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REPORTS

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GROUNDWATER TECHNOLOGY ®

Groundwater Technology, Inc.
2501 Yale Boulevard S.E., Suite 204, Albuquerque, NM 87106 USA

SOIL VAPOR EXTRACTION AND AIR SPARGE PILOT TEST REPORT BLOOMFIELD REFINING COMPANY #50 COUNTY ROAD 4990 BLOOMFIELD, NEW MEXICO JUNE 13 - 16, 1994

PROJECT NO. 023353014

August 23, 1994

Prepared for:

Mr. Chris Hawley
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Groundwater Technology, Inc.
Written/Submitted by

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GROUNDWATER TECHNOLOGY ®

Groundwater Technology, Inc.
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August 24, 1994

Mr. Greg J. Lyssy
Project Coordinator
RCRA Technical Section - Enforcement Branch
U.S. Environmental Protection Agency
Region 6
1445 Ross Avenue, Suite 1200
Dallas, Texas 75202-2733

RE: Bloomfield Refining Company
#50 County Road 4990
Bloomfield, New Mexico 87413
EPA ID #NM089416416
Administrative Order On Consent - Docket No. VI-303-H
Results of the Phase IV RFI - Soil Vapor Extraction and Air Sparge Pilot Test

Dear Mr. Lyssy:

Enclosed is the report entitled "Soil Vapor Extraction and Air Sparge Pilot Test" for the above-referenced site. This report described the procedures and findings of the soil vent and air sparge pilot testing conducted as part of the Phase IV RCRA Facility Investigation (RFI) at the Bloomfield Refining Company (BRC) site during the third week of June 1994.

Should you have any questions concerning this report, please do not hesitate to contact me or Ms. Sara Brothers at (505) 242-3113.

Sincerely,

Groundwater Technology, Inc.

Teresa J. Bennett for

Cymantha Liakos
Project Manager

Enclosure

cc: Chris Hawley - BRC
Joe Warr - BRC
Dave Roderick - BRC
Roger Anderson - NM Oil Conservation Division
Ed Horst - NMED Hazardous Waste Bureau

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1.0 INTRODUCTION

1.1 Purpose of Investigation

This report summarizes the results of soil vapor extraction and air sparge pilot tests conducted as part of the Phase IV RCRA Facility Investigation (RFI) at the Bloomfield Refining Company (BRC) site located in Bloomfield, New Mexico. The objective of the pilot testing was to determine the feasibility of these technologies for application at the BRC site. The work scope for the investigation included the installation of pilot test wells and monitor points, and short-term soil vapor extraction, air sparge, and combined pilot tests conducted on the test wells.

1.2 Background

The BRC facility consists of 287 acres and is located at #50 County Road 4990 (Sullivan Road) in Bloomfield, San Juan County, New Mexico (Figure 1). The refinery is situated on a bluff approximately 100 feet above and immediately south of the San Juan River, which flows westerly. On the bluff and between the river and the process area of the facility is the Hammond Ditch. The ditch is an unlined man-made channel for irrigation water supply which borders all but the southern side of the process area of the facility.

1.3 Setting

The current facility layout is shown in Figure 1. The refinery offices, warehouse space, maintenance shops, drum storage area and raw water ponds are located in the western portion of the property and along Sullivan Road. Process areas are located east of the offices. The eastern most portion of the property contains the tank farm, the waste water treatment and evaporation ponds, and the fire training area.

2.0 SITE HYDROGEOLOGY

The site is underlain by Quaternary Jackson Lake Terrace deposits comprised of 10 to 15 feet of coarse-grained fluvioglacial outwash deposits blanketed by wind-blown loess. These coarse grained sediments (sands grading to cobbles) unconformably overlie the Nacimiento Formation which is a thick (570 feet) layer of black carbonaceous mudstone with interbedded white sandstones. Seeps have been observed along the contact between the consolidated Nacimiento and unconsolidated Jackson Lake deposits. Perched, shallow groundwater in the Quaternary deposits is encountered between 6 and 40 feet below ground surface, generally increasing in depth from west to east across the site. Groundwater flows to the northwest and west, toward Hammond Ditch and the San Juan River. The ditch is known to influence groundwater flow at the site; during the non-irrigation season, BRC dikes the ditch to maintain a mounding effect year-round which inhibits groundwater flow to the north (toward the seeps).

3.0 INSTALLATION OF PILOT TESTS WELLS AND MONITOR POINTS

3.1 Drilling and Well Completion Operations

On May 13 - 17, 1994, Groundwater Technology, Inc. (Groundwater Technology) supervised the installation of seven wells on the southwestern part of the BRC site for use in the aquifer testing and soil vent/air sparge pilot studies. Drilling was performed by Layne Environmental Services, Inc., the subcontracted driller, using a Drill Systems 180 air percussion drill rig. One nested vapor extraction well (VEW-1), one air sparge well (AS-1) and five monitor points (MP-1 through MP-5) were installed. Well locations are shown in Figure 1.

Soil samples were collected from select borings at 5-foot intervals for lithologic identification and field and laboratory analysis using a 2-foot long split-spoon sampler. Detailed geologic logs based on the samples were recorded by an experienced Groundwater Technology scientist during drilling and are presented in Appendix A. The soil samples were field-screened for relative concentrations of volatile organic compounds using a photoionization detector (PID) calibrated to 100 parts per million (ppm) isobutylene gas. Soil samples for field-screening were placed in 16-ounce glass jars, sealed with aluminum foil, agitated, and allowed to equilibrate for five to ten minutes prior to analysis. The PID results are included on the geologic logs in Appendix A. Select soil samples retained for laboratory analysis were placed in 250-ml glass jars with teflon septa, sealed, labeled, placed on ice in an insulated shipping cooler, and transported to Inter-Mountain Laboratories, Inc. in Bozeman, Montana via overnight courier. The samples were analyzed for volatile organic compounds in accordance with EPA method 8240. Laboratory Certificates of Analysis and Chain-of-Custody documentation are included in Appendix B.

Following completion of drilling, each soil boring was converted to a well. A summary of well construction specifications is included in Appendix A. Vapor extraction well VEW-1 was drilled to a total depth of 26 feet and completed as a nested well with two screened intervals to allow for separate vent testing of discreet stratigraphic zones. The screened intervals are 5 -13 feet (0.040-inch slot PVC screen) across the upper silt and clay interval; and 16 - 26 feet (0.040-inch slot PVC screen from 16 - 21 feet and 0.020-inch slot screen from 21 - 26 feet) across the lower sand and cobble zone. Each well nest was separated from one other in the borehole by a gravel pack and a 2-foot thick bentonite and grout seal.

Air sparge well AS-1 was drilled to a total depth of approximately 32 feet below the ground surface (top of bedrock) and screened approximately five feet below the water table from 29 to 31 feet, followed by blank casing to the surface. The well was completed with 2-inch diameter, 0.020-inch slotted PVC well screen and casing and the bottom of the well was fitted with a PVC well cap. The annular space was backfilled with 10-20 silica sand to 26.5 feet below the surface, followed by bentonite to 22.5 feet, and grout to the surface.

Monitor points MP-1 through MP-5 were drilled to total depths of 30 - 32 feet and completed with 20 to 25 feet of 2-inch diameter schedule 40 PVC screen (0.020-inch slotted) and 5 to 10 feet of blank casing. The bottom of each well was fitted with a PVC cap and the annular space was backfilled to one to two feet above the well screen with sand pack, followed by a one to 2-foot thick bentonite seal and grout to the surface.

3.2 Soil Sampling and Analytical Results

The wells (except VEW-1) were generally installed to the top of the Nacimiento Formation (30 to 32 feet below grade) which appeared as a weathered limestone at each location. The vadose zone consists of poorly graded silt and clay to approximately 18 to 20 feet beneath the surface. Below this upper fine-grained unit is a sand and cobble layer occurring from approximately 20 to 30 feet below grade and which directly overlies the limestone (Figure 2).

Soil samples from borings VEW-1 and MP-3 were field-screened with a Photovac Microtip PID during drilling for relative concentrations of volatile organic compounds. Headspace readings for soil samples collected from both borings ranged from 21 ppm to 2,415 ppm. Laboratory results for soil samples collected during drilling and analyzed per EPA method 8240 are provided in Appendix B. Identified hydrocarbon compounds included 0.5 mg/kg total xylenes in the soil sample obtained from VEW-1 from a depth of 24 feet, and 1.4 mg/kg total xylenes in the sample from MP-3 from 27 feet.

4.0 SOIL VENT/AIR SPARGE PILOT TESTS

On June 13 - 16, 1994, Groundwater Technology conducted short-term air sparge and soil vapor extraction pilot tests at the BRC facility. The purpose of the pilot tests was to determine the following information:

- The effective radius of influence for a proposed air sparge/vapor extraction (ASVE) remediation system at the site;
- Engineering criteria and equipment specifications for use in designing a full-scale remediation system; and
- Hydrocarbon mass extraction rates for selection of air emissions treatment methodology.

Pilot testing consisted of three stages: a soil vapor extraction test, an air sparge test, and a combined air sparge/soil vent test. The tests consisted of actual field operation of a soil vacuum blower and air compressor temporarily connected to vapor extraction and air sparge wells. Induced response in the subsurface as a result of the tests was measured in surrounding monitor points. The sparge and vent tests were performed first to define the individual radii of influence and to determine the most effective operational conditions (pressure and vacuum settings) for these individual systems. The combined test documented actual field response to the optimum pressure and vacuum identified during the individual tests and allowed for balancing of the two systems.

Pilot tests at the BRC facility were performed using the newly installed air sparge (AS-1) and vapor extraction (VEW-1) wells as the test wells. Monitoring points were selected to provide multi-directional data at varying distances from the test wells, and to provide information concerning potential vertical differences in response both in the unsaturated and saturated zones. Figure 3 shows the layout of the pilot test monitoring array. The monitoring network utilized for the pilot tests consisted of five existing monitor or recovery wells (P-2, P-3, MW-4, RW-2, MW-25, and MW-26), newly installed monitor points MP-1, MP-2, and MP-4, and the soil vapor extraction nested well (VEW-1). Construction of all test wells and monitor points are detailed on the well logs included in Appendix A and a generalized geologic cross-section showing well screen intervals is provided in Figure 2.

4.1 Soil Vent Test Equipment

Soil vapor extraction pilot tests were performed by attaching a 1.5-horsepower (HP) regenerative vacuum blower with an explosion-proof motor to the pilot test well, VEW-1. The blower system included a particulate filter, vacuum gauges, and an ambient air intake valve to control flow/vacuum. The blower was powered by a portable generator. Blower exhaust was discharged directly to the atmosphere via a 10-foot high, 2-inch diameter PVC pipe effluent stack. One in-line air sampling port for collection of air samples and PID measurements was installed in the effluent stack.

Blower performance and vacuum were monitored using pre- and post-filter Ashcroft vacuum gauges with a range of 0 to 100 inches of water (in 1-inch increments). The vacuum gauges have an accuracy of $\pm$ 1%. Air velocity measurements were obtained at a port installed in the 4-inch diameter PVC pipe at a point located approximately midway between the extraction wellhead and the blower. Measurements were obtained using a Dwyer Instruments thermal anemometer (Model 470). The thermal anemometer was calibrated following manufacturer's instruction prior to initiating each test.

Ambient air temperature and process flow temperature were measured using an Omega HH-70KF pocket thermometer, which has a range of -112 to 1,383 °F and an accuracy of $\pm$ 1% for ambient air temperatures between 68°F to 86°F. Process air stream temperature was measured during the test at inlet ports installed in the piping prior to the blower (pre-blower temperature) and on the discharge side of the blower (post-blower temperature) to monitor blower performance and for use in hydrocarbon mass extraction calculations.

Organic vapor concentrations were monitored at the air sampling port located on the discharge side of the blower using a Microtip PID calibrated with 100 ppm isobutylene gas. The lower explosive limit (LEL) of the discharge vapors was also monitored using an Industrial Science Mx251 meter.

Induced vacuum at monitor wells surrounding the vapor extraction well were measured using a combination of Dwyer Instruments, Inc. magnehelic gauges (Model Nos. 2000-00, 2000-0C, 2002, and 2010). Gauges were attached to the pressure monitoring ports with 1- to 2-foot lengths of flexible rubber tubing.

4.2 Soil Vent Test Protocol

Following equipment set-up and calibration, Groundwater Technology conducted two short-term soil vent pilot tests on nested well VEW-1: one test was conducted on VEW-1S, screened across the vadose zone from 5 to 13 feet below the ground surface (corresponding to a silt and clay stratigraphic zone) and one test was conducted on VEW-1D, screened across both the vadose zone and into the saturated zone from 16 to 26 feet below the surface (corresponding to a sand and gravel stratigraphic zone). Each test was conducted at the maximum obtainable extraction vacuum for approximately three hours or until stabilization occurred in the monitoring parameters. A complete round of static vacuum, temperature, velocity, and organic vapor concentrations were collected prior to the start of each test. After each test was started, the following parameters were measured at approximate 5-minute intervals for the first elapsed 15 minutes, at approximate 15-minute intervals for the remainder of the first elapsed hour, and hourly thereafter:

- Pre- and post filter vacuum at the blower;
- Induced vacuum at surrounding monitor points;
- Applied vacuum at the vapor extraction wellhead;
- Pre- and post-blower air stream temperature;
- Process air stream velocity; and
- Air effluent organic vapor concentrations.

Air effluent samples were collected for laboratory analysis near the end of each test. The samples were collected in 1-liter Tedlar bags from the air sampling port located on the blower discharge stack. Following sample collection, the Tedlar bags were labeled and stored at ambient air temperature inside shipping coolers and shipped via overnight courier with full Chain-of-Custody documentation to Coast-to-Coast Analytical Services in Camarillo, California. The samples were analyzed for total non-methane hydrocarbons and volatile organic compounds per EPA method TO-14, and for fixed gases (carbon dioxide, oxygen, nitrogen, and carbon monoxide) and methane in accordance with method GC/TCD.

4.3 Soil Vent Pilot Test Results

The field data collected during the June 14, 1994 soil vent pilot tests is provided in Appendix C. Tables 1 and 2 summarize the applied vs. the induced vacuum response observed in surrounding monitoring points while venting on test wells VEW-1S and VEW-1D, respectively. A map depicting the pilot test results as observed in the field while venting on test well VEW-1 is provided in Figure 4.

4.3.1 Pilot Test Results - VEW-1S

The maximum vacuum obtained while venting on the shallow zone from VEW-1S during the pilot test ranged from 42 to 43 inches of water. The maximum process air velocity reading obtained was 1,600 feet per minute (fpm). Conversion to standard cubic feet per minute (scfm) yielded 115 scfm.

Maximum induced vacuum (0.15 to 0.19 inches of water) due to venting on VEW-1S was observed in wells MP-1 and RW-2, located 19 and 33 feet from the test well, respectively. An induced vacuum of 0.10 inches of water was detected in MW-4, the most distant monitor point (57 feet) from the test well in which a response was observed. A graph of the log of the induced vacuum vs. distance from extraction well VEW-1S for the pilot test is included in Figure 5.

While venting on VEW-1S, no organic vapor concentrations were detected in the air stream when measured with a PID. However, maximum LEL readings in the process air stream were on the order of 310% to 403%.

A summary of air sample analytical data obtained from well VEW-1S is provided in Table 3, and Laboratory Certificates of Analysis, Chain-of-Custody documentation, and QA/QC data are included in Appendix D. Air sample analytical data collected during the vent pilot test on June 14, 1994 from well VEW-1S indicates that effluent air concentrations were 2.2 milligrams per cubic meter (mg/m^3) benzene, 0.4 mg/m^3 toluene, 0.53 mg/m^3 ethylbenzene, 3.2 mg/m^3 total xylenes, and 460 mg/m^3 total fuel (non-methane hydrocarbons). EDC and EDB were not detected in the air stream. Fixed gases and methane concentrations from well VEW-1S were 0.3% carbon dioxide, 18% oxygen, and 18% methane.

A step-test was also conducted on well VEW-1S. For each step, the applied vacuum was progressively lowered and the resulting air velocity was measured at the wellhead for the various applied vacuums. At applied vacuums of 42, 40, 28, and 16 inches of water, air velocities of 1,600,

1,300, 1,150, and 750 fpm, respectively, were measured in 4-inch diameter pipe. Conversion to scfm yielded air flow rates of 115, 94, 83, and 54 scfm for the four vacuum settings, respectively. A graph of air flow rate versus applied vacuum for the step test is provided in Figure 6.

4.3.2 Pilot Test Results - VEW-1D

The maximum vacuum obtained while venting on the deep zone from VEW-1D during the pilot test ranged from 20 to 21 inches of water. The maximum process air velocity reading was 1,750 fpm or 131 scfm.

At the maximum applied vacuum of 20 to 21 inches of water, maximum induced vacuum measured at the monitor points ranged from 0.08 inches of water in well MP-4 (located approximately 225 feet from VEW-1) to 4.0 inches of water at MP-1 (located approximately 19 feet from VEW-1). A graph of the log of the induced vacuum vs. distance from extraction well VEW-1D for the pilot test is shown in Figure 7.

Maximum organic vapor concentrations of the extracted vapors (based on PID readings) were 110 ppm. LEL readings in the process air stream ranged from 76 to 109% throughout the test.

Air sample analytical data collected during the vent pilot test on June 14, 1994 from well VEW-1D indicates that effluent air concentrations were 380 mg/m^3 benzene, 16 mg/m^3 toluene, 57 mg/m^3 ethylbenzene, 280 mg/m^3 total xylenes, and 11,000 mg/m^3 total fuel. EDC and EDB were not detected in the air stream. Fixed gases and methane concentrations from well VEW-1D were 2.3% carbon dioxide, 4.3% oxygen, and 68% methane (Table 3, Appendix D).

A step-test was also conducted on well VEW-1D. For each step, the applied vacuum was progressively lowered and the resulting air velocity was measured at the wellhead for the various applied vacuums. At applied vacuums of 21, 18, 13, and 10 inches of water, air velocities of 1,750, 1,250, 900, and 650 fpm, respectively, were measured in 4-inch diameter pipe. Conversion to scfm yielded air flow rates of 131, 94, 67, and 48 scfm for the four vacuum settings, respectively. A graph of air flow rate versus applied vacuum for the step test is provided in Figure 6.

4.4 Soil Vent Pilot Test Analysis

The data collected from the soil vent pilot tests on VEW-1 were analyzed using Groundwater Technology's software program, VENT-ROI Version 3.0. VENT-ROI is based on a simple one-dimensional analytical model that provides a rough estimate of the effective cleanup radius (defined as "the maximum distance from a vapor extraction point through which sufficient air is drawn to remove the required fraction of contamination in the desired time"). The effective radius (R_E) is based on site-specific conditions and SVES parameters, and is specific to the contaminant, cleanup goals, and cleanup time frame (Bass, 1993). A more detailed explanation of the model is included in the scientific paper provided in Appendix E.

Using VENT-ROI, data from the pilot tests was analyzed for each separate zone vented at the site: shallow (5 to 13 feet below grade); and deep (16 to 26 feet). Computer-generated output from the R_E calculations is provided in Appendix F. A summary of the calculated R_E values based on the optimum set of parameters is detailed below.

Assuming an approximate 24-foot thickness of vented soil interval for the shallow zone beneath the site (defined as the depth to top of groundwater), a soil gas temperature of 50°F, an air flow rate of 118 scfm per well, a cleanup time of 730 days, and 90% removal of xylene/ethylbenzene, the single well effective radius of influence (for volatilization plus biodegradation) for the shallow zone was approximately 36 feet, and the calculated interwell effective radius of influence was approximately 31 feet at an applied vacuum of 42 inches water column.

For the deep zone, keeping the input variables the same except for an 11-foot thick vented interval (defined as the thickness of the more permeable sand/cobble zone beneath the less permeable upper silt/clay zone) and an air flow rate of 105 scfm per well, the calculated single well R_E was 84 feet with an interwell effective radius of 18 feet at an applied vacuum of 21 inches water column.

For vapor extraction/bioventing to work, the contaminant of concern must be either volatile or biodegradable. Light-end products are treated primarily by volatilization, heavy-end products by biodegradation. Effective radius is most sensitive to the volatility of the contaminant; contaminants with high volatility are easier to remove than those with just high degradability. Taking this into consideration, the effective radii of influence for the shallow and deep zones were also calculated for removal of weathered gasoline/JP-4 and diesel/No. 2 fuel oil contaminant mixtures. Keeping all other input variables the same as above, the calculated single well R_E for the shallow zone for

removal of weathered gasoline/JP-4 was 34 feet and 2 feet for removal of diesel/No. 2 fuel oil. For the deep zone, the calculated R_E values were 78 feet for weathered gasoline and 3 feet for diesel.

4.5 Air Sparge Test Equipment

The air sparge pilot test was performed by connecting a compressed air line to the top of the air sparge well. The compressed air system consisted of a 90 pounds per square inch (psi) (105 cfm) air compressor, 3/4-inch diameter air hose, an in-line oil/water filter, and a pressure regulator to control flow/pressure.

Air velocity measurements were obtained using a combination of Dwyer air flowmeters (Model Nos. RMC and VFC) plumbed into the air line at the air sparge wellhead. Induced pressure at monitoring points surrounding the air sparge well was measured using a combination of Dwyer magnehelic gauges, (Model Nos. 2000-00, 2000-0C, 2002, and 2010). Organic vapor concentrations were measured at the surrounding monitor points using a properly calibrated Microtip PID. Depth-to-water and dissolved oxygen (DO) in surrounding monitor wells screened across the water table were measured using an ORS electronic interface probe (IP) and a YSI Model 51B Dissolved Oxygen Meter, respectively.

4.6 Air Sparge Test Protocol

The sparge test was performed at two different pressures, 3 psi and 5 psi (approximately 30% and 120% over the pressure needed for air to overcome the 5-foot water column above the screened interval of the sparge well). A complete round of static pressure, DO (in wells without separate-phase hydrocarbons (SPH)), fluid-level, and volatile organic compound (VOC) concentration measurements were collected from each monitor point prior to starting the sparge test.

The following parameters were collected during each pressure setting at periodic intervals. Field measurements are included in Appendix C:

- Applied air pressure at the sparge wellhead;
- Air flow rate of compressed air injected into the sparge well;
- Induced pressure at surrounding monitor points;
- VOC concentrations at the surrounding monitor points; and

- DO and depth-to-water were recorded in the monitor wells at the end of each pressure setting (removal of the pressure caps during sparging would interfere with the pressure readings).

4.7 Air Sparge Test Results

At the maximum applied pressure of 5 psi, maximum induced pressure measured at the monitor wells ranged from 0.20 inches of water in well MP-4 (located approximately 230 feet from AS-1) to 2.90 inches of water at VEW-1D (located approximately 10 feet from AS-1) (Table 4). The maximum induced pressure versus distance for each of the injection pressures is plotted in Figures 8 and 9.

VOC concentrations recorded at each monitor point throughout the test are included in Appendix C and summarized in Table 5. The most significant increase in VOC concentrations was observed during the sparge test at 5 psi injection pressure and in those monitor points located closest to the sparge well. After approximately three hours of sparging, VOC concentrations increased from less than approximately 145 ppm (background) to greater than 2,500 ppm in wells VEW-1D and MP-1, located 10 and 14 feet from AS-1, respectively. Significant increases in VOC concentrations were also observed in wells RW-2 (from 193 to 855 ppm) and MP-4 (from 16 to 760 ppm), located 27 and 230 feet from AS-1, respectively.

Fluid levels and DO concentrations in water were measured in those wells screened across the water table prior to pilot testing at each sparge pressure. An increase in the DO concentration is indicative of aeration during the sparge test, which in turn indicates the transport of injected air through the aquifer. The data indicate a significant increase in the DO concentration in the sparge well (AS-1) after approximately three hours of sparging, from background concentrations of 0.2 ppm to maximum concentrations of approximately 4.2 ppm at the end of the test. Because SPH was present in all other monitoring points, DO measurements could not be obtained in these wells.

An increase in the groundwater elevation as a result of sparging (i.e., water-table mounding) was detected in wells RW-2, P-2, MW-4, and MP-4. The maximum difference (pre-test minus post-test values) in depth-to-water values (uncorrected for SPH) ranged from 0.05 feet in MP-4 (located 230 feet from AS-1) to 0.16 feet in MW-4 (located 47 feet from AS-1).

4.8 Combination Air Sparge/Soil Vent Test Protocol

The last phase of pilot testing consisted of a combined air sparge/soil vent test conducted on wells AS-1 and VEW-1D. The objective of the combination test was to ensure that a net vacuum could be established across the site under maximum operating conditions so that all sparge vapors were contained. The combination test was run at 5 psi pressure and 17 - 19 inches of water vacuum, which were the maximum sparging and venting levels recorded during the individual sparge and vent tests, respectively.

The same parameters measured above for the individual vent and sparge tests were collected periodically during the combination test. An effluent air sample was collected at the end (approximately 2.5 hours) of the combination test. The sample was collected in 1-liter Tedlar bags from the sampling port located on the vacuum blower discharge stack. The sample was shipped at ambient air temperature under full Chain-of-Custody to Coast-to-Coast Analytical Services, Inc. in Camarillo, California for analysis of total non-methane hydrocarbons and volatile organics in accordance with EPA method TO-14 and for fixed gases and methane per method GC/TCD.

4.9 Combination Air Sparge/Soil Vent Test Results

The final test involved simultaneous operation of both the vent and sparge pilot systems. Monitoring results for the combined test are included in Appendix C and induced pressure/vacuum responses are summarized in Table 6. Readings taken during the corresponding vent only and sparge only tests are also presented in Table 6 for comparison.

During the combined test at 18 inches of water vacuum and 5 psi, net negative (vacuum) readings were observed in all monitor points at the site, indicating that sparge vapors were being contained by the vent system (Table 6).

PID readings at the monitor points during the combined test were substantially reduced as compared to PID readings measured under sparging conditions alone, indicating that the vacuum system was collecting the sparged vapors. After approximately 125 minutes of the combined test, PID readings at the monitor points ranged from 0 to 240 ppm, as compared to 1.3 to greater than 2,500 ppm obtained during the sparge only test at 5 psi after 185 minutes (Appendix C).

Air sample analytical data collected after 145 minutes of the combined test at 5 psi sparge pressure and 22 inches of water vacuum indicate that benzene concentrations were 460 mg/m^3 in the air effluent, toluene concentrations were 170 mg/m^3, 140 mg/m^3 ethylbenzene, 1,100 mg/m^3 xylenes, and total fuel concentrations were 13,000 mg/m^3. A summary of air sample analytical data obtained during the combined test from well VEW-1D is provided in Table 3, and Laboratory Certificates of Analysis, Chain-of-Custody documentation, and QA/QC packages are included in Appendix D.

4.10 Hydrocarbon Mass Extraction Rates

Based on the air effluent analytical results from vent wells VEW-1S and VEW-1D, hydrocarbon mass extraction rates were calculated for BTEX and total fuel (non-methane hydrocarbons). Mass extraction rates while venting only on the shallow zone (5 to 13 feet below grade) at an air flow rate of 115 scfm were 9.5×10^{-4} pounds per hour (lb/hr) benzene, 1.72×10^{-4} lb/hr toluene, and 0.20 lb/hr total fuel. Mass extraction rates while venting only on the deep zone (16 to 26 feet below grade) at an air flow rate of 131 scfm were 0.19 lb/hr benzene, 0.008 lb/hr toluene, and 5.4 lb/hr total fuel. Mass extraction rates while venting from the deep zone at an air flow rate of 112 scfm and sparging at 5 psi were 0.19 lb/hr benzene, 0.07 lb/hr toluene, and 5.5 lb/hr total fuel. A summary of the hydrocarbon mass extraction rates is presented in Table 7 and mass extraction rate calculations are provided in Appendix G.

4.11 Pilot Testing Conclusions

Based on the results of the pilot tests, the following conclusions are made:

- Induced vacuum as a result of venting on the shallow zone (5 to 13 feet below grade) at the site was measured in wells up to 57 feet away from the vent well. At the maximum applied vacuum of 42 inches of water column, induced vacuum response was low (less than 0.19 inches water column), reflecting the low permeability sediments (clay) characteristic of this zone. Calculated *effective* radii of influence for the shallow zone ranged from 2 feet (for removal of diesel products) to 36 feet for removal of gasoline (xylene/ethylbenzene) products.

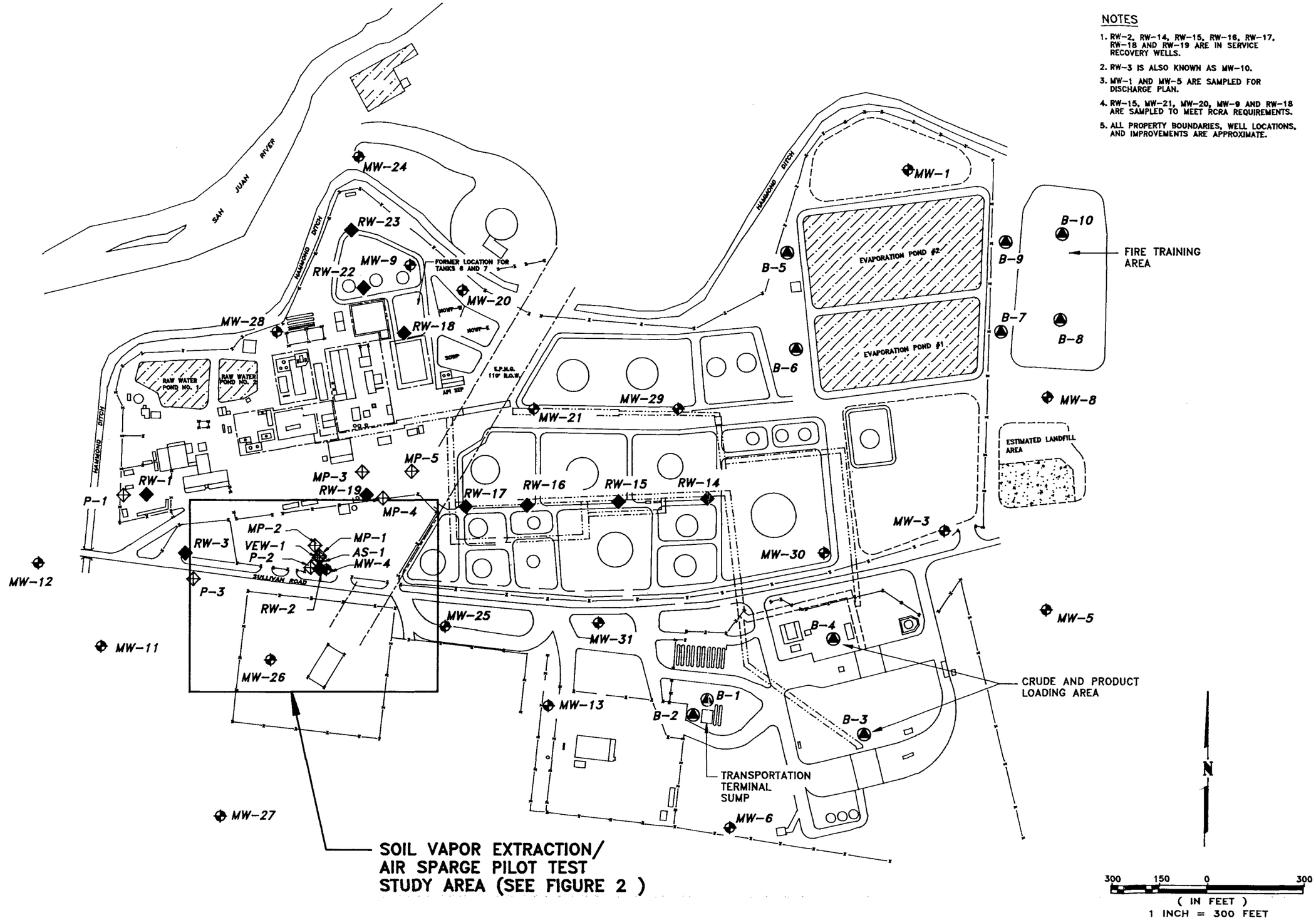
- Induced vacuum response measured while venting on the deep zone (16 to 26 feet below grade) at a maximum applied vacuum of 21 inches water column ranged from 1.9 to 4.0 inches of water at distances of 19 to 57 feet from the vent well.

Extrapolation of the observed data indicate that significant response (greater than 1% of the applied vacuum) would occur as far away as 175 feet from the vent well. Greater response to venting in the deep zone is probably attributable to the high permeability sands and gravels occurring at this depth. Calculated *effective* radii of influence for the deep zone ranged from 3 feet (for diesel) to 84 feet for removal of gasoline components.

- Aquifer sparging effectiveness was evaluated based on observed induced pressure and VOC concentrations while sparging at applied pressures of 3 to 5 psi. A conservative value of 50 feet was selected as the effective radius of influence for the sparge test, based on the observed pressure responses.

- Based on the results of the combined pilot test, a net negative vacuum was observed in all monitor points while venting at near maximum vacuum (18 inches water column) and sparging at approximately 120% (5 psi) above breakthrough pressure. This indicates that any vapors generated as a result of sparging can be captured and contained by the vacuum system. For the combined test, vacuum measured in the monitor points was generally reduced by more than one-half (when compared to the vacuum measured in these same points while venting only) as a result of sparge pressure, further confirming the effectiveness of sparging at the site.

- Hydrocarbon mass removal rates ranged from 0.20 lb/hr total fuel for the shallow zone to 5.5 lb/hr total fuel while venting and sparging on the deep zone. Elevated concentrations of methane ranging from 18 to 68% were also detected in the vented effluent and oxygen levels ranged from 4.3 to 18%.



NOTES

1. RW-2, RW-14, RW-15, RW-16, RW-17, RW-18 AND RW-19 ARE IN SERVICE RECOVERY WELLS.
2. RW-3 IS ALSO KNOWN AS MW-10.
3. MW-1 AND MW-5 ARE SAMPLED FOR DISCHARGE PLAN.
4. RW-15, MW-21, MW-20, MW-9 AND RW-18 ARE SAMPLED TO MEET RCRA REQUIREMENTS.
5. ALL PROPERTY BOUNDARIES, WELL LOCATIONS, AND IMPROVEMENTS ARE APPROXIMATE.

NO.	DATE	BY	REVISION

LEGEND

- PIPEWAY
- UNDERGROUND PIPEWAY
- FENCE
- MW-1 MONITORING WELL
- RW-1 RECOVERY WELL
- B-1 SOIL BORING
- P-1 PIEZOMETER

SIGNATURE	DATE
PROJECT GEO:	
PROJECT ENGR:	
PROJECT MGR:	
CLIENT:	

Bloomfield Refining Company
A Gary Energy Corporation Subsidiary
#50 COUNTY ROAD 4990
BLOOMFIELD, NEW MEXICO

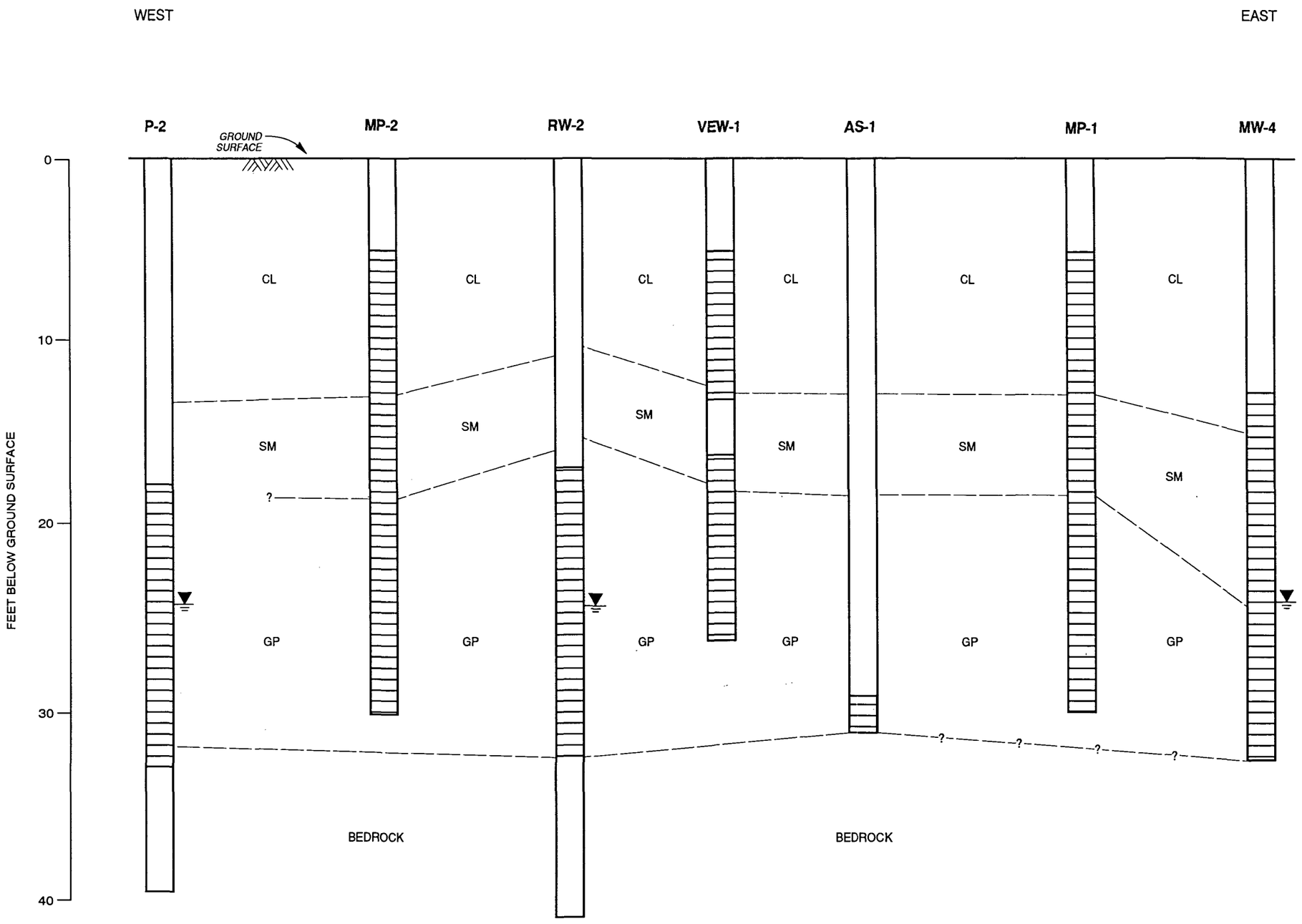
GROUNDWATER TECHNOLOGY
2501 YALE BLVD. SE, SUITE 204
ALBUQUERQUE, NEW MEXICO 87106
(505) 242-3113

SITE MAP

DESIGNED BY:	DRAFTED BY:	CHECKED BY:
	J. ML	TB

DATE:	FILE:
AUG. 9, 1994	SITEMAP
PROJECT NO.: 023353014	CONTRACT:
DRAWING:	REVISION:

FIGURE 1



LEGEND

MW-4	WELL ID
	SCREENED INTERVAL OF MONITOR WELL
	DEPTH TO GROUNDWATER AUGUST 2, 1994
CL	BROWN SILTY CLAY
SM	FINE, POORLY-GRADED SILTY SAND
GP	GRAVEL AND COBBLES WITH SOME FINES
BEDROCK	NACIMIENTO FORMATION (CARBONACEOUS MUDSTONE WITH INTERBEDDED SANDSTONE)

VERTICAL SCALE: 1" = 60'

HORIZONTAL SCALE: 1"~ 6'

NOTE: ALL WELLS PROJECTED INTO LINE OF SECTION.

BLOOMFIELD REFINING COMPANY / NO. 50 COUNTY ROAD 4990

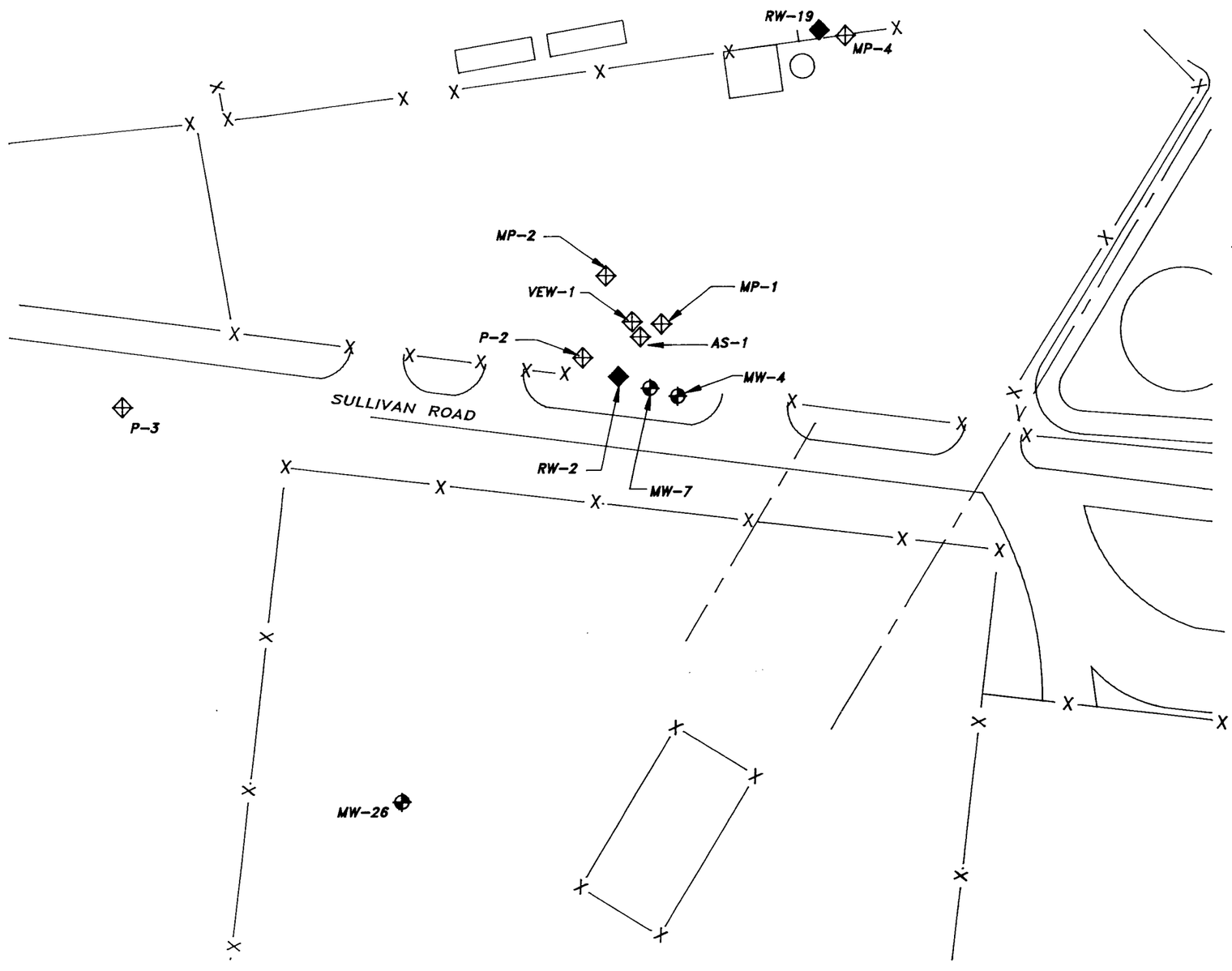
PROJECT NO.: 023353014 | **LOCATION: BLOOMFIELD, N.M.**

GENERALIZED GEOLOGIC CROSS-SECTION SHOWING LOCATIONS OF SCREENED INTERVALS AT SOIL VENT PILOT TEST WELLS

DRAWN BY: JU	DATE: 8/10/94	CHECKED BY: TB	DATE: 8/11/94
FOLDER: CHV/Alamogordo FILE: XSECT 8/94		APPROVED BY: TB	DATE: 8/11/94

FIGURE 2

GROUNDWATER TECHNOLOGY



NOTE

1. ALL PROPERTY BOUNDARIES, WELL LOCATIONS, AND IMPROVEMENTS ARE APPROXIMATE.

LEGEND

- PIPEWAY
- UNDERGROUND PIPEWAY
- FENCE
- MW-1 MONITORING WELL
- RW-1 RECOVERY WELL
- B-1 SOIL BORING
- P-1 PIEZOMETER OR MONITOR POINT
- AS-1 AIR SPARGE WELL
- VEW-1 VAPOR EXTRACTION WELL

SIGNATURE	DATE
PROJECT GEO:	
PROJECT ENGR:	
PROJECT MGR:	
CLIENT:	

Bloomfield Refining Company
A Gary Energy Corporation Subsidiary
#50 COUNTY ROAD 4990
BLOOMFIELD, NEW MEXICO

GROUNDWATER TECHNOLOGY
2501 YALE BLVD. SE, SUITE 204
ALBUQUERQUE, NEW MEXICO 87106
(505) 242-3113

N

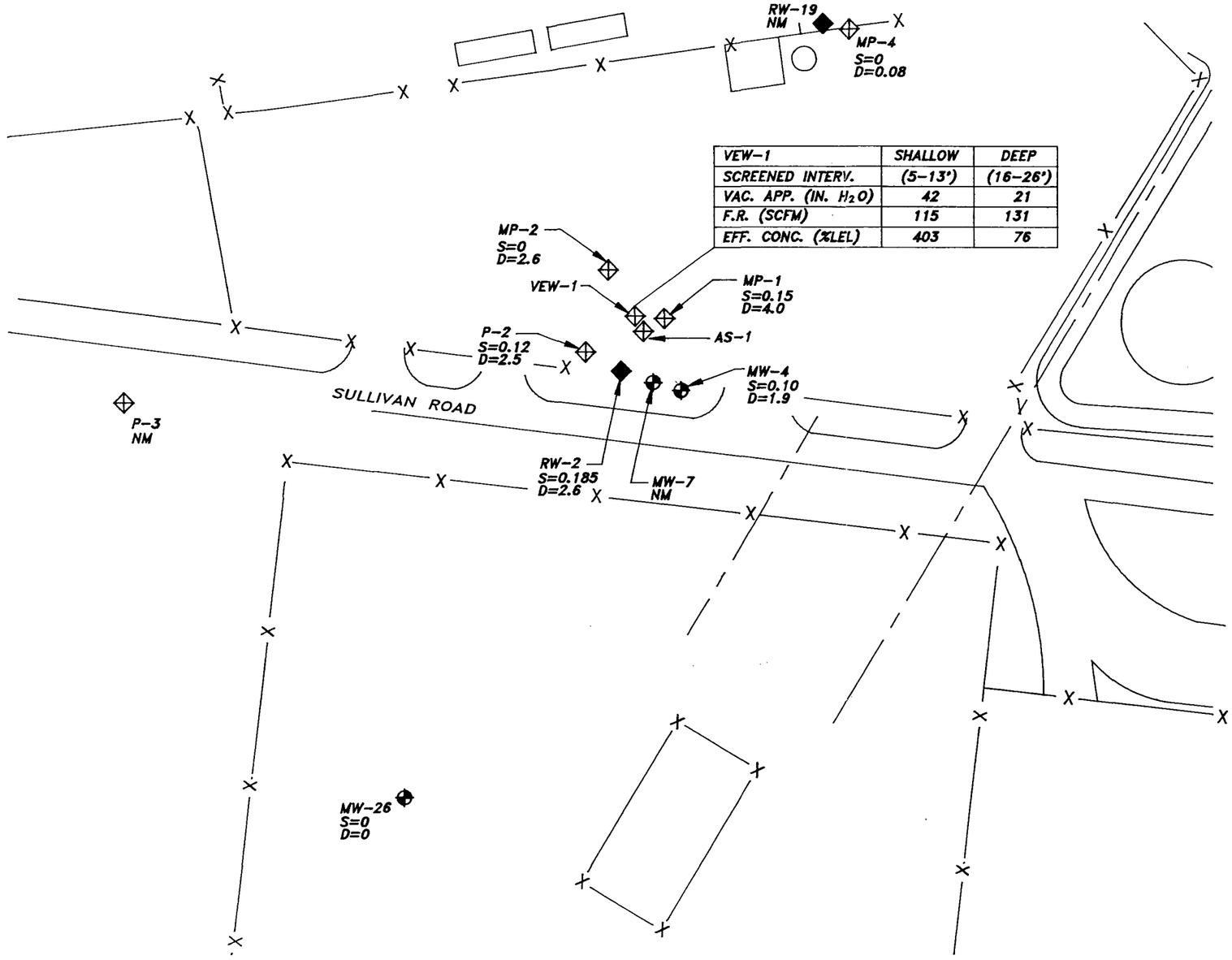
80 40 0 80
(IN FEET)
1 INCH = 80 FEET

SOIL VAPOR EXTRACTION/AIR SPARGE PILOT TEST STUDY AREA

DESIGNED BY:	DRAFTED BY:	CHECKED BY:
	J. ML	TB
DATE: AUG. 9, 1994		FILE: VAPOR-EX
PROJECT NO.: 023353014		CONTRACT:

DRAWING: REVISION:

FIGURE 3



VEW-1	SHALLOW	DEEP
SCREENED INTERV.	(5-13')	(16-26')
VAC. APP. (IN. H_2O)	42	21
F.R. (SCFM)	115	131
EFF. CONC. (%LEL)	403	76

NOTE

1. ALL PROPERTY BOUNDARIES, WELL LOCATIONS, AND IMPROVEMENTS ARE APPROXIMATE.

VAC. APP.	VACUUM APPLIED (IN. H_2O)
F.R.	AIR FLOW RATE AT INDICATED VACUUM (SCFM)
EFF. CONC. @ VAC.	EFFLUENT VAPOR CONCENTRATION AT INDICATED VACUUM (% LEL)
(5-13')	SCREENED INTERVAL OF WELL
S	SHALLOW ZONE TEST MAXIMUM INDUCED VACUUM READING (IN H_2O)
D	DEEP ZONE TEST MAXIMUM INDUCED VACUUM READING
NM	NOT MEASURED

N

80 40 0 80
(IN FEET)
1 INCH = 80 FEET

LEGEND

- PIPEWAY
- UNDERGROUND PIPEWAY
- FENCE
- MW-1 MONITORING WELL
- RW-1 RECOVERY WELL
- B-1 SOIL BORING
- P-1 PIEZOMETER OR MONITOR POINT
- AS-1 AIR SPARGE WELL
- VEW-1 VAPOR EXTRACTION WELL

SIGNATURE	DATE
PROJECT GEO:	
PROJECT ENGR:	
PROJECT MGR:	
CLIENT:	

Bloomfield Refining Company
A Gary Energy Corporation Subsidiary
#50 COUNTY ROAD 4990
BLOOMFIELD, NEW MEXICO

GROUNDWATER TECHNOLOGY
2501 YALE BLVD. SE, SUITE 204
ALBUQUERQUE, NEW MEXICO 87106
(505) 242-3113

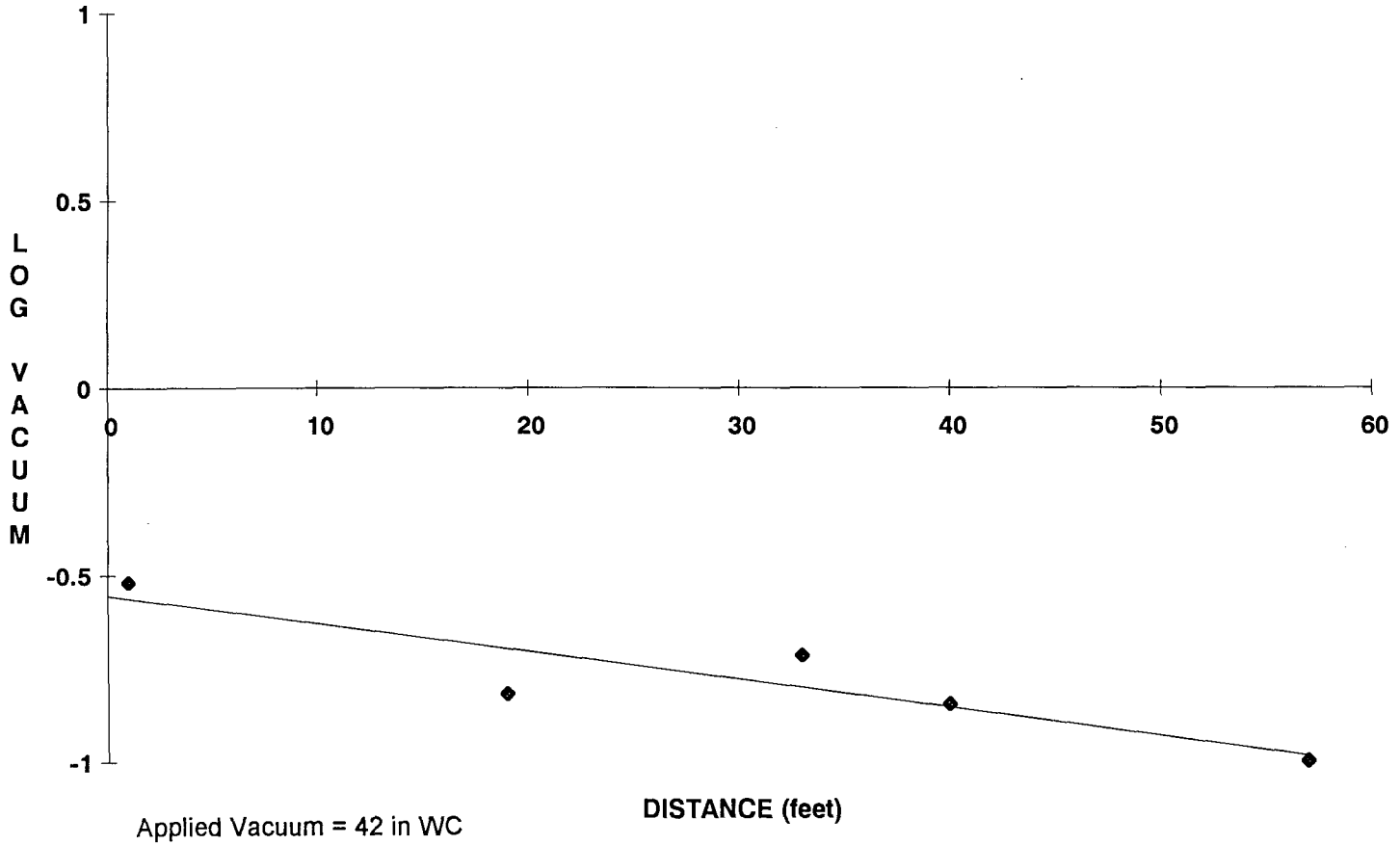
FIELD RESULTS FOR SOIL VENT PILOT TESTS ON WELL VEW-1

DESIGNED BY:	DRAFTED BY:	CHECKED BY:
	J. ML	TB

DATE:	FILE:
AUG. 9, 1994	VEW-1
PROJECT NO.: 023353014	CONTRACT:
DRAWING:	REVISION:

FIGURE 4

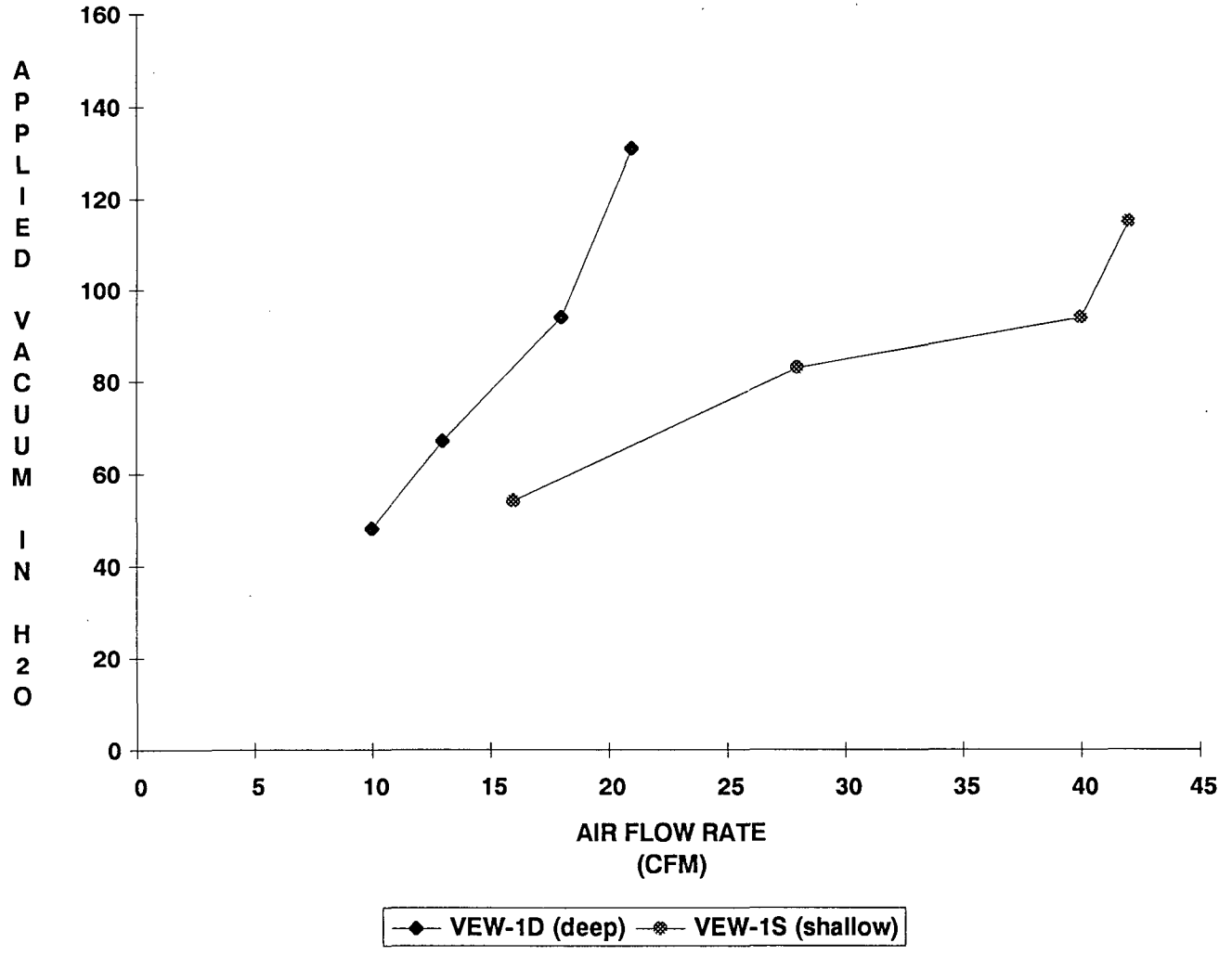
FIGURE 5
LOG OF INDUCED VACUUM VS. DISTANCE FROM VAPOR EXTRACTION WELL VEW-1S, SHALLOW ZONE TEST BLOOMFIELD REFINING COMPANY JUNE 14, 1994



Applied Vacuum = 42 in WC

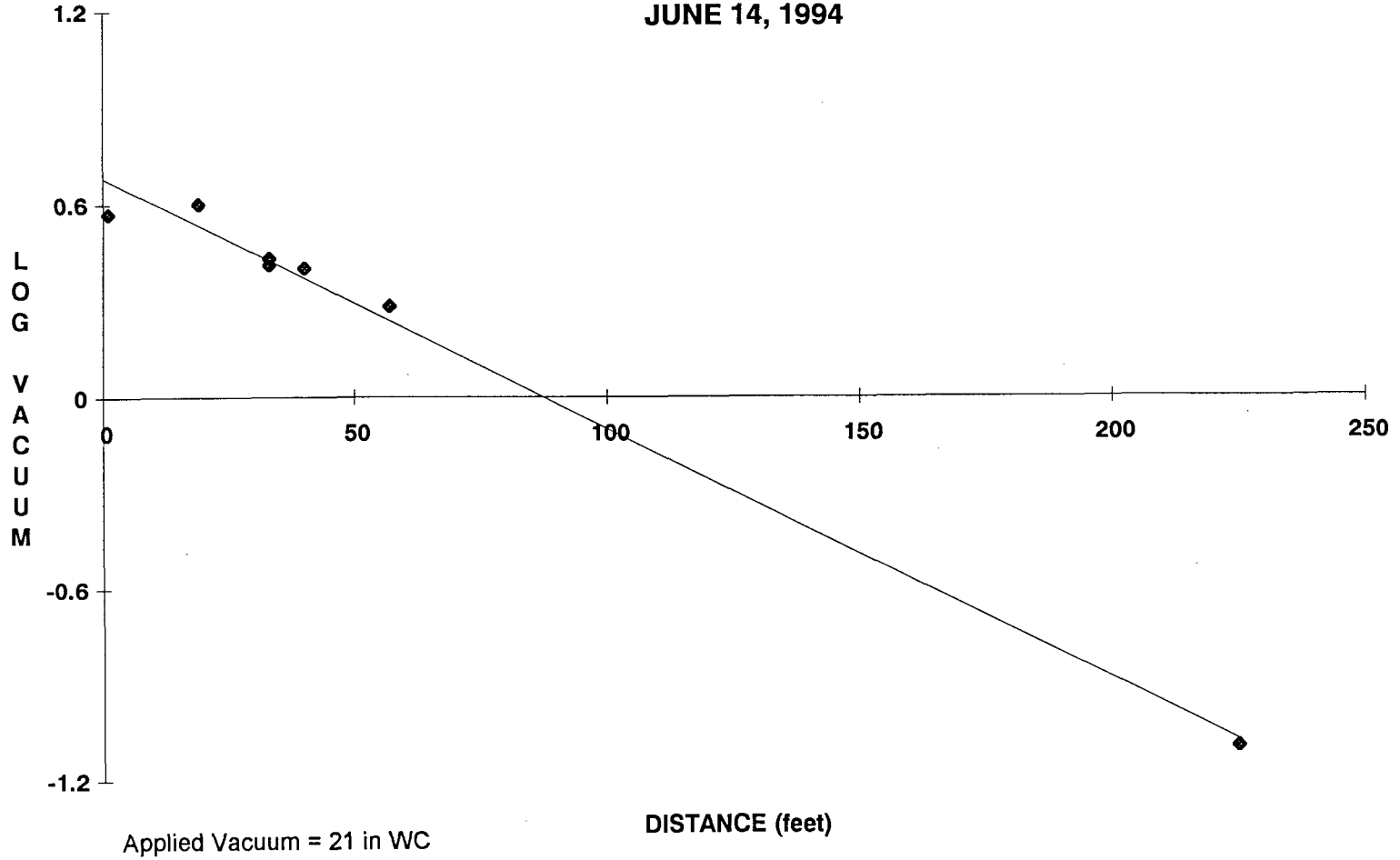
GROUNDWATER TECHNOLOGY ®

FIGURE 6
APPLIED VACUUM VS. AIR FLOW RATE
FOR VENT STEP-TESTS ON NESTED WELL VEW-1
BLOOMFIELD, NEW MEXICO
JUNE 14, 1994



GROUNDWATER TECHNOLOGY

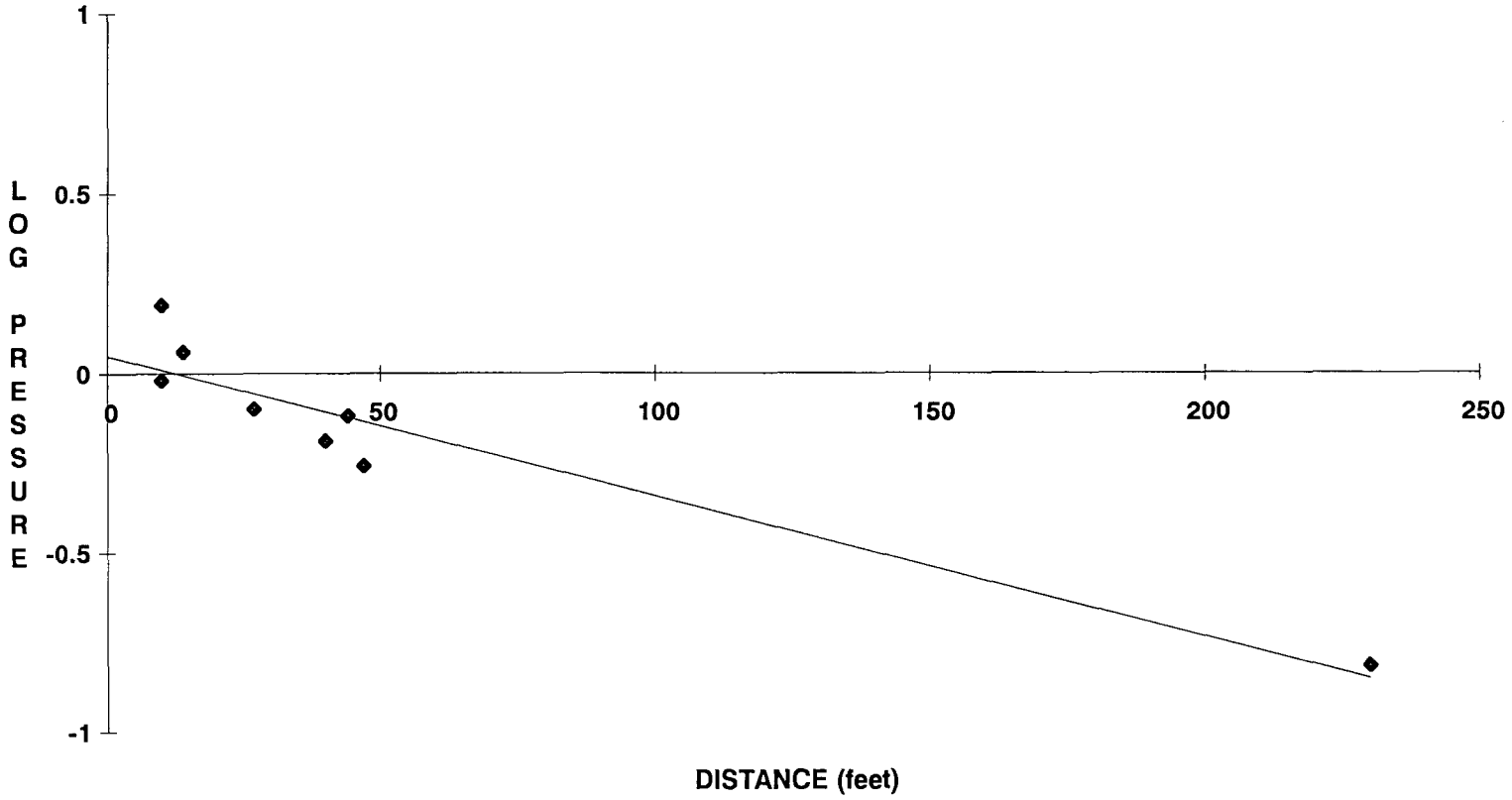
FIGURE 7
LOG OF INDUCED VACUUM VS. DISTANCE FROM VAPOR EXTRACTION WELL VEW-1D, DEEP ZONE TEST
BLOOMFIELD REFINING COMPANY
JUNE 14, 1994



Applied Vacuum = 21 in WC

GROUNDWATER TECHNOLOGY ®

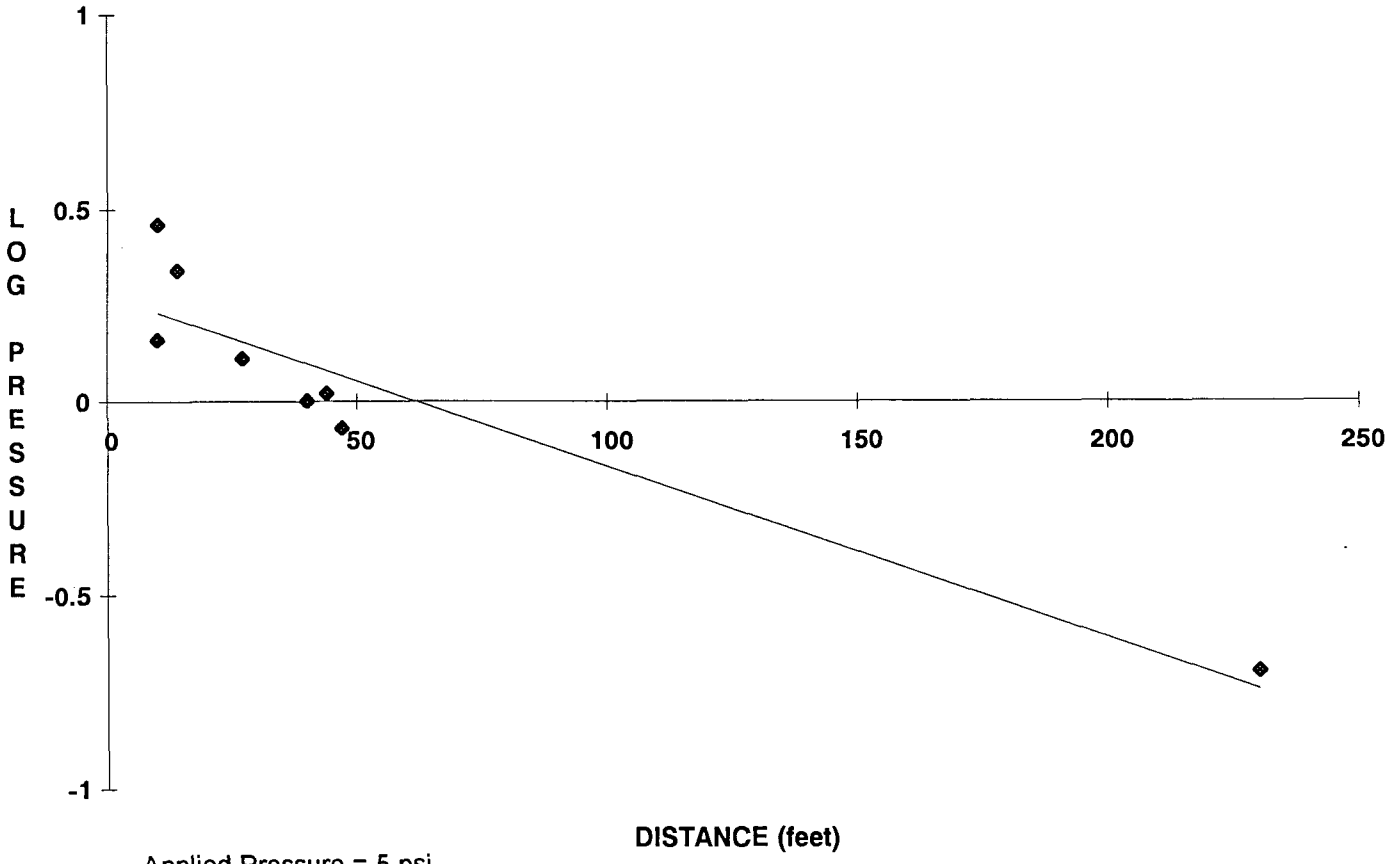
FIGURE 8
LOG OF INDUCED PRESSURE VS. DISTANCE
FROM SPARGE WELL AS-1
BLOOMFIELD REFINING COMPANY
JUNE 15, 1994



Applied Pressure = 3 psi
Flow rate = 11 scfm

GROUNDWATER TECHNOLOGY

FIGURE 9
LOG OF INDUCED PRESSURE VS. DISTANCE
FROM SPARGE WELL AS-1
BLOOMFIELD REFINING COMPANY
JUNE 15, 1994



Applied Pressure = 5 psi
Flow rate = 19 scfm

GROUNDWATER TECHNOLOGY

TABLE 1

MAXIMUM INDUCED VACUUM RESPONSE
SOIL VENT PILOT TEST ON VEW-1S (SHALLOW ZONE)
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14, 1994

(Induced vacuum response reported in inches of water)

MONITOR POINT	DISTANCE FROM VEW-1S (FT.)	APPLIED VACUUM (in. H_2O)			
		42	40	28	16
VEW-1D	0	0.30	0.20	0.15	0.05
MP-1	19	0.15	0.10	0.05	0.025
MP-2	33	0.0	0.0	+0.05[1]	+0.15
RW-2	33	0.19	0.13	0.09	0.015
P-2	40	0.14	0.10	0.075	0.0
MW-4	57	0.10	0.05	0.025	0.0
MP-4	225	+0.10	NM[2]	NM	NM
MW-26	400	0	NM	NM	NM

(1) (+) Indicates that a positive (pressure) reading was detected in well as opposed to a negative (vacuum) reading.

(2) NM = Not Measured.

TABLE 2

MAXIMUM INDUCED VACUUM RESPONSE
SOIL VENT PILOT TEST ON VEW-1D (DEEP ZONE)
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14, 1994

(Induced vacuum response reported in inches of water)

MONITOR POINT	DISTANCE FROM VEW-1D (FT.)	APPLIED VACUUM (in. H_2O)			
		21	18	13	10
VEW-1S	0	3.7	3.4	2.5	1.7
MP-1	19	4.0	3.4	2.6	1.9
MP-2	33	2.6	2.4	1.7	1.2
RW-2	33	2.7	2.4	1.8	1.2
P-2	40	2.5	2.1	1.6	1.1
MW-4	57	1.9	1.7	1.2	1.0
MP-4	225	0.08	0.05	0.05	0.035
MW-26	400	0.0	NM(1)	NM	NM
MW-25	450	0.0	NM	NM	NM

(1) NM = Not measured

TABLE 3
SUMMARY OF AIR SAMPLE ANALYTICAL RESULTS[1]
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14 AND 16, 1994

SAMPLE ID[2]	BENZENE (mg/m^3)	TOLUENE (mg/m^3)	ETHYL-BENZENE (mg/m^3)	TOTAL XYLENES (mg/m^3)	TOTAL FUEL (NON-METHANE HYDROCARBONS) (mg/m^3)	EDC (mg/m^3)	EDB (mg/m^3)	CARBON DIOXIDE (%)	OXYGEN (%)	METHANE (%)
VEW-1S Effluent	2.2	0.4	0.53	3.2	460	ND[3]	ND	0.3	18	18
VEW-1D EFF	380	16	57	280	11,000	ND	ND	2.3	4.3	68
VEW-1D V/S	460	170	140	1,100	13,000	ND	ND	0.4	14	28

(1) Air samples analyzed in accordance with methods EPA TO-14 and GC/TCD.

(2) Sample VEW-1S Effluent collected during vent only pilot test on shallow zone (5-13'); sample VEW-1D EFF collected during vent only pilot test on deep zone (16-26'); and VEW-1D V/S collected during combined air sparge/soil vent pilot test.

(3) ND = Not detected at or above the practical quantification limit (PQL).

TABLE 4

MAXIMUM INDUCED PRESSURE RESPONSE
AIR SPARGE PILOT TEST
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 15, 1994

(Induced pressure response reported in inches of water)

MONITOR POINT	DISTANCE FROM AS-1 (FT.)	APPLIED SPARGING PRESSURE	
		3 PSI	5 PSI
VEW-1S	10	0.95	1.45
VEW-1D	10	1.55	2.90
MP-1	14	1.15	2.20
RW-2	27	0.80	1.30
P-2	40	0.65	1.0
MP-2	44	0.75	1.05
MW-4	47	0.55	0.85
MP-4	230	0.15	0.20

TABLE 5

MAXIMUM CHANGE IN VOC CONCENTRATIONS[1]
AIR SPARGE PILOT TEST
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 15, 1994

(VOC concentrations reported in ppm)

MONITOR POINT	DISTANCE FROM AS-1 (FT.)	APPLIED SPARGING PRESSURE	
		3 PSI	5 PSI
VEW-1S	10	1	1.4
VEW-1D	10	1,476	>2,355
MP-1	14	168	>2,443
RW-2	27	157	662
P-2	40	31	71
MP-2	44	1.7	1.3
MW-4	47	-50	-112
MP-4	230	5	744

(1) Calculated by subtracting the background concentrations measured in each well before start-up from the maximum concentration observed in each well for each applied sparging pressure.

TABLE 6

MAXIMUM INDUCED PRESSURE/VACUUM RESPONSE COMBINED AIR SPARGE/SOIL VENT PILOT TEST ON WELLS VEW-1D AND AS-1 BLOOMFIELD REFINING COMPANY BLOOMFIELD, NEW MEXICO

JUNE 16, 1994

(Induced pressure/vacuum responses reported in inches of water)

MONITOR POINT	AVERAGE DISTANCE (FEET)	VACUUM ONLY (18" H_2O)	SPARGE ONLY (5 PSI)	COMBINED TEST (18" H_2O & 5 PSI)
VEW-1S	10 (from AS-1)	-3.4	+1.45	-1.70
VEW-1D	10 (from AS-1)	NA(1)	+2.90	NA
MP-1	16	-3.4	+2.20	-1.20
RW-2	30	-2.4	+1.30	-0.75
P-2	40	-2.1	+1.0	-0.90
MP-2	39	-2.4	+1.05	-1.25
MW-4	52	-1.7	+0.85	-0.50
MP-4	228	-0.05	+0.20	-0.05

(1) NA = Not applicable

TABLE 7

SUMMARY OF HYDROCARBON MASS EXTRACTION RATES[1]
AIR SPARGE/SOIL VENT PILOT TESTS
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

JUNE 14 AND 16, 1994

SAMPLE ID	PILOT TEST	BENZENE (lb/hr)	TOLUENE (lb/hr)	ETHYL-BENZENE (lb/hr)	TOTAL XYLENES (lb/hr)	TOTAL FUEL (lb/hr)
VEW-1S Effluent	Soil vent only, shallow zone (5-13')	9.5×10^{-4}	1.72×10^{-4}	2.3×10^{-4}	1.4×10^{-3}	0.20
VEW-1D EFF	Soil vent only; deep zone (16-26')	0.19	0.008	0.03	0.14	5.4
VEW-1D V/S	Combined air sparge/soil vent	0.19	0.07	0.06	0.46	5.45

(1) Mass extraction rate calculations provided in Appendix G.

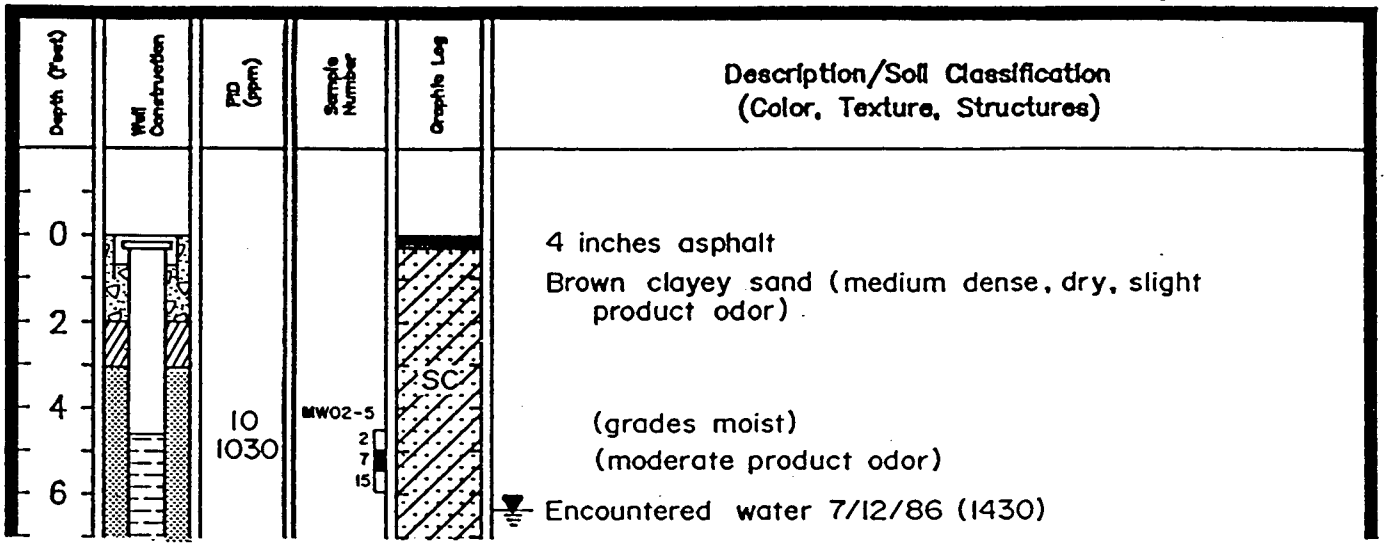
APPENDIX A

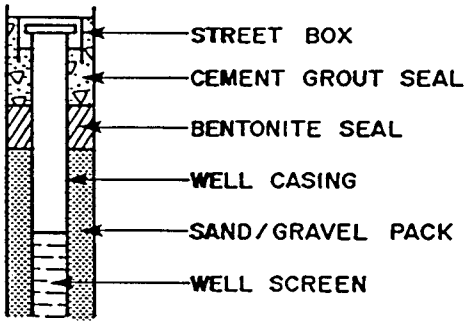
SUMMARY OF WELL COMPLETION INFORMATION AND MONITOR WELL INSTALLATION/LITHOLOGIC LOGS

WELL CONSTRUCTION SPECIFICATIONS
FOR PILOT TEST WELLS
BLOOMFIELD REFINING COMPANY

Well #	Date Installed	Diameter/Material	Total Well Depth (Feet)	Screened Interval (Feet)
VEW-1	5/16/94	2" PVC (nested)	26	5-13 16-26
AS-1	5/16/94	2" PVC	31	29-31
MP-1	5/13/94	2" PVC	30	5-30
MP-2	5/16/94	2" PVC	30	5-30
MP-3	5/17/94	2" PVC	31	11-31
MP-4	5/17/94	2" PVC	32	12-32
MP-5	5/17/94	2" PVC	31	11-31

KEY TO BORING LOG





10
1030 — ORGANIC VAPOR CONCENTRATION DETERMINED BY PHOTO IONIZATION DETECTOR (P.I.D.) IN PARTS PER MILLION (ppm) FROM SOIL SAMPLES (TIME COLLECTED)

MW02-5 — SAMPLE IDENTIFICATION (TEST HOLE - SAMPLE DEPTH)

2
7
15 — BLOW COUNTS TO DRIVE A SPLIT BARREL SAMPLER USING A 140 lb. HAMMER FALLING 30 INCHES. COUNTS ARE FOR EACH 6 INCH INCREMENT THE SAMPLER IS DRIVEN.

INTERVAL SAMPLED
SAMPLE INCREMENT RETAINED FOR LABORATORY ANALYSES

SOIL CLASSIFICATION GRAPHIC/SYMBOL (SEE UNIFIED SOIL CLASSIFICATION SYSTEM)

DEPTH TO WATER, DATE, TIME

GROUNDWATER TECHNOLOGY, INC.

Drilling Log

GROUNDWATER TECHNOLOGY

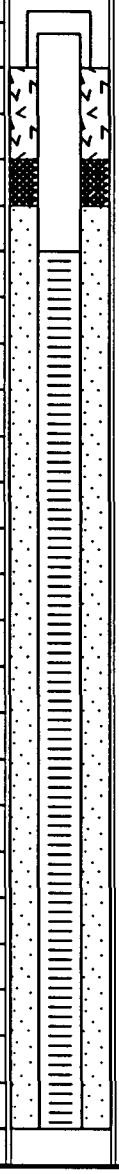
Monitoring Point **MP-1**

Project BRC Owner Bloomfield Refining Co.
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014
Surface Elev. _____ Total Hole Depth 30 ft. Diameter 10 in.
Top of Casing _____ Water Level Initial 25 ft. Static _____
Screen: Dia 2 in. Length 25 ft. Type/Size PVC 0.020 in.
Casing: Dia 2 in. Length 5 ft. Type PVC
Fill Material 10/20 Co. Silica Rig/Core Drill Systems 180
Drill Co. Layne Method Air Percussion
Driller Gabby Rodriguez Log By Jerry May Date 05/13/94 Permit # _____
Checked By JAM License No. _____

See Site Map For Boring Location

COMMENTS:

Start @ 1315 hrs.

Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
-2 to 24						See drilling log VEW-1 for lithology

Drilling Log

GROUNDWATER TECHNOLOGY

Monitoring Point **MP-1**

Project *BRC* Owner *Bloomfield Refining Co.*

Location *50 County Road 4990, Bloomfield, New Mexico* Proj. No. *023353014*

Depth (ft.)	Well Completion	PID (ppm)	Sample ID	Blow Count/ % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
24							▽ *Groundwater encountered at 25 feet on 5/13/94*
26							
28							
30							End of boring at 30 feet (1335 hrs). Installed well screened from 5 to 30 feet on 5/13/94.
32							
34							
36							
38							
40							
42							
44							
46							
48							
50							
52							
54							
56							

Drilling Log

GROUNDWATER TECHNOLOGY

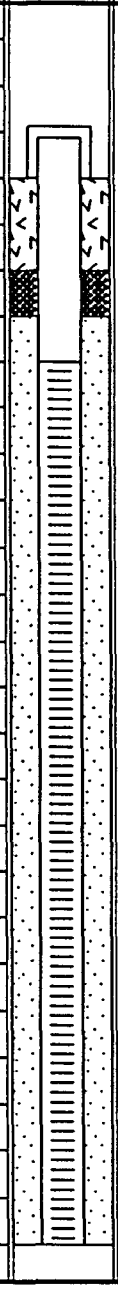
Monitoring Point **MP-2**

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014
Surface Elev. _____ Total Hole Depth 30 ft. Diameter 10 in.
Top of Casing _____ Water Level Initial 24 ft. Static _____
Screen: Dia 2 in. Length 25 ft. Type/Size PVC .020 in.
Casing: Dia 2 in. Length 5 ft. Type PVC
Fill Material 10/20 Co. Silica Rig/Core Drill Systems 180
Drill Co. Layne Method Air Percussion
Driller Gabby Rodriguez Log By Jerry May Date 05/16/94 Permit # _____
Checked By JAM License No. _____

See Site Map For Boring Location

COMMENTS:

Start at 1615 hrs.

Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
-2 to 24						See well VEW-1 for lithology

Drilling Log

GROUNDWATER TECHNOLOGY

Monitoring Point **MP-2**

Project *BRC* Owner *Bloomfield Refining Company*

Location *50 County Road 4990, Bloomfield, New Mexico* Proj. No. *023353014*

Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
24						▽ *Groundwater encountered at 24 feet on 5/16/94*
26						
28						
30						End of boring at 30 feet (1640 hrs). Installed well screened from 5 to 30 feet on 5/16/94.
32						
34						
36						
38						
40						
42						
44						
46						
48						
50						
52						
54						
56						

Drilling Log

GROUNDWATER TECHNOLOGY

Monitoring Point MP-3

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014
Surface Elev. ____ Total Hole Depth 31 ft. Diameter 10 in.
Top of Casing ____ Water Level Initial 28 ft. Static ____
Screen: Dia 2 in. Length 20 ft. Type/Size PVC .020 in.
Casing: Dia 2 in. Length 11 ft. Type PVC
Fill Material 10/20 Co. Silica Rig/Core Drill Systems 180
Drill Co. Layne Method Air Percussion
Driller Gabby Rodriquez Log By Jerry May Date 05/17/94 Permit # ____
Checked By JAM License No. ____

See Site Map For Boring Location

COMMENTS:

Start at 0950 hrs.

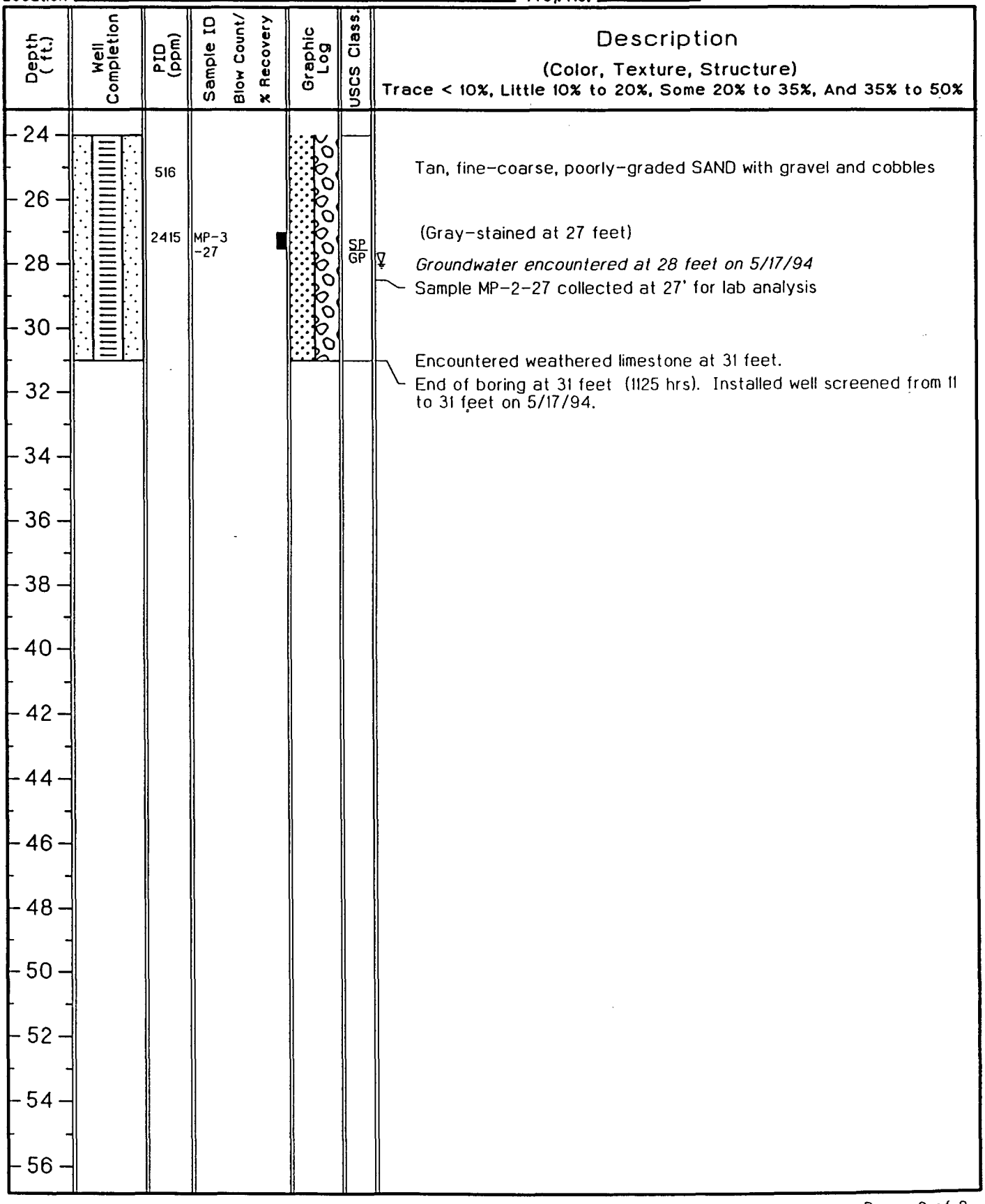
Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
-2						
0					SM	Tan, fine, poorly-graded silty SAND (dry)
2						
4		62				(Same as above)
6						
8					SM/SC	Tan, fine, poorly-graded silty/clayey SAND (moist)
10		70				
12						
14		238			CL	Brown/gray-stained, silty CLAY (moist, low-medium plasticity)
16						
18						
20		61			SP	Tan, fine-coarse, poorly-graded SAND (moist)
22					SP/GP	(Same with gravel and cobbles at 22 +/- feet)
24						

GROUNDWATER TECHNOLOGY

Drilling Log

Monitoring Point MP-3

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014



Drilling Log

GROUNDWATER TECHNOLOGY

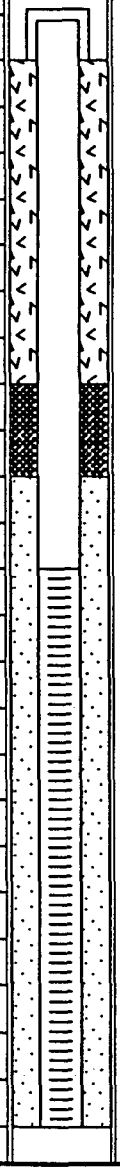
Monitoring Point MP-4

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014
Surface Elev. ____ Total Hole Depth 32 ft. Diameter 10 in.
Top of Casing ____ Water Level Initial 28 ft. Static ____
Screen: Dia 2 in. Length 20 ft. Type/Size PVC 0.020 in.
Casing: Dia 2 in. Length 12 ft. Type PVC
Fill Material 10/20 Co. Silica Rig/Core Drill Systems 180
Drill Co. Layne Method Air Percussion
Driller Gabby Rodriguez Log By Jerry May Date 05/17/94 Permit # ____
Checked By JAM License No. ____

See Site Map For Boring Location

COMMENTS:

Start at 0845 hrs.

Depth (ft.)	Well Completion	PID (ppm)	Sample ID	Blow Count/ % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
-2 to 24							See well MP-3 for lithology

GROUNDWATER TECHNOLOGY

Drilling Log

Monitoring Point **MP-4**

Project *BRC* Owner *Bloomfield Refining Company*

Location *50 County Road 4990, Bloomfield, New Mexico* Proj. No. *023353014*

Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
24						
26						
28						▽ *Groundwater encountered at 28 feet on 5/17/94*
30						
32						Encountered weathered limestone at 32 feet. End of boring at 32 feet (0910 hrs). Installed well screened from 12 to 32 feet on 5/17/94.
34						
36						
38						
40						
42						
44						
46						
48						
50						
52						
54						
56						

Drilling Log

GROUNDWATER TECHNOLOGY

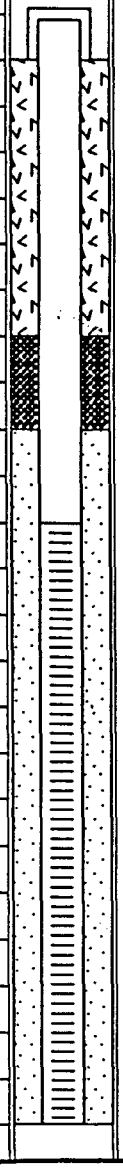
Monitoring Point **MP-5**

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014
Surface Elev. _____ Total Hole Depth 31 ft. Diameter 10 in.
Top of Casing _____ Water Level Initial 28 ft. Static _____
Screen: Dia 2 in. Length 20 ft. Type/Size PVC 0.020 in.
Casing: Dia 2 in. Length 11 ft. Type PVC
Fill Material 10/20 Co. Silica Rig/Core Drill Systems 180
Drill Co. Layne Method Air Percussion
Driller Gabby Rodriguez Log By Jerry May Date 05/17/94 Permit # _____
Checked By JAM License No. _____

See Site Map For Boring Location

COMMENTS:

Start at 0720 hrs.

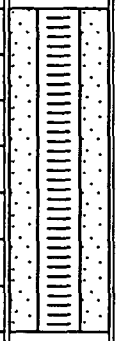
Depth (ft.)	Well Completion	PID (ppm)	Sample ID	Blow Count/ % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
-2 to 24							See well MP-3 for lithology

GROUNDWATER TECHNOLOGY

Drilling Log

Monitoring Point MP-5

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014

Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
24						
26						
28						▽ *Groundwater encountered at 28 feet on 5/17/94*
30						
32						Encountered weathered limestone at 31 feet. End of boring at 31 feet (0755 hrs). Installed well screened from 11 to 31 feet on 5/17/94.
34						
36						
38						
40						
42						
44						
46						
48						
50						
52						
54						
56						

Drilling Log

GROUNDWATER TECHNOLOGY

Air Sparge Well **AS-1**

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014
Surface Elev. ____ Total Hole Depth 32 ft. Diameter 10 in.
Top of Casing ____ Water Level Initial 24 ft. Static ____
Screen: Dia 2 in. Length 2 ft. Type/Size PVC .020 in.
Casing: Dia 2 in. Length 29 ft. Type PVC
Fill Material 10/20 Co. Silica Rig/Core Drill Systems 180
Drill Co. Layne Method Air Percussion
Driller Gabby Rodriguez Log By Jerry May Date 05/16/94 Permit # ____
Checked By JAM License No. ____

See Site Map For Boring Location

COMMENTS:

Start at 1200 hrs.

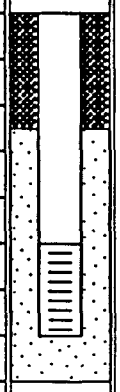
Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
-2						
0						(See well VEW-1 for lithology)
2						
4						
6						
8						
10						
12						
14						
16						
18						
20						
22						
24						

GROUNDWATER TECHNOLOGY

Drilling Log

Air Sparge Well AS-1

Project BRC Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico Proj. No. 023353014

Depth (ft.)	Well Completion	PID (ppm)	Sample ID	Blow Count/ % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
24							▽ *Groundwater encountered at 24 feet on 5/16/94*
26							
28							
30							
32							Encountered weathered limestone at 31 feet End of boring at 32 feet (1225 hrs). Installed well screened from 29 to 31 feet on 5/16/94.
34							
36							
38							
40							
42							
44							
46							
48							
50							
52							
54							
56							

GROUNDWATER TECHNOLOGY

Drilling Log

Vapor Extraction Well **VEW-1**

Project BRC — Owner Bloomfield Refining Company
Location 50 County Road 4990, Bloomfield, New Mexico — Proj. No. 023353014
Surface Elev. ____ — Total Hole Depth 26 ft. — Diameter 10 in.
Top of Casing ____ — Water Level Initial 24 ft. — Static ____
Screen: Dia 2 in. — Length See comments — Type/Size PVC 0.020" & 0.040 in.
Casing: Dia 2 in. — Length See comments — Type PVC
Fill Material 10/20 & 6/16 Co. Silica — Rig/Core Drill Systems 180
Drill Co. Layne — Method Air Percussion
Driller Gabby Rodriguez — Log By Jerry May — Date 05/16/94 — Permit # ____
Checked By JMM — License No. ____

See Site Map For Boring Location

COMMENTS:

Start at 1410 hrs. Set nested well. Deep well screened from 21 to 26 feet (0.020 in. slot, 10/20 sand) and 16 to 21 feet (0.040 in. slot, 6/16 sand). Shallow well screened from 5 to 13 feet (0.040 in. slot, 6/16/ sand)

Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
-2						
0					SM	Tan, fine, poorly-graded, silty SAND (dry-moist)
2						
4						
6		357			CL	Brown, silty CLAY (moist, low plasticity)
8						
10		21				(Tan, same as above)
12						
14					SM	Gray-stained, fine poorly-graded, silty SAND (moist)
16		343				(Cobbles at 17 feet)
18						
20		610			GP	Gravel and cobbles with some fines (moist)
22						
24		2048			SP	

GROUNDWATER TECHNOLOGY

Drilling Log

Vapor Extraction Well **VEW-1**

Project *BRC* Owner *Bloomfield Refining Company*

Location *50 County Road 4990, Bloomfield, New Mexico* Proj. No. *023353014*

Depth (ft.)	Well Completion	PID (ppm)	Sample ID / Blow Count / % Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure) Trace < 10%, Little 10% to 20%, Some 20% to 35%, And 35% to 50%
24		2048	VEW-1 -24		SP	Gray-stained, fine-coarse, poorly-graded SAND with gravel and cobbles (moist-wet)
26					GM	*Groundwater encountered at 24 feet on 5/16/94*
						Sample VEW-1-24 collected at 24'
						End of boring at 26 feet (1500 hrs). Installed nested wells screened from 5 to 13 feet and from 16 to 26 feet (see comments) on 5/16/94.
28						
30						
32						
34						
36						
38						
40						
42						
44						
46						
48						
50						
52						
54						
56						

APPENDIX B

SOIL SAMPLE CERTIFICATES OF ANALYSIS CHAIN-OF-CUSTODY DOCUMENTATION AND QA/QC DATA, MAY 16 - 17, 1994

Inter·Mountain Laboratories, Inc.

1160 Research Drive
Bozeman, Montana 59715

CASE NARRATIVE

On May 20, 1994, two samples were received for analysis at Inter-Mountain Laboratories, Bozeman, Montana. The chain of custody form requested analysis for volatile organic compounds by method 8240. Client name/Project name was listed as Groundwater Technology / Bloomfield Refinery.

Detectable amounts of targeted compounds were present in the samples.

Limits of detection for each instrument/analysis are determined by sample matrix effects, instrument performance under standard conditions, and dilution requirements to maintain chromatography output within calibration ranges.

Wy Sudtelgte

Wynn Sudtelgte
IML-Bozeman

0615gt

Inter·Mountain Laboratories, Inc.

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Bozeman, Montana 59715

EPA METHOD 8240
HSL VOLATILE COMPOUNDS

Client:	GROUNDWATER TECHNOLOGY		
Sample ID:	VEW-1-24	Date Reported:	06/14/94
Project ID:	Bloomfield Refinery	Date Sampled:	05/16/94
Laboratory ID:	B944823	Date Received:	05/20/94
Sample Matrix:	Soil	Date Extracted:	05/26/94
Preservation:	Cool	Date Analyzed:	05/27/94
Condition:	Intact		

Parameter	Analytical Result		Detection Limit	Units
1,1,1-Trichloroethane	ND		0.2	mg/kg
1,1,2,2-Tetrachloroethane	ND		0.2	mg/kg
1,1,2-Trichloroethane	ND		0.2	mg/kg
1,1-Dichloroethane	ND		0.2	mg/kg
1,1-Dichloroethene	ND		0.2	mg/kg
1,2-Dichloroethane	ND		0.2	mg/kg
1,2-Dichloropropane	ND		0.2	mg/kg
2-Butanone (MEK)	ND		1.5	mg/kg
2-Hexanone	ND		0.2	mg/kg
4-Methyl-2-pentanone (MIBK)	ND		0.2	mg/kg
Acetone	ND		1	mg/kg
Benzene	ND		0.2	mg/kg
Bromodichloromethane	ND		0.2	mg/kg
Bromoform	ND		0.2	mg/kg
Bromomethane	ND		0.2	mg/kg
Carbon Disulfide	ND		0.2	mg/kg
Carbon Tetrachloride	ND		0.2	mg/kg
Chlorobenzene	ND		0.2	mg/kg
Chloroethane	ND		0.2	mg/kg
Chloroform	ND		0.2	mg/kg
Chloromethane	ND		0.2	mg/kg
cis-1,3-Dichloropropene	ND		0.2	mg/kg
Dibromochloromethane	ND		0.2	mg/kg
Ethylbenzene	ND		0.2	mg/kg
m,p-Xylene	0.3		0.2	mg/kg
Methylene chloride	ND		1	mg/kg
o-Xylene	0.2	J	0.2	mg/kg
Styrene	ND		0.2	mg/kg

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EPA METHOD 8240
HSL VOLATILE COMPOUNDS

Client:	GROUNDWATER TECHNOLOGY		
Sample ID:	VEW-1-24	Date Reported:	06/14/94
Laboratory ID:	B944823	Date Sampled:	05/16/94
Sample Matrix:	Soil	Date Analyzed:	05/27/94

Parameter	Analytical Result	Detection Limit	Units
Tetrachloroethene (PCE)	ND	0.2	mg/kg
Toluene	ND	0.2	mg/kg
trans-1,2-Dichloroethene	ND	0.2	mg/kg
trans-1,3-Dichloropropene	ND	0.2	mg/kg
Trichloroethene (TCE)	ND	0.2	mg/kg
Vinyl Chloride	ND	0.2	mg/kg

ND - Compound not detected at stated Detection Limit.
J - Meets identification criteria, below Detection Limit.
B - Compound detected in method blank.

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Bozeman, Montana 59715

EPA METHOD 8240
TENTATIVELY IDENTIFIED COMPOUNDS

Client:	GROUNDWATER TECHNOLOGY		
Sample ID:	VEW-1-24	Date Reported:	06/14/94
Laboratory ID:	B944823	Date Sampled:	05/16/94
Sample Matrix:	Soil	Date Analyzed:	05/27/94

Tentative Identification	Retention Time (min)	Concentration	Units
Unknown Hydrocarbon	18.94	20	mg/kg
Unknown Substituted Benzene	19.42	10	mg/kg
Unknown Hydrocarbon	19.82	10	mg/kg
Unknown Hydrocarbon	20.78	30	mg/kg
Unknown Hydrocarbon	22.44	10	mg/kg

Unknown concentrations calculated assuming a Relative Response Factor = 1.

QUALITY CONTROL:

Surrogate Recovery	%	Soil QC Limits
1,2-Dichloroethane-d4	103	70 - 121
Toluene-d8	104	81 - 117
Bromofluorobenzene	98	74 - 121

References:

Method 8240, Gas Chromatography/Mass Spectrometry for Volatile Organics, Test Methods for Evaluating Solid Wastes, SW-846, United States Environmental Protection Agency, Third Edition, November 1986.

Analyst

Reviewed

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EPA METHOD 8240
HSL VOLATILE COMPOUNDS

Client:	GROUNDWATER TECHNOLOGY		
Sample ID:	MP-3-27	Date Reported:	06/14/94
Project ID:	Bloomfield Refinery	Date Sampled:	05/17/94
Laboratory ID:	B944824	Date Received:	05/20/94
Sample Matrix:	Soil	Date Extracted:	05/26/94
Preservation:	Cool	Date Analyzed:	05/27/94
Condition:	Intact		

Parameter	Analytical Result		Detection Limit	Units
1,1,1-Trichloroethane	ND		0.2	mg/kg
1,1,2,2-Tetrachloroethane	ND		0.2	mg/kg
1,1,2-Trichloroethane	ND		0.2	mg/kg
1,1-Dichloroethane	ND		0.2	mg/kg
1,1-Dichloroethene	ND		0.2	mg/kg
1,2-Dichloroethane	ND		0.2	mg/kg
1,2-Dichloropropane	ND		0.2	mg/kg
2-Butanone (MEK)	ND		1.5	mg/kg
2-Hexanone	ND		0.2	mg/kg
4-Methyl-2-pentanone (MIBK)	ND		0.2	mg/kg
Acetone	ND		1	mg/kg
Benzene	ND		0.2	mg/kg
Bromodichloromethane	ND		0.2	mg/kg
Bromoform	ND		0.2	mg/kg
Bromomethane	ND		0.2	mg/kg
Carbon Disulfide	ND		0.2	mg/kg
Carbon Tetrachloride	ND		0.2	mg/kg
Chlorobenzene	ND		0.2	mg/kg
Chloroethane	ND		0.2	mg/kg
Chloroform	ND		0.2	mg/kg
Chloromethane	ND		0.2	mg/kg
cis-1,3-Dichloropropene	ND		0.2	mg/kg
Dibromochloromethane	ND		0.2	mg/kg
Ethylbenzene	ND		0.2	mg/kg
m,p-Xylene	1.2		0.2	mg/kg
Methylene chloride	ND		1	mg/kg
o-Xylene	0.2	J	0.2	mg/kg
Styrene	ND		0.2	mg/kg

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EPA METHOD 8240
HSL VOLATILE COMPOUNDS

Client:	GROUNDWATER TECHNOLOGY		
Sample ID:	MP-3-27	Date Reported:	06/14/94
Laboratory ID:	B944824	Date Sampled:	05/17/94
Sample Matrix:	Soil	Date Analyzed:	05/27/94

Parameter	Analytical Result	Detection Limit	Units
Tetrachloroethene (PCE)	ND	0.2	mg/kg
Toluene	ND	0.2	mg/kg
trans-1,2-Dichloroethene	ND	0.2	mg/kg
trans-1,3-Dichloropropene	ND	0.2	mg/kg
Trichloroethene (TCE)	ND	0.2	mg/kg
Vinyl Chloride	ND	0.2	mg/kg

ND - Compound not detected at stated Detection Limit.
J - Meets identification criteria, below Detection Limit.
B - Compound detected in method blank.

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Bozeman, Montana 59715

EPA METHOD 8240
TENTATIVELY IDENTIFIED COMPOUNDS

Client:	GROUNDWATER TECHNOLOGY		
Sample ID:	MP-3-27	Date Reported:	06/14/94
Laboratory ID:	B944824	Date Sampled:	05/17/94
Sample Matrix:	Soil	Date Analyzed:	05/27/94

Tentative Identification	Retention Time (min)	Concentration	Units
Unknown Hydrocarbon	18.94	20	mg/kg
Unknown Substituted Benzene	19.43	10	mg/kg
Unknown Hydrocarbon	19.80	10	mg/kg
Unknown Hydrocarbon	20.79	20	mg/kg
Unknown Hydrocarbon	22.45	10	mg/kg

Unknown concentrations calculated assuming a Relative Response Factor = 1.

QUALITY CONTROL:

Surrogate Recovery	%	Soil QC Limits
1,2-Dichloroethane-d4	101	70 - 121
Toluene-d8	104	81 - 117
Bromofluorobenzene	110	74 - 121

References:

Method 8240, Gas Chromatography/Mass Spectrometry for Volatile Organics, Test Methods for Evaluating Solid Wastes, SW-846, United States Environmental Protection Agency, Third Edition, November 1986.

Analyst

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QUALITY ASSURANCE / QUALITY CONTROL

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LAB QA/QC
VOLATILE COMPOUNDS BY GC/MS
METHOD BLANK

Date Analyzed: 05/27/94
Laboratory ID: 2MB-147A
Sample Matrix: Water

Parameter	Analytical Result	Detection Limit	Units
Chloromethane	ND	5	ug/L
Bromomethane	ND	5	ug/L
Vinyl Chloride	ND	5	ug/L
Chloroethane	ND	5	ug/L
Methylene Chloride	ND	20	ug/L
Acetone	ND	20	ug/L
Carbon Disulfide	ND	5	ug/L
1,1-Dichloroethene	ND	5	ug/L
1,1-Dichloroethane	ND	5	ug/L
1,2-Dichloroethene	ND	5	ug/L
Chloroform	ND	5	ug/L
1,2-Dichloroethane	ND	5	ug/L
2-Butanone	ND	20	ug/L
1,1,1-Trichloroethane	ND	5	ug/L
Cyclohexane	ND	5	ug/L
Carbon Tetrachloride	ND	5	ug/L
Bromodichloromethane	ND	5	ug/L
1,2-Dichloropropane	ND	5	ug/L
1,4-Dioxane	ND	500	ug/L
cis-1,3-Dichloropropene	ND	5	ug/L
Trichloroethene	ND	5	ug/L
Dibromochloromethane	ND	5	ug/L
1,1,2-Trichloroethane	ND	5	ug/L
Benzene	ND	5	ug/L
trans-1,3-Dichloropropene	ND	5	ug/L
1,2-Dibromoethane	ND	5	ug/L
Bromoform	ND	5	ug/L
4-Methyl-2-pentanone	ND	5	ug/L
2-Hexanone	ND	5	ug/L
Tetrachloroethene	ND	5	ug/L
1,1,2,2-Tetrachloroethane	ND	5	ug/L

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VOLATILE COMPOUNDS BY GC/MS

Date Analyzed: 05/27/94
Laboratory ID: 2MB-147A
Sample Matrix: Water

Parameter	Analytical Result	Detection Limit	Units
Toluene	ND	5	ug/L
Chlorobenzene	ND	5	ug/L
Ethylbenzene	ND	5	ug/L
Styrene	ND	5	ug/L
m,p-Xylene	ND	5	ug/L
o-Xylene	ND	5	ug/L

ND - Compound not detected at stated Detection Limit.
J - Meets identification criteria, below Detection Limit.
B - Compound detected in method blank.

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TENTATIVELY IDENTIFIED COMPOUNDS
METHOD BLANK ANALYSIS

Date Analyzed: 05/27/94
Laboratory ID: 2MB-147A
Sample Matrix: Water

Tentative Identification	Retention Time (min)	Concentration	Units

No additional compounds found at reportable levels.

Unknown concentrations calculated assuming a Relative Response Factor = 1.

QUALITY CONTROL:

Surrogate Recovery	%	Water QC Limits
1,2-Dichloroethane-d4	100	76 - 114
Toluene-d8	103	88 - 110
Bromofluorobenzene	99	86 - 115

References:

Method 8240, Gas Chromatography/Mass Spectrometry for Volatile Organics, Test Methods for Evaluating Solid Wastes, SW-846, United States Environmental Protection Agency, Third Edition, November 1986.

Analyst

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LAB QA/QC
VOLATILE COMPOUNDS BY GC/MS
EXTRACTION BLANK

Date Analyzed: 05/26/94
Laboratory ID: 2EB-146
Sample Matrix: Soil
Date Extracted: 05/26/94

Parameter	Analytical Result	Detection Limit	Units
Chloromethane	ND	0.2	mg/kg
Bromomethane	ND	0.2	mg/kg
Vinyl Chloride	ND	0.2	mg/kg
Chloroethane	ND	0.2	mg/kg
Methylene Chloride	ND	1	mg/kg
Acetone	ND	1	mg/kg
Carbon Disulfide	ND	0.2	mg/kg
1,1-Dichloroethene	ND	0.2	mg/kg
1,1-Dichloroethane	ND	0.2	mg/kg
1,2-Dichloroethene	ND	0.2	mg/kg
Chloroform	ND	0.2	mg/kg
1,2-Dichloroethane	ND	0.2	mg/kg
2-Butanone	ND	1.5	mg/kg
1,1,1-Trichloroethane	ND	0.2	mg/kg
Carbon Tetrachloride	ND	0.2	mg/kg
Bromodichloromethane	ND	0.2	mg/kg
1,2-Dichloropropane	ND	0.2	mg/kg
cis-1,3-Dichloropropene	ND	0.2	mg/kg
Trichloroethene	ND	0.2	mg/kg
Dibromochloromethane	ND	0.2	mg/kg
1,1,2-Trichloroethane	ND	0.2	mg/kg
Benzene	ND	0.2	mg/kg
trans-1,3-Dichloropropene	ND	0.2	mg/kg
Bromoform	ND	0.2	mg/kg
4-Methyl-2-pentanone	ND	0.2	mg/kg
2-Hexanone	ND	0.2	mg/kg
Tetrachloroethene	ND	0.2	mg/kg
1,1,2,2-Tetrachloroethane	ND	0.2	mg/kg

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Bozeman, Montana 59715

VOLATILE COMPOUNDS BY GC/MS

Date Analyzed: 05/26/94
Laboratory ID: 2EB-146
Sample Matrix: Soil
Date Extracted: 05/26/94

Parameter	Analytical Result	Detection Limit	Units
Toluene	ND	0.2	mg/kg
Chlorobenzene	ND	0.2	mg/kg
Ethylbenzene	ND	0.2	mg/kg
Styrene	ND	0.2	mg/kg
m,p-Xylene	ND	0.2	mg/kg
o-Xylene	ND	0.2	mg/kg

ND - Compound not detected at stated Detection Limit.
J - Meets identification criteria, below Detection Limit.
B - Compound detected in method blank.

Inter·Mountain Laboratories, Inc.

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Bozeman, Montana 59715

TENTATIVELY IDENTIFIED COMPOUNDS
EXTRACTION BLANK ANALYSIS

Date Analyzed: **05/26/94**
Laboratory ID: 2EB-146
Sample Matrix: Soil
Date Extracted: 05/26/94

Tentative Identification	Retention Time (min)	Concentration	Units

No additional compounds found at reportable levels.

Unknown concentrations calculated assuming a Relative Response Factor = 1.

QUALITY CONTROL:

Surrogate Recovery	%	Soil QC Limits
1,2-Dichloroethane-d4	101	70 - 121
Toluene-d8	103	81 - 117
Bromofluorobenzene	97	74 - 121

References:

Method 8240, Gas Chromatography/Mass Spectrometry for Volatile Organics, Test Methods for Evaluating Solid Wastes, SW-846, United States Environmental Protection Agency, Third Edition, November 1986.

Analyst

Reviewed

Inter-Mountain Laboratories, Inc.

1160 Research Drive
Bozeman, Montana 59715

LAB QA/QC
PURGEABLE ORGANIC COMPOUNDS BY GC/MS
MATRIX SPIKE SUMMARY

Date Analyzed: 05/31/94
Laboratory ID: 3EMS4804
Sample Matrix: Soil
Date Extracted: 5/26/94

ORIGINAL SAMPLE PARAMETERS

Parameter	Spike Added (mg/kg)	Sample Conc. (mg/kg)	MS Conc. (mg/kg)	MS Recovery (%)	QC Limits (% Rec.)
1,1-Dichloroethene	2.0	0	1.7	81	59-172
Trichloroethene	2.0	0	1.7	85	62-137
Benzene	2.0	0	1.9	95	66-142
Toluene	2.0	0	2.0	96	59-139
Chlorobenzene	2.0	0	2.0	100	60-133

Spike Recovery: 0 out of 5 outside QC limits.

QUALITY CONTROL:

Surrogate Recovery	%	Soil QC Limits
1,2-Dichloroethane-d4	104	70 - 121
Toluene-d8	105	81 - 117
Bromofluorobenzene	95	74 - 121

Analyst

Reviewed

Inter- Mountain Laboratories, Inc.

CHAIN OF CUSTODY RECORD

Client/Project Name	Project Location	ANALYSES / PARAMETERS
Bloomfield Refinery	Bloomfield	
Sampler: (Signature)	**Chain of Custody Tape No.**	

Sample No./ Identification	Date	Time	Lab Number	Matrix	No. of Containers	8240				Remarks
VEW-1-24	5/16	11:50	B944823	Soil	2	✓				Wrong Bottle (good luck)
MW-3-24	5/17	11:20	B944824	↓	2	✓				
										Cooler temps. 13.7°
										1 BOTTLE OF VEW-1-24 BROKEN MSia

Relinquished by: (Signature)	Date	Time	Received by: (Signature)	Date	Time
Christine Walker	5/18/24	1600	Ben J. Mc	5/19/24	0940
Relinquished by: (Signature)	Date	Time	Received by: (Signature)	Date	Time
Michael R. Scott	5/19/24	1100	FEDEX (carrier)	5/19/24	1100
Relinquished by: (Signature)	Date	Time	Received by laboratory: (Signature)	Date	Time
FEDEX (carrier)			Valerie Herrera	5/20/24	1100

Inter-Mountain Laboratories, Inc.

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21787

APPENDIX C

SOIL VENT AND AIR SPARGE PILOT TEST FIELD DATA

SOIL VENTING PILOT TEST DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/14/94
Measured by:	JERRY MAY, CHUCK BRISCOE

Extraction Well: VEW-1S

Time	Elapsed Time (min.)	Vacuum at Test Well (ins. H2O)	Pre/Post Vacuum at Blower (ins. H2O)	Pre-Blower Anemom. Reading (ft/min)	Pre/Post Blower Temp (oF)	Vapor Concentration (Eff) PID (ppmv)	Vapor Concentration (Eff) LEL Meter (%LEL) (% O2)	Vacuum at Observation Wells (ins. H2O) Distance from Extraction Well: MP-1 (19 ft)	MP-2 (33 ft)	MP-4 (230 ft)	RW-2 (33 ft)	P-2 (40 ft)	MW-25 (450 ft)	MW-26 (400 ft)	P-3 (ft)	VEW-1D (1 ft)	MW-4 (57 ft)
0820	CALB. PID PHOTOVAC TS-3000 # UA9403						100 PPM ISOBUTYLENE										
		1.4/0.2	MSA #261														
0830	DTP/DTW	VEW-1S = Dry															
0850	"	"	VEW-1D	23.92/24.20													
0845	STATIC READINGS							+0.0	+0.15	+0.05	0	+0.075	0.00	0.00	NA	0.00	0.00
0930	0	START BLOWER (1.5 HP ROTRON)															
0935	5	42	38/40	1600	82/97	0	>100/15%	0.05	+0.05	NC	0.05	0	NC	NC	—	0	0.025
0940	10	42	39/40	1250	80/83	0	* NA	0.15	+0.05	NC	0.10	0.05	NC	NC	—	NC	0.075
0945	15	43	38/40	1250	84/93	0	* NA	0.15	+0.05	NC	0.15	0.05	NC	NC	—	0.25	0.05
1000	30	43	38/40	1250	80/86	0	* NA 19.3/348 *	0.15	0.0	NC	0.12	0.05	NC	NC	—	0.25	0.05
1015	45	43	38/40	1600	80/106	0	53/20.5	0.15	0.0	NC	0.19	0.115	NC	NC	—	0.25	0.10
1030	60	43	38/40	1600	82/104	0	368 20.5	0.15	0.0	+0.10	0.185	0.12	NC	0.0	—	0.30	0.10
1040	CALB PID																
1130	120	42	38/40	1600	83/105	0	310 20.2	0.15	0.0	+0.10	0.180	0.14	NC	0.0	—	0.26	0.10
1230	180	42	38/40	1600	84/108	0	403/19.9	0.15	0.0	+0.10	0.185	0.12	NC	0.0	—	0.26	0.10
	STEP TEST																
10% DI	1245	195	40	35/39	1300	85/115	1.3	322/20.0	0.10	0.0	NC	0.125	0.10	NC	NC	—	0.20	0.05
20% DI	1300	210	28	25/30	1150	85/103	2.0	363/19.3	0.05	+0.05	NC	0.09	0.075	NC	NC	—	0.15	0.025
30% DI	1315	225	16	15/22	750	92/114	0	169/19.9	0.025	+0.15	NC	0.015	0.0	NC	NC	—	0.05	0.0
SHUT DOWN 320	1320	DTW/DTP	VEW-1D AT SHUT DOWN = 23.88/24.25														

- * MAXED OUT LEL
- NC - NOT CHECKED
- P-3 = NO ACCESS

INDUSTRIAL SCIENTIFIC MX 251

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SOIL VENTING PILOT TEST DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/14/94
Measured by:	JERRY MAY, CHUCK BARCOT

Extraction Well: VEW-1D

%O2

Time	Elapsed Time (min.)	Vacuum at Test Well (ins. H2O)	Pre/Post Vacuum at Blower (ins. H2O)	Pre-Blower Anemom. Reading (ft/min)	Pre/Post Blower Temp (oF)	Vapor Concentration (Eff) PID (ppmv)	Vapor Concentration (Eff) LEL Meter (%LEL)	Vacuum at Observation Wells (ins H2O) Distance from Extraction Well: MP-1 19 ft	MP-2 33 ft	MP-4 125 ft	RW-2 53 ft	P-2 40 ft	MW-25 450 ft	MW-26 400 ft	P-3 NA ft	MW-4 57 ft	VEW-1S 1 ft
DTW/DTP		VEW-1D	23.87/24.29		23.56 OUR DTW												
1420	0	CALB. P.D. /						~~0~~ 0.20	+0.25	+0.015	0.0	0.0	0.0	0.0	NA	+0.10	+0.20
1430	START	2							~~1.45~~								
1435	5	20	20/25	1750	74/95	103	93/5.0	2.80	1.45	NC	1.80	1.70	NC	NC	✓	1.00	2.40
1440	10	20	20/25	1750	63/96	101	102/13.9	3.20	1.80	NC	2.10	1.90	NC	NC	—	1.40	2.70
1445	15	20	20/25	1750	65/98	101	81/5.2	3.40	2.00	NC	2.30	2.10	NC	NC	—	1.50	3.10
1500	30	20	20/25	1750	64/91	102	85/6.5	3.80	2.40	0.0	2.6	2.3	NC	NC	—	1.80	3.50
1515	45	20	20/25	1750	63/93	103	78/11.5	3.8	2.5	0.0	2.6	2.4	NC	NC	—	1.80	3.60
1530	60	20	20/25	1750	63/96	104	109/5.5	3.8	2.5	0.02	2.6	2.4	0.0	0.0	—	1.80	3.60
1630	120	20	21/25	1750	63/93	110	92/100	4.0	2.6	0.08	2.7	2.5	NC	NC	—	1.90	3.70
1730	180	21	21/25	1750	62/93	102	76/4.5	4.0	2.6	0.8	2.6	2.5	NC	NC	—	1.9	3.70
STEP DOWN																	
~~1745~~ 1745	180	18	18/25	1250	62/92	111	124/12.4	3.4	2.4	0.05	2.4	2.1	NC	NC	—	1.7	3.4
~~1800~~ 1800	195	13	14/21	900	62/92	122	141/13.9	2.6	1.7	0.05	1.8	1.6	NC	NC	—	1.2	2.5
1815	210	10	10/20	650	68/92	137	260/15.8	1.9	1.2	0.035	1.2	1.1	NC	NC	—	1.0	1.7
SHUT DOWN 1820																	
(1820) VEW-1D		DTP/DTW = 23.60/24.~~27~~															

LEL - BRL INDUSTRIAL SOURCE MX 251 NO CALIB. ~~GAS~~

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AIR SPARGE PILOT TEST FIELD DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/15/94
Measured by:	JAm CTB

Air Sparge Test Well:	AS-1
Static DTW in AS-1:	23.77
Static DO in AS-1:	0.2
Compressor type/size:	BRC Air Supply 90 PSI

Distance from sparge well to monitoring point							
14 ft	44 ft	10 ft	47 ft	40 ft	27 ft	230 ft	10 ft
MP-1	MP-2	VEW-1D	MW-4	P-2	RW-2	MP-4	VEW-1S

3/4" ϕ AIR LINE

Time	Elapsed Time (min.)	Pressure at Regulator (psi)	Pressure at Sparge Well (psi)	Air flow at Sparge Well (scfm)	Monitoring Point (MP)	Dissolved Oxygen at MP (mg/l)	DTW in MP (ft.)	PID at MP (ppmv)	Pressure at MP (in H2O)
	CALB. PID								
STATICS									
1500	0				MP-1	PSH	23.78/24.24	57	+0.125
					MP-2		24.56/25.03	0.0	+0.20
					MP-4		25.61/25.83	16	+0.005
					VEW-1S	DRY	DRY	0.0	+0.15
					VEW-1D		23.85/24.32	145	+0.10
					MW-4		25.09/25.44	362	0.0
					RW-2		24.29/24.70	193	+0.10
					P-2		24.63/24.77	202	+0.05
					AS-1	0.2			
1510	START	AIR SPARGE @ 3 PSI							
1530	20	3	3	10	MP-1			59	+1.0
					MP-2			1.5	+0.55
					MP-4			20	+0.10
					VEW-1S			0.0	+0.75
					VEW-1D			140	+0.20
					MW-4			334	+0.40
					RW-2			317	+0.60
					P-2			146	+0.55

2

AIR SPARGE PILOT TEST FIELD DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/15/94
Measured by:	JAN CTB

Air Sparge Test Well:	
Static DTW in AS-1:	
Static DO in AS-1:	
Compressor type/size:	

Distance from sparge well to monitoring point							
ft	ft	ft	ft	ft	ft	ft	ft
MP-1	MP-2	VEW-1D	MW-4	P-2	RW-2	MP-4	VEW-1S

Time	Elapsed Time (min.)	Pressure at Regulator (psi)	Pressure at Sparge Well (psi)	Air flow at Sparge Well (scfm)	Monitoring Point (MP)	Dissolved Oxygen at MP (mg/l)	DTW in MP (ft.)	PID at MP (ppmv)	Pressure at MP (in H2O)
1550	40	3	3	11	MP-1			140	+1.15
					MP-2			1	+0.7
					MP-4			20	+0.15
					VEW-1S			0	+0.90
					VEW-1D			625	+1.50
					MW-4			322	+0.50
					RW-2			355	+0.75
					P-2			174	+0.55
1610	60	3	3	11	MP-1			225	+1.15
					MP-2			1.7	+0.75
					MP-4			21	+0.15
					VEW-1S			1	+0.95
					VEW-1D			1621	+1.55
					MW-4			312	+0.55
					RW-2			350	+0.80
					P-2			233	+0.65
1615	ADJUST	TO 5 PSI							
1630	80	5	5	17.5	MP-1			245	+1.75
					MP-2			1	+0.90
					MP-4			16	+0.15
					VEW-1S			0	+1.20
					VEW-1D			1908	+2.40
					MW-4			258	+0.75
					RW-2			478	+1.20
					P-2			233	+0.90

AIR SPARGE PILOT TEST FIELD DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/15/94
Measured by:	VAM, CTG

Air Sparge Test Well:	
Static DTW in AS-1:	
Static DO in AS-1:	
Compressor type/size:	

Distance from sparge well to monitoring point							
ft	ft	ft	ft	ft	ft	ft	ft
MP-1	MP-2	VEW-1D	MW-4	P-2	RW-2	MP-4	VEW-1S

Time	Elapsed Time (min.)	Pressure at Regulator (psi)	Pressure at Sparge Well (psi)	Air flow at Sparge Well (scfm)	Monitoring Point (MP)	Dissolved Oxygen at MP (mg/l)	DTW in MP (ft.)	PID at MP (ppmv)	Pressure at MP (in H2O)
1715	~~120~~ 125	5	19	19	MP-1			1785	+2.20
					MP-2			2.8	+1.10
					MP-4			630	+0.20
					VEW-1S			0.8	+1.50
					VEW-1D			>2500	+2.80
					MW-4			285	+0.90
					RW-2			710	+1.35
					P-2			260	+1.0
~~1745~~	~~140~~ 155	5	19.5	19.5	MP-1			>2500	+2.20
					MP-2			3.0	+1.05
					MP-4			735	+0.20
					VEW-1S			2	+1.45
					VEW-1D			>2500	+2.80
					MW-4			235	+0.85
					RW-2			825	+1.30
					P-2			230	+0.95
1815	185	5	20		MP-1			>2500	+2.20
					MP-2			1.3	+1.05
					MP-4			760	+0.20
					VEW-1S			1.4	+1.45
					VEW-1D			>2500	+2.90
					MW-4			250	+0.85
					RW-2			855	+1.30
					P-2			273	+1.0

AIR SPARGE PILOT TEST FIELD DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/15/94
Measured by:	JAM CTB

Air Sparge Test Well:	
Static DTW in AS-1:	
Static DO in AS-1:	
Compressor type/size:	

Distance from sparge well to monitoring point							
ft	ft	ft	ft	ft	ft	ft	ft
MP-1	MP-2	VEW-1D	MW-4	P-2	RW-2	MP-4	VEW-1S

Time	Elapsed Time (min.)	Pressure at Regulator (psi)	Pressure at Sparge Well (psi)	Air flow at Sparge Well (scfm)	Monitoring Point (MP)	Dissolved Oxygen at MP (mg/l)	DTW in MP (ft.)	PID at MP (ppmv)	Pressure at MP (in H2O)
1830	SHUT DOWN AIR								
1830					AS-1	4.2	-/26.55		
					MP-1	↑	24.43/24.97		
					MP-2	PSH	24.61/25.00		
					MP-4	↓	25.64/25.78		
					VEW-1S	T	DRY		
					VEW-1D	↑	25.14/25.90		
					MW-4	PSH	25.11/25.28		
					RW-2	↓	24.46/24.60		
		DTP			P-2	↓	24.64/24.65		
1845	END LOADING	DTW							
1915					AS-1		-/25.47		
					MP-1		24.20/24.78		+0.01
					MP-2		24.61/25.01		+0.01
					MP-4		25.66/25.80		0.0
					VEW-1S		DRY		+0.0
					VEW-1D		25.02/25.78		0.08
					MW-4		25.15/25.45		0.0
					RW-2		24.32/24.69		+0.05
					P-2		24.70/24.82		0.0

25.14 25.90

AIR SPARGE/SOIL VENTING PILOT TEST FIELD DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

3/4" ϕ AIR HOSE

Date:	6/16/94
Measured by:	JAM, CTB

Air Sparge Test Well:	AS-1
Vent Test Well:	VEW-1D

Monitor Points:
MP-1
MP-2
MP-4
VEW-1S
MW-4
P-2
RW-2
and possibly
MW-25
MW-26
P-3

Time	Elapsed Time (min.)	Pressure at Regulator (psi)	Pressure at Sparge Well (psi)	Air flow at Sparge Well (scfm)	Vacuum at Vent Well (in. H2O)	Pre/Post Vacuum at Blower (in. H2O)	Pre-Blower Anemom. Reading (ft/min)	Pre/Post Blower Temp (oF)	Vapor Con. at Blower (eff) PID (ppmv)	Monitoring Point (MP)	Dissolved Oxygen at MP (mg/l)	DTW / DTW in MP (ft.)	PID at MP (ppmv)	Pressure at MP (in H2O)	LEL/02
CALIB. PID, DO METER NOT WORKING															
0815	STATICS									AS-1	NA	-/2384			
										MP-2	↑	2463/2520	63	+0.12	
										MP-1	PSH	2390/2432	153	+0.01	
										MP-4	↓	2568/2600	927	0.0	
										VEW-1S	DNA	DRY	2	+0.06	
										VEW-1D	↑	2448/2489	2230	0.0	
										MW-4	PSH	2517/2546	90	0.0	
										RW-2	↓	2460/2469	101	0.0	
										P-2	↓	2424/2484	704	0.0	
0845	END STATICS														
0900	START SVE'S (0% DILUTION)														
0915	START AIR SPARGE (5 PSI)														
0930	15	5		17	23	27/33			430	MP-1					
										MP-2					
0935	SHUT DOWN - WATER IN SVE'S PIPING/BLOWER									MP-4					
										VEW-1S					
										MW-4					
										RW-2					
RE-CALB. PID										P-2					
0950	RESTART SVE'S (25% DILUTION)														
0955	RESTART AIR SPARGE (5 PSI)														
1015	20	5	-	20	19	20/26	1200	63/65	35	MP-1			85	1.10	6/20.3
										MP-2			13	1.05	
										MP-4			1055	0.0	
										VEW-1S			10	1.65	
										MW-4			11	0.40	
										RW-2			5	0.70	
										P-2			8.1	0.80	

BRC/Excel/Spaven.xls

LEL/02 IND - INDUST.
MSA -

AIR SPARGE/SOIL VENTING PILOT TEST FIELD DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/16/94
Measured by:	JAM, CTB

Air Sparge Test Well:	AS-1
Vent Test Well:	VEW-1D

Monitor Points:
MP-1
MP-2
MP-4
VEW-1S
MW-4
P-2
RW-2
and possibly
MW-25
MW-26
P-3

Time	Elapsed Time (min.)	Pressure at Regulator (psi)	Pressure at Sparge Well (psi)	Air flow at Sparge Well (scfm)	Vacuum at Vent Well (in. H2O)	Pre/Post Vacuum at Blower (in. H2O)	Pre-Blower Anemom. Reading (ft/min)	Pre/Post Blower Temp. (oF)	Vapor Con. at Blower (eff) PID (ppmv)	Monitoring Point (MP)	Dissolved Oxygen at MP (mg/l)	DTW in MP (ft.)	PID at MP (ppmv)	Pressure at MP (in H2O)	LEL/O_2
1030	35	5	—	21	17	20/26	1200	68/90	314	MP-1			100	1.05	7/20.1
										MP-2			0.0	1.10	IND
										MP-4			970	0.0	
										VEW-1S			0.0	1.7	
										MW-4			3.5	0.4	
										RW-2			0.0	0.65	
										P-2			1	0.80	
1045	50	5	—	21	19	20/27	1200	64/90	342	MP-1			48	1.15	1/20.5 IND
										MP-2			0.0	1.15	
										MP-4			731	0.05	
										VEW-1S			0.0	1.70	
										MW-4			2.5	0.45	
										RW-2			0.0	0.70	
										P-2			2.2	0.80	
1100	65	5	—	21	18	20/27	1200	67/90	337	MP-1			43	1.15	15/19.9 IND
										MP-2			4	1.15	
										MP-4			425	0.05	
										VEW-1S			0	1.7	
										MW-4			3	0.45	
										RW-2			0	0.70	
										P-2			0	0.85	
1130	95	5	—	21	18	20/27	1200	64/97	168	MP-1			90	1.20	7.1/20/14.5 IN SA
										MP-2			0	1.15	
										MP-4			339	0.05	
										VEW-1S			0	1.70	IND. BATTERY DEAD
										MW-4			0	0.50	
										RW-2			0	0.75	
										P-2			0	0.90	

AIR SPARGE/SOIL VENTING PILOT TEST FIELD DATA
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO

Date:	6/16/94
Measured by:	VAM, CTB

Air Sparge Test Well:	AS-1
Vent Test Well:	VEW-1D

Monitor Points:
MP-1
MP-2
MP-4
VEW-1S
MW-4
P-2
RW-2
and possibly
MW-25
MW-26
P-3

Time	Elapsed Time (min.)	Pressure at Regulator (psi)	Pressure at Sparge Well (psi)	Air flow at Sparge Well (scfm)	Vacuum at Vent Well (in. H2O)	Pre/Post Vacuum at Blower (in. H2O)	Pre-Blower Anemom. Reading (ft/min)	Pre/Post Blower Temp (oF)	Vapor Con. at Blower (eff) PID (ppmv)	Monitoring Point (MP)	Dissolved Oxygen at MP (mg/l)	DTP. DTW in MP (ft.)	PID at MP (ppmv)	Pressure at MP (in H2O)
1200	125	5	–	21	17	20/27	1200	65/99	172	MP-1			87	
										MP-2			0	1.25
										MP-4			240	0.05
										VEW-1S			0	1.15
										MW-4			1	0.45
										RW-2			0	0.70
										P-2			0	0.85
1210	SHUT SVES DILUTION TO 0%													
1220	AIR SAMPLES AT 0% DILUTION 22						1500	/98						
12-30	SHUT DOWN SVES													
	AIR SPARGE STILL ON													
1235	~~VENT~~ FLUID LEVELS									MP 1		23.82/24.14		
										MP-2		24.63/25.00		
1245	SHUT DOWN AIR SPARGE									MP-4		25.64/25.88		
										VEW-1D		23.65/24.40		
										VEW-1S		DRY		
										MW-4		25.12/25.43		
										RW-2		24.34/24.65		
										P-2		24.67/24.77		
1330										MP-1		24.03/24.59		
										MP-2		24.65/25.14		
										VEW-1D		24.18/24.68		
1345										MP-1				+0.15
										MP-2				+0.20
										VEW-1S				+0.20
										VEW-1D				+0.15

6/16/94 NA

BRC/Excel/Spaven.xls

APPENDIX D

AIR SAMPLE CERTIFICATES OF ANALYSIS, CHAIN-OF-CUSTODY DOCUMENTATION, AND QA/QC DATA, JUNE 14 AND 16, 1994

COAST-TO-COAST ANALYTICAL SERVICES, INC.

EXCELLENCE IN ANALYSIS

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Terry Bennett
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-2892-1
Project : BRC/023353014.32

Analyzed : 06/15/94
Analyzed by: EJ
Method : EPA TO-14

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-1S Effluent	Air	Jerry A. May	06/14/94 1230	06/15/94

CONSTITUENT	*PQL ppbv	RESULT ppbv	RESULT µg/cu M	NOTE
FUEL FINGERPRINT in AIR				1
Benzene	20.	690.	2200.	
Toluene	20.	110.	400.	
Ethylbenzene	20.	120.	530.	
Xylenes	20.	740.	3200.	
Ethylene Dichloride	20.	ND	ND	
Ethylene Dibromide	10.	ND	ND	
Total Fuel (non-methane hydrocarbons)	1000.	130000.	460000	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/17/94
MS2/2V04E
GD/geepr(dw)/yl
MS2*A

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory) (805) 389-1353
4765 Calle Quetzal, Camarillo, California 93012 FAX (805)389-1438

CLIENT: Terry Bennett
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-2892-1
Project : BRC/023353014.32

Analyzed : 06/15/94
Analyzed by: EJ
Method : GC/TCD

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-1S Effluent	Air	Jerry A. May	06/14/94 1230	06/15/94

CONSTITUENT	(CAS RN)	*PQL PERCENT	RESULT PERCENT	NOTE
FIXED GASES AND METHANE				
Carbon Dioxide	(124389)	0.1	0.3	
Oxygen	(7782447)	0.01	18.	
Nitrogen	(7727379)	0.02	64.	
Methane	(74828)	0.005	18.	
Carbon Monoxide	(630080)	0.1	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/27/94
TCD/06159411
GD/geepr(dw)/yl
KF15TA

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

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COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory) (805) 389-1353
4765 Calle Quetzal, Camarillo, California 93012 FAX (805)389-1438

CLIENT: Terry Bennett
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

QC Batch ID: MS2*A CK-2892-1
Project : BRC/023353014.32

Analyzed : 06/15/94
Analyzed by: EJ
Method : EPA TO-14

QC DUPLICATE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
VEW-1S Effluent	Air	Jerry A. May	06/14/94	06/15/94

CONSTITUENT	*PQL ppbv	RESULT ppbv	RESULT µg/cu M	%DIFF	NOTE
FUEL FINGERPRINT in AIR					1
Benzene	20.	780.	2500.	13.	
Toluene	20.	130.	480.	18.	
Ethylbenzene	20.	140.	600.	12.	
Xylenes	20.	900.	3900.	20.	
Ethylene Dichloride	20.	ND	ND		
Ethylene Dibromide	10.	ND	ND		
Total Fuel (non-methane hydrocarbons)	1000.	140000.	490000	6.3	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/17/94
MS2/2V05E
GD/geepr(dw)/yl
CK2892-1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/15/94
Analyzed by: EJ
Method : EPA TO-14

QC SPIKE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED DATE	RECEIVED
QC SPIKE	Air			

CONSTITUENT	*PQL µg/cu M	SPIKE AMOUNT	RESULT µg/cu M	%REC	NOTE
FUEL FINGERPRINT in AIR					1,2
Benzene	50.	7100.	7200.	101.	
Toluene	100.	28000.	23000.	82.	
Ethylbenzene	100.	3200.	2600.	81.	
Xylenes	100.	19000.	15000.	79.	
Ethylene Dichloride	100.	5500.	5400.	98.	
Ethylene Dibromide	100.	4100.	3600.	88.	
Total Fuel (non-methane hydrocarbons)	4000.	230000	190000	83.	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.
(2) Zero Air spiked with premium unleaded gasoline.

06/17/94
MS2/2V06E
GD/gegcc(dw)/yl
CK9406-15

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/15/94
Analyzed by: EJ
Method : EPA TO-14

INSTRUMENT BLANK
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
INSTRUMENT BLANK	Air			

CONSTITUENT	(CAS RN)	*PQL µg/cu M	RESULT µg/cu M	NOTE
FUEL FINGERPRINT in AIR				1
Benzene	(71432)	50.	ND	
Toluene	(108883)	100.	ND	
Ethylbenzene	(100411)	100.	ND	
Xylenes		100.	ND	
Ethylene Dichloride	(107062)	100.	ND	
Ethylene Dibromide	(106934)	100.	ND	
Total Fuel (non-methane hydrocarbons)		4000.	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/17/94
MS2/2V03E
GD/gegcc(dw)/yl
CK9406-15

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

COAST-TO-COAST ANALYTICAL SERVICES, INC.

EXCELLENCE IN ANALYSIS

SoCal Division (Camarillo Laboratory) (805) 389-1353
4765 Calle Quetzal, Camarillo, California 93012 FAX (805) 389-1438

QC Batch ID: KF15TA

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/15/94
Analyzed by: EJ
Method : GC/TCD

QC SPIKE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED DATE RECEIVED
QC SPIKE	Air		

CONSTITUENT	*PQL PERCENT	SPIKE AMOUNT	RESULT PERCENT	%REC	NOTE
FIXED GASES AND METHANE					
Carbon Dioxide	0.1	15.	15.	100.	
Oxygen	0.01	7.1	7.0	99.	
Nitrogen	0.02	66.	66.	100.	
Methane	0.005	4.6	4.6	100.	
Carbon Monoxide	0.1	7.1	7.2	101.	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/27/94
TCD/06159413
GD/geepr(dw)/yl
CK2891-1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

COAST ANALYTICAL SERVICES

141 Suburban Road	San Luis Obispo, CA 93401	(805) 543-2553	FAX (805) 543-2685
751 S. Kellogg, Suite A	Goleta, CA 93117	(805) 964-7838	FAX (805) 967-4386
6006 Egret Ct.	Benicia, CA 94510	(707) 747-2757	FAX (707) 747-2765
2400 Cumberland Dr.	Valparaiso, Indiana 46383	(219) 464-2389	FAX (219) 462-2953
4765 Calle Quetzal	Camarillo, CA 93012	(805) 389-1353	FAX (805) 389-1438
340 County Road No. 5	Westbrook, ME 04092	(207) 874-2400	FAX (207) 775-4029

[redacted] Chain of Custody

• PLEASE PRINT IN PEN

Client: Blomfield Refining Company	Contact: Chris Hawley	Phone #: (505) 632-8013	FAX #: (505) 632-3911
Address: #50 County Road 4990	City: Blomfield	State: NM	Zip:
Project Name/Number: BRC / 23353014.32		Project MGR: Terry Bennett	
Bill (If different than above): Groundwater Technology	Address: 2501 Yale Blvd SE, Suite 204	Albuquerque, NM 87106	Cynthia Liakos
Sampler (Print and sign): Terry A Bennett / Terry A Bennett	Due Date:	Circle for RUSH*	Copies To: Auth. Init.

Sample Description	Date/Time Coll'd	*Matrix	# of Containers	Pres.	Filt. y/n	* Subject to Availability Analysis	Remarks	Lab ID #
VEW-1D VENT EFF.	6/14/94	AIR	2	—		Total Petroleum Hydrocarbons (EPA TO-14), EPA 8010/8020 (Aromatic & Halocarbons), and (CO2, O2, & Methane)	CK 28923-1	
VEW-1S EFF.	6/14/94 1230	AIR	2	—		" " " " "		-1A

Relinquished By	Date/Time	Received By	Relinquished By	Date/Time	Received By
Terry A Bennett	6/14/94 1400				

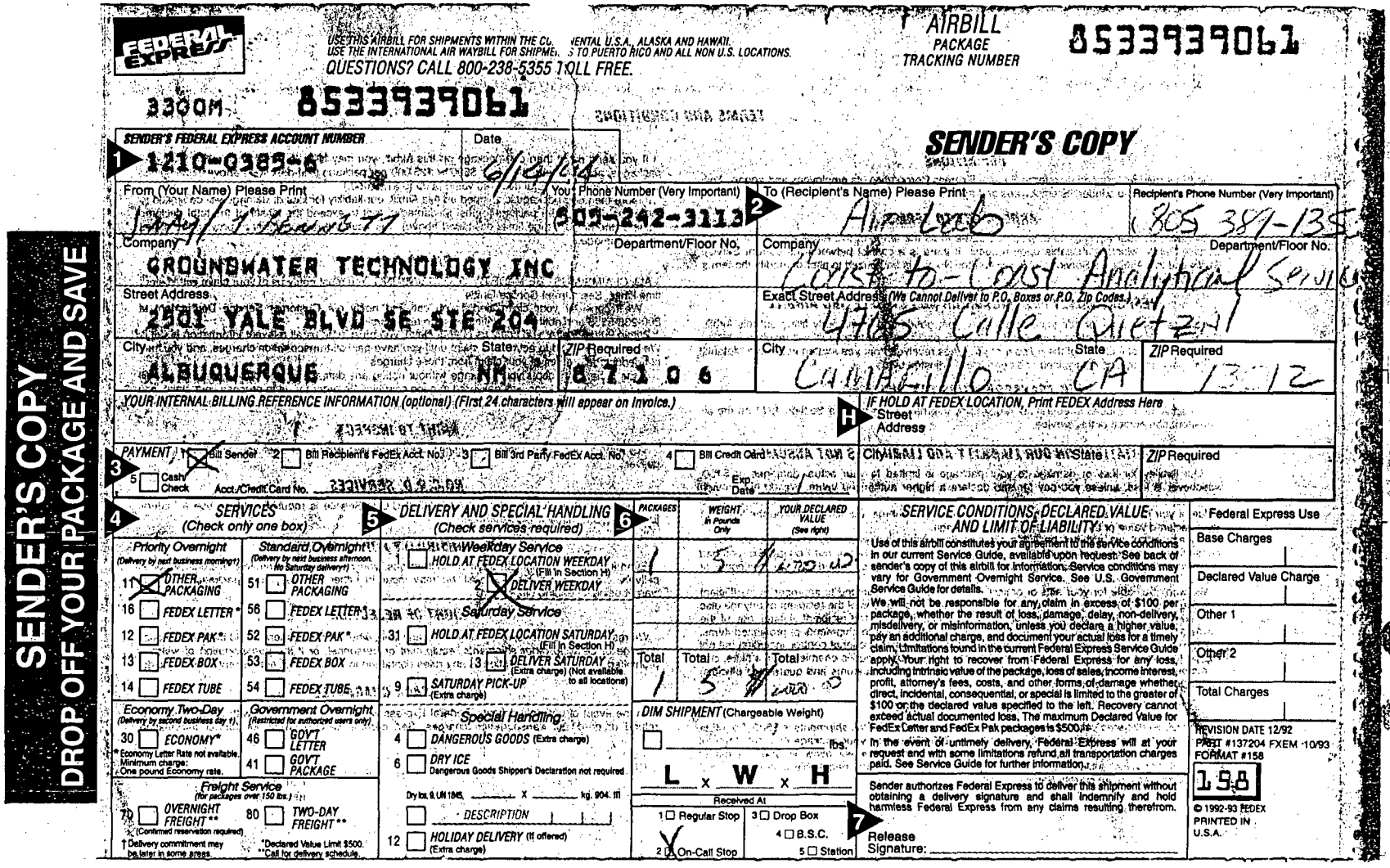
FOR LAB USE ONLY

Shipping Method	Shipping #	Received By	Date/Time	Condition (See Remarks) Cold	Sealed	Intact
FED EX	853393706 1	D Ramani	6/15/94 1030	N	Y	Y

REMARKS: Rcvd 2 Tedlar Bags

* Matrix:
DW - Drinking Water
WW - Wastewater
GW - Groundwater
SW - Surface Water
IM - Impinger
FI - Filter
FP - Free Product
A/G - Air/Gas
SL - Sludge/Soil/Solid
OT - Other

SAMPLE CONTROL



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1 SENDER'S FEDERAL EXPRESS ACCOUNT NUMBER: 1210-0389-6 | Date: 6/14/94

From (Your Name) Please Print: Jeffrey T. Beard II | Your Phone Number (Very Important): 505-242-3113

Company: GROUNDWATER TECHNOLOGY INC | Department/Floor No.:

Street Address: 2501 YALE BLVD SE STE 204

City: ALBUQUERQUE | State: NM | ZIP Required: 8 7 1 0 6

2 To (Recipient's Name) Please Print: Al Lee | Recipient's Phone Number (Very Important): (805 387-135[illegible]

Company: Coast to Coast Analytical Servi[illegible] | Department/Floor No.:

Exact Street Address (We Cannot Deliver to P.O. Boxes or P.O. Zip Codes.): 4706 Calle Quetzal

City: Camarillo | State: CA | ZIP Required: 13 12

YOUR INTERNAL BILLING REFERENCE INFORMATION (optional) (First 24 characters will appear on Invoice.)

H IF HOLD AT FEDEX LOCATION, Print FEDEX Address Here
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City: | State: | ZIP Required:

3 PAYMENT: 1 [X] Bill Sender 2 [ ] Bill Recipient's FedEx Acct. No. 3 [ ] Bill 3rd Party FedEx Acct. No. 4 [ ] Bill Credit Card
5 [ ] Cash/Check Acct./Credit Card No. [illegible] Exp. Date:

4 SERVICES (Check only one box)

Priority Overnight (Delivery by next business morning†)
11 [X] OTHER PACKAGING
16 [ ] FEDEX LETTER*
12 [ ] FEDEX PAK*
13 [ ] FEDEX BOX
14 [ ] FEDEX TUBE

Standard Overnight (Delivery by next business afternoon. No Saturday delivery†)
51 [ ] OTHER PACKAGING
56 [ ] FEDEX LETTER*
52 [ ] FEDEX PAK*
53 [ ] FEDEX BOX
54 [ ] FEDEX TUBE

Economy Two-Day (Delivery by second business day †)
30 [ ] ECONOMY*
* Economy Letter Rate not available. Minimum charge: One pound Economy rate.

Government Overnight (Restricted for authorized users only)
46 [ ] GOVT LETTER
41 [ ] GOVT PACKAGE

Freight Service (for packages over 150 lbs.)
70 [ ] OVERNIGHT FREIGHT** (Confirmed reservation required)
80 [ ] TWO-DAY FREIGHT**
† Delivery commitment may be later in some areas. *Declared Value Limit $500. **Call for delivery schedule.

5 DELIVERY AND SPECIAL HANDLING (Check services required)

Weekday Service
1 [ ] HOLD AT FEDEX LOCATION WEEKDAY (Fill in Section H)
2 [X] DELIVER WEEKDAY

Saturday Service
31 [ ] HOLD AT FEDEX LOCATION SATURDAY (Fill in Section H)
3 [ ] DELIVER SATURDAY (Extra charge) (Not available to all locations)
9 [ ] SATURDAY PICK-UP (Extra charge)

Special Handling
4 [ ] DANGEROUS GOODS (Extra charge)
6 [ ] DRY ICE Dangerous Goods Shipper's Declaration not required.
Dry Ice, 9, UN 1845, ____ X ____ kg, 904. III
[ ] DESCRIPTION
12 [ ] HOLD DELIVERY (If offered) (Extra charge)

6

PACKAGES	WEIGHT In Pounds Only	YOUR DECLARED VALUE (See right)
1	5 lbs	[illegible] .00
Total 1	Total 5 lbs	Total [illegible] .00

DIM SHIPMENT (Chargeable Weight)
[ ] ____ lbs.
L x W x H

Received At
1 [ ] Regular Stop
2 [X] On-Call Stop
3 [ ] Drop Box
4 [ ] B.S.C.
5 [ ] Station

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REVISION DATE 12/92
PART #137204 FXEM 10/93
FORMAT #158
198

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Terry Bennett
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-2970-1
Project : BRC/023353014132

Analyzed : 06/16/94
Analyzed by: EJ
Method : EPA TO-14

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-ID EFF	Air	Jerry A. May	06/14/94 1730	06/16/94

CONSTITUENT	*PQL ppmv	RESULT ppmv	RESULT mg/cu M	NOTE
FUEL FINGERPRINT in AIR				1
Benzene	0.1	120.	380.	
Toluene	0.1	4.3	16.	
Ethylbenzene	0.1	13.	57.	
Xylenes	0.1	65.	280.	
Ethylene Dichloride	0.1	ND	ND	
Ethylene Dibromide	0.05	ND	ND	
Total Fuel (non-methane hydrocarbons)	5.	3100.	11000	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/17/94
MS2/2V10E
GD/gegcc(dw)/yl
MS2*A
CC: Chris Hawley
Bloomfield Refining Company
#50 Country Road 4990
Bloomfield, NM 87413

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

COAST-TO-COAST ANALYTICAL SERVICES, INC.

EXCELLENCE IN ANALYSIS

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805) 389-1438

CLIENT: Terry Bennett
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-2970-1
Project : BRC/023353014132

Analyzed : 06/16/94
Analyzed by: GD
Method : GC/TCD

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-ID EFF	Air	Jerry A. May	06/14/94 1730	06/16/94

CONSTITUENT	(CAS RN)	*PQL PERCENT	RESULT PERCENT	NOTE
FIXED GASES AND METHANE				
Carbon Dioxide	(124389)	0.1	2.3	
Oxygen	(7782447)	0.01	4.3	
Nitrogen	(7727379)	0.02	25.	
Methane	(74828)	0.005	68.	
Carbon Monoxide	(630080)	0.1	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/17/94
TCD/06169403
GD/gegcc(dw)
KF16TA
CC: Chris Hawley
Bloomfield Refining Company
#50 Country Road 4990
Bloomfield, NM 87413

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

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SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

QC Batch ID: MS2*A CK-2970-1
Project : BRC/023353014132

CLIENT: Terry Bennett
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Analyzed : 06/16/94
Analyzed by: EJ
Method : EPA TO-14

QC DUPLICATE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
VEW-ID EFF	Air	Jerry A. May	06/14/94	06/16/94

CONSTITUENT	*PQL ppmv	RESULT ppmv	RESULT mg/cu M	%DIFF	NOTE
FUEL FINGERPRINT in AIR					1
Benzene	0.1	110.	350.	8.2	
Toluene	0.1	4.	15.	6.5	
Ethylbenzene	0.1	12.	52.	9.2	
Xylenes	0.1	62.	270.	3.6	
Ethylene Dichloride	0.1	ND	ND		
Ethylene Dibromide	0.05	ND	ND		
Total Fuel (non-methane hydrocarbons)	5.	2800.	10000	9.5	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/17/94
MS2/2V11E
GD/gegcc(dw)/yl
CK2970-1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/16/94
Analyzed by: EJ
Method : EPA TO-14

INSTRUMENT BLANK
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED DATE RECEIVED
INSTRUMENT BLANK	Air		

CONSTITUENT	(CAS RN)	*PQL µg/cu M	RESULT µg/cu M	NOTE
FUEL FINGERPRINT in AIR				1
Benzene	(71432)	50.	ND	
Toluene	(108883)	100.	ND	
Ethylbenzene	(100411)	100.	ND	
Xylenes		100.	ND	
Ethylene Dichloride	(107062)	100.	ND	
Ethylene Dibromide	(106934)	100.	ND	
Total Fuel (non-methane hydrocarbons)		4000.	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/17/94
MS2/2V08E
GD/gegcc(dw)/yl
CK9406-16

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/16/94
Analyzed by: EJ
Method : EPA TO-14

QC SPIKE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
QC SPIKE	Air			

CONSTITUENT	*PQL µg/cu M	SPIKE AMOUNT	RESULT µg/cu M	%REC	NOTE
FUEL FINGERPRINT in AIR					1,2
Benzene	50.	7100.	8200.	115.	
Toluene	100.	28000.	24000.	86.	
Ethylbenzene	100.	3200.	4100.	128.	
Xylenes	100.	19000.	22000.	116.	
Ethylene Dichloride	100.	5500.	5400.	98.	
Ethylene Dibromide	100.	4100.	3800.	93.	
Total Fuel (non-methane hydrocarbons)	4000.	230000	290000	126.	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.
(2) Zero Air spiked with premium unleaded gasoline.

06/17/94
MS2/2V12E
GD/gegcc(dw)/yl
CK9406-16

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Terry Bennett
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

QC Batch ID: KF16TA CK-2970-1
Project : BRC/023353014132

Analyzed : 06/16/94
Analyzed by: GD
Method : GC/TCD

QC DUPLICATE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
VEW-ID EFF	Air	Jerry A. May	06/14/94	06/16/94

CONSTITUENT	(CAS RN)	*PQL PERCENT	RESULT PERCENT	%DIFF	NOTE
FIXED GASES AND METHANE					
Carbon Dioxide	(124389)	0.1	2.2	4.4	
Oxygen	(7782447)	0.01	5.1	17.	
Nitrogen	(7727379)	0.02	28.	11.	
Methane	(74828)	0.005	65.	4.5	
Carbon Monoxide	(630080)	0.1	ND		

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/17/94
TCD/06169404
GD/gegcc(dw)
CK2970-1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory) (805) 389-1353
4765 Calle Quetzal, Camarillo, California 93012 FAX (805)389-1438

QC Batch ID: KF16TA

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/16/94
Analyzed by: GD
Method : GC/TCD

QC SPIKE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
QC SPIKE	Air			

CONSTITUENT	*PQL PERCENT	SPIKE AMOUNT	RESULT PERCENT	%REC	NOTE
FIXED GASES AND METHANE					
Carbon Dioxide	0.1	15.	15.	100.	
Oxygen	0.01	7.1	7.1	100.	
Nitrogen	0.02	66.	66.	100.	
Methane	0.005	4.6	4.7	102.	
Carbon Monoxide	0.1	7.1	7.1	100.	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/17/94
TCD/06169405
GD/gegcc(dw)
CK2970-1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

Chain of Custody

COAST - TO - COAST ANALYTICAL SERVICES

141 Suburban Road	San Luis Obispo, CA 93401	(805) 543-2553	FAX (805) 543-2685
751 S. Kellogg, Suite A	Goleta, CA 93117	(805) 964-7838	FAX (805) 967-4386
6006 Egret Ct.	Benicia, CA 94510	(707) 747-2757	FAX (707) 747-2765
2400 Cumberland Dr.	Valparaiso, Indiana 46383	(219) 464-2389	FAX (219) 462-2953
4765 Calle Quetzal	Camarillo, CA 93012	(805) 389-1353	FAX (805) 389-1438
340 County Road No. 5	Westbrook, ME 04092	(207) 874-2400	FAX (207) 775-4029

• PLEASE PRINT IN PEN

Client	Contact	Phone #	FAX #

Address	City	State	Zip

Project Name/Number	Project MGR
SEC 1 T33S R14E 32	

Bill (If different than above)	Address

Sampler (Print and sign)	Due Date	Circle for RUSH*	Copies To:	Auth. Init.

* Subject to Availability

Sample Description	Date/Time Coll'd	*Matrix	# of Containers	Pres.	Filt. y/n	Analysis	Remarks	Lab ID #
VGW-1D PFF	6/14/94 1330	AQ	2				CK 3970-1	1
								2
								3
								4
								5
								6
								7
								8

Relinquished By	Date/Time	Received By	Relinquished By	Date/Time	Received By
	6/15/94 1330				

FOR LAB USE ONLY

Shipping Method	Shipping #	Received By	Date/Time	Condition (See Remarks) Cold	Sealed	Intact
FED EX	798528671 2		6/16/94 1130	N	Y	Y

REMARKS Panama

Hold = Teflon Bags

* Matrix:
DW - Drinking Water
WW - Wastewater
GW - Groundwater
SW - Surface Water
IM - Impinger
FI - Filter
FP - Free Product
A/G - Air/Gas
SL - Sludge/Soil/Solid
OT - Other

LAB

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1 SENDER'S FEDERAL EXPRESS ACCOUNT NUMBER: 1210-0385-6 | Date: 3/1/94

From (Your Name) Please Print: [illegible] | Your Phone Number (Very Important): 505-242-3113

Company: GROUNDWATER TECHNOLOGY INC | Department/Floor No.:

Street Address: 2501 YALE BLVD SE STE 204

City: ALBUQUERQUE | State: NM | ZIP Required: 8 7 1 0 6

2 To (Recipient's Name) Please Print: | Recipient's Phone Number (Very Important):

Company: | Department/Floor No.:

Exact Street Address (We Cannot Deliver to P.O. Boxes or P.O. Zip Codes.):

City: | State: | ZIP Required:

YOUR INTERNAL BILLING REFERENCE INFORMATION (optional) (First 24 characters will appear on invoice.)

H IF HOLD FOR PICK-UP, Print FEDEX Address Here
Street Address:
City: | State: | ZIP Required:

3 PAYMENT 1 [X] Bill Sender 2 [ ] Bill Recipient's FedEx Acct. No. 3 [ ] Bill 3rd Party FedEx Acct. No. 4 [ ] Bill Credit Card
5 [ ] Cash/Check Acct./Credit Card No. _____ Exp. Date _____

4 SERVICES (Check only one box)

Priority Overnight (Delivery by next business morning†)	Standard Overnight (Delivery by next business afternoon†)
11 [X] YOUR PACKAGING	51 [ ] YOUR PACKAGING
16 [ ] FEDEX LETTER *	56 [ ] FEDEX LETTER *
12 [ ] FEDEX PAK *	52 [ ] FEDEX PAK *
13 [ ] FEDEX BOX	53 [ ] FEDEX BOX
14 [ ] FEDEX TUBE	54 [ ] FEDEX TUBE
Economy Two-Day (Delivery by second business day†)	**Government Overnight** (Restricted to authorized users only)
30 [ ] ECONOMY	46 [ ] GOVT LETTER
	41 [ ] GOVT PACKAGE

Freight Service (for Extra Large or any package over 150 lbs.)
70 [ ] OVERNIGHT FREIGHT ** (Confirmed reservation required)
80 [ ] TWO-DAY FREIGHT **
† Delivery commitment may be later in some areas
*Declared Value Limit $100
**Call for delivery schedule.

5 DELIVERY AND SPECIAL HANDLING (Check services required)

1 [ ] HOLD FOR PICK-UP (Fill in Box H)
2 [X] DELIVER WEEKDAY
3 [ ] DELIVER SATURDAY (Extra charge) [ ] (Not available to all locations)
4 [ ] DANGEROUS GOODS (Extra charge)
5 [ ]
6 [ ] DRY ICE _____ Lbs.
7 [ ] OTHER SPECIAL SERVICE _____
8 [ ]
9 [ ] SATURDAY PICK-UP (Extra charge)
10 [ ]
11 [ ]
12 [ ] HOLIDAY DELIVERY (If offered) (Extra charge)

6

PACKAGES	WEIGHT In Pounds Only	YOUR DECLARED VALUE (See right)
1		
Total	Total	Total

DIM SHIPMENT (Chargeable Weight)
[ ] _____ lbs
_____ X _____ X _____ = _____

Received At
1 ☐ Regular Stop 3 ☐ Drop Box
2 ☐ On-Call Stop 4 ☐ BSC 5 ☐ Station

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EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory) (805) 389-1353
4765 Calle Quetzal, Camarillo, California 93012 FAX (805)389-1438

CLIENT: T. Bennett / C. Liakos
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-3124-1
Project : (CK2992) Bloomfield NM, #023353014.32
Analyzed : 06/17/94
Analyzed by: ZS
Method : EPA TO-14

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-1D V/S (CK2992-1)	Air	Jerry A. May	06/16/94 1220	06/17/94

CONSTITUENT	*PQL ppmv	RESULT ppmv	RESULT mg/cu M	NOTE
VOLATILE ORGANICS BY EPA TO-14				1
Acetone	1.	ND	ND	
Benzene	0.2	140.	460.	
Bromodichloromethane	0.1	ND	ND	
Bromomethane (Methyl Bromide)	0.2	ND	ND	
Bromoform	0.1	ND	ND	
1,3-Butadiene	0.5	ND	ND	
2-Butanone (MEK)	0.2	ND	ND	
Carbon Disulfide	2.	ND	ND	
Carbon Tetrachloride	0.2	ND	ND	
Chlorobenzene	0.1	ND	ND	
Chloroethane (Ethyl Chloride)	0.2	ND	ND	
2-Chloroethyl Vinyl Ether	1.	ND	ND	
Chloroform	0.5	ND	ND	
Chloromethane (Methyl Chloride)	0.2	ND	ND	
Dibromochloromethane	0.1	ND	ND	
1,2-Dibromoethane (EDB)	0.2	ND	ND	
1,2-Dichlorobenzene	0.2	ND	ND	
1,3-Dichlorobenzene	0.2	ND	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/29/94
MS1/1M97L
GD/geepr(dw)/yl
KF17M1

EXCELLENCE IN ANALYSIS

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4765 Calle Quetzal, Camarillo, California 93012 FAX (805)389-1438

CLIENT: T. Bennett / C. Liakos
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-3124-1
Project : (CK2992) Bloomfield NM, #023353014.32
Analyzed : 06/17/94
Analyzed by: ZS
Method : EPA TO-14

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-1D V/S (CK2992-1)	Air	Jerry A. May	06/16/94 1220	06/17/94

CONSTITUENT	*PQL ppmv	RESULT ppmv	RESULT mg/cu M	NOTE
1,4-Dichlorobenzene	0.2	ND	ND	
1,1-Dichloroethane	0.1	ND	ND	
1,2-Dichloroethane (EDC)	0.2	ND	ND	
1,1-Dichloroethene	0.2	ND	ND	
cis-1,2-Dichloroethene	0.2	ND	ND	
trans-1,2-Dichloroethene	0.2	ND	ND	
Dichloromethane	1.	ND	ND	
1,2-Dichloropropane	0.1	ND	ND	
cis-1,3-Dichloropropene	0.1	ND	ND	
trans-1,3-Dichloropropene	0.1	ND	ND	
Ethylbenzene	0.2	32.	140.	
2-Hexanone	0.1	ND	ND	
4-Methyl-2-Pentanone (MIBK)	0.1	ND	ND	
Styrene	0.2	ND	ND	
1,1,2,2-Tetrachloroethane	0.1	ND	ND	
Tetrachloroethene (PCE)	0.1	ND	ND	
Toluene	0.2	45.	170.	
1,1,1-Trichloroethane (TCA)	0.2	ND	ND	
1,1,2-Trichloroethane	0.2	ND	ND	
Trichloroethene (TCE)	0.1	ND	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/29/94
MS1/1M97L
GD/geepr(dw)/yl
KF17M1

EXCELLENCE IN ANALYSIS

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CLIENT: T. Bennett / C. Liakos
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-3124-1
Project : (CK2992) Bloomfield NM, #023353014.32
Analyzed : 06/17/94
Analyzed by: ZS
Method : EPA TO-14

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-1D V/S (CK2992-1)	Air	Jerry A. May	06/16/94 1220	06/17/94

CONSTITUENT	*PQL ppmv	RESULT ppmv	RESULT mg/cu M	NOTE
Trichlorofluoromethane (F-11)	0.2	ND	ND	
Trichlorotrifluoroethane (F-113)	0.2	ND	ND	
Vinyl Acetate	0.5	ND	ND	
Vinyl Chloride	0.2	ND	ND	
Xylenes	0.2	250.	1100.	
Percent Surrogate Recovery			109.	
Total Fuel (non-methane hydrocarbons)	50.	3700.	13000	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/29/94
MS1/1M97L
GD/geepr(dw)/yl
KF17M1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

COAST-TO-COAST ANALYTICAL SERVICES, INC.

EXCELLENCE IN ANALYSIS

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: T. Bennett / C. Liakos
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-2992-1
Project : Bloomfield NM, #023353014.32
Analyzed : 06/17/94
Analyzed by: ZS
Method : EPA TO-14

R E V I S E D
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-1D V/S	Air	Jerry A. May	06/16/94 1220	06/17/94

CONSTITUENT	*PQL ppmv	RESULT ppmv	RESULT mg/cu M	NOTE
BTEX & Total Fuel In Air				1
Benzene	0.2	140.	460.	
Toluene	0.2	45.	170.	
Ethylbenzene	0.2	32.	140.	
Xylenes	0.2	250.	1100.	
Total Fuel (non-methane hydrocarbons)	50.	3700.	13000	
1,2-Dichloroethane (EDC)	0.2	ND	ND	
1,2-Dibromoethane (EDB)	0.1	ND	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/29/94
MS1/1M97L
GD/gegcc(dw)/yl
MS1*A

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: T. Bennett / C. Liakos
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

Lab Number : CK-2992-1
Project : Bloomfield NM, #023353014.32
Analyzed : 06/17/94
Analyzed by: GD
Method : GC/TCD

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	RECEIVED
VEW-1D V/S	Air	Jerry A. May	06/16/94 1220	06/17/94

CONSTITUENT	(CAS RN)	*PQL PERCENT	RESULT PERCENT	NOTE
FIXED GASES AND METHANE				
Carbon Dioxide	(124389)	0.1	0.4	
Oxygen	(7782447)	0.01	14.	
Nitrogen	(7727379)	0.02	58.	
Methane	(74828)	0.005	28.	
Carbon Monoxide	(630080)	0.1	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/20/94
TCD/06179403
GD/gegcc(dw)/yl
KF17TA

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/17/94
Analyzed by: ZS
Method : EPA TO-14

INSTRUMENT BLANK
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
INSTRUMENT BLANK	Air			

CONSTITUENT	(CAS RN)	*PQL µg/cu M	RESULT µg/cu M	NOTE
VOLATILE ORGANICS BY EPA TO-14				1
Acetone	(67641)	3.	ND	
Benzene	(71432)	0.5	ND	
Bromodichloromethane	(75274)	1.	ND	
Bromomethane (Methyl Bromide)	(74839)	1.	ND	
Bromoform	(75252)	1.	ND	
1,3-Butadiene	(106990)	1.	ND	
2-Butanone (MEK)	(78933)	1.	ND	
Carbon Disulfide	(75150)	5.	ND	
Carbon Tetrachloride	(56235)	1.	ND	
Chlorobenzene	(108907)	0.5	ND	
Chloroethane (Ethyl Chloride)	(75003)	0.5	ND	
2-Chloroethyl Vinyl Ether	(110758)	5.	ND	
Chloroform	(67663)	3.	ND	
Chloromethane (Methyl Chloride)	(74873)	0.5	ND	
Dibromochloromethane	(124381)	1.	ND	
1,2-Dibromoethane (EDB)	(106934)	2.	ND	
1,2-Dichlorobenzene	(95501)	1.	ND	
1,3-Dichlorobenzene	(541731)	1.	ND	
1,4-Dichlorobenzene	(106467)	1.	ND	
1,1-Dichloroethane	(75343)	0.5	ND	
1,2-Dichloroethane (EDC)	(107062)	1.	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.

06/20/94
MS1/1M87L
GD/gegcc(dw)/yl
CK9406-17

COAST-TO-COAST ANALYTICAL SERVICES, INC.

EXCELLENCE IN ANALYSIS

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/17/94
Analyzed by: ZS
Method : EPA TO-14

INSTRUMENT BLANK
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED DATE RECEIVED
INSTRUMENT BLANK	Air		

CONSTITUENT	(CAS RN)	*PQL µg/cu M	RESULT µg/cu M	NOTE
1,1-Dichloroethene	(75354)	1.	ND	
cis-1,2-Dichloroethene	(156694)	1.0	ND	
trans-1,2-Dichloroethene	(156605)	1.	ND	
Dichloromethane	(75092)	5.	ND	
1,2-Dichloropropane	(78875)	0.5	ND	
cis-1,3-Dichloropropene	(10061015)	0.5	ND	
trans-1,3-Dichloropropene	(10061026)	0.5	ND	
Ethylbenzene	(100411)	1.	ND	
2-Hexanone	(591786)	0.5	ND	
4-Methyl-2-Pentanone (MIBK)	(108101)	0.5	ND	
Styrene	(100425)	1.	ND	
1,1,2,2-Tetrachloroethane	(79345)	1.	ND	
Tetrachloroethene (PCE)	(127184)	1.	ND	
Toluene	(108883)	1	ND	
1,1,1-Trichloroethane (TCA)	(71556)	1.	ND	
1,1,2-Trichloroethane	(79005)	1.	ND	
Trichloroethene (TCE)	(79016)	0.5	ND	
Trichlorofluoromethane (F-11)	(75694)	1.	ND	
Trichlorotrifluoroethane (F-113)	(76131)	2.	ND	
Vinyl Acetate	(108054)	2.	ND	
Vinyl Chloride	(75104)	0.5	ND	
Xylenes	(1330207)	1.	ND	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/20/94
MS1/1M87L
GD/gegcc(dw)/yl
CK9406-17

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory) (805) 389-1353
4765 Calle Quetzal, Camarillo, California 93012 FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/17/94
Analyzed by: EJ
Method : EPA TO-14

QC SPIKE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED DATE RECEIVED
QC SPIKE	Air		

CONSTITUENT	*PQL µg/cu M	SPIKE AMOUNT	RESULT µg/cu M	%REC	NOTE
VOLATILE ORGANICS BY EPA TO-14					1,2
Acetone	3.		NS		
Benzene	0.5	16.	17.	106.	
Bromodichloromethane	1.		NS		
Bromomethane (Methyl Bromide)	1.	21.	15.	71.	
Bromoform	1.		NS		
1,3-Butadiene	1.	10.	8.8	88.	
2-Butanone (MEK)	1.		NS		
Carbon Disulfide	5.		NS		
Carbon Tetrachloride	1.	31.	35.	113.	
Chlorobenzene	0.5	23.	24.	104.	
Chloroethane (Ethyl Chloride)	0.5		NS		
2-Chloroethyl Vinyl Ether	5.		NS		
Chloroform	3.	25.	27.	108.	
Chloromethane (Methyl Chloride)	0.5		NS		
Dibromochloromethane	1.		NS		
1,2-Dibromoethane (EDB)	2.	10.	8.6	86.	
1,2-Dichlorobenzene	1.		NS		
1,3-Dichlorobenzene	1.		NS		
1,4-Dichlorobenzene	1.		NS		
1,1-Dichloroethane	0.5		NS		

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
* RESULTS listed as 'NS' were not spiked. PQL = Practical Quantitation Limit
(1) Concentration in ug/cu M or mg/cu M reported at 760mm Hg pressure and 298 deg. K.
(2) Zero Air spiked with NIST SRM 1804, Cylinder # ALM-000881.

06/20/94
MS1/1M99L
GD/gegcc(dw)/yl
CK9406-17

COAST-TO-COAST ANALYTICAL SERVICES, INC.

EXCELLENCE IN ANALYSIS

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/17/94
Analyzed by: EJ
Method : EPA TO-14

QC SPIKE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED DATE RECEIVED
QC SPIKE	Air		

CONSTITUENT	*PQL µg/cu M	SPIKE AMOUNT	RESULT µg/cu M	%REC	NOTE
1,2-Dichloroethane (EDC)	1.	20.	22.	110.	
1,1-Dichloroethene	1.		NS		
cis-1,2-Dichloroethene	1.0		NS		
trans-1,2-Dichloroethene	1.		NS		
Dichloromethane	5.	17.	21.	124.	
1,2-Dichloropropane	0.5	23.	23.	100.	
cis-1,3-Dichloropropene	0.5		NS		
trans-1,3-Dichloropropene	0.5		NS		
Ethylbenzene	1.	15.	15.	100.	
2-Hexanone	0.5		NS		
4-Methyl-2-Pentanone (MIBK)	0.5		NS		
Styrene	1.		NS		
1,1,2,2-Tetrachloroethane	1.		NS		
Tetrachloroethene (PCE)	1.	34.	38.	112.	
Toluene	1	18.	19.	106.	
1,1,1-Trichloroethane (TCA)	1.	28.	29.	104.	
1,1,2-Trichloroethane	1.		NS		
Trichloroethene (TCE)	0.5	27.	30.	111.	
Trichlorofluoromethane (F-11)	1.	29.	24.	83.	
Trichlorotrifluoroethane (F-113)	2.		NS		
Vinyl Acetate	2.		NS		
Vinyl Chloride	0.5	14.	13.	93.	
Xylenes	1.	15.	15.	100.	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
* RESULTS listed as 'NS' were not spiked. PQL = Practical Quantitation Limit

06/20/94
MS1/1M99L
GD/gegcc(dw)/yl
CK9406-17

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai

Gesheng Dai, Ph.D.
Group Leader

COAST-TO-COAST ANALYTICAL SERVICES, INC.

EXCELLENCE IN ANALYSIS

SoCal Division (Camarillo Laboratory)
4765 Calle Quetzal, Camarillo, California 93012

(805) 389-1353
FAX (805)389-1438

CLIENT: T. Bennett / C. Liakos
Groundwater Technology
2501 Yale Boulevard SE, Suite 204
Albuquerque, NM 87106

QC Batch ID: KF17TA CK-2992-1
Project : Bloomfield NM, #023353014.32
Analyzed : 06/17/94
Analyzed by: GD
Method : GC/TCD

QC DUPLICATE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED	DATE RECEIVED
VEW-1D V/S	Air	Jerry A. May	06/16/94	06/17/94

CONSTITUENT	(CAS RN)	*PQL PERCENT	RESULT PERCENT	%DIFF	NOTE
FIXED GASES AND METHANE					
Carbon Dioxide	(124389)	0.1	0.4	0.	
Oxygen	(7782447)	0.01	14.	0.	
Nitrogen	(7727379)	0.02	58.	0.	
Methane	(74828)	0.005	27.	3.6	
Carbon Monoxide	(630080)	0.1	ND		

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/20/94
TCD/06179404
GD/gegcc(dw)/yl
CK2992-1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

EXCELLENCE IN ANALYSIS

COAST-TO-COAST ANALYTICAL SERVICES, INC.

SoCal Division (Camarillo Laboratory) (805) 389-1353
4765 Calle Quetzal, Camarillo, California 93012 FAX (805)389-1438

QC Batch ID: KF17TA

CLIENT: Coast-to-Coast Analytical Services, Inc.

Analyzed : 06/17/94
Analyzed by: YL
Method : GC/TCD

QC SPIKE
REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	MATRIX	SAMPLED BY	SAMPLED DATE RECEIVED
QC SPIKE	Air		

CONSTITUENT	*PQL PERCENT	SPIKE AMOUNT	RESULT PERCENT	%REC	NOTE
FIXED GASES AND METHANE					
Carbon Dioxide	0.1	15.	15.	100.	
Oxygen	0.01	7.1	7.0	99.	
Nitrogen	0.02	66.	66.	100.	
Methane	0.005	4.6	4.6	100.	
Carbon Monoxide	0.1	7.1	7.0	99.	

Lab Certifications: CAELAP #1598; UTELAP #E-142; AZELAP #AZ0162; A2LA #0136-01; L.A.Co.CSD #10187
*RESULTS listed as 'ND' were not detected at or above the listed PQL (Practical Quantitation Limit)

06/20/94
TCD/06179405
GD/gegcc(dw)/yl
CK2992-1

Respectfully submitted,
COAST-TO-COAST ANALYTICAL SERVICES, INC.

Gesheng Dai, Ph.D.
Group Leader

[redacted] COAST-TO-COAST

CHAIN-OF-CUSTODY RECORD AND ANALYSIS REQUEST

33758

Company Name: GROUNDWATER TECHNOLOGY

Phone #: 505 242 3113

FAX #: 505 242 1103

Company Address: 2501 YALE BLVD SE #204 ALBUQUERQUE NM 87106

Site Location: BLOOMFIELD, N.M.

Project Manager: TERRY BURNETT CYNANTHA LIAKOS

Client Project ID: (#) 023353014.32 (NAME)

I attest that the proper field sampling procedures were used during the collection of these samples.

Sampler Name (Print): JERRY A. MAY

ANALYSIS REQUEST

- BTEX 602 ☐ 8020 ☐ with MTBE ☐
- BTEX/Gas Hydrocarbons PID/FID ☐ with MTBE ☐
- Hydrocarbons GC/FID Gas ☐ Diesel ☐ Screen ☐
- Hydrocarbon Profile (SIMDIS) ☐
- Oil and Grease 413.1 ☐ 413.2 ☐ SM-503 ☐
- TPH/IR 418.1 ☐ SM 503 ☐
- EDB by 504 ☐ DBCP by 504 ☐
- EPA 503.1 ☐ EPA 502.2 ☐
- EPA 601 ☐ EPA 8010 ☐
- EPA 602 ☐ EPA 8020 ☐
- EPA 608 ☐ 8080 ☐ PCB only ☐
- EPA 624/PPL ☐ 8240/TAL ☐ NBS (+15) ☐
- EPA 625/PPL ☐ 8270/TAL ☐ NBS (+25) ☐
- EPA 610 ☐ 8310 ☐
- EP TOX Metals ☐ Pesticides ☐ Herbicides ☐
- TCLP Metals ☐ VOA ☐ Semi-VOA ☐ Pest ☐ Herb ☐
- EPA Metals - Priority Pollutant ☐ TAL ☐ RCRA ☐
- CAM Metals TTLC ☐ STLC ☐
- Lead 239.2 ☐ 200.7 ☐ 7420 ☐ 7421 ☐ 6010 ☐
- Organic Lead ☐
- Corrosivity ☐ Flash Point ☐ Reactivity ☐

OTHER

- TOTAL NON-METHANE HYDROCARBONS (EPA TO-14), EPA 8010/8020
- CO2, C2, METHANE

Field Sample ID	Lab # (Lab Use only)	# CONTAINERS	Matrix: WATER	SOIL	AIR	SLUDGE	PRODUCT	OTHER	Method Preserved: HCl	HNO3	H2SO4	ICE	UNPRESERVED	OTHER (Specify)	Sampling: DATE	TIME	Analysis	Other: Total Non-Methane Hydrocarbons	Other: CO2, C2, Methane
VEW-ID V/S		2			X										6/16/94	1220	CK2992-1	X	X

TAT	Special Handling	
Priority (24 hr) ☐	GTEL Contact	SPECIAL DETECTION LIMITS
Expedited (48 hr) ☐	Quote/Contract #	
7 Business Days ☐	Confirmation #	SPECIAL REPORTING REQUIREMENTS
Other Business Days ☐	P.O. #	FAX ☐

QA/QC Level: Blue ☐ CLP ☐ Other ☐

REMARKS: FED EX. 853 394 0192

Lab Use Only Lot #: Storage Location

Work Order #:

CUSTODY RECORD

Relinquished by	Date	Time	Received by
Relinquished by Sampler: Jerry A May	6/16/94	1500	Received by: FED EX
Relinquished by: FED EX #8533940192	6/17/94	1010	Received by: [signature] TEDLAR BAG INTACT, 58A/20
Relinquished by:	Date	Time	Received by Laboratory: Waybill #

FEDERAL EXPRESS

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AIRBILL PACKAGE TRACKING NUMBER 8533940192

3300M 8533940192

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SENDER'S COPY
DROP OFF YOUR PACKAGE AND SAVE

1 SENDER'S FEDERAL EXPRESS ACCOUNT NUMBER: 1210-0389-6 Date: 6/16/94

From (Your Name) Please Print: Jenny Burns / Sarah May Your Phone Number (Very Important): 505-242-3113
Company: GROUNDWATER TECHNOLOGY INC Department/Floor No.:
Street Address: 2501 YALE BLVD SE STE 204
City: ALBUQUERQUE State: NM ZIP Required: 87106

2 To (Recipient's Name) Please Print: SAMPLE RECEIVING Recipient's Phone Number (Very Important): (805) 543-2553
Company: COAST TO COAST Department/Floor No.:
Exact Street Address (We Cannot Deliver to P.O. Boxes or P.O. Zip Codes.): 4765 CALLE QUETZAL
City: CAMARILLO State: CA ZIP Required: 93012

YOUR INTERNAL BILLING REFERENCE INFORMATION (optional) (First 24 characters will appear on invoice.): 0233-5114-32

H IF HOLD AT FEDEX LOCATION, Print FEDEX Address Here
Street Address:
City: State: ZIP Required:

3 PAYMENT 1 [X] Bill Sender 2 [ ] Bill Recipient's FedEx Acct. No. 3 [ ] Bill 3rd Party FedEx Acct. No. 4 [ ] Bill Credit Card
5 [ ] Cash/Check Acct./Credit Card No. Exp. Date

4 SERVICES (Check only one box)

Priority Overnight (Delivery by next business morning†)
- 11 [X] OTHER PACKAGING
- 16 [ ] FEDEX LETTER*
- 12 [ ] FEDEX PAK*
- 13 [ ] FEDEX BOX
- 14 [ ] FEDEX TUBE

Standard Overnight (Delivery by next business afternoon. No Saturday delivery)
- 51 [ ] OTHER PACKAGING
- 56 [ ] FEDEX LETTER*
- 52 [ ] FEDEX PAK*
- 53 [ ] FEDEX BOX
- 54 [ ] FEDEX TUBE

Economy Two-Day (Delivery by second business day.†)
- 30 [ ] ECONOMY**
- * Economy Letter Rate not available. Minimum charge: One pound Economy rate.

Government Overnight (Restricted for authorized users only)
- 46 [ ] GOVT LETTER
- 41 [ ] GOVT PACKAGE

Freight Service (for packages over 150 lbs.)
- 70 [ ] OVERNIGHT FREIGHT** (Confirmed reservation required)
- 80 [ ] TWO-DAY FREIGHT**
- † Delivery commitment may be later in some areas.
- *Declared Value Limit $500. **Call for delivery schedule.

5 DELIVERY AND SPECIAL HANDLING (Check services required)

Weekday Service
- 1 [ ] HOLD AT FEDEX LOCATION WEEKDAY (Fill in Section H)
- 2 [X] DELIVER WEEKDAY

Saturday Service
- 31 [ ] HOLD AT FEDEX LOCATION SATURDAY (Fill in Section H)
- 3 [ ] DELIVER SATURDAY (Extra charge) (Not available to all locations)
- 9 [ ] SATURDAY PICK-UP (Extra charge)

Special Handling
- 4 [ ] DANGEROUS GOODS (Extra charge)
- 6 [ ] DRY ICE Dangerous Goods Shipper's Declaration not required
  - Dry Ice, 9, UN 1845, ____ X ____ kg, 904 III
- [ ] DESCRIPTION
- 12 [ ] HOLIDAY DELIVERY (If offered) (Extra charge)

6

PACKAGES	WEIGHT In Pounds Only	YOUR DECLARED VALUE (See right)
1	5	$500.00
Total 1	Total 5	Total $500.00

DIM SHIPMENT (Chargeable Weight)
[ ] _____ lbs.
L x W x H

Received At
- 1 [ ] Regular Stop
- 2 [ ] On-Call Stop
- 3 [ ] Drop Box
- 4 [ ] B.S.C.
- 5 [ ] Station

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Use of this airbill constitutes your agreement to the service conditions in our current Service Guide, available upon request. See back of sender's copy of this airbill for information. Service conditions may vary for Government Overnight Service. See U.S. Government Service Guide for details.

We will not be responsible for any claim in excess of $100 per package, whether the result of loss, damage, delay, non-delivery, misdelivery, or misinformation, unless you declare a higher value, pay an additional charge, and document your actual loss for a timely claim. Limitations found in the current Federal Express Service Guide apply. Your right to recover from Federal Express for any loss, including intrinsic value of the package, loss of sales, income interest, profit, attorney's fees, costs, and other forms of damage whether direct, incidental, consequential, or special is limited to the greater of $100 or the declared value specified to the left. Recovery cannot exceed actual documented loss. The maximum Declared Value for FedEx Letter and FedEx Pak packages is $500.

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7 Sender authorizes Federal Express to deliver this shipment without obtaining a delivery signature and shall indemnify and hold harmless Federal Express from any claims resulting therefrom.

Release Signature: _____

Federal Express Use

Base Charges	
Declared Value Charge	
Other 1	
Other 2	
Total Charges	

REVISION DATE 12/92
PART #137204 FXEM 10/93
FORMAT #158

158

APPENDIX E

"ESTIMATION OF EFFECTIVE CLEANUP RADIUS FOR SOIL-VAPOR EXTRACTION SYSTEMS", SCIENTIFIC PAPER FROM JOURNAL OF SOIL CONTAMINATION

Journal of Soil Contamination, 2(2):191–202 (1993)

Estimation of Effective Cleanup Radius for Soil-Vapor Extraction Systems

David H. Bass, Sc.D., CHMM

Groundwater Technology, Inc., 3 Edgewater Drive, Norwood, MA 02062

ABSTRACT: Soil-vapor extraction (SVE) is a standard and effective *in situ* treatment for the removal of volatile contaminants from vadose-zone soil. The duration of SVE operation required to reach site closure is quite variable, however, ranging up to several years or more. An understanding of the contaminant recovery rate as a function of distance from each vapor-extraction well allows SVE systems to be designed so that cleanup goals can be achieved within a specified time frame.

A simple one-dimensional model has been developed that provides a rough estimate of the effective cleanup radius (defined as "the maximum distance from a vapor extraction point through which sufficient air is drawn to remove the required fraction of contamination in the desired time") for SVE systems. Because the model uses analytical rather than numerical methods, it has advantages over more sophisticated, multidimensional models, including simplicity, speed, versatility, and robustness.

The contaminant removal rate at a given distance from the vapor-extraction point is assumed to be a function of the local rate of soil-gas flow, the contaminant soil concentration, and the contaminant volatility. Soil-gas flow rate as a function of distance from the vapor-extraction point is estimated from pilot test data by assuming that the infiltration of atmospheric air through the soil surface is related to the vacuum in the soil. Although widely applicable, the model should be used with some caution when the vadose zone is highly stratified or when venting contaminated soil greater than 30 ft below grade. Since 1992, Groundwater Technology, Inc. has been using this model routinely as a design tool for SVE systems.

KEY WORDS: soil-vapor extraction, modeling, design tool, effective radius.

I. BACKGROUND

Soil-vapor extraction (SVE) is a widely used *in situ* remediation technique for treatment of contaminated vadose-zone soil. SVE removes volatile organic compounds (VOCs) from vadose-zone soils by inducing air flow through contaminated

1058-8337/93/$.50

areas. SVE is typically performed by applying a vacuum to vertical vapor-extraction wells screened through the level of soil contamination, using a vacuum blower. The resulting pressure gradient causes the soil gas to migrate through the soil pores toward the vapor-extraction wells. VOCs are volatilized and transported out of the subsurface by the migrating soil gas. In addition, SVE increases oxygen flow to contaminated areas, thus stimulating natural biodegradation of aerobically degradable contaminants.

The performance of SVE systems improves as the air permeability of the vadose-zone soil increases. SVE is applicable to any compound with a vapor pressure greater than about 1 mmHg. This includes a wide variety of common contaminants such as benzene, toluene, ethylbenzene, xylene, gasoline hydrocarbons, mineral spirits, methyl *t*-butyl ether, tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, methanol, acetone, and butanone. Because vapor pressure increases with temperature, SVE also can be applied to semivolatile compounds by heating the vadose zone with steam or hot air.

The efficacy of a SVE system is determined by its ability to draw sufficient air through the contaminated portion of the vadose zone. The number and spacing of vapor-extraction wells and the soil-gas extraction rate are the critical parameters determining air flow through the subsurface. In addition, several modifications to SVE systems are sometimes used in an effort to enhance the flow of air through the contamination zone. These include air injection (forcing air or allowing air to be drawn through wells screened at the level of the vadose-zone contamination) and surface sealing (paving a surface or covering an unpaved surface with a layer of polyethylene film to prevent infiltration of air and water from the surface).

Vapor-extraction well spacing is typically determined by performing a field pilot test to determine the radius-of-influence (ROI) at the site under specified SVE conditions. Historically, pilot test data were interpreted by assessing the distance from the vapor-extraction well where an arbitrary vacuum level (usually 0.01 to 1 in of water column) could be measured in the soil. Although such "rules of thumb" often result in adequate SVE system design, they do not yield any information on the quantity of air moving through the vadose zone. This approach, therefore, cannot provide any assessment of remediation time, nor can it provide design information specific to the contaminant (a system designed to remove benzene will be less effective on the less volatile xylene, for example).

Several alternative approaches to interpretation of SVE pilot test data have recently been developed based on multidimensional modeling of vacuum and soil-gas flow fields in the vadose zone. Johnson *et al.* (1990a, 1990b) derived equations describing air flow in the vadose zone beneath a sealed surface and applied these equations to the SVE remediation of gasoline contaminated soil. Baehr *et al.* (1989) and Marley *et al.* (1990) and others have used numerical solutions for systems with unsealed or partially sealed surfaces, and Lingineni and Dhir (1992) superimposed variable temperature on this approach. Joss and Baehr (1993) have

recently adapted MODFLOW, a groundwater numerical modeling program, to SVE applications.

II. MOTIVATION AND OBJECTIVES

The modeling efforts discussed in the previous section represent important advances in the understanding of SVE and provide a basis for more effective design of SVE systems. However, they are not universally applicable. The data available at many small sites where SVE is considered, such as retail gasoline stations and dry cleaning facilities, are often sparse, and budgets rarely exist for gathering the more extensive data required for sophisticated models. Most of these sites have been repeatedly excavated and refilled, creating subsurface anisotropies that confound the limited data. Furthermore, many of the models assume that the surface is sealed, a condition not commonly encountered (and sometimes not even feasible) at such retail sites. Finally, multidimensional models typically require substantial time to input variables and to run, making the design process tedious.

Therefore, the need exists for a model that can provide rapid order-of-magnitude assessments of potential SVE performance based on very limited data. For this application, a simpler one-dimensional model is adequate; the data quality is ordinarily too poor and the subsurface too laden with unidentified anisotropies to warrant a more sophisticated, multidimensional approach. To be most useful, such a model must exhibit the following characteristics:

- Simplicity: cumbersome computer models are intimidating and tend not to be used; a really useful model must be readily accessible by the most junior of engineers.
- Speed: instantaneously, solutions enable an engineer to apply many "what if" scenarios in a short period of time, and hence rapidly converge on an optimum design.
- Versatility: depending on the specific project requirements, the model may be called on to specify SVE well spacing, soil-gas extraction rate, cleanup level, or cleanup time at sites with sealed or unsealed surfaces.
- Robustness: the model must provide reasonable estimates of SVE performance over wide ranges of soil permeability, soil-gas extraction rate, soil temperature, and contaminant volatility.

III. MODEL DERIVATION

The goal of the model is to determine the maximum distance from the vapor-extraction well through which sufficient air is drawn to remove the required

fraction of contamination in the desired time. This is the effective radius, R_E, and it differs from the ROI, which is the distance from the vapor-extraction well that vacuum can be detected. The effective radius is based on site-specific conditions and SVE system parameters, and it is specific to the contaminant, cleanup goals, and cleanup time frame.

This derivation is applicable to sites with unsealed surfaces and single-well SVE systems or multiple-well systems in which each well is operated individually, rather than simultaneously (as if often done when surface infiltration of air is insufficient to achieve adequate remediation between vapor-extraction wells). This approach has also been extended to simultaneously operated multiple-well systems and to sites at which an engineered surface seal is to be applied, and these will be the subject of future publications.

Figure 1 illustrates the general air-flow patterns through soil during SVE. Because this derivation is for a single-well SVE system, it is assumed that the effective radius will extend to the edge of the contaminant plume. At the outer edge of the plume, all air entering the contamination zone is initially uncontaminated. As the air flows through the soil, contaminants rapidly equilibrate between soil and air phases (the rapid approach to equilibrium was demonstrated by Johnson *et al.*, 1990a). This equilibration is determined by contaminant-soil concentration, vapor pressure, and water solubility, and by the moisture and organic content of the soil. Of these parameters, only the contaminant soil concentration changes dramatically during the course of the vapor extraction, and so for a given site and contaminant, the equilibrium-gas concentration can be expressed generally as a function of soil concentration:

$$C_g = f(C_s) \tag{1}$$

The rate at which contaminant mass is lost from soil must equal the rate at which the soil gas flowing through the soil carries the contamination away:

$$\frac{dM_s}{dt} = \frac{d(V_s C_s)}{dt} = C_g q = f(C_s) q \tag{2}$$

or

$$\frac{dC_s}{f(C_s)} = \frac{q}{V_s} dt \tag{3}$$

where M_s = mass rate of contaminant removal from soil, t = time, V_s = volume of soil (control volume), q = flow rate of gas through control volume.

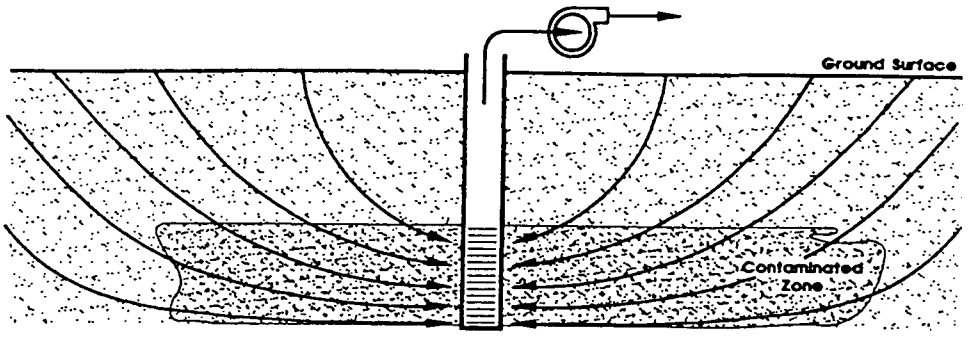

FIGURE 1. Generalized air flow paths in a soil-vapor extraction system.

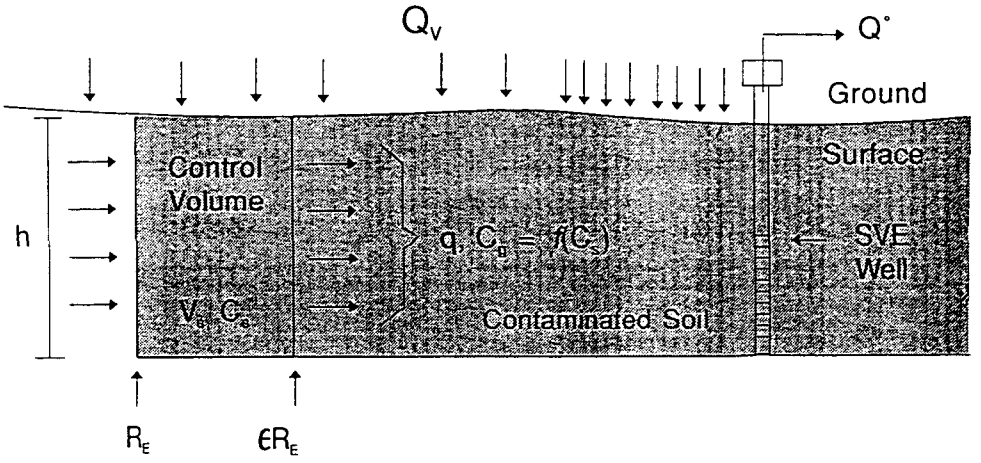

FIGURE 2. Conceptualization of the model. The system is to be designed so that the effective radius, R_E, corresponds to the extent of contamination. Clean air enters the contaminated zone by horizontal movement through the soil and by vertical infiltration through the ground surface. The overall cleanup time is dominated the remediation rate for the contaminated soil between εR_E and R_E ("control volume"), which is determined by the air flow rate, q, through this portion of the contaminated zone.

The contaminated zone is represented as a uniform cylinder of radius R_E and height h, as indicated in Figure 2. Remediation will occur from the outside of the plume inward (due to lateral introduction of uncontaminated air into the contamination zone) and from the top down (due to vertical infiltration of air). Although the outermost portion of the contamination zone will be treated first, the rate of treatment at this location will be the slowest because the air flux decreases rapidly with distance from the vapor-extraction well. The control volume is therefore taken

as a fraction of the contamination zone furthest from the vapor-extraction well, that is, an annulus of outer radius R_E and inner radius εR_E, where $O < \varepsilon < 1$.* The control volume is then

$$V_s = \pi\left(R_E^2 - \left(\varepsilon R_E\right)^2\right)h = \left(1-\varepsilon^2\right)\pi R_E^2 h \tag{4}$$

The gas flow through the control volume, q, is calculated by assuming that, at a distance r from the vapor-extraction well, any infiltration of atmospheric air through the soil surface is related to the vacuum in the soil and the area of the ground surface:

$$dQ_v = k_v\left(P_a^2 - P_r^2\right)dA = k_v\left(P_a^2 - P_r^2\right)2\pi r\, dr \tag{5}$$

where Q_v = vertical infiltration of atmospheric air, r = distance from the vapor extraction well, P_a = absolute atmospheric pressure, P_r = absolute pressure at distance r from the vapor-extraction well, k_v = constant, A = area of ground surface. The term $k_v(P_a^2 - P_r^2)$ comes from Darcy's Law for flow of a compressible fluid. The constant k_v is related to the permeability of the soil to vertical gas infiltration, as well as to the gas viscosity, density, and travel distance.

Because all the air collected at the vapor-extraction well must come ultimately from the atmosphere through the ground surface, the integral of Equation 5 from the well radius to the radius of influence yields the rate of total soil-gas recovery, Q^o:

$$\int_{r_w}^{R_I} dQ_v = 2\pi k_v \int_{r_w}^{R_I} \left(P_a^2 - P_r^2\right)r\, dr = Q^o \tag{6}$$

where r_w = radius of vapor-extraction well, R_I = radius of influence.

Substituting Equation 6 into Equation 5 and integrating again, this time from the well radius to the inner edge of the control volume, yields

$$\frac{Q_v}{Q^o} = \frac{\int_{r_w}^{\varepsilon R_E} \left(P_a^2 - P_r^2\right)r\, dr}{\int_{r_w}^{R_I} \left(P_a^2 - P_r^2\right)r\, dr} \tag{7}$$

* The value of the parameter ε is selected so that vertical infiltration at distances less than εR_E from the vapor-extraction well provides a rate of remediation at least comparable with the remediation rate within the control volume due to lateral and vertical introduction of clean air. In other words, by the time the control volume is clean, the rest of the contaminated zone will have been remediated as well. For most sites where SVE is considered, ε ranges from 0.7 to 0.9. Within this range, the precise value of ε selected is not crucial, because values of R_E computed from the design equation derived later are not particularly sensitive to changes in ε, varying typically by 10% or less.

The gas passing through the control volume is the total gas flow collected less the vertical infiltration that occurs closer to the SVE well

$$q = Q_v^o - Q_v = Q_v^o \frac{\int_{r_w}^{R_I} \left(P_a^2 - P_r^2\right) r\, dr - \int_{r_w}^{\varepsilon R_E} \left(P_a^2 - P_r^2\right) r\, dr}{\int_{r_w}^{R_I} \left(P_a^2 - P_r^2\right) r\, dr} \tag{8}$$

Combining Equations 3, 4, and 8 and integrating yields

$$\int_{C_s}^{C_s^o} \frac{dC_s}{f(C_s)} = \frac{\int_{r_w}^{R_I} \left(P_a^2 - P_r^2\right) r\, dr - \int_{r_w}^{\varepsilon R_E} \left(P_a^2 - P_r^2\right) r\, dr}{\left(1-\varepsilon^2\right)\pi R_E^2 \int_{r_w}^{R_I} \left(P_a^2 - P_r^2\right) r\, dr} \frac{Q^o t}{h} \tag{9}$$

where C_s^o = initial contaminant concentration in the soil.

Whenever $dC_s/f(C_s)$ and $P_r^2 r\, dr$ are analytically integrable, Equation 9 provides a vehicle for relating the effective radius (R_E) to soil concentration in the control volume (C_s), soil-gas recovery rate (Q^o), and remediation time (t) without the use of cumbersome numerical methods. Depending on site-specific conditions, any of a number of expressions for P_r and $f(C_s)$ are appropriate.

For example, Johnson *et al.* (1990a) derived the following expression for P_r, which is applicable when the ground surface is sealed:

$$P_r^2 = P_w^2 + \left(P_a^2 - P_w^2\right) \frac{\ln\left(r/r_w\right)}{\ln\left(R_I/r_w\right)} \tag{10}$$

where P_w = absolute pressure in the vapor extraction well.

When the ground surface is not sealed, P_r can be approximated by the following simple exponential relationship over a substantial range of distances from the vapor-extraction well (i.e., when r is greater than a few feet) (Mohr, personal communication, 1992):

$$\ln\left(P_r\right) = c_1 r + c_2 \tag{11}$$

where c_1 and c_2 are fitted constants.

At lower soil concentrations, it is proper to assume ideal partitioning between soil and gas ($f(C_s) = K_{gs}C_s$), whereas above a compound-specific threshold soil concentration, vapor concentration becomes independent of soil concentration

(Lyman *et al.*, 1990); under such conditions, $f(C_s)$ is simply the contaminant saturated-vapor density and is constant. More complex representations of $f(C_s)$ are required for soil contaminated with a diverse mixture of compounds, such as gasoline. As SVE proceeds, the more volatile species are preferentially removed and the remaining contamination becomes less volatile. Therefore, $f(C_s)$ must decrease as C_s decreases, and this effect is demonstrated in Figure 3 for fresh and weathered gasoline. As is evident from the figure, the decrease in $f(C_s)$ with decreasing C_s is roughly exponential.

IV. MODEL IMPLEMENTATION AND LIMITATIONS

Equation 9 contains the following parameters:

- gas-soil equilibrium relationship ($f(C_s)$), which is a function of soil-gas temperature and contaminant volatility
- pressure as a function of distance from the vapor-extraction well (P_r), which is a function of vapor-extraction well pressure (P_w) if Equation 10 is used the fitted constants c_1 and c_2 if Equation 11 is used
- depth of vented interval (h)†
- soil-gas recovery rate (Q^o)
- treatment time (t)
- effective radius (R_E)
- vapor-extraction well radius (r_w)
- radius of influence (R_I) and
- extent of remediation ($1 - C_s/C_s^o$).

Equation 9 can be evaluated to solve for any of these variables, provided all others are specified. The model has been implemented in a computer program written in Basic that prompts the user to choose which variable to solve for (effective radius, cleanup time, extent of remediation, or soil-gas recovery rate). The user then

† The vented interval is the portion of the vadose zone through which air movement is induced during SVE. If the vadose zone is fairly homogeneous, air movement will be induced throughout, and it is appropriate to consider the vented interval to be the depth to the bottom of the vapor-extraction well. When the vadose zone is stratified, each contaminated stratum is vented separately. If a contaminated low permeability stratum underlying a clean higher permeability stratum is being vented, the vented interval should be considered to be the thickness of the low permeability stratum. This approach is not applicable, however, for a higher permeability stratum underlying a substantial, continuous lower permeability stratum.

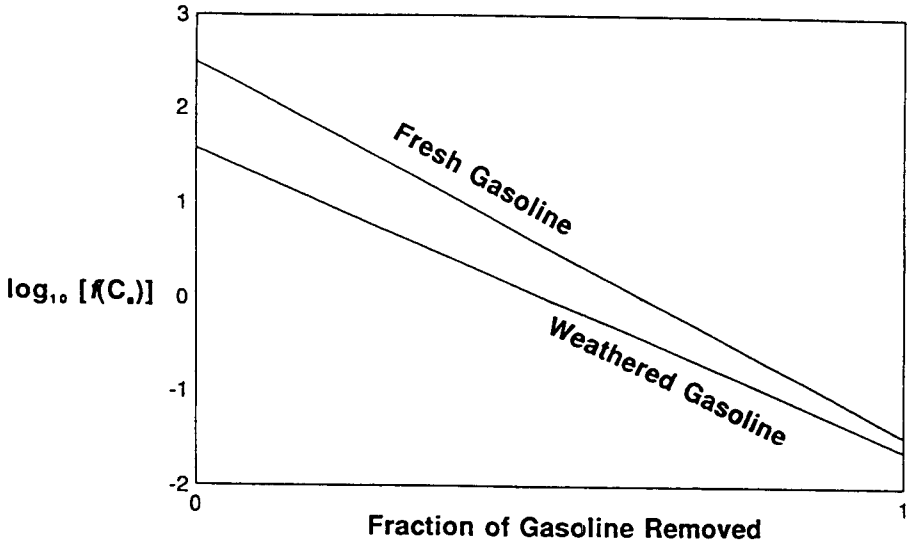

FIGURE 3. $f(C_s)$ for fresh and weathered gasoline. This figure is derived from constituent data in Johnson *et al.* (1990a).

specifies the contaminant, choosing from a list of common volatile soil contaminants or entering a new contaminant with its vapor pressure and vaporization enthalpy. Values for all other parameters are then entered, and the value of the dependent variable is displayed virtually instantaneously.

Of course, the simplifying assumptions that provide this ease of calculation also contribute to the uncertainty in the result. Significant subsurface anisotropies (sewers, foundations, etc.) can upset the assumed radial symmetry of the air flow, and extreme stratification can make the assumption of uniform air flow across the vented stratum inappropriate. However, site data are often inadequate to characterize the anisotropies in any event, and it is rare that horizontal and vertical permeabilities differ by more than an order of magnitude within a vented stratum. Equation 9 can therefore provide reasonable rough estimates of SVE system performance over a wide range of site conditions.

However, because the model assumes the vadose-zone conditions to be uniform with depth, caution should be exercised when applying this model to SVE systems venting strata greater than about 30 ft below grade. In addition, Equation 9 is not appropriate when vertical infiltration of air through the ground surface is virtually nonexistent. Such a situation would arise during venting of a high permeability stratum underlying an extensive, substantial, and continuous stratum of much lower permeability. Fortunately, such situations occur only rarely, and they can be modeled effectively using the sealed surface approach taken by Johnson *et al.* (1990a, 1990b).

V. EXAMPLES

Equation 9 indicates that for a fixed cleanup level, changes in vapor extraction rate (Q^o), cleanup time (t), and depth of the vented interval (h) will not effect the effective radius so long as $Q^o t/h$ remains constant. In other words, the same system performance can be obtained in half the time by doubling the vapor-extraction rate or halving the depth of the vented interval.

Figure 4 shows an example of how effective radius varies with $Q^o t/h$ for a variety of common volatile soil contaminants (where cleanup is defined as 90% removal, ideal soil-vapor partitioning and an unsealed surface are assumed). The conditions in this example are typical for SVE systems, and the resulting effective radius varies from a few feet to as much as 70 ft. Effective radius is most sensitive to the volatility of the contaminant; the effective radius for weathered gasoline is 3 to 10 times less than for 1,1,1-trichloroethane under the same conditions. Large changes in $Q^o t/h$ are required to substantially affect effective radius, especially for the more volatile contaminants; doubling the effective radius generally requires increasing $Q^o t/h$ by a factor of 10 to 50.

This relationship between effective radius and $Q^o t/h$ has profound implications regarding SVE system design. Decreasing the spacing between vapor-extraction wells increases the number of wells required, but also decreases the effective radius required. This greatly reduces remediation time and/or soil-gas recovery rate requirements. For example, a reduction in effective radius from 40 ft to 30 ft would

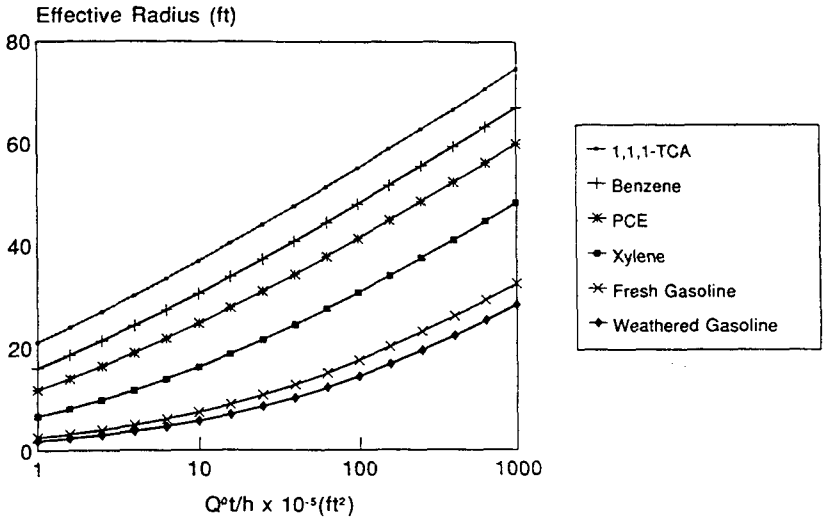

FIGURE 4. Effective radius at a typical SVE site as a function of $Q^o t/h$ for several volatile contaminants (90% cleanup, ideal soil-vapor partitioning, and unsealed surface assumed).

nearly double the number of vapor-extraction wells but would also reduce remediation time by nearly an order of magnitude. The lower soil-gas recovery rates required when effective radius is reduced in many cases results in lower costs associated with less powerful blowers that more than make up for the costs associated with additional vapor-extraction wells.

Effective radius also varies with desired cleanup level, as shown in Figure 5 for a typical unsealed system where Q^o is 30 scfm per vapor extraction well, h is 10 ft, and t is 1 year. Contaminant volatility has a large impact on effective radius, but increasing cleanup level from 90% to 99.99% only decreases the effective radius for single component systems by 35 to 50%. For contaminant mixtures such as gasoline, however, changing cleanup level can have a more dramatic effect. This is because the volatility of the mixture decreases over the course of the SVE process, because the most volatile components are removed first. The volatility of contaminant mixtures is thus a function of cleanup level, and so effective radius is strongly affected by changes in cleanup level.

This model can also be used to assess the effect of soil temperature on effective radius, cleanup level, or remediation time. The effectiveness of SVE can be significantly enhanced by injecting hot air, steam, or radio frequency to heat vadose-zone soil, because $f(C_s)$ increases rapidly with increasing temperature. Evaluating Equation 9 at various temperatures gives an indication of the magnitude of SVE enhancement. For example, 90% removal of fresh gasoline from a 10-ft depth of medium sand, 20 ft from a vapor-extraction well pulling 30 cfm is

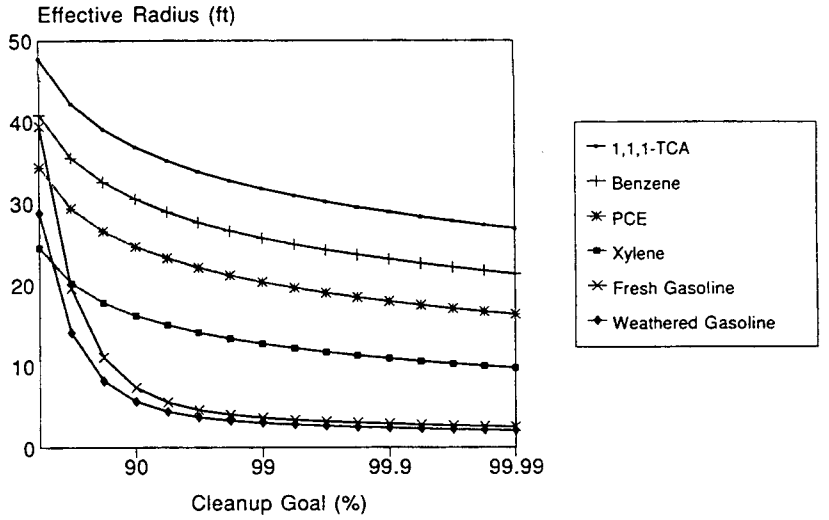

FIGURE 5. Effective radius at a typical SVE site as a function of cleanup goal ($Q^o t/h = 1.6 \times 10^6$ ft²; ideal soil-vapor partitioning and unsealed surface assumed).

estimated to require almost 5 years of SVE operation at 50°F, but 16 months at 100°F, 6 months at 150°F, and 10 weeks at 200°F.

VI. CONCLUSIONS

A simple one-dimensional model has been developed that can provide rapid order-of-magnitude assessments of potential SVE performance based on very limited data. Because the model uses analytical rather than numerical methods, it has advantages over more sophisticated, multidimensional models, including simplicity, speed, versatility, and robustness. Although accuracy and resolution are somewhat reduced, the use of this model instead of more complicated approaches is generally justified, given the limited site characterization data ordinarily available and the subsurface anisotropies commonly encountered at most small SVE sites. Since 1992, Groundwater Technology, Inc. has been using this model routinely as a design tool for SVE systems.

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APPENDIX F

COMPUTER-GENERATED OUTPUT FROM VENT-ROI 3.0

VEW-1S ANALYSIS

ANALYSIS OF VACUUM DISSIPATION DATA FROM PILOT TEST

42 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	.15	-.824
* MP2	33	0	
rw2	33	.185	-.733
p2	40	.12	-.921
mw4	57	.1	-1

* = outlier, not considered in analysis
Additional data point based on applied vacuum:
8.4 inches of water column at 0 feet from SVE well

Slope = -.031 per foot
Intercept = 2.585 inches of water column
R squared = .682

40 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	.1	-1
* MP2	33	0	
rw2	33	.13	-.886
p2	40	.1	-1
mw4	57	.05	-1.301

* = outlier, not considered in analysis
Additional data point based on applied vacuum:
8 inches of water column at 0 feet from SVE well

Slope = -.035 per foot
Intercept = 2.387 inches of water column
R squared = .714

28 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	.05	-1.301
* MP2	33	0	
rw2	33	.09	-1.046
p2	40	.08	-1.097
mw4	57	.03	-1.523

* = outlier, not considered in analysis
Additional data point based on applied vacuum:
5.6 inches of water column at 0 feet from SVE well

Slope = -.035 per foot
Intercept = 1.533 inches of water column
R squared = .67

16 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	.03	-1.523
* MP2	33	0	
rw2	33	.015	-1.824
* p2	40	0	
* mw4	57	0	

* = outlier, not considered in analysis
Additional data point based on applied vacuum:
3.2 inches of water column at 0 feet from SVE well

Slope = -.073 per foot
Intercept = 2.053 inches of water column
R squared = .903

Average slope from tests at 4 applied vacuums = -.043 per foot.

Warning! Calculated ratio of horizontal to vertical permeability is .73 which may indicate either a short circuit during the pilot test (caused perhaps by a poor well seal or the proximity of a past excavation) or a failure to reach steady state subsurface vacuum during the test. The pilot test results are therefore suspect, and the site may be unsuitable for SVE. Kh/Kv will be adjusted to 1.0 for the remainder of the analysis.

(Press any key to continue)

OBSERVED AND PREDICTED FLOW RESPONSE TO APPLIED VACUUM

	Applied Vacuum (inches w.c.)	Observed Flow Response (scfm)	Predicted Flow Response (scfm)	Relative Percent Difference
1.	42	115	118.22	2.8 %
2.	40	94	112.88	18.3 %
3.	28	83	80.24	-3.4 %
4.	16	54	46.55	-14.8 %

Mean Value of Relative Percent Difference:	.7 %
Mean Absolute Value of Relative Percent Difference:	9.8 %
Standard Deviation of Prediction:	12 scfm
Soil Permeability in Horizontal Direction (sq cm):	1.87E-07
Standard Deviation of Soil Permeability Estimation (sq cm):	2.5E-08
Ratio of Horizontal to Vertical Permeability:	1

RESULTS OF VENT-ROI ANALYSIS

EFFECTIVE RADIUS CALCULATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

BRC site in BLOOMFIELD, NM

Xylene/Ethylbenzene (single component, volatile and biodegradable)

Molecular Weight	= 106
Vapor Pressure	= 3.48 mm Hg
Temperature Constant	= 1904 deg K
Liquid Density	= .87 g/cc
Zero Order Bioremediation Rate Constant	= 5 ppm/day
Initial Total Soil Contaminant Concentration	= 7750 ppm
Residual (Non-degradable) Soil Concentration	= 1 ppm

Vertical wells in 10 inch boreholes, not extending to groundwater, screened from 5 to 13 feet

Thickness of Vented Soil Interval	= 23.6 feet
Slope of log10(P) vs Distance from Pilot Test	= .043 per ft
Soil Gas Temperature	= 50 deg F
Applied Vacuum	= 42 in. water column
Air Flow Rate per Vapor Extraction Well	= 118.2 scfm
Desired Time to Cleanup	= 730 days
Cleanup Goal	= 90 % removal

VOLATILIZATION:	SINGLE WELL EFFECTIVE RADIUS	= 30.93 FEET
	INTERWELL EFFECTIVE RADIUS	= 24.6 FEET
BIODEGRADATION:	SINGLE WELL RADIUS OF INFLUENCE	= 36.01 FEET
	INTERWELL RADIUS OF INFLUENCE	= 30.6 FEET
VOL. PLUS BIO.:	SINGLE WELL EFFECTIVE RADIUS	= 36.01 FEET
	INTERWELL EFFECTIVE RADIUS	= 30.6 FEET

RESULTS OF VENT-ROI ANALYSIS

EFFECTIVE RADIUS CALCULATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

BRC site in BLOOMFIELD, NM

Weathered Gasoline/JP-4 (contaminant mixture, volatile and biodegradable)

log10(MW P*)	= 1.34 - 3.19 ðm
Temperature Constant	= 1904 deg K
Liquid Density	= .7 g/cc
Zero Order Bioremediation Rate Constant	= 5 ppm/day
Initial Total Soil Contaminant Concentration	= 7750 ppm
Residual (Non-degradable) Soil Concentration	= 1 ppm

Vertical wells in 10 inch boreholes, not extending to groundwater, screened from 5 to 13 feet

Thickness of Vented Soil Interval	= 23.6 feet
Slope of log10(P) vs Distance from Pilot Test	= .043 per ft
Soil Gas Temperature	= 50 deg F
Applied Vacuum	= 42 in. water column
Air Flow Rate per Vapor Extraction Well	= 118.2 scfm
Desired Time to Cleanup	= 730 days
Cleanup Goal	= 90 % removal

VOLATILIZATION:	SINGLE WELL EFFECTIVE RADIUS	= 16.17 FEET
	INTERWELL EFFECTIVE RADIUS	= 3.93 FEET
BIODEGRADATION:	SINGLE WELL RADIUS OF INFLUENCE	= 36.01 FEET
	INTERWELL RADIUS OF INFLUENCE	= 30.6 FEET
VOL. PLUS BIO.:	SINGLE WELL EFFECTIVE RADIUS	= 34.42 FEET
	INTERWELL EFFECTIVE RADIUS	= 28.74 FEET

RESULTS OF VENT-ROI ANALYSIS

EFFECTIVE RADIUS CALCULATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

BRC site in BLOOMFIELD, NM

Diesel/No. 2 Fuel Oil (contaminant mixture, volatile and biodegradable)

log10(MW P*)	=-.05 - 6.03 ðm
Temperature Constant	= 1904 deg K
Liquid Density	= .8 g/cc
Zero Order Bioremediation Rate Constant	= 5 ppm/day
Initial Total Soil Contaminant Concentration	= 7750 ppm
Residual (Non-degradable) Soil Concentration	= 1 ppm

Vertical wells in 10 inch boreholes, not extending to groundwater, screened from 5 to 13 feet

Thickness of Vented Soil Interval	= 23.6 feet
Slope of log10(P) vs Distance from Pilot Test	= .043 per ft
Soil Gas Temperature	= 50 deg F
Applied Vacuum	= 42 in. water column
Air Flow Rate per Vapor Extraction Well	= 118.2 scfm
Desired Time to Cleanup	= 730 days
Cleanup Goal	= 90 % removal

VOLATILIZATION:	SINGLE WELL EFFECTIVE RADIUS	= .22 FEET
	INSUFFICIENT SURFACE INFILTRATION FOR MULTIPLE WELL SYSTEM	
BIODEGRADATION:	SINGLE WELL RADIUS OF INFLUENCE	= 36.01 FEET
	INTERWELL RADIUS OF INFLUENCE	= 30.6 FEET
VOL. PLUS BIO.:	SINGLE WELL EFFECTIVE RADIUS	= 2.37 FEET
	INTERWELL EFFECTIVE RADIUS	= .1 FEET

VEW-1D ANALYSIS

10 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	1.9	.279
MP2	33	1.2	.079
MP4	225	.035	-1.456
RW2	33	1.2	.079
P2	40	1.1	.041
MW4	57	1	0

Additional data point based on applied vacuum:
2 inches of water column at 0 feet from SVE well

Slope = -.008 per foot
Intercept = 2.348 inches of water column
R squared = .992

21 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	4	.602
MP2	33	2.6	.415
MP4	225	.08	-1.097
RW2	33	2.6	.415
P2	40	2.5	.398
MW4	57	1.9	.279

Additional data point based on applied vacuum:
4.2 inches of water column at 0 feet from SVE well

Slope = -.008 per foot
Intercept = 4.928 inches of water column
R squared = .995

Average slope from tests at 4 applied vacuums = -.008 per foot.

ANALYSIS OF VACUUM DISSIPATION DATA FROM PILOT TEST

18 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	3.4	.531
MP2	33	2.4	.38
MP4	225	.05	-1.301
RW2	33	2.4	.38
P2	40	2.1	.322
MW4	57	1.7	.23

Additional data point based on applied vacuum:
3.6 inches of water column at 0 feet from SVE well

Slope	= -.009 per foot
Intercept	= 4.542 inches of water column
R squared	= .994

13 INCHES APPLIED VACUUM:

Monitoring Well	Distance from SVE Well (ft)	Measured Vacuum (inches w.c.)	log10(Vac)
MP1	19	2.6	.415
MP2	33	1.7	.23
MP4	225	.05	-1.301
RW2	33	1.8	.255
P2	40	1.6	.204
MW4	57	1.2	.079

Additional data point based on applied vacuum:
2.6 inches of water column at 0 feet from SVE well

Slope	= -.008 per foot
Intercept	= 3.202 inches of water column
R squared	= .994

OBSERVED AND PREDICTED FLOW RESPONSE TO APPLIED VACUUM

	Applied Vacuum (inches w.c.)	Observed Flow Response (scfm)	Predicted Flow Response (scfm)	Relative Percent Difference
1.	18	94	93.77	-.2 %
2.	13	67	72.73	8.2 %
3.	10	48	58.28	19.3 %
4.	21	131	104.57	-22.4 %

Mean Value of Relative Percent Difference:	1.2 %
Mean Absolute Value of Relative Percent Difference:	12.6 %
Standard Deviation of Prediction:	16.7 scfm
Soil Permeability in Horizontal Direction (sq cm):	6.59E-07
Standard Deviation of Soil Permeability Estimation (sq cm):	1.21E-07
Ratio of Horizontal to Vertical Permeability:	6.6

GROUNDWATER TECHNOLOGY

RESULTS OF VENT-ROI ANALYSIS

EFFECTIVE RADIUS CALCULATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

BRC site in BLOOMFIELD, NM

Weathered Gasoline/JP-4 (contaminant mixture, volatile and biodegradable)

log10(MW P*)	= 1.34 - 3.19 ðm
Temperature Constant	= 1904 deg K
Liquid Density	= .7 g/cc
Zero Order Bioremediation Rate Constant	= 5 ppm/day
Initial Total Soil Contaminant Concentration	= 7750 ppm
Residual (Non-degradable) Soil Concentration	= 1 ppm

Vertical wells in 10 inch boreholes, extending to groundwater, screened from 16 to 23.6 feet

Thickness of Vented Soil Interval	= 11.1 feet
Slope of log10(P) vs Distance from Pilot Test	= .008 per ft
Soil Gas Temperature	= 50 deg F
Applied Vacuum	= 21 in. water column
Air Flow Rate per Vapor Extraction Well	= 104.6 scfm
Desired Time to Cleanup	= 730 days
Cleanup Goal	= 90 % removal

VOLATILIZATION:	SINGLE WELL EFFECTIVE RADIUS	= 27.01 FEET
	INSUFFICIENT SURFACE INFILTRATION FOR MULTIPLE WELL SYSTEM	
BIODEGRADATION:	SINGLE WELL RADIUS OF INFLUENCE	= 84.22 FEET
	INTERWELL RADIUS OF INFLUENCE	= 17.78 FEET
VOL. PLUS BIO.:	SINGLE WELL EFFECTIVE RADIUS	= 78.5 FEET
	INTERWELL EFFECTIVE RADIUS	= 7.44 FEET

GROUNDWATER TECHNOLOGY

RESULTS OF VENT-ROI ANALYSIS

EFFECTIVE RADIUS CALCULATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

BRC site in BLOOMFIELD, NM

Xylene/Ethylbenzene (single component, volatile and biodegradable)

Molecular Weight	= 106
Vapor Pressure	= 3.48 mm Hg
Temperature Constant	= 1904 deg K
Liquid Density	= .87 g/cc
Zero Order Bioremediation Rate Constant	= 5 ppm/day
Initial Total Soil Contaminant Concentration	= 7750 ppm
Residual (Non-degradable) Soil Concentration	= 1 ppm

Vertical wells in 10 inch boreholes, extending to groundwater, screened from 16 to 23.6 feet

Thickness of Vented Soil Interval	= 11.1 feet
Slope of log10(P) vs Distance from Pilot Test	= .008 per ft
Soil Gas Temperature	= 50 deg F
Applied Vacuum	= 21 in. water column
Air Flow Rate per Vapor Extraction Well	= 104.6 scfm
Desired Time to Cleanup	= 730 days
Cleanup Goal	= 90 % removal

VOLATILIZATION:	SINGLE WELL EFFECTIVE RADIUS	= 66.91 FEET
	INSUFFICIENT SURFACE INFILTRATION FOR MULTIPLE WELL SYSTEM	
BIODEGRADATION:	SINGLE WELL RADIUS OF INFLUENCE	= 84.22 FEET
	INTERWELL RADIUS OF INFLUENCE	= 17.78 FEET
VOL. PLUS BIO.:	SINGLE WELL EFFECTIVE RADIUS	= 84.22 FEET
	INTERWELL EFFECTIVE RADIUS	= 17.78 FEET

GROUNDWATER TECHNOLOGY ®

RESULTS OF VENT-ROI ANALYSIS

EFFECTIVE RADIUS CALCULATION FOR CONVENTIONAL SOIL VAPOR EXTRACTION SYSTEM

BRC site in BLOOMFIELD, NM

Diesel/No. 2 Fuel Oil (contaminant mixture, volatile and biodegradable)

log10(MW P*)	=-.05 - 6.03 ðm
Temperature Constant	= 1904 deg K
Liquid Density	= .8 g/cc
Zero Order Bioremediation Rate Constant	= 5 ppm/day
Initial Total Soil Contaminant Concentration	= 7750 ppm
Residual (Non-degradable) Soil Concentration	= 1 ppm

Vertical wells in 10 inch boreholes, extending to groundwater, screened from 16 to 23.6 feet

Thickness of Vented Soil Interval	= 11.1 feet
Slope of log10(P) vs Distance from Pilot Test	= .008 per ft
Soil Gas Temperature	= 50 deg F
Applied Vacuum	= 21 in. water column
Air Flow Rate per Vapor Extraction Well	= 104.6 scfm
Desired Time to Cleanup	= 730 days
Cleanup Goal	= 90 % removal

OLATILIZATION:	SINGLE WELL EFFECTIVE RADIUS	= .3 FEET
	INSUFFICIENT SURFACE INFILTRATION FOR MULTIPLE WELL SYSTEM	
IODEGRADATION:	SINGLE WELL RADIUS OF INFLUENCE	= 84.22 FEET
	INTERWELL RADIUS OF INFLUENCE	= 17.78 FEET
VOL. PLUS BIO.:	SINGLE WELL EFFECTIVE RADIUS	= 3.24 FEET
	INTERWELL EFFECTIVE RADIUS	= .1 FEET

GROUNDWATER TECHNOLOGY ®

APPENDIX G

HYDROCARBON MASS EXTRACTION RATE CALCULATIONS

AIR SPARGE/SOIL VENT PILOT TEST
HYDROCARBON MASS EXTRACTION RATE CALCULATIONS
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14 AND 16, 1994

Air sample effluent analytical data were used to calculate maximum extraction rates for the soil vent pilot tests on well VEW-1.

$$ER = Q \times C \times \frac{28.32 l}{ft^3} \times \frac{lb}{454 \times 10^6 ug} \times \frac{60 min}{hr}$$

Where:

ER = Extraction rate (lb/hr)
Q = Air velocity under standard temperature and pressure conditions (scfm)
C = Soil vapor concentration (ug/l) (1 mg/m^3 = 1 ug/l)

and final three terms are conversion factors

$$SCFM = cfm \times \frac{P_{field}}{P_{lab}} \times \frac{(T_{lab} + 460^o R)}{(T_{field} + 460^o R)}$$

Where:

cfm	=	Air velocity in cubic feet per minute (fpm x π x r^2)
P_{lab}	=	Standard Pressure (29.92 inches Hg at sea level)
P_{field}	=	25 inches Hg (average for Albuquerque, NM; National Weather Service)
T_{field}	=	Average Temperature in field (°F)
T_{lab}	=	Standard Temperature (60°F, standard laboratory temperature)
°R	=	Temperature in Rankin

AIR SPARGE/SOIL VENT PILOT TEST
HYDROCARBON MASS EXTRACTION RATE CALCULATIONS
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14 AND 16, 1994
(cont.)

I. SVES Extraction Rate Calculations - Well VEW-1 Shallow and Deep Zone Pilot Tests

- Air sample VEW-1S collected 180 minutes after start of shallow zone soil vent test at 42 inches of water applied vacuum, 115 scfm.
- Air sample VEW-1D collected 180 minutes after start of deep zone soil vent test at 21 inches of water applied vacuum, 131 scfm.

Extraction rates in pounds per hour (lb/hr) were calculated in the following manner:

A. Benzene Calculations

1. Sample VEW-1S Effluent

$$(115 scfm) \times (2.2 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **9.5×10^{-4} lb/hr Benzene**

2. Sample VEW-1D EFF

$$(131 scfm) \times (380 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **0.19 lb/hr Benzene**

AIR SPARGE/SOIL VENT PILOT TEST
HYDROCARBON MASS EXTRACTION RATE CALCULATIONS
BLOOMFIELD REFINING COMPANY
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JUNE 14 AND 16, 1994
(cont.)

B. Toluene Calculations

1. Sample VEW-1S Effluent

$$(115 scfm) \times (0.4 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}min}{ft^3\text{-}ug\text{-}hr}$$

= **1.72×10^{-4} lb/hr Toluene**

2. Sample VEW-1D EFF

$$(131 scfm) \times (16 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}min}{ft^3\text{-}ug\text{-}hr}$$

= **0.008 lb/hr Toluene**

C. Ethylbenzene Calculations

1. Sample VEW-1S Effluent

$$(115 scfm) \times (0.53 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}min}{ft^3\text{-}ug\text{-}hr}$$

= **2.3×10^{-4} lb/hr Ethylbenzene**

2. Sample VEW-1D EFF

$$(131 scfm) \times (57 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}min}{ft^3\text{-}ug\text{-}hr}$$

= **0.03 lb/hr Ethylbenzene**

AIR SPARGE/SOIL VENT PILOT TEST
HYDROCARBON MASS EXTRACTION RATE CALCULATIONS
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14 AND 16, 1994
(cont.)

D. Total Xylenes Calculations

1. Sample VEW-1S Effluent

$$(115 scfm) \times (3.2 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **1.4 x 10^{-3} lb/hr Total Xylenes**

2. Sample VEW-1D EFF

$$(131 scfm) \times (280 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **0.14 lb/hr Total Xylenes**

E. Total Fuel (non-methane hydrocarbons) Calculations

1. Sample VEW-1S Effluent

$$(115 scfm) \times (460 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **0.20 lb/hr Total Fuel**

2. Sample VEW-1D EFF

$$(131 scfm) \times (11{,}000 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **5.4 lb/hr Total Fuel**

AIR SPARGE/SOIL VENT PILOT TEST
HYDROCARBON MASS EXTRACTION RATE CALCULATIONS
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14 AND 16, 1994
(cont.)

II. SVES Extraction Rate Calculations - Well VEW-1D and AS-1 Combined Air Sparge/Soil Vent Test

- Air sample VEW-1D V/S collected 145 minutes after start of combined air sparge/soil vent test at 22 inches of water applied vacuum and 5 psi.

Extraction rates in pounds per hour (lb/hr) were calculated in the following manner:

A. Benzene Calculations

1. Sample VEW-1D V/S

$$(112 scfm) \times (460 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}min}{ft^3\text{-}ug\text{-}hr}$$

= **0.19 lb/hr Benzene**

B. Toluene Calculations

1. Sample VEW-1D V/S

$$(112 scfm) \times (170 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}min}{ft^3\text{-}ug\text{-}hr}$$

= **0.07 lb/hr Toluene**

C. Ethylbenzene Calculations

1. Sample VEW-1D V/S

$$(112 scfm) \times (140 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}min}{ft^3\text{-}ug\text{-}hr}$$

= **0.06 lb/hr Ethylbenzene**

AIR SPARGE/SOIL VENT PILOT TEST
HYDROCARBON MASS EXTRACTION RATE CALCULATIONS
BLOOMFIELD REFINING COMPANY
BLOOMFIELD, NEW MEXICO
JUNE 14 AND 16, 1994
(cont.)

D. Total Xylenes Calculations

1. Sample VEW-1D V/S

$$(112 scfm) \times (1{,}100 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **0.46 lb/hr Total Xylenes**

E. Total Fuel (non-methane hydrocarbons) Calculations

1. Sample VEW-1D V/S

$$(112 scfm) \times (13{,}000 ug/l) \times 3.74 \times 10^{-6} \frac{l\text{-}lb\text{-}\min}{ft^3\text{-}ug\text{-}hr}$$

= **5.45 lb/hr Total Fuel**