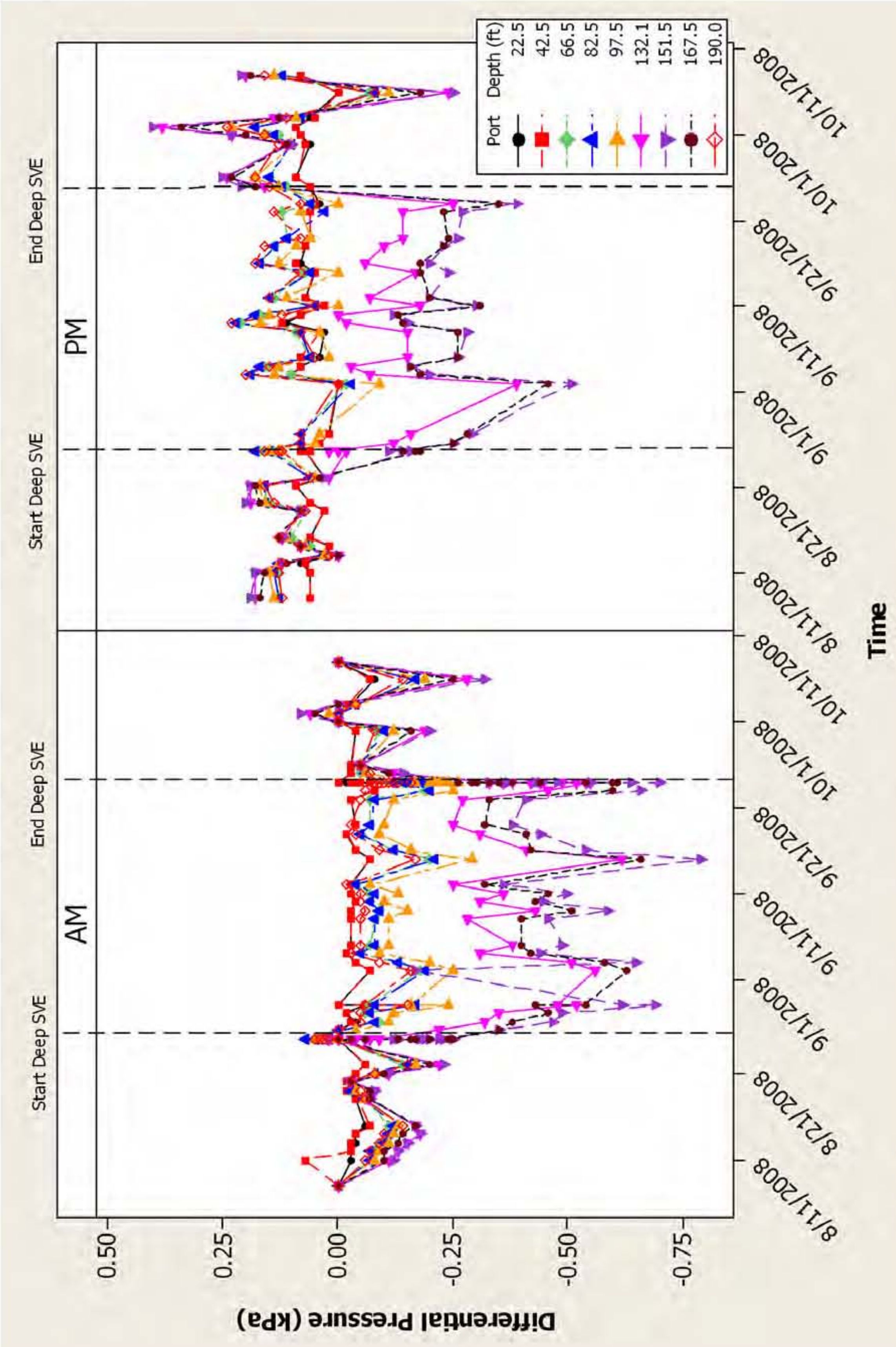

Figure 4.3-4 Differential pressure measured in monitoring borehole location 54-24378 during the deep-extraction test

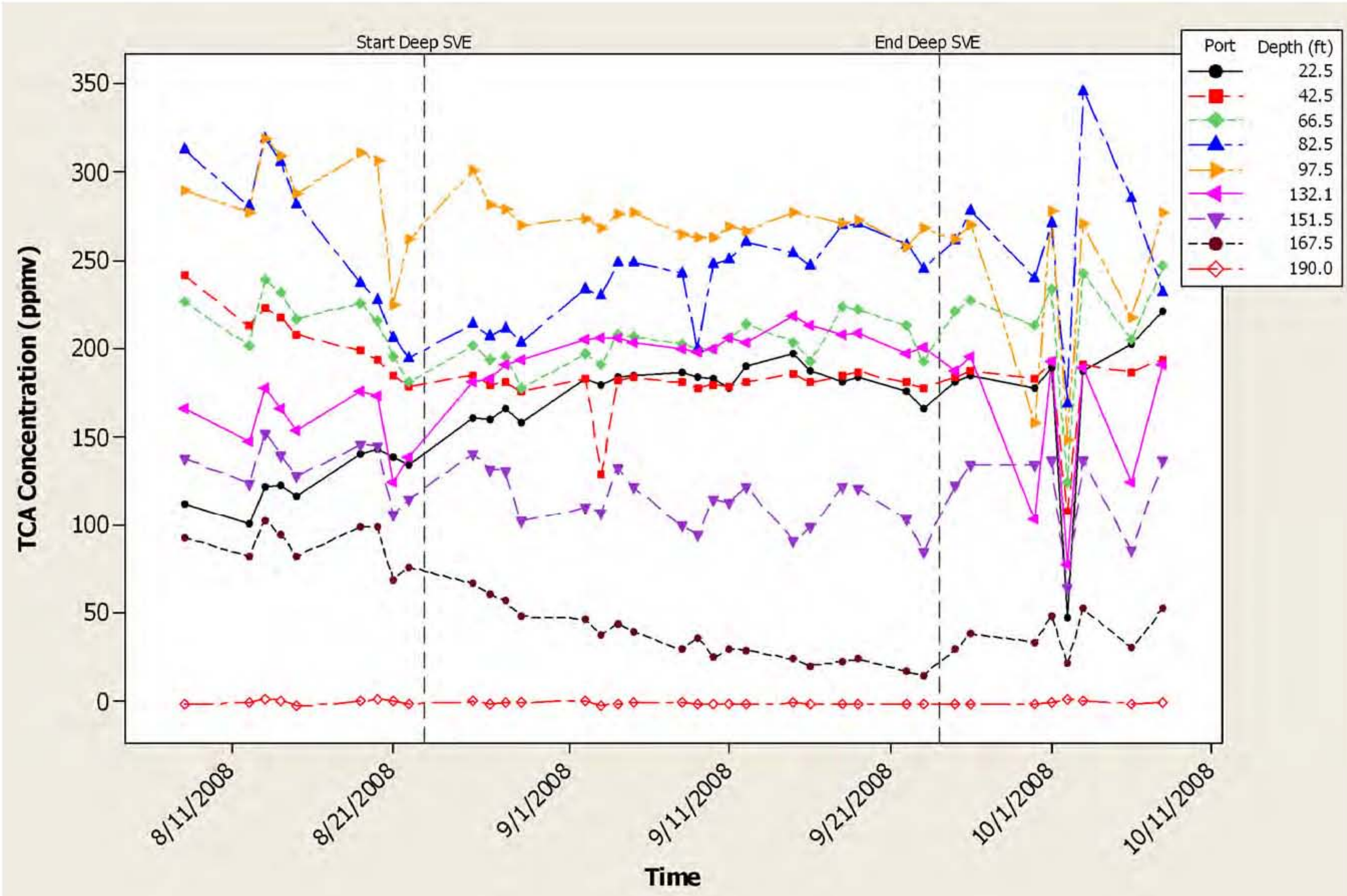

Figure 4.3-5 TCA concentrations measured in monitoring borehole location 54-24378 during the deep-extraction test

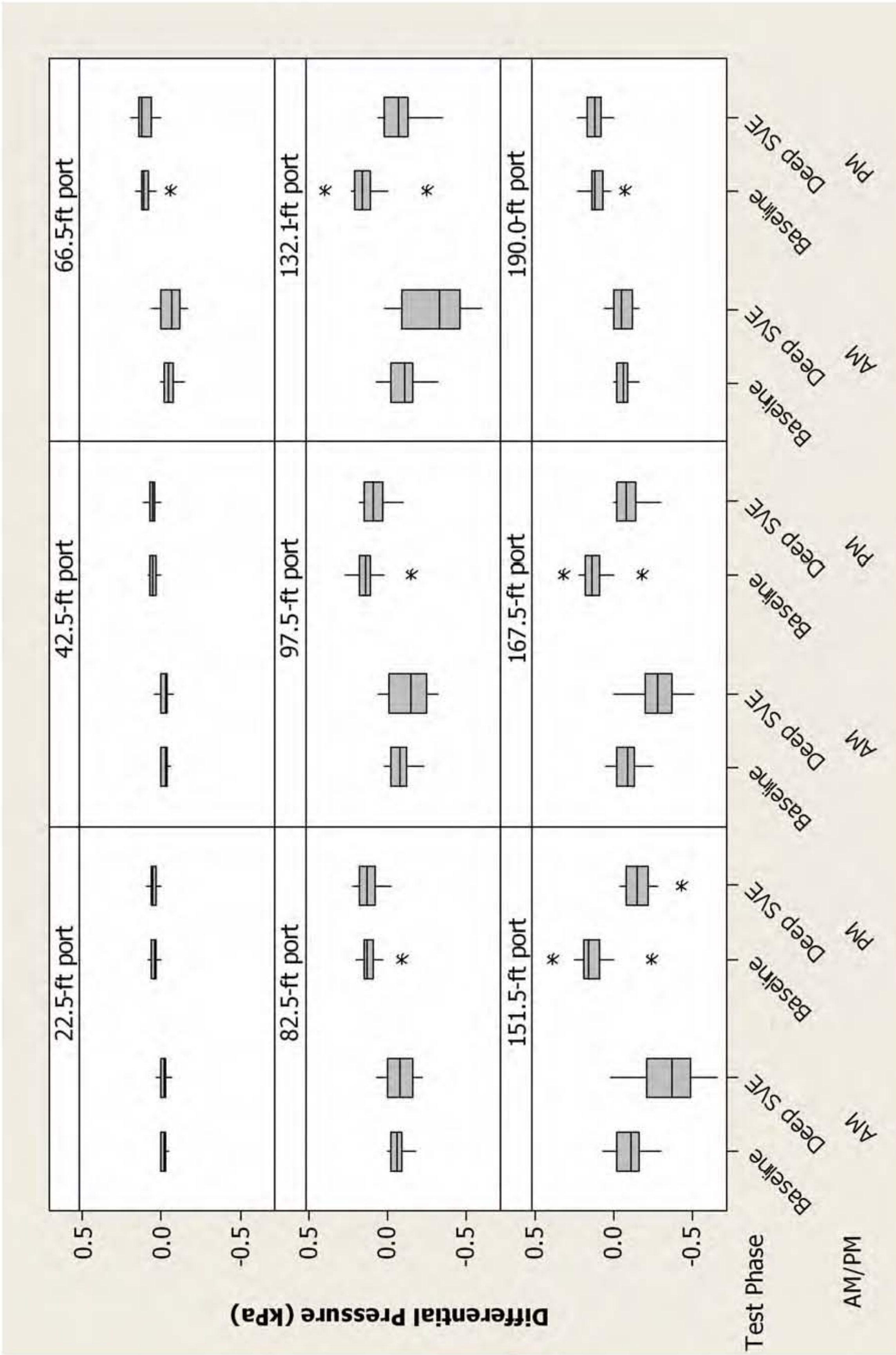

Figure 4.3-6 Comparison of baseline and deep extraction-test differential pressure measured in monitoring borehole location 54-01116

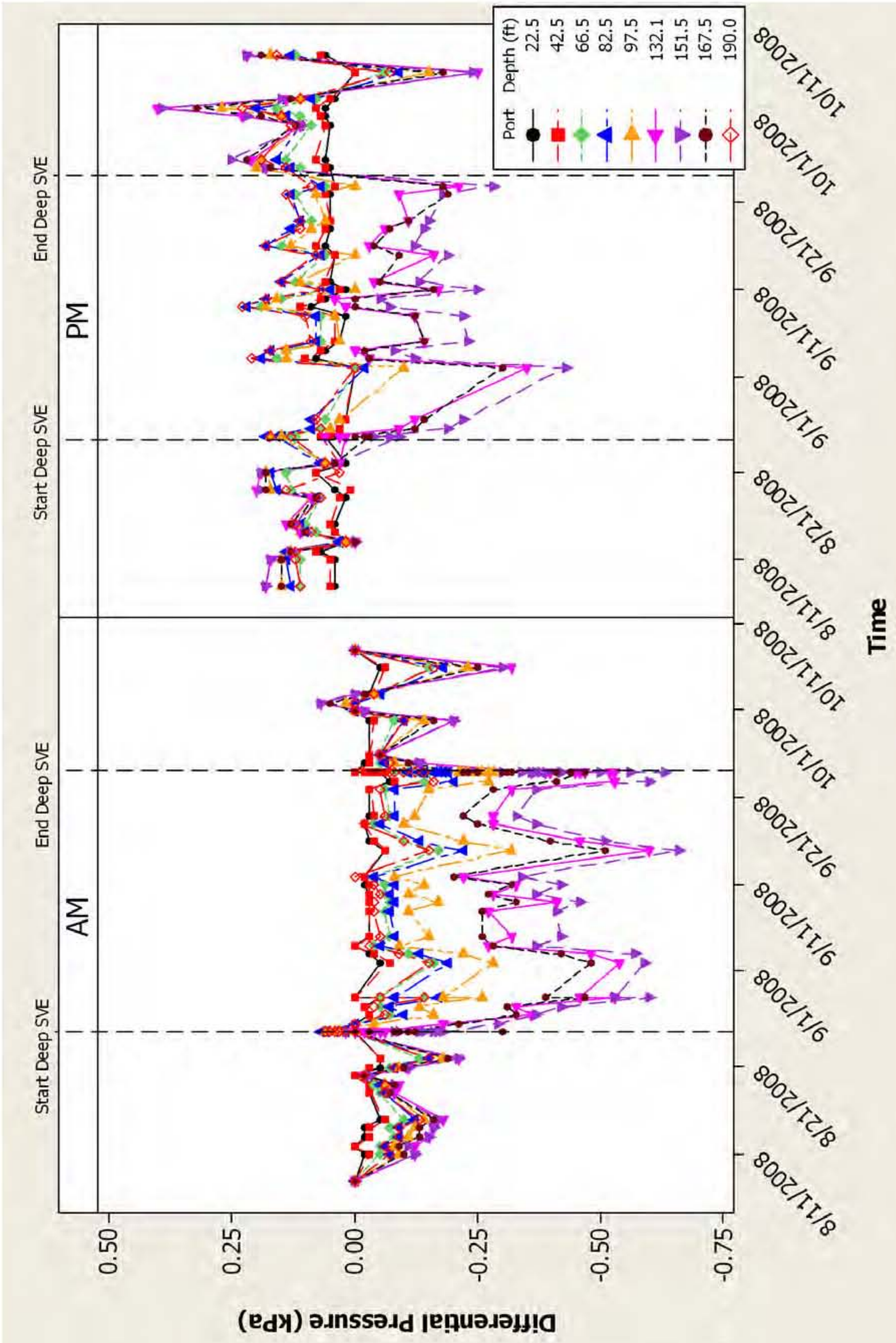

Figure 4.3-7 Differential pressure measured in monitoring borehole location 54-01116 during the deep-extraction test

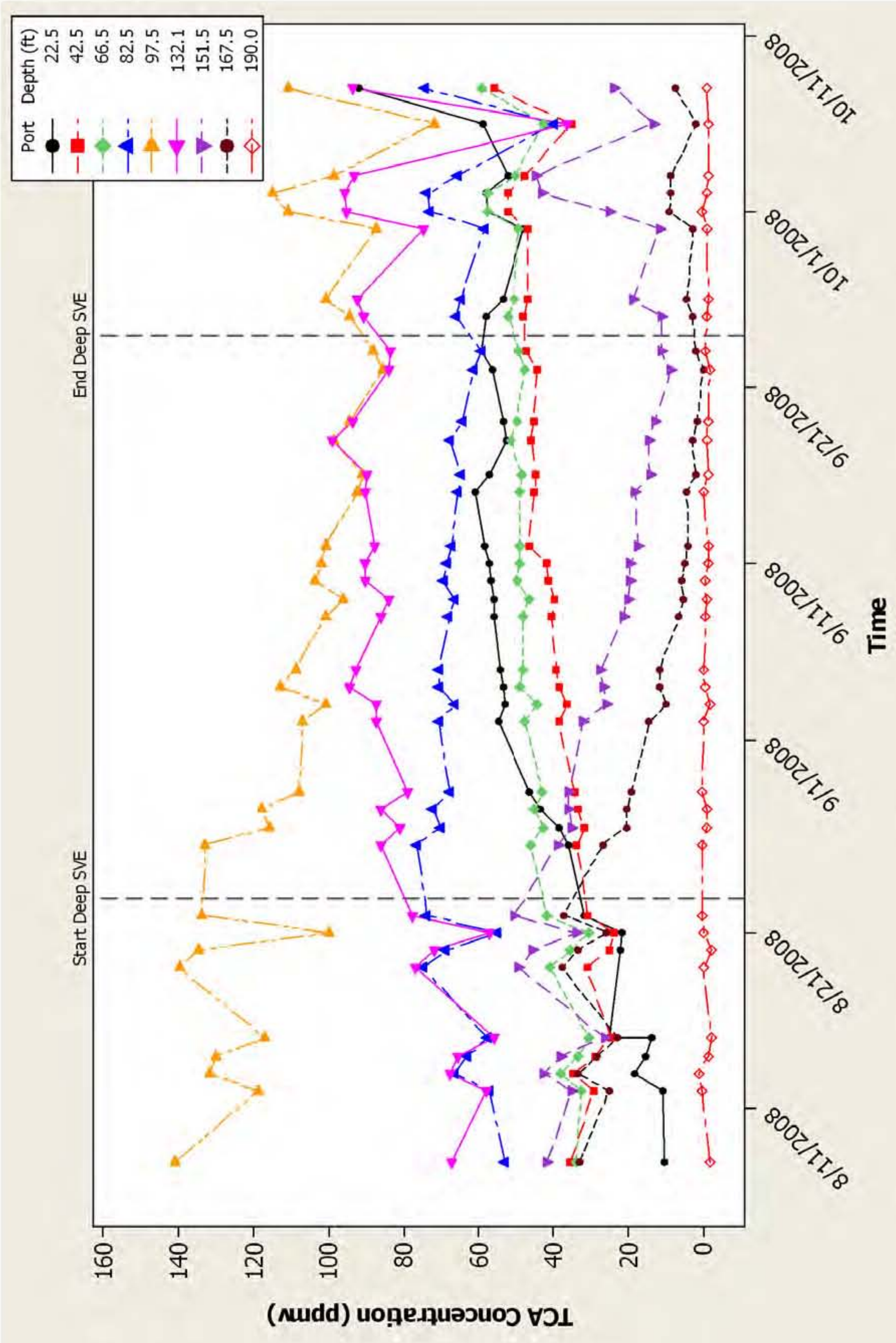

Figure 4.3-8 TCA concentrations measured in monitoring borehole location 54-01116 during the deep-extraction test

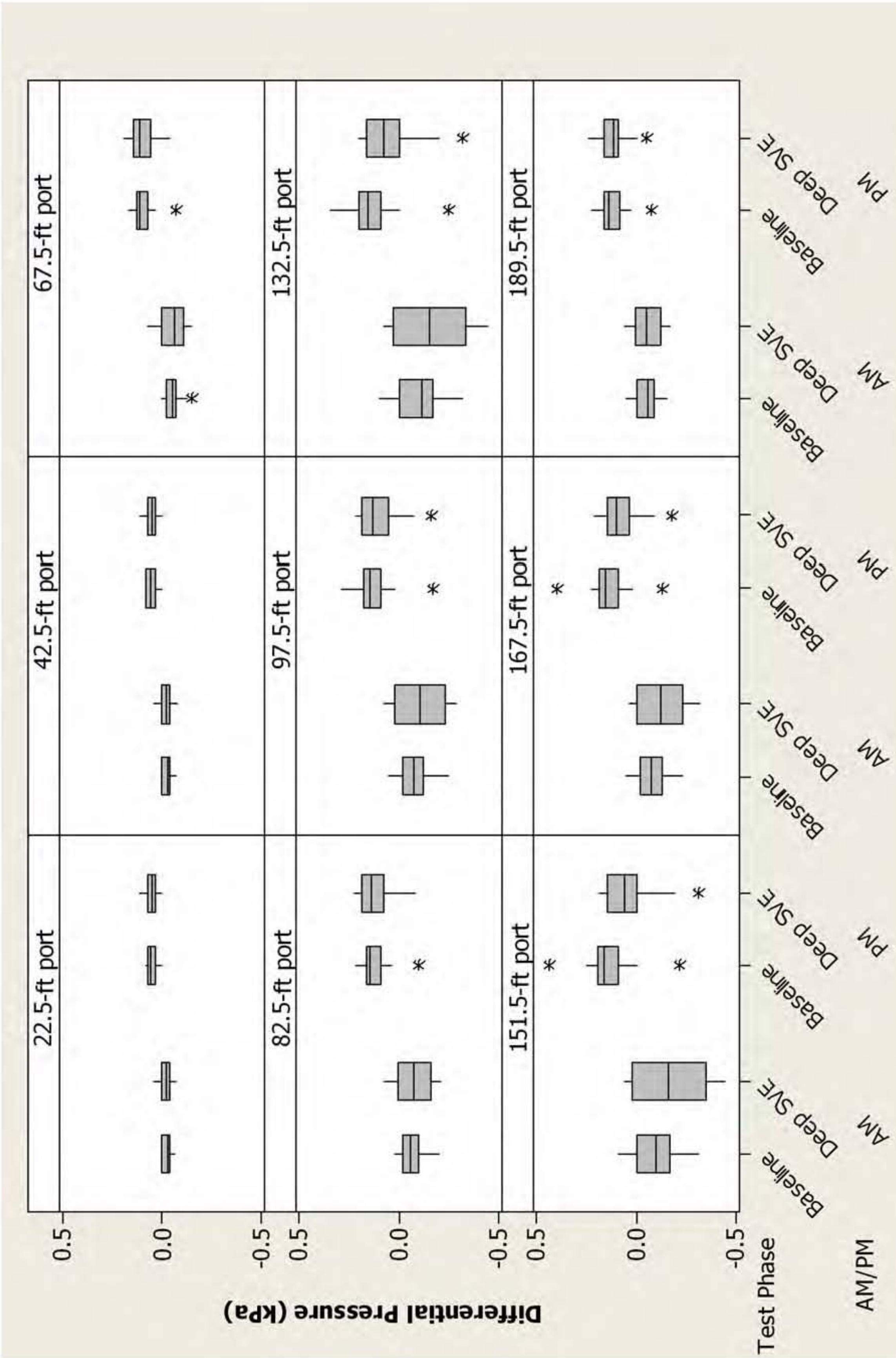

Figure 4.3-9 Comparison of baseline and deep-extraction test differential pressure measured in monitoring borehole location 54-24388

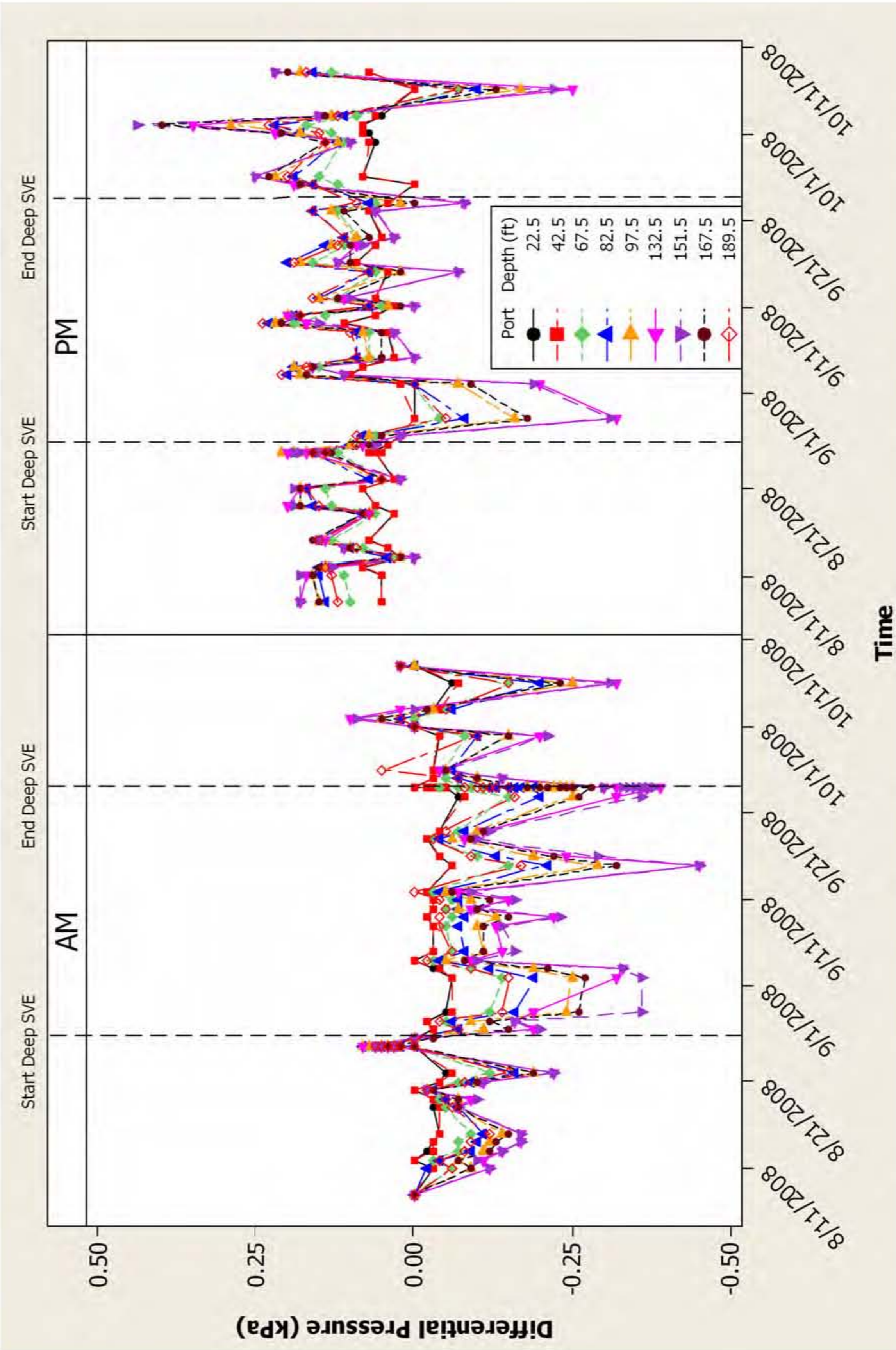

Figure 4.3-10 Scatter plot of deep-test differential pressure for borehole location 54-24388

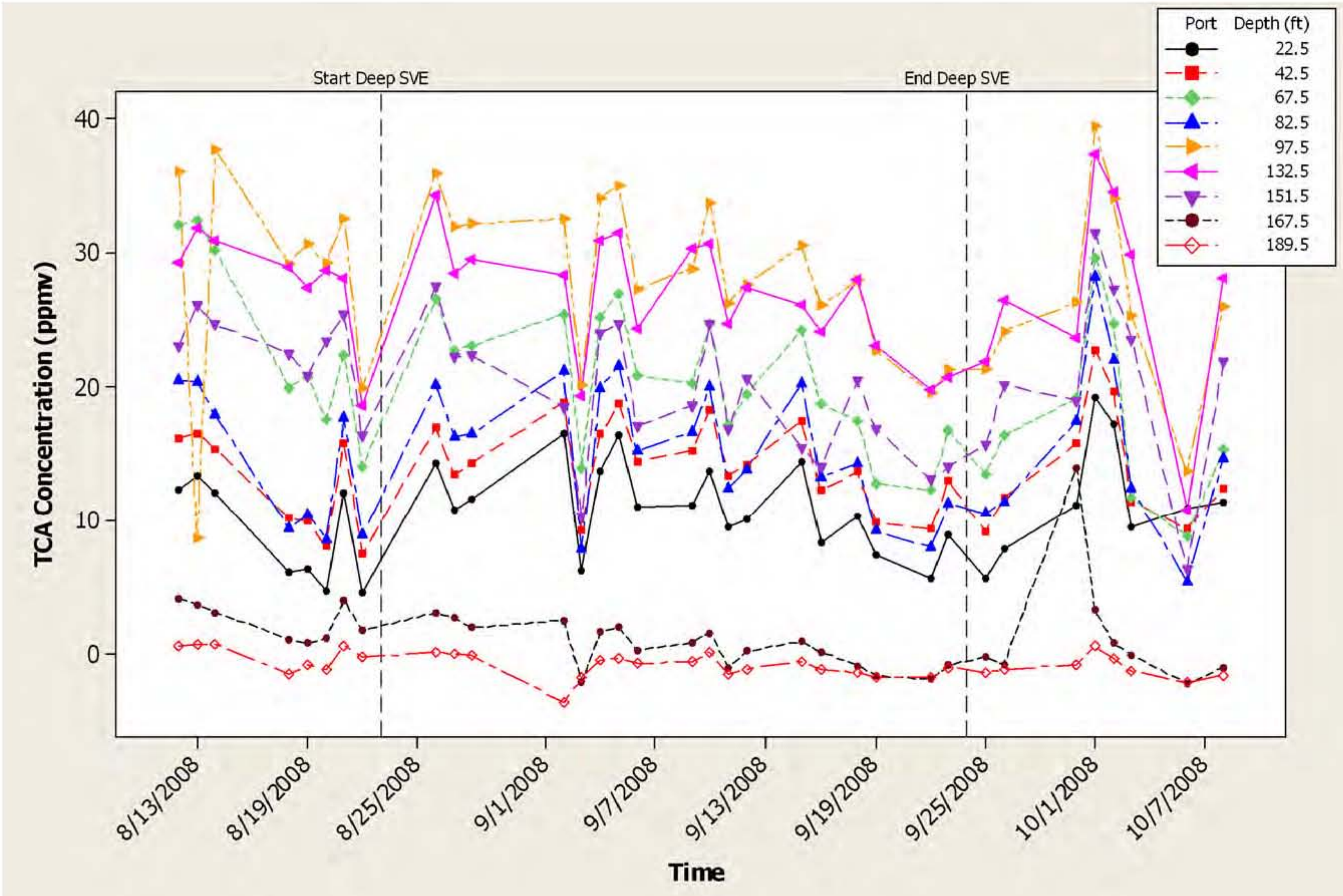

Figure 4.3-11 TCA concentrations measured in monitoring borehole location 54-24388 during the deep-extraction test

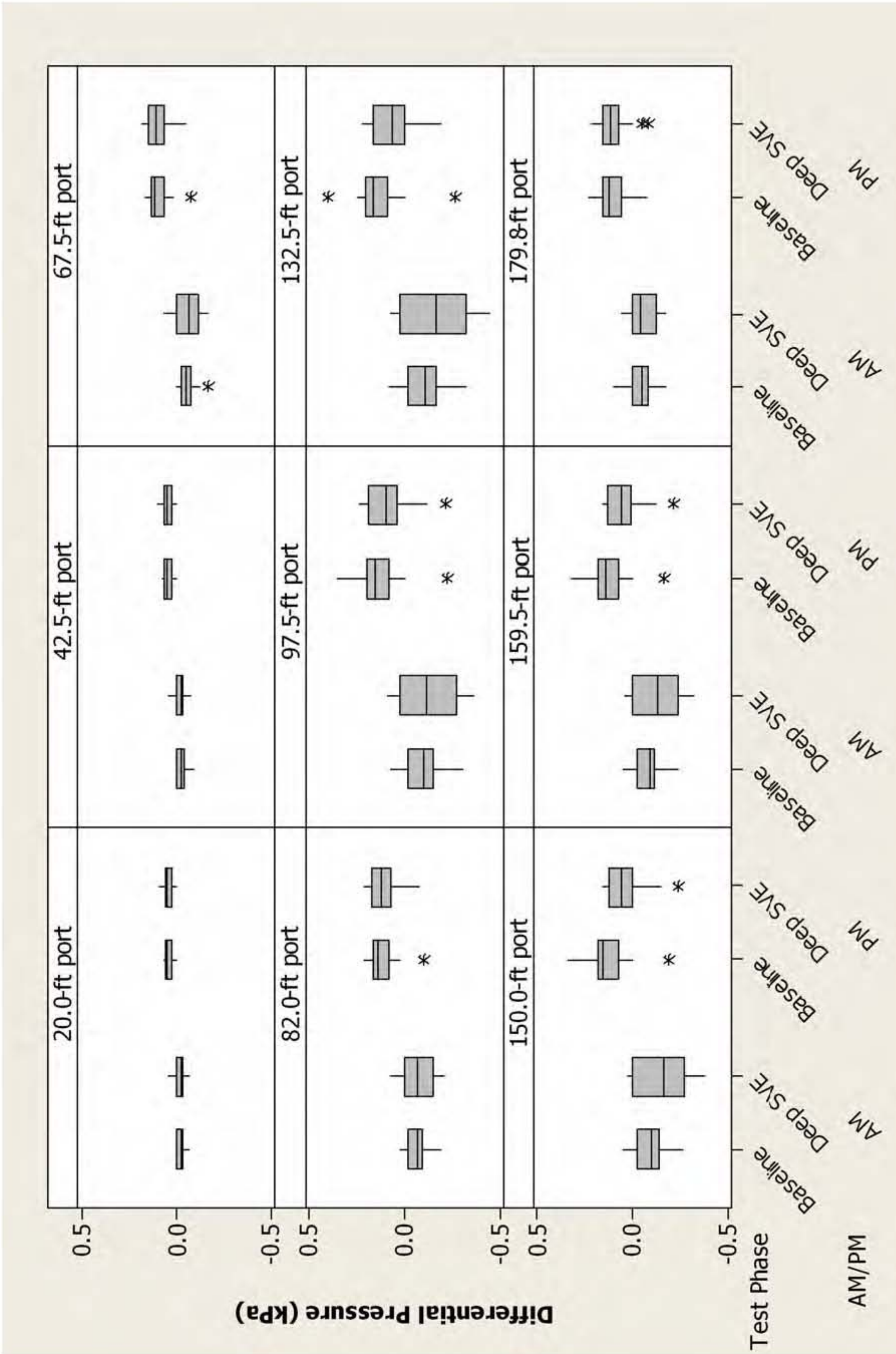

Figure 4.3-12 Comparison of baseline and deep-extraction test differential pressure measured in monitoring borehole location 54-01117

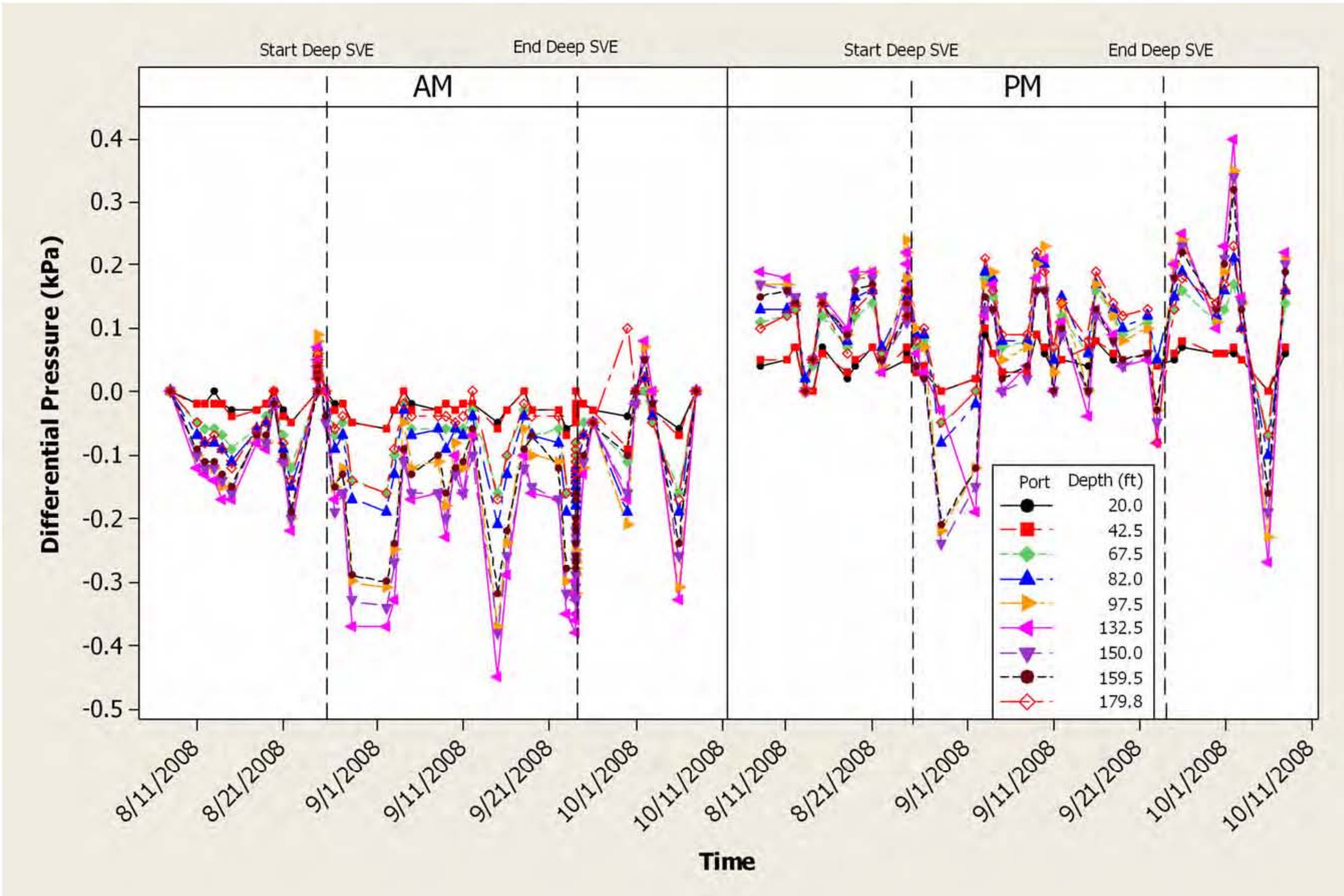

Figure 4.3-13 Differential pressure measured in monitoring borehole location 54-01117 during the deep-extraction test

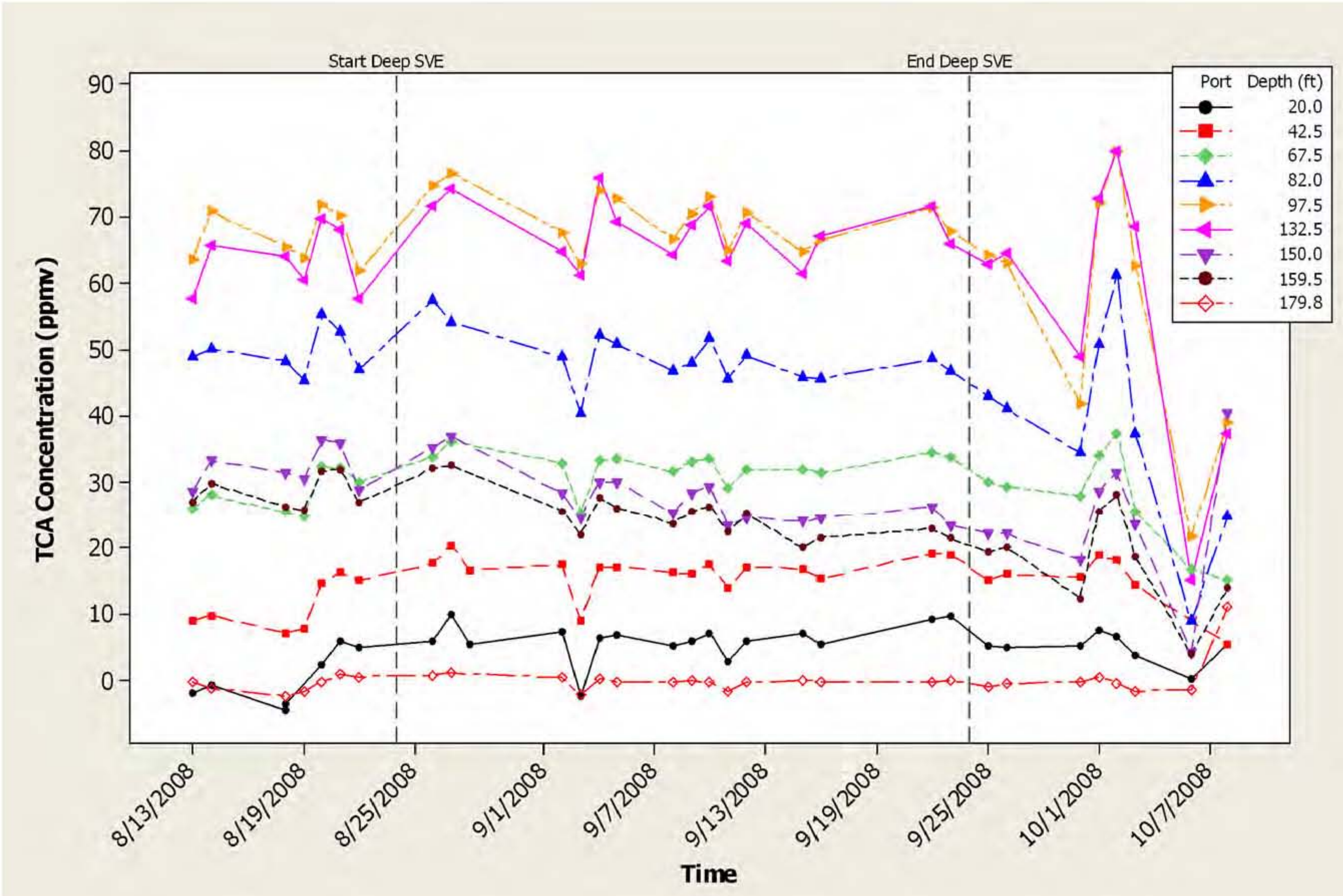

Figure 4.3-14 TCA concentrations measured in monitoring borehole location 54-01117 during the deep-extraction test

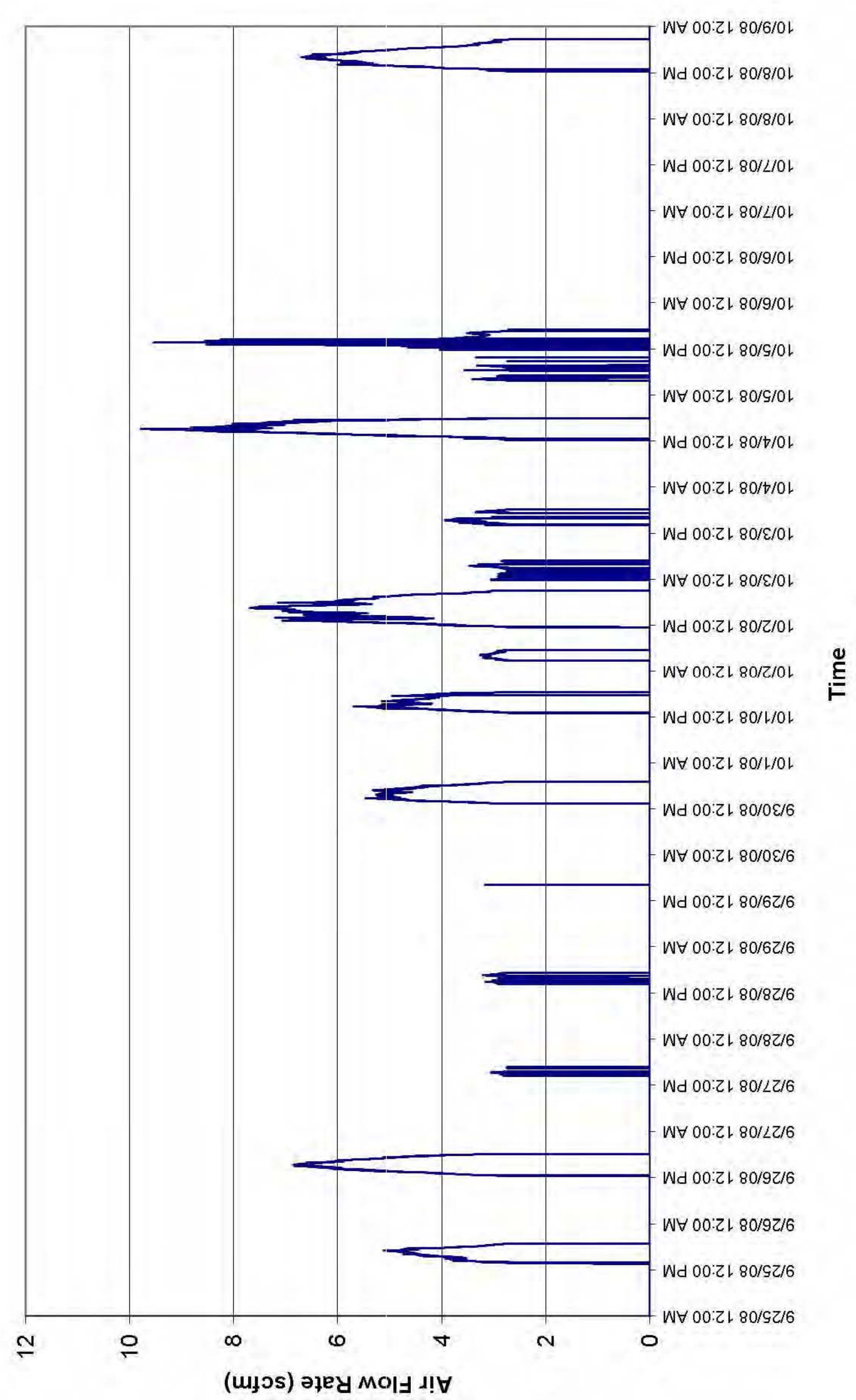

Figure 4.4-1 Air flow measured in the shallow-extraction borehole during passive venting

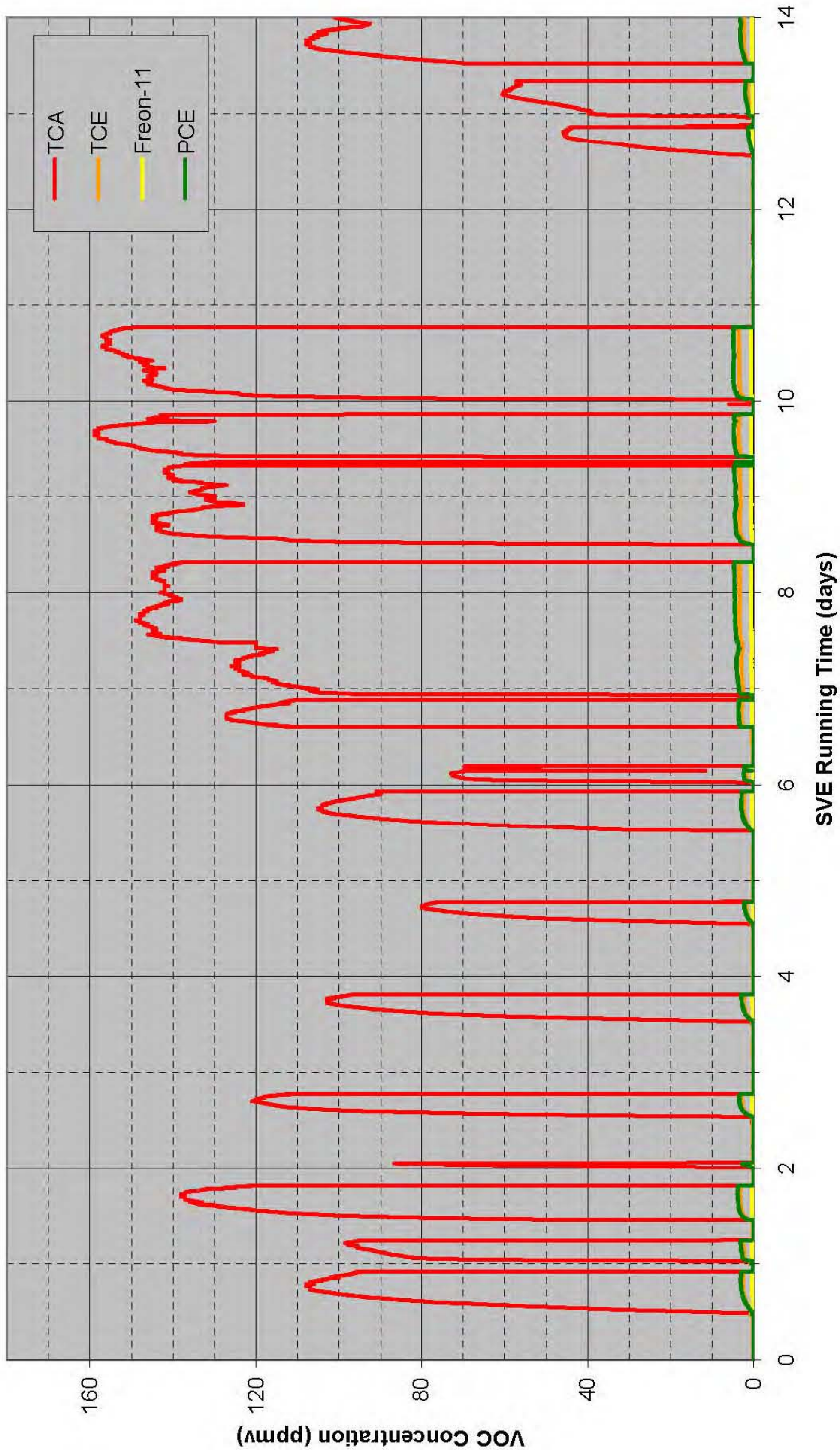

Figure 4.4-2 VOC concentrations measured in the shallow-extraction borehole during passive venting

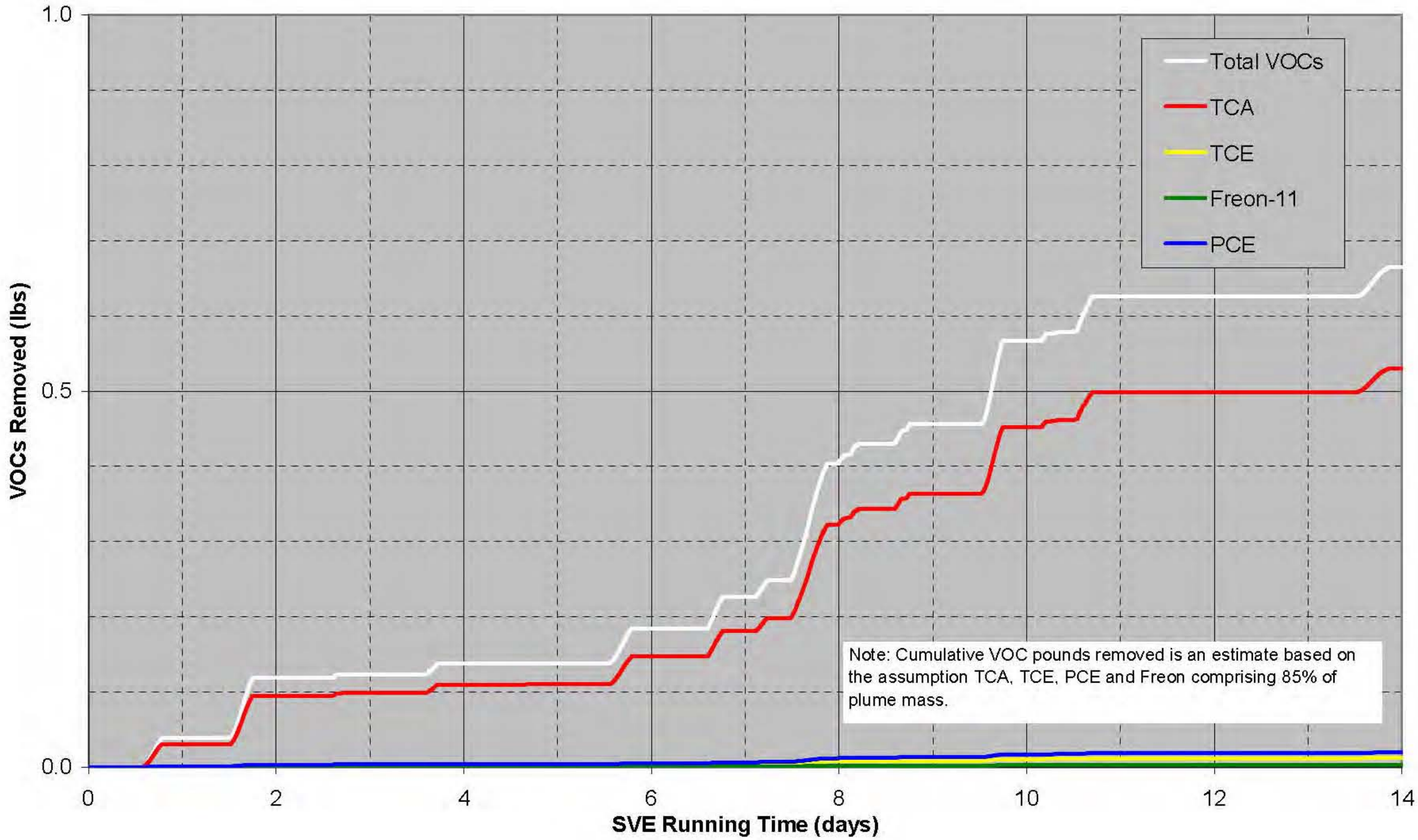

Figure 4.4-3 Estimated mass of VOCs extracted during passive venting

Table 2.2-1
Geohydrologic and Hydraulic Properties for Stratigraphic Layers at TA-54

Stratigraphic Units/Subunits		Hydraulic Properties[a]						Geohydrologic Characteristics[b]		
Stratigraphic Unit	Stratigraphic Subunit	Bulk Density (lb/in.^{3})	Porosity (%)	In Situ Permeability (Darcies)[c]	Volumetric Moisture Content (%)	Saturation (%)	Saturated Hydraulic Conductivity (ft/d)	Gravimetric Moisture Content (%)	Induration[d]	Fractures[e]
2	2(u)	0.0495	45.7	0.5–1	2.57	5.7	1.24	2.12	Mod	Many
	2(l)							1.24	Strong	Many
1v(u)	1v(u_2)	0.0448	48.7	0.4–.9	1.89	3.7	0.42	1.03	Slight	Mod
	1v(u_1)							1.79	Non	None
1v(c)	1v(c)	0.0426	49.3	0.1–1.2	10.88	21.3	0.47	5.11	Mod	Mod
1g	1g(u)	0.0415	46.2	0.5–1	8.94	16.9	0.53	5.77	Mod	Mod
	1g							5.83	Non	None
Tsankawi/ Cerro Toledo		0.0404	47.3	7–10	14	30.3	2.43	10.8	Mod	Rare
								8.49	Slight	Rare

[a] From Table 2-1, “Pilot Vapor Extraction Test at TA-54” (ERM/Golder 1997, 070334), values converted to English units.

[b] From MDA L and MDA G RFI boreholes.

[c] Straddle packer permeability results for borehole 54-01018, data measured from 10 ft to 310 ft bgs (Lowry 1997, 087818).

[d] Qualitative induration (hardness) scale is non = nonindurated, slight = slightly indurated, mod = moderately indurated, strong = strongly indurated.

[e] Qualitative fracture scale is none = not present, rare = few present, mod = some present, many = fractures abundant.

Table 2.3-1
Chemical Properties of Measured VOCs

VOC	Molecular Weight[a] (g/mol)	Solubility[a] (mg/L)	Vapor Pressure[a] (mmHg)	Boiling Point[b] (°C)	Henry's Law Constant[a] (atm at 25°C)	Henry's Law Constant[a] (dimensionless)
TCA	133.4	950 (25°C)	124 (25°C)	74.1	8.97E+2	0.66
TCE	131.39	1100 (25°C)	72.6 (25°C)	87.0	5.04E+2	0.37
Freon-11	137.37	1240 (25°C)	792 (25°C)	23.8	9.57E+4	70.71
PCE	165.83	150 (25°C)	20 (25°C)	121.0	8.47E+2	0.63
DCA	98.96	5060 (25°C)	234 (25°C)	57.5	3.25E+2	0.24
DCE	96.94	5000 (25°C)	591 (25°C)	31.7[c]	1.16E+3	0.86

[a] Suthersan 1997, 093755.

[b] Schwarzenbach et al. 1993, 104511.

[c] University of Oxford 2009, 104510.

Table 3.2-1
Monitoring and Extraction Borehole Location Characteristics

Characteristics	54-24378	54-01116	54-27388	54-01117	Shallow Extraction Borehole	Deep Extraction Borehole
Completed depth (ft)	~192	~192	~190	~180	145	177
Total depth (ft)	195.5	195	195	184	182.5	185
Completion unit	Otowi	Otowi	Otowi	Otowi	Tshirege Member	Otowi Member
Distance from shallow extraction borehole (ft)	25	40	110	125	0	10
Distance from deep extraction borehole (ft)	27	50	115	135	10	0

Table 3.2-2
Monitoring Borehole Location Port Depths and Corresponding Stratigraphy

Formation	Member	Unit	54-24378	54-01116	54-27388	54-01117
Bandelier Tuff	Tshirege Member	Qbt 2	22.5 ft	22.5 ft	22.5 ft	20 ft
		Qbt 2	42.5 ft	42.5 ft	42.5 ft	42.5 ft
		Qbt 1v-u	66.5 ft	66.5v	67.5 ft	67.5 ft
		Qbt 1v-c	82.5 ft	82.5 ft	82.5 ft	82 ft
		Qbt 1g	97.5 ft	97.5 ft	97.5 ft	97.5 ft
		Qbt 1g	132.1 ft	132.5 ft	132.5 ft	132.5 ft
	Cerro Toledo Interval	Qct	151.5 ft	151.5 ft	151.5 ft	150 ft
Bandelier Tuff	Otowi Member	Qbo	167.5 ft	167.5 ft	167.5 ft	159.5 ft
	Cerros del Rio Basalt	Tb 4	190 ft	190 ft	189.5 ft	179.5 ft

Table 3.2-3
Test Phase Parameters

Test Phase	Baseline	Active, Shallow Extraction	Shallow Rebound Monitoring	Active, Deep Extraction	Passive Monitoring
Dates	5/29/08–6/16/08	7/8/08–8/6/08	8/7/08–8/24/08	8/25/08–9/23/08	9/24/08–10/8/08
Time Period (days)	14	30	14	30	14
Geologic Unit Evaluated	n/a[a]	Tshirege Member	n/a	Otowi Member	Tshirege and Otowi Members
Monitored Parameters					
VOCs (B&K)	Monitoring boreholes (daily)	Monitoring boreholes (daily); Extraction borehole (every 3 min)	Monitoring boreholes (daily)	Monitoring boreholes (daily); Extraction borehole (every 3 min)	Monitoring boreholes (daily); Extraction borehole (shallow) (every 3 min)
Differential Pressure (manometer)	Monitoring boreholes (daily)	Monitoring boreholes (twice daily)	monitoring boreholes (twice daily)	Monitoring boreholes (twice daily)	Monitoring boreholes (twice daily)
Airflow (orifice plate differential pressure)	NA[b]	Extraction borehole (shallow) (every 1 min)	NA	Extraction borehole (deep) (every 1 min)	Extraction borehole (shallow and deep) (every 1 min)
Vacuum (vacuum gauge)	NA	Extraction borehole (shallow) (daily)	NA	Extraction borehole (deep) (daily)	NA
Temperature (Viasala probe)	NA	Extraction borehole (shallow) (every 1 min)	NA	Extraction borehole (deep) (every 1 min)	Extraction borehole (shallow) (every 1 min)
Relative Humidity (Viasala probe)	NA	Extraction borehole (shallow) (every 1 min)	NA	Extraction borehole (deep) (every 1 min)	Extraction borehole (shallow) (every 1 min)
Waste Management					
Waste Managed (GAC drums)	0	5	0	2	<1

[a] n/a = Not applicable.

[b] NA = Not analyzed.

Table 3.2-4
Contaminant Distribution Based on Historical Analytical Results

Depth (ft)	Analysis Date	Analyte	Result
37	2/28/2007	Dichloroethane[1,1-]	36,000 µg/m^3
37	2/28/2007	Dichloroethene[1,1-]	41,000 µg/m^3
37	2/28/2007	PCE	6500 µg/m^3
37	2/28/2007	TCA	790,000 µg/m^3
37	2/28/2007	TCE	6400 µg/m^3
		Total	879,900 µg/m^3
		SVE Monitored Total	802,900 µg/m^3
		SVE Monitored Total/Total	91.2%
38	8/17/2007	Dichloroethane[1,1-]	34,000 µg/m^3
38	8/17/2007	Dichloroethene[1,1-]	38,000 µg/m^3
38	8/17/2007	TCA	770,000 µg/m^3
38	8/17/2007	TCE	4400 µg/m^3
		Total	846,400 µg/m^3
		SVE Monitored Total	774,400 µg/m^3
		SVE Monitored Total/Total	91.5%
38	7/28/2008	Dichloroethane[1,1-]	42,000 µg/m^3
38	7/28/2008	Dichloroethene[1,1-]	54,000 µg/m^3
38	7/28/2008	PCE	6900 µg/m^3
38	7/28/2008	Trichloro-1,2,2-trifluoroethane[1,1,2-]	7100 µg/m^3
38	7/28/2008	TCA	1,000,000 µg/m^3
38	7/28/2008	TCE	7300 µg/m^3
		Total	1,117,300 µg/m^3
		SVE Monitored Total	1,014,200 µg/m^3
		SVE Monitored Total/Total	90.8%
80	2/28/2007	Dichloroethane[1,1-]	32,000 µg/m^3
80	2/28/2007	Dichloroethene[1,1-]	46,000 µg/m^3
80	2/28/2007	PCE	6100 µg/m^3
80	2/28/2007	TCA	640,000 µg/m^3
80	2/28/2007	TCE	7900 µg/m^3
		Total	732,000 µg/m^3
		SVE Monitored Total	654,000 µg/m^3
		SVE Monitored Total/Total	89.3%

Table 3.2-4 (continued)

Depth (ft)	Analysis Date	Analyte	Result
80	8/18/2007	Dichloroethane[1,1-]	25,000 µg/m^3
80	8/18/2007	Dichloroethene[1,1-]	38,000 µg/m^3
80	8/18/2007	PCE	2900 µg/m^3
80	8/18/2007	TCA	380,000 µg/m^3
80	8/18/2007	TCE	4200 µg/m^3
		Total	450,100 µg/m^3
		SVE Monitored Total	387,100 µg/m^3
		SVE Monitored Total/Total	86.0%
115	2/28/2007	Dichloroethane[1,1-]	32,000 µg/m^3
115	2/28/2007	Dichloroethene[1,1-]	56,000 µg/m^3
115	2/28/2007	PCE	5900 µg/m^3
115	2/28/2007	TCA	400,000 µg/m^3
115	2/28/2007	TCE	8300 µg/m^3
		Total	502,200 µg/m^3
		SVE Monitored Total	414,200 µg/m^3
		SVE Monitored Total/Total	82.5%
115	8/17/2007	Dichloroethane[1,1-]	32,000 µg/m^3
115	8/17/2007	Dichloroethene[1,1-]	66,000 µg/m^3
115	8/17/2007	PCE	3000 µg/m^3
115	8/17/2007	TCA	420,000 µg/m^3
115	8/17/2007	TCE	5600 µg/m^3
		Total	526,600 µg/m^3
		SVE Monitored Total	428,600 µg/m^3
		SVE Monitored Total/Total	81.4%
130	2/28/2007	Dichloroethane[1,1-]	17,000 µg/m^3
130	2/28/2007	Dichloroethene[1,1-]	33,000 µg/m^3
130	2/28/2007	PCE	3400 µg/m^3
130	2/28/2007	TCA	240,000 µg/m^3
130	2/28/2007	TCE	4800 µg/m^3
		Total	298,200 µg/m^3
		SVE Monitored Total	248,200 µg/m^3
		SVE Monitored Total/Total	83.2%
130	8/17/2007	Dichloroethane[1,1-]	330 µg/m^3
130	8/17/2007	Dichloroethene[1,1-]	650 µg/m^3
130	8/17/2007	PCE	34 µg/m^3
130	8/17/2007	TCA	4400 µg/m^3
130	8/17/2007	TCE	62 µg/m^3
		Total	5476 µg/m^3
		SVE Monitored Total	4496 µg/m^3

Table 3.2-4 (continued)

Depth (ft)	Analysis Date	Analyte	Result
		SVE Monitored Total/Total	82.1%
191	2/28/2007	Dichloroethane[1,1-]	1900 µg/m^3
191	2/28/2007	Dichloroethene[1,1-]	3400 µg/m^3
191	2/28/2007	PCE	440 µg/m^3
191	2/28/2007	TCA	23,000 µg/m^3
191	2/28/2007	TCE	600 µg/m^3
		Total	29,340 µg/m^3
		SVE Monitored Total	24,040 µg/m^3
		SVE Monitored Total/Total	81.9%
191	8/20/2007	Dichloroethane[1,1-]	3600 µg/m^3
191	8/20/2007	Dichloroethene[1,1-]	7000 µg/m^3
191	8/20/2007	PCE	990 µg/m^3
191	8/20/2007	TCA	45,000 µg/m^3
191	8/20/2007	TCE	1000 µg/m^3
		Total	57,590 µg/m^3
		SVE Monitored Total	46,990 µg/m^3
		SVE Monitored Total/Total	81.6%
191	7/28/2008	Dichloroethane[1,1-]	3000 µg/m^3
191	7/28/2008	Dichloroethene[1,1-]	6600 µg/m^3
191	7/28/2008	PCE	880 µg/m^3
191	7/28/2008	Trichloro-1,2,2-trifluoroethane[1,1,2-]	450 µg/m^3
191	7/28/2008	TCA	45,000 µg/m^3
191	7/28/2008	TCE	910 µg/m^3
		Total	56,840 µg/m^3
		SVE Monitored Total	46,790 µg/m^3
		SVE Monitored % of Total	82.3%
		Average SVE Monitored % of Total	85.3%

Table 4.0-1
Summary of Field Results for Select VOCs

Port Depth Range (ft)	Freon-11 Range (ppmv)				PCE Range (ppmv)			
	Baseline	Shallow	Deep	Passive	Baseline	Shallow	Deep	Passive
20.0–22.5	0.07–2.87	0.0–70.10	0.0–0.94	0.01–0.77	1.52–22.40	0.01–16.20	0.31–5.24	0.38–5.24
42.5–42.5	0.11–3.01	0.0–13.20	0.0–85.60	0.05–85.60	1.95–19500.0	0.21–18.30	0.52–4.26	0.62–4.26
66.5–67.5	0.21–4.45	0.01–2.81	0.0–0.96	0.01–0.96	2.22–23.0	0.22–17.30	0.84–6.50	0.84–6.50
82.0–82.5	0.11–3.94	0.02–3.99	0.0–1.63	0.00–1.63	1.48–24.30	0.35–24.40	0.53–10.20	0.53–10.20
97.5–97.5	0.16–2.98	0.03–2.57	0.03–1.99	0.08–1.69	2.24–18.50	0.46–16.0	1.24–12.10	1.24–10.30
132.1–132.5	0.05–2.06	0.12–1.90	0.15–1.94	0.17–1.85	1.46–12.20	0.76–9.75	0.70–10.50	0.70–9.91
150.0–151.5	0.09–1.49	0.03–2.38	0.0–1.47	0.02–1.44	0.86–8.64	0.61–8.03	0.24–7.27	0.38–6.86
159.5–167.5	0.02–6.67	0.02–1.14	0.0–0.54	0.00–0.45	0.18–6.98	0.01–6.30	0.07–3.19	0.07–2.43
179.8–190.0	0.01–0.53	0.0–0.87	0.0–0.10	0.03–0.08	0.01–7.39	0.0–0.66	0.0–0.90	0.00–0.90

Table 4.0-1 (continued)

Port Depth Range (ft)	TCA Range (ppmv)				TCE Range (ppmv)			
	Baseline	Shallow	Deep	Passive	Baseline	Shallow	Deep	Passive
20.0–22.5	17.60–586.0	0.82–543.0	0.31–221.0	0.31–221.0	0.82–5.26	0.10–4.17	0.53–3.05	0.55–3.05
42.5–42.5	31.10–585.0	7.11–570.0	5.41–194.0	5.41–194.0	1.17–6.62	0.55–5.05	0.62–2.64	0.62–2.49
66.5–67.5	4.90–501.0	14.10–462.0	8.84–247.0	8.84–247.0	0.80–4.62	1.0–3.69	0.61–4.82	0.87–4.82
82.0–82.5	17.80–496.0	4.16–740.0	5.40–346.0	5.40–346.0	1.02–3.59	0.22–12.80	0.66–10.90	0.66–8.16
97.5–97.5	29.40–385.0	14.50–339.0	13.70–301.0	13.70–278.0	0.92–3.58	0.41–2.94	0.68–4.76	0.68–4.76
132.1–132.5	24.10–236.0	15.70–207.0	10.80–219.0	10.80–196.0	0.37–2.87	0.53–3.52	0.57–2.25	0.57–2.05
150.0–151.5	10.60–180.0	12.70–178.0	0.49–141.0	0.49–137.0	0.18–2.42	0.27–2.57	0.01–2.46	0.21–2.46
159.5–167.5	1.98–140.0	0.80–140.0	0.03–66.70	0.85–53.10	0.19–2.91	0.13–2.40	0.07–1.28	0.21–1.17
179.8–190.0	0.02–46.5	0.0–3.21	0.03–11.0	0.33–11.0	0.0–2.0	0.02–2.02	0.02–1.34	0.02–0.99

Table 4.1-1
Average, Minimum, and Maximum Concentrations of Select VOCs Monitored during the Baseline Test

Borehole ID	Port Depth (ft)	Freon-11			PCE			TCA			TCE		
		Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)
54-01116	22.5	1.26	1.02	1.59	8.83	6.99	10.60	277.31	232.00	322.00	3.12	2.64	3.99
	42.5	1.54	1.43	1.65	10.56	9.20	11.20	270.08	256.00	290.00	2.87	2.30	3.56
	66.5	1.78	1.54	1.91	11.73	10.90	12.80	241.77	222.00	263.00	2.62	2.13	3.93
	82.5	1.74	1.49	1.85	11.25	10.50	11.70	223.54	196.00	285.00	2.40	1.95	3.14
	97.5	1.61	1.48	1.70	10.10	8.92	10.90	189.85	164.00	213.00	2.17	1.54	3.12
	132.1	1.05	0.85	1.30	5.92	4.34	6.67	120.25	106.00	135.00	1.53	0.44	2.57
	151.5	0.78	0.40	0.98	4.68	3.67	5.52	92.30	71.80	109.00	1.46	1.04	2.28
	167.5	0.60	0.34	0.72	3.20	1.86	3.74	65.41	48.40	73.40	0.96	0.71	1.48
	190	0.04	0.03	0.05	0.41	0.02	2.01	0.87	0.26	1.41	0.34	0.09	1.10
54-01117	20	0.14	0.07	0.18	1.65	1.52	1.90	27.23	17.60	33.90	1.39	0.85	1.84
	42.5	0.29	0.26	0.33	2.10	1.95	2.22	42.67	31.10	51.10	1.57	1.17	1.99
	67.5	0.37	0.35	0.38	2.65	2.22	3.07	51.57	35.60	63.00	1.77	1.11	2.20
	82	0.43	0.41	0.46	2.68	2.61	2.71	54.07	43.10	64.10	1.62	1.02	2.13
	97.5	0.48	0.44	0.55	2.52	2.41	2.65	57.93	42.90	72.20	1.54	0.92	2.03
	132.5	0.45	0.38	0.54	2.36	2.02	2.87	47.83	33.50	63.60	1.19	0.69	1.67
	150	0.25	0.16	0.40	1.13	0.86	1.41	18.00	10.60	25.70	0.54	0.18	0.75
	159.5	0.26	0.20	0.39	0.87	0.72	1.10	18.27	9.40	27.50	0.55	0.19	0.92
	179.8	0.06	0.04	0.07	0.32	0.10	0.54	0.99	0.14	1.84	0.13	0.00	0.26

Table 4.1-1 (continued)

Borehole ID	Port Depth (ft)	Freon-11 Average (ppmv)	Freon-11 Min (ppmv)	Freon-11 Max (ppmv)	PCE Average (ppmv)	PCE Min (ppmv)	PCE Max (ppmv)	TCA Average (ppmv)	TCA Min (ppmv)	TCA Max (ppmv)	TCE Average (ppmv)	TCE Min (ppmv)	TCE Max (ppmv)
54-24378	22.5	2.46	2.19	2.87	16.90	14.10	22.40	537.17	481.00	586.00	4.16	1.62	5.26
	42.5	2.87	2.52	3.01	1642.68	17.10	19500.00	556.33	525.00	585.00	4.23	3.38	6.62
	66.5	3.19	2.39	4.45	20.08	16.40	23.00	422.24	4.90	501.00	3.27	2.50	4.62
	82.5	2.62	1.71	3.94	16.90	10.50	24.30	388.08	284.00	496.00	2.67	2.14	3.59
	97.5	2.80	2.58	2.98	17.76	16.80	18.50	351.58	331.00	385.00	2.54	1.86	3.58
	132.1	1.75	1.28	2.06	10.55	8.39	12.20	210.25	184.00	236.00	1.87	0.37	2.87
	151.5	1.35	0.99	1.49	7.86	6.87	8.64	159.33	100.00	180.00	1.79	1.39	2.41
	167.5	1.57	0.77	6.67	5.70	1.09	6.98	126.17	103.00	140.00	1.55	1.16	2.91
	190	0.12	0.01	0.53	1.10	0.12	7.39	10.88	0.66	46.50	0.49	0.12	2.00
54-24388	22.5	0.23	0.09	0.35	2.84	2.43	3.47	55.58	39.00	68.30	1.49	0.82	2.15
	42.5	0.21	0.11	0.31	2.72	2.43	3.14	52.43	36.20	64.00	1.75	1.20	3.28
	67.5	0.31	0.21	0.44	2.96	2.37	3.54	49.52	36.80	61.80	1.63	0.80	2.18
	82.5	0.27	0.11	0.49	2.84	1.48	3.62	44.73	17.80	57.40	1.73	1.04	2.21
	97.5	0.28	0.16	0.35	2.61	2.24	2.86	41.35	29.40	51.50	1.61	1.14	2.19
	132.5	0.22	0.05	0.51	2.31	1.46	3.10	34.95	24.10	45.40	1.67	0.85	2.75
	151.5	0.23	0.09	0.33	1.92	0.96	2.44	30.19	20.60	38.40	1.44	0.99	2.42
	167.5	0.08	0.02	0.15	0.58	0.18	1.25	5.05	1.98	8.65	0.62	0.26	1.25
	189.5	0.01	0.01	0.02	0.13	0.01	0.37	0.79	0.02	1.51	0.40	0.04	1.01

Table 4.2-1
Average, Minimum, and Maximum Concentrations of Select VOCs Monitored during the Shallow-Extraction Test

Borehole ID	Port Depth (ft)	Freon-11			PCE			TCA			TCE		
		Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)
54-01116	22.5	3.60	0.01	70.10	1.63	0.01	8.04	67.34	10.20	257.00	2.33	1.37	3.09
	42.5	0.48	0.00	1.46	2.95	0.21	9.48	107.27	23.90	262.00	2.36	1.06	3.15
	66.5	0.40	0.03	1.61	2.76	0.22	10.10	93.83	30.40	236.00	2.16	1.30	2.84
	82.5	0.39	0.09	0.95	2.63	1.16	6.09	63.57	31.00	136.00	1.33	0.63	2.24
	97.5	0.98	0.30	1.43	5.77	1.85	8.45	117.66	42.70	165.00	1.45	0.72	2.35
	132.1	0.68	0.47	1.02	3.43	2.34	5.56	76.24	56.10	111.00	1.22	0.87	1.51
	151.5	0.40	0.05	0.70	2.25	1.36	3.72	51.72	26.30	77.40	1.02	0.79	1.50
	167.5	0.30	0.10	0.63	1.63	0.73	3.09	38.18	22.80	64.60	0.78	0.30	1.19
	190	0.02	0.00	0.07	0.06	0.00	0.24	0.64	0.00	1.25	0.21	0.04	0.43
54-01117	20	0.08	0.00	0.26	0.57	0.20	1.16	10.67	0.82	22.90	0.67	0.10	1.40
	42.5	0.11	0.00	0.23	0.90	0.23	1.84	19.79	7.11	40.00	0.95	0.55	1.56
	67.5	0.23	0.11	0.52	1.69	0.97	3.07	37.82	24.70	57.90	1.36	1.00	2.38
	82	0.41	0.07	0.65	2.42	0.35	3.58	47.75	8.64	69.20	1.13	0.22	1.54
	97.5	0.60	0.22	0.80	3.17	1.07	4.07	61.53	22.40	76.20	1.23	0.41	1.85
	132.5	0.64	0.27	0.85	3.01	1.29	3.92	59.80	28.00	73.80	1.05	0.53	1.39
	150	0.44	0.28	0.66	1.83	1.30	2.47	33.40	28.30	38.60	0.58	0.27	0.93
	159.5	0.34	0.12	0.52	1.43	0.17	2.00	27.75	11.10	36.40	0.52	0.19	0.76
	179.8	0.09	0.00	0.32	0.15	0.01	0.66	0.83	0.20	1.40	0.20	0.06	0.38

Table 4.2-1 (continued)

Borehole ID	Port Depth (ft)	Freon-11			PCE			TCA			TCE		
		Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)
54-24378	22.5	0.81	0.13	2.55	5.60	1.66	16.20	238.18	101.00	543.00	2.53	1.55	4.17
	42.5	1.22	0.38	2.86	8.14	3.08	18.30	334.75	179.00	570.00	3.19	2.51	5.05
	66.5	1.23	0.41	2.81	7.50	0.70	17.30	303.61	181.00	462.00	2.97	2.54	3.47
	82.5	2.10	0.92	3.99	12.73	6.49	24.40	382.36	195.00	740.00	3.85	2.73	5.19
	97.5	1.70	0.55	2.57	9.86	2.99	16.00	212.60	63.00	339.00	1.83	0.57	2.90
	132.1	1.73	1.39	1.90	8.96	6.90	9.75	174.04	125.00	207.00	1.87	1.27	3.52
	151.5	1.25	0.92	1.50	6.54	4.69	8.03	131.29	96.10	178.00	1.50	0.93	2.57
	167.5	0.85	0.58	1.14	4.50	2.98	6.30	96.21	69.00	140.00	1.31	1.01	2.40
	190	0.13	0.01	0.87	0.14	0.03	0.55	0.93	0.03	3.21	0.32	0.09	2.02
54-24388	22.5	0.12	0.01	0.77	0.77	0.01	1.86	15.66	4.65	44.80	1.07	0.79	1.34
	42.5	1.93	0.01	13.20	0.96	0.25	1.85	18.31	7.27	42.90	1.41	0.94	1.69
	67.5	0.11	0.01	0.31	1.60	0.92	2.84	35.27	14.10	55.70	2.05	1.21	3.69
	82.5	0.05	0.02	0.07	1.51	0.70	2.10	15.33	4.16	26.10	8.60	2.75	12.80
	97.5	0.22	0.03	0.36	1.93	0.46	2.66	31.95	14.50	44.00	1.76	0.91	2.94
	132.5	0.23	0.12	0.38	1.79	0.76	2.56	28.72	15.70	37.10	1.20	0.75	1.96
	151.5	0.25	0.03	2.38	1.28	0.61	1.92	22.01	12.70	28.60	1.08	0.79	1.52
	167.5	0.10	0.02	0.64	0.21	0.01	0.53	4.01	0.80	6.56	0.42	0.13	0.61
	189.5	0.08	0.00	0.28	0.09	0.01	0.20	0.59	0.01	1.26	0.16	0.02	0.38

Table 4.3-1
Average, Minimum, and Maximum Concentrations of Select VOCs Monitored during the Deep-Extraction Test

Borehole	Depth (ft)	Freon-11			PCE			TCA			TCE		
		Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)
54-01116	22.5	0.19	0.12	0.27	1.49	0.95	1.81	52.91	36.10	61.20	2.30	1.64	2.70
	42.5	0.09	0.00	0.14	1.02	0.59	1.40	40.38	31.60	47.30	2.01	1.80	2.35
	66.5	0.15	0.05	0.22	1.43	0.94	1.65	47.54	42.60	51.60	1.87	1.74	2.03
	82.5	0.39	0.29	0.46	2.68	2.17	3.25	67.84	59.50	76.60	1.78	1.60	1.86
	97.5	0.74	0.57	0.97	4.59	3.61	6.20	103.16	85.80	133.00	1.77	1.60	2.02
	132.1	0.81	0.71	0.90	4.37	3.42	5.09	88.16	79.20	99.30	1.26	1.09	1.42
	151.5	0.11	0.00	0.23	0.76	0.24	1.47	22.91	8.63	39.00	0.79	0.01	0.99
	167.5	0.08	0.01	0.22	0.37	0.08	1.12	9.15	0.03	26.90	0.51	0.26	0.77
	190	0.03	0.02	0.03	0.10	0.01	0.32	0.18	0.17	0.19	0.21	0.02	0.49
54-01117	20	0.06	0.01	0.09	0.60	0.31	1.02	6.68	2.84	9.95	0.68	0.53	0.92
	42.5	0.06	0.02	0.13	0.74	0.57	1.06	16.64	8.99	20.40	0.94	0.75	1.22
	67.5	0.21	0.14	0.45	1.45	1.19	1.59	32.41	25.30	36.20	1.10	0.61	1.27
	82	0.38	0.31	0.49	2.33	2.08	2.80	48.82	40.50	57.50	1.26	1.10	1.39
	97.5	0.69	0.56	0.89	3.64	3.24	4.03	69.65	62.80	76.60	1.37	1.08	1.53
	132.5	0.75	0.60	1.09	3.60	3.17	4.43	68.03	61.40	75.90	1.24	0.99	1.72
	150	0.30	0.18	0.42	1.25	0.37	1.85	27.63	23.30	36.90	0.72	0.56	1.15
	159.5	0.27	0.14	0.39	1.13	0.68	1.50	25.00	20.00	32.50	0.63	0.36	0.83
	179.8	na*	na	na	0.09	0.04	0.15	0.52	0.03	1.08	0.33	0.06	1.34

Table 4.3-1 (continued)

Borehole	Depth (ft)	Freon-11 Average (ppmv)	Freon-11 Min (ppmv)	Freon-11 Max (ppmv)	PCE Average (ppmv)	PCE Min (ppmv)	PCE Max (ppmv)	TCA Average (ppmv)	TCA Min (ppmv)	TCA Max (ppmv)	TCE Average (ppmv)	TCE Min (ppmv)	TCE Max (ppmv)
54-24378	22.5	0.55	0.47	0.61	3.93	3.36	4.29	178.47	158.00	197.00	2.09	1.92	2.35
	42.5	0.46	0.35	0.69	3.48	3.02	3.86	181.42	176.00	187.00	2.34	1.85	2.64
	66.5	0.70	0.59	0.82	4.96	4.13	5.63	202.79	178.00	224.00	2.74	2.01	2.96
	82.5	1.03	0.62	1.18	7.01	4.88	7.77	239.32	200.00	271.00	3.08	2.79	3.32
	97.5	1.53	1.35	1.99	9.50	8.51	12.10	272.11	258.00	301.00	3.05	2.86	3.37
	132.1	1.82	1.72	1.94	9.99	9.27	10.50	201.32	181.00	219.00	1.88	1.53	2.25
	151.5	1.16	0.88	1.47	5.65	4.22	7.27	112.75	85.00	141.00	1.32	1.04	1.52
	167.5	0.25	0.07	0.54	1.51	0.58	3.19	35.33	14.70	66.70	0.89	0.61	1.28
	190	0.01	0.00	0.03	0.06	0.02	0.18	0.49	0.49	0.49	0.28	0.08	0.98
54-24388	22.5	0.32	0.00	0.94	0.86	0.40	1.49	11.10	5.63	16.50	1.31	1.06	2.01
	42.5	0.05	0.02	0.10	0.95	0.52	1.32	14.42	9.31	18.90	1.52	1.10	1.89
	67.5	0.05	0.00	0.11	1.35	1.16	1.80	20.52	12.30	27.00	4.06	3.65	4.53
	82.5	0.05	0.00	0.12	1.70	1.08	2.11	15.46	7.91	21.60	9.38	7.56	10.90
	97.5	0.20	0.03	0.32	2.23	1.89	2.68	28.59	19.60	36.00	3.89	3.24	4.71
	132.5	0.24	0.15	0.40	2.00	1.68	2.24	26.78	19.30	34.30	1.28	0.95	1.47
	151.5	0.17	0.06	0.25	1.40	0.92	1.82	19.00	10.30	27.50	1.15	0.98	1.42
	167.5	0.03	0.00	0.06	0.17	0.07	0.72	1.51	0.18	3.12	0.40	0.07	0.87
	189.5	0.05	0.00	0.10	0.08	0.02	0.25	0.12	0.04	0.18	0.21	0.05	0.36

* na = Not available.

Table 4.4-1
Average, Minimum, and Maximum Concentrations of Select VOCs Monitored during the Passive Extraction Test

Borehole	Depth (ft)	Freon-11			PCE			TCA			TCE		
		Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)
54-01116	22.5	0.19	0.12	0.37	1.65	1.12	2.60	59.89	47.90	92.10	2.67	1.92	3.05
	42.5	10.82	0.10	85.60	1.35	1.06	1.63	48.15	35.20	56.20	2.04	1.61	2.22
	66.5	0.20	0.16	0.25	1.67	1.33	1.95	52.49	42.50	59.40	1.85	1.50	1.98
	82.5	0.34	0.22	0.40	2.51	1.65	2.93	64.64	39.90	74.50	1.75	1.19	1.96
	97.5	0.71	0.51	0.83	4.39	3.38	5.14	98.89	72.10	115.00	1.71	1.32	1.91
	132.1	0.78	0.32	0.89	4.19	1.90	4.79	84.06	36.30	95.70	1.24	0.80	1.42
	151.5	0.19	0.02	0.44	1.25	0.38	2.51	23.96	11.20	44.60	0.69	0.50	0.88
	167.5	0.02	0.00	0.05	0.27	0.17	0.42	5.71	1.84	8.93	0.47	0.21	0.65
	190	0.04	0.04	0.04	0.13	0.04	0.47	0.33	0.33	0.33	0.19	0.03	0.31
54-01117	20	0.05	0.01	0.09	0.55	0.38	0.70	4.92	0.31	7.66	0.72	0.55	0.91
	42.5	0.14	0.05	0.38	1.20	0.62	2.61	23.45	5.41	61.30	1.03	0.62	2.02
	67.5	0.28	0.10	0.75	1.81	0.84	4.04	37.08	15.10	79.80	1.12	0.87	1.43
	82	0.38	0.03	0.77	2.07	0.53	3.87	42.81	8.90	79.90	1.13	0.66	2.10
	97.5	0.47	0.24	0.69	2.34	1.24	3.59	44.06	21.70	64.20	1.09	0.68	1.81
	132.5	0.51	0.19	0.96	2.29	0.70	4.10	43.83	15.20	68.50	0.84	0.57	1.11
	150	0.25	0.07	0.43	1.27	0.40	2.83	18.75	0.49	40.40	0.57	0.21	0.92
	159.5	0.18	0.03	0.34	0.80	0.34	1.36	17.74	3.93	28.00	0.60	0.35	0.93
	179.8	0.08	0.08	0.08	0.23	0.01	0.62	5.74	0.49	11.00	0.31	0.02	0.99

Table 4.4-1 (continued)

Borehole	Depth (ft)	Freon-11			PCE			TCA			TCE		
		Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)	Average (ppmv)	Min (ppmv)	Max (ppmv)
54-24378	22.5	0.57	0.14	0.77	4.02	1.16	5.24	174.08	47.60	221.00	2.00	0.98	2.46
	42.5	0.53	0.32	0.61	3.81	2.40	4.26	178.50	108.00	194.00	2.23	1.43	2.49
	66.5	0.83	0.57	0.96	5.56	3.57	6.50	214.50	125.00	247.00	2.78	1.63	3.16
	82.5	1.17	0.80	1.63	7.47	4.60	10.20	260.25	169.00	346.00	3.05	2.21	3.64
	97.5	1.40	0.73	1.69	8.61	5.18	10.30	235.38	149.00	278.00	2.66	1.62	3.34
	132.1	1.46	0.59	1.85	7.82	3.30	9.91	157.85	77.80	196.00	1.71	1.31	2.05
	151.5	1.18	0.44	1.44	5.86	2.68	6.86	118.98	64.30	137.00	1.67	1.24	2.46
	167.5	0.27	0.02	0.45	1.66	0.55	2.43	38.36	21.40	53.10	0.91	0.28	1.17
	190	0.03	0.03	0.03	0.20	0.00	0.90	0.90	0.67	1.12	0.24	0.07	0.45
54-24388	22.5	na*	na	na	0.87	0.73	1.17	11.61	5.63	19.20	1.27	1.09	1.42
	42.5	na	na	na	1.03	0.91	1.29	14.04	9.19	22.70	1.60	1.51	1.68
	67.5	0.03	0.01	0.06	1.34	1.01	1.48	17.44	8.84	29.70	4.18	3.47	4.82
	82.5	0.04	0.00	0.09	1.70	1.47	1.92	15.28	5.40	28.30	7.46	6.29	8.16
	97.5	0.16	0.08	0.21	2.05	1.73	2.31	26.33	13.70	39.50	4.10	3.23	4.76
	132.5	0.23	0.17	0.28	1.98	1.36	2.26	26.61	10.80	37.40	1.33	0.93	1.55
	151.5	0.18	0.09	0.23	1.60	0.90	1.95	20.70	6.38	31.50	1.19	0.80	1.38
	167.5	0.04	0.02	0.06	0.14	0.07	0.18	6.04	0.85	14.00	0.37	0.30	0.46
	189.5	na	na	na	0.06	0.00	0.10	0.57	0.57	0.57	0.19	0.13	0.25

* na= Not available.

Table 4.5-1
Tritium Concentrations in the Shallow- and Deep-Extraction Boreholes

Sample ID	Collection Date	Tritium Concentration (pCi/L)
Shallow-extraction borehole during active extraction	09-Jul-08	432,600
Shallow-extraction borehole following active extraction	20-Aug-08	656,900
Deep-extraction borehole during active extraction	10-Sep-08	42,360

Table 6.0-1
Mass of Measured VOCs Removed

Test Phase	TCA	TCE	Freon-11	PCE	Other	Total
Shallow Extraction (Active)	220.0 lb (79.2%)*	4.4 lb (1.6%)	1.2 lb (0.4%)	10.4 lb (3.7%)	41.7 lb (15%)	**277.7 lb**
Deep Extraction (Active)	11.5 lb (77.5%)	0.2 lb (1.6%)	0.1 lb (0.8%)	0.8 lb (5.1%)	2.2 lb (15%)	**14.8 lb**
Passive Test (Shallow)	0.53 lb (79.8%)	0.01 lb (1.9%)	0.003 lb (0.3%)	0.02 lb (3.0%)	0.11 lb (15%)	**0.67 lb**

* % of total VOC.

Appendix A

Acronyms and Abbreviations,
Metric Conversion Table, and Data Qualifier Definitions

A-1.0 ACRONYMS AND ABBREVIATIONS

B&K	Brüel and Kjær
bgs	below ground surface
CMI	corrective measures implementation
GAC	granular active carbon
HSA	hollow-stem auger
kPa	kilopascals
LANL	Los Alamos National Laboratory
LLW	low-level radioactive waste
MDA	material disposal area
NMED	New Mexico Environment Department
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
ppmv	parts per million by volume
RFI	Resource Conservation and Recovery Act facility investigation
RPF	Records Processing Facility
scfm	standard cubic feet per minute
SVE	soil-vapor extraction
TA	technical area
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TD	total depth
TRU	transuranic
VOC	volatile organic compound

A-2.0 METRIC CONVERSION TABLE

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

A-3.0 DATA QUALIFIER DEFINITIONS

Data Qualifier	Definition
U	The analyte was analyzed for but not detected.
J	The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.
J+	The analyte was positively identified, and the result is likely to be biased high.
J-	The analyte was positively identified, and the result is likely to be biased low.
UJ	The analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.
R	The data are rejected as a result of major problems with quality assurance/quality control (QA/QC) parameters.

Appendix B

Pilot Study Data
(on CD included with this document)

Appendix B includes five separate Excel files. Below is an explanation of the contents of each file.

- B-1, MDA G Extraction Borehole Data, contains the differential pressure data measured at two different extraction boreholes: shallow and deep. Differential pressure, temperature, and relative humidity were measured at the shallow-extraction borehole during active extraction and passive phases of the pilot test. Differential pressure data were measured at the deep borehole during an active-extraction phase only. Field-screening measurements using the Brüel and Kræjer (B&K) were collected during the active shallow- and deep-extraction tests. Therefore, the workbook B-1 contains 6 worksheets: shallow active extraction, shallow rebound, shallow passive extraction, deep active extraction, shallow-extraction B&K, and deep-extraction B&K.
- B-2, MDA G Monitoring Boreholes—Baseline, contains field-screening data obtained prior to the commencement of the pilot test for each of the four monitoring boreholes (locations 54-01116, 54-01117, 54-24378, and 54-24388).
- B-3, MDA G Monitoring Boreholes—Deep, contains field-screening data obtained during the active deep-extraction phase of the pilot test for each of the four monitoring boreholes.
- B-4, MDA G Monitoring Boreholes—Shallow, contains field-screening data obtained during the active shallow-extraction phase of the pilot test for each of the four monitoring boreholes.
- B-5, MDA G Monitoring Boreholes—Differential Pressure, contains differential pressure data obtained during all four phases (shallow active extraction, shallow rebound, shallow passive extraction, and deep active extraction) of the pilot test for each of the four monitoring boreholes.

Appendix C

Permeability Testing Results

C-1.0 OBJECTIVE

Discrete point air permeability testing was conducted within the open intervals of both the Material Disposal Area (MDA) G shallow and deep soil-vapor extraction (SVE) pilot study extraction boreholes as part of the MDA G SVE pilot study conducted by Los Alamos National Laboratory (the Laboratory). Permeability testing was conducted to provide data suitable for subsurface transport model calibration and to provide data for comparison with earlier in situ permeability measurements collected during the 1995 pilot vapor extraction test at MDA L (ERM/Golder 1997, 070334).

C-2.0 METHODOLOGY

Permeability testing was conducted within the open intervals of the SVE extraction boreholes on October 10, 2008, using methodology and a dual straddle packer apparatus similar to those described by Wykoff et al. (1998, 098069). The packers are each 6 ft in length and are made of a lightweight packer material. The packer apparatus was lowered into the open interval of the borehole, and the packers were inflated to 5 pounds per square inch (psi) internal pressure to segregate a 2-ft segment within the interval. Air was then extracted through vacuum tubing from the segregated interval. Ambient and extracted air temperature, differential and atmospheric pressure, and airflow rate were recorded at the surface during extraction. The process was repeated every 5 ft within the open interval of the borehole.

Permeability was calculated based on a steady-state spherical flow model (Wykoff et al. 1997, 098069). By approximating the air extraction as a sphere, the steady-state airflow, the source equivalent radius, the source pressure, and the ambient soil-gas pressure were used to infer the effective gas permeability, k, by the following equation:

$$k = \frac{\mu R T m}{2\pi M (P_o^2 - P^2)} \cdot \left(\frac{1}{r_o}\right)$$

Where μ = dynamic gas viscosity

R = universal gas constant

T = absolute temperature

m = gas mass flow out of soil

M = gas molecular weight

P_o = absolute pressure of source

P = ambient absolute soil gas pressure

r = source radius (radius of open borehole)

C-3.0 RESULTS

The results of permeability testing are inconclusive. Permeability values are summarized in Table C-3.0-1 and shown in Figures C-3.0-1 and C-3.0-2. In the shallow-extraction borehole, permeability ranged from 0.039 Darcies at 85 ft below ground surface (bgs) to 0.068 Darcies at 105 ft bgs. In the deep-extraction borehole, permeability ranged from 0.055 Darcies at 173 ft bgs to 0.074 Darcies at 168 ft bgs. These calculations and resulting values are not indicative of the permeability of the stratigraphic units and likely underestimate the actual permeability due to the design of the sampling system. This method of determining permeability assumes downhole instrumentation and does not allow for the effects of sample tubing (e.g., friction loss) on measured values. During this test, differential pressure readings were obtained at the surface using a manometer when they should have been obtained from a pressure transducer located downhole.

Because the permeability values obtained as part of the SVE pilot study are inconclusive, the values are not appropriate for modeling purposes.

C-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

ERM/Golder, October 1997. "Pilot Vapor Extract Test at TA-54, MDA L," report prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (ERM/Golder 1997, 070334)

Wykoff, D., J. Stockton, and B. Lowry, February 1998. "Air-Flow Measurements in Los Alamos TA-49-700," Science & Engineering Associates report no. SEASF-TR-97-186, Santa Fe, New Mexico. (Wykoff et al. 1998, 098069)

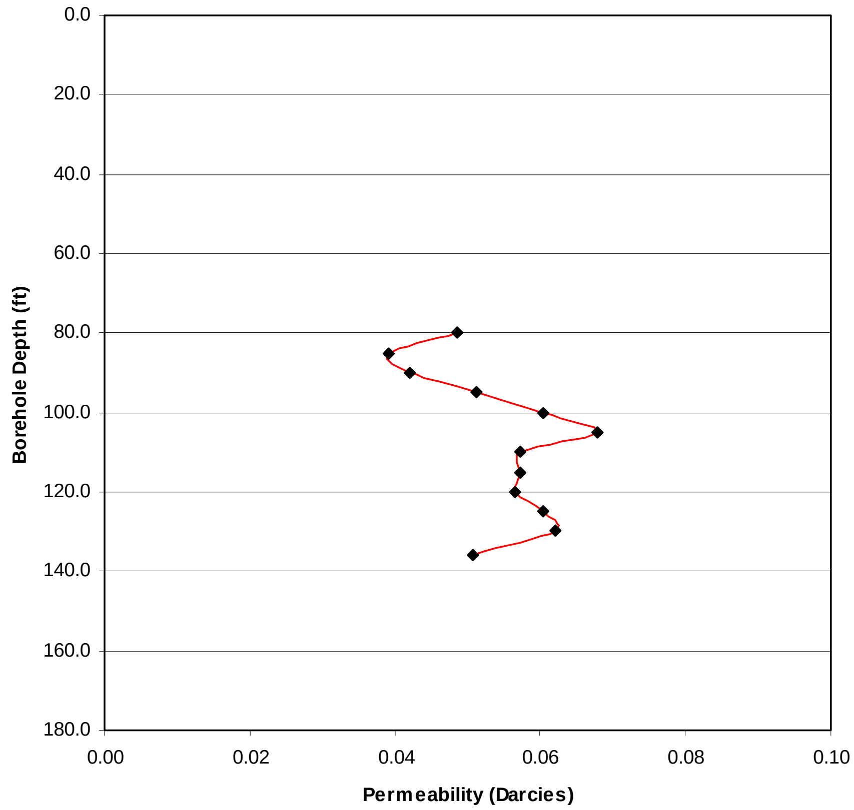

Figure C-3.0-1 Permeability—shallow extraction borehole

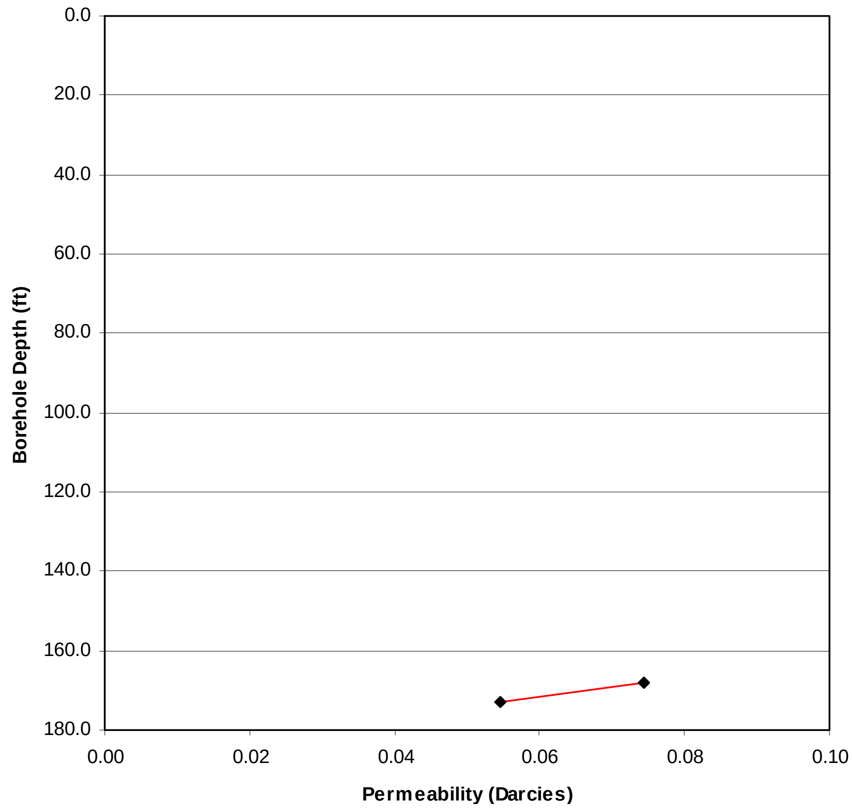

Figure C-3.0-2 Permeability—deep extraction borehole

Table C-3.0-1
Results of Permeability Testing

Test Phase	Port Depth (ft)	Permeability (Darcies)	Permeability (m^2)
Shallow-Extraction (Tshirege Member)	79.70	0.048	4.79E-14
	84.95	0.039	3.87E-14
	89.87	0.042	4.16E-14
	94.79	0.051	5.05E-14
	99.97	0.060	5.96E-14
	104.96	0.068	6.7E-14
	109.88	0.057	5.64E-14
	114.96	0.057	5.65E-14
	119.95	0.057	5.59E-14
	124.97	0.060	5.97E-14
	129.89	0.062	6.12E-14
	135.79	0.051	5.01E-14
Deep Extraction (Otowi Member)	167.96	0.07433	7.34E-14
	172.95	0.054643	5.39E-14

Appendix D

Dwyer Calculations

For use with Dwyer Series PE orifice plate flow meter, the air flow rate in standard cubic feet per minute (SCFM) is provided by the following formulas.

$$SCFM = \frac{5.9816 \times (d^2) \times (K) \times (Y) \times \sqrt{h/w} \times \sqrt{2.703 \times P_L \times SG)/(460 + T_L)}}{\frac{2.703 \times 14.7 \times SG}{460 + T_b}}$$

$$K = C \times ((1)/\sqrt{1-\beta^4}))$$

$$Y = 1 - (.41 + .35\beta^4)((h/w \times .0361)/(P_L \times 1.4))$$

$$C = 0.5959 + 0.0312\beta^{2.1} - 0.1840\beta^8 + 91.71\beta^{2.5} R_n^{-0.75}$$

$$R_n = \frac{\rho v D}{\mu}$$

Where 5.9816	=	physical constant
d	=	bore (inches)
D	=	pipe inside diameter (inches)
K	=	flow coefficient
Y	=	expansion factor
h/w	=	differential pressure (inches-H_20)
P_L	=	line pressure (psia)
T_L	=	line temperature (°F)
T_b	=	base temperature (°F)
ß	=	beta ratio (d/D)
SG	=	specific gravity at line conditions
SH	=	specific heat ratio cp/cv
R_n	=	Reynolds number at max flow in pipe
ρ	=	density (kg/m^3)
v	=	velocity (m/s)
μ	=	viscocity (Pa·s)

Reynolds number (R_n) requires the calculation of the maximum velocity in the pipe. This value was determined from the flow rate that was determined to be 3.4 m^3/min.

All variable values pertinent to the shallow- and deep-extraction test calculations of SCFM are listed below:

d	=	2 in
D	=	4 in
h/w	=	4.95 in-H_20 for shallow; 0.15 in-H_20 for deep
P_L	=	10.77 psia for shallow; 9.16 psia for deep
T_L	=	59 °F
T_b	=	68 °F
SG	=	1.00
SH	=	1.4
ρ	=	0.8 kg/m^3
v	=	7.0 m/s
μ	=	1.8 E-5 Pa·s

Appendix E

Specifications for
Soil-Vapor Extraction and Monitoring Equipment
(on CD included with this document)