0013227

EGG-WM-9301

SUMMARY REPORT OF RESULTS OF THE VAPOR VACUUM EXTRACTION TEST AT THE RWMC

J. B. Sisson
G. C. Ellis

MAR 1991
RECEIVED
EDMC

Published November 1990

Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared For The
U.S. Department of Energy
Idaho Operations Office
Under DOE Contract No. DE-AC07-76ID01570

SUMMARY REPORT OF RESULTS OF THE VAPOR VACUUM EXTRACTION TEST AT THE RWMC

Reviewed by:

J. B. Hebdon
Unit Manager, WAG-7

11/21/90
Date

J. P. Shea
EIRC Chairman

Nov 21 1990
Date

Approved by:

J. B. Hebdon
Unit Manager, WAG-7

11/21/90
Date

ABSTRACT

A test scale vapor vacuum extraction system was operated for four months at the Radioactive Waste Management Complex. The extraction system removed more than 65 million ft^3 of soil gas containing 429 Kg of Carbon Tetrachloride and 164 Kg of TCE. Hydraulic properties of the basalts were estimated and input into a numerical transport model. The model simulations indicated that a rubble zone at 190 ft dominated the soil gas flow pattern. Refined calibration of transport models will allow enhancement of the production system design to increase operational efficiency and effectiveness.

CONTENTS

ABSTRACT iii

ACRONYMS vi

1. INTRODUCTION 1

1.1 Purpose 1

1.2 Background 1

1.3 VVE, An Alternative Removal Action 2

2. TEST SCALE VAPOR VACUUM EXTRACTION SYSTEM DESCRIPTION 4

2.1 Extraction Well and Extraction System Hardware 4

2.2 Monitoring Wells 4

2.3 Data Acquisition System 9

2.4 Gas Sampling and Analysis System 10

3. TEST SCALE VAPOR VACUUM EXTRACTION SYSTEM OPERATIONS 11

3.1 Gas Sampling and Data Collection 11

3.2 Data Acquisition System 12

3.3 Data Analysis 13

3.3.1 Extraction Well 13
3.3.2 Downhole Pressure Analysis 15
3.3.3 Gas Sampling Data 18

4. GEOLOGICAL PROPERTIES, SYSTEM VARIABLES, AND OPERATION 26

4.1 Testing 27

4.1.1 Tracer Tests - Cross Hole and Cross Port 27
4.1.2 Sample Port Tests 28
4.1.3 Flow Tests 28

5. TRANSPORT MODELING STATUS 29

6. TEST SCALE VAPOR VACUUM SYSTEM OPERATION PROBLEMS AND CORRECTIVE ACTIONS 32

7. CONCLUSIONS 34

8. REFERENCES 35

APPENDIX A--THE FOUR MONTH TEST START/STOP TIMES A-1

APPENDIX B--PRODUCTION SCALE VAPOR VACUUM EXTRACTION SYSTEM CONSIDERATIONS B-1

FIGURES

1. TSVVE system at RWMC 5

2. Extraction well 8901D construction 6

3. Extraction well and extraction system hardware 7

4. Construction of typical sample port 8

5. Extraction flow rate vs time for TSVVE test 14

6. Wellbore flow test in the extraction well 14

7. Vacuum pressure in the extraction well as a function of flow rate 16

8. Barometric and downhole pressures from selected depths 16

9. Real part of transfer function 17

10. Downhole pressure after correcting for barometric effects 17

11. Corrected downhole pressures with pump startup event 19

12. Concentration of CCl_4 in the extraction stream 19

13. Cumulative CCl_4, TCE and CCl_4 + TCE extracted 20

14. Concentration of CCl_4 as a function of depth in the monitoring wells 21

15. Concentration of CCl_4 in monitoring well 8801D as a function of time 22

16. Concentration of CCl_4 in monitoring well 8902D as a function of time 23

17. Concentration of CCl_4 in monitoring well D02 as a function of time 24

18. Soil gas flow pattern around the extraction well as a function of depth and radius 30

ACRONYMS

AID	Argon Ionization Detector
AWQC	ambient water quality criteria
CCl_4	Carbon Tetrachloride
DAS	Data Acquisition System
GC	Gas Chromatograph
HEPA	high-efficiency particulate air
INEL	Idaho National Engineering Laboratory
PSVVE	production scale vapor vacuum extraction
QC	quality control
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SWEPP	Stored Waste Examination Pilot Plant
TSVVE	test scale vapor vacuum extraction
TSVVED	test scale vapor vacuum extraction demonstration
VOC	Volatile Organic Compound
VVE	vapor vacuum extraction

SUMMARY REPORT OF RESULTS OF THE VAPOR VACUUM EXTRACTION TEST AT THE RWMC

1. INTRODUCTION

1.1 Purpose

The purpose of this report is to summarize the reasons for conducting the test scale vapor vacuum extraction demonstration (TSVVED) and to present the results of the four month test conducted at the Radioactive Waste Management Complex (RWMC). This report also discusses considerations in the design of a production scale vapor vacuum extraction (PSVVE) system.

1.2 Background

In 1982 chlorinated volatile organic compounds (VOCs) were discovered at the RWMC (Leenheer and Bagby, 1982). By 1987, VOCs were found in the:

- Drinking water
- Samples of perched water
- Gas samples (from soil and vadose zones)
- Atmosphere above the soil surface (EG&G, 1988).

The VOCs found to date include:

- Carbon tetrachloride (CCl_4)
- Trichloroethylene
- Chloroform

- 1,1,1-trichloroethane
- 1,1,2-trichlorotrifluoroethane
- Tetrachloroethylene.

These are common industrial solvents used to clean metal parts. In order to prevent further migration of VOCs that could result in unacceptable contaminant levels in the Snake River Plain Aquifer, a vapor vacuum extraction (VVE) system was considered (EGG, 1990).

1.3 VVE, An Alternative Interim Remedial Action

The VVE system is a process where contaminated soil gases are removed by pumping and displaced by atmospheric air. Therefore, the volume of the plume, and the rate and efficiency of the extraction process control the time required to cleanup the site.

A computer simulation of VOC transport was carried out for the RWMC to evaluate the feasibility of the VVE method (Baca, et al., 1988). The simulation indicated that VVE would be a viable technology for contaminant removal. However, more accurate simulations of transport processes and better estimates of geological material properties at the RWMC will support final remediation.

VVE technology has been used at sites where the contaminated zones extend from ground surface to a ground water depth of less than 30 ft; however, the contaminant plume beneath the SDA extends from the ground surface to a ground water depth of 585 ft. Because the contaminant plume at the RWMC has 1000 - 10,000 times more volume than plumes where VVE technology has been used, a system at least 100 times larger than a typical VVE system must be considered. Such a large scale system will require establishing operating characteristics under conditions found at the Idaho National Engineering Laboratory (INEL). Thus, a TSVVE system was designed, constructed, and

installed at the RWMC to collect: (a) sufficient data for estimating geological material properties for transport modes, (b) to acquire experience in operating VVE systems under conditions found at the INEL, and (c) to evaluate the effectiveness for application as an interim remedial action.

2. TEST SCALE VAPOR VACUUM EXTRACTION SYSTEM DESCRIPTION

The TSVVE system deployed at the RWMC consisted of an extraction well with sampling ports, an extraction pump and hardware used in its control (i.e., the extractor), five monitoring wells, a Data Acquisition System (DAS), and a gas sampling and analysis system. The physical layout of the TSVVE system is shown in Figure 1 where the five monitoring wells are denoted as 8801D, 8902D, D02,77-4, and WWW-1. The extraction well is indicated as 8901D.

2.1 Extraction Well and Extraction System Hardware

The extraction well was completed to a depth of 234 ft, cased from ground surface to 90 ft and screened from 90-230 ft (Figure 2). The extraction well was connected to a centrifugal pump through an in-line heater, cyclone separator, high-efficiency particulate air (HEPA) filters, and a carbon bed absorber (Figure 3). The pump provided a vacuum source. The in-line heater provided relative humidity control to minimize moisture condensation in the filters and carbon beds. The cyclone separator and HEPA filters removed particulate from the flowstream. The carbon beds removed the VOCs from the extraction stream prior to its discharge to the atmosphere. To reduce VOC discharges to the atmosphere following carbon bed saturation, a VOC detector in the form of an HNu-201 gas analyzer sampled the discharge stream and shut down the TSVVE system when gross VOC concentrations exceeded 25 ppm. Once the HNu-201 gas analyzer shut down, a fresh carbon bed was valved on-line and the system was restarted. The VOC saturated carbon bed was then transported out of the RWMC to a EPA permitted recycling facility for replenishment of the carbon. All maintenance work was conducted in accordance with the Health and Safety Plan (Spang, 1990).

2.2 Monitoring Wells

Each of the five monitoring wells used in this test were equipped with sampling ports at depths ranging from 30-240 ft (Figure 4). Each well had

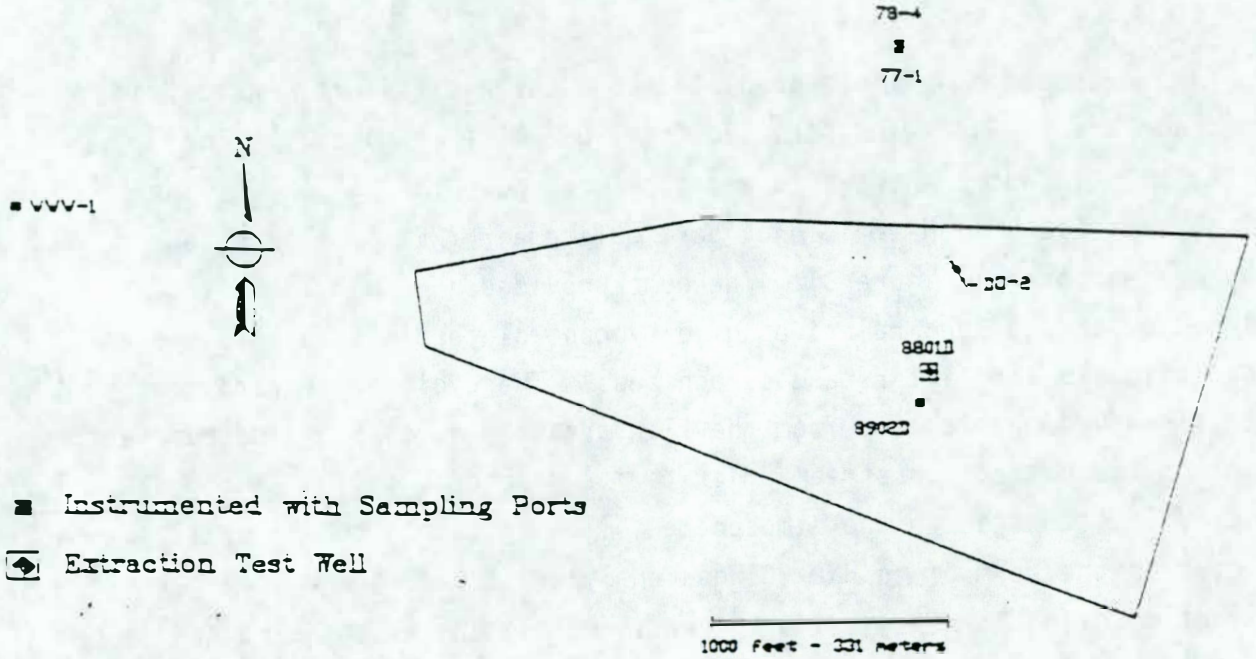


Figure 1. TSVVE system at RWMC.

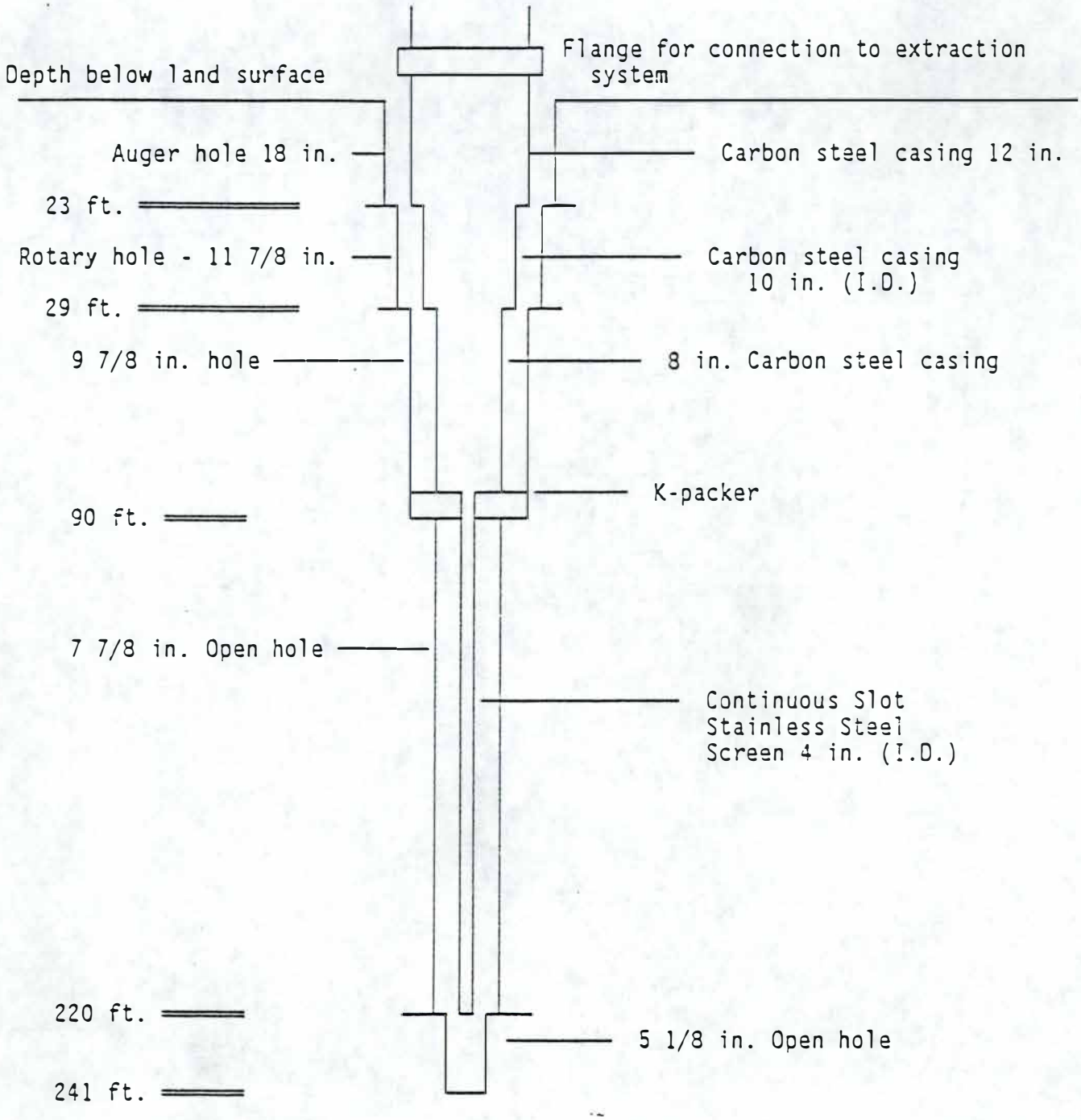


Figure 2. Extraction well 8901D construction.

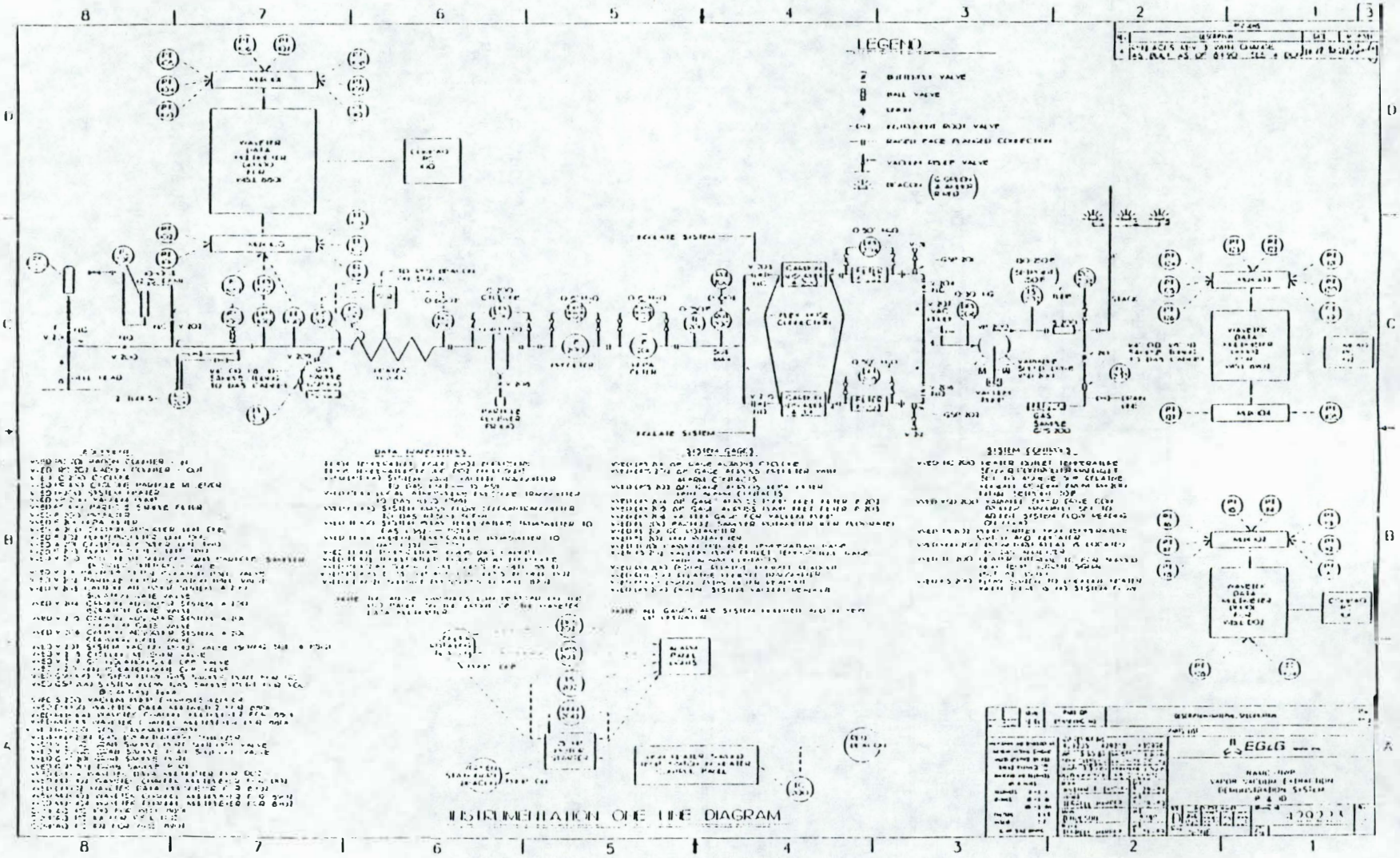


Figure 3. Extraction well and extraction system hardware.

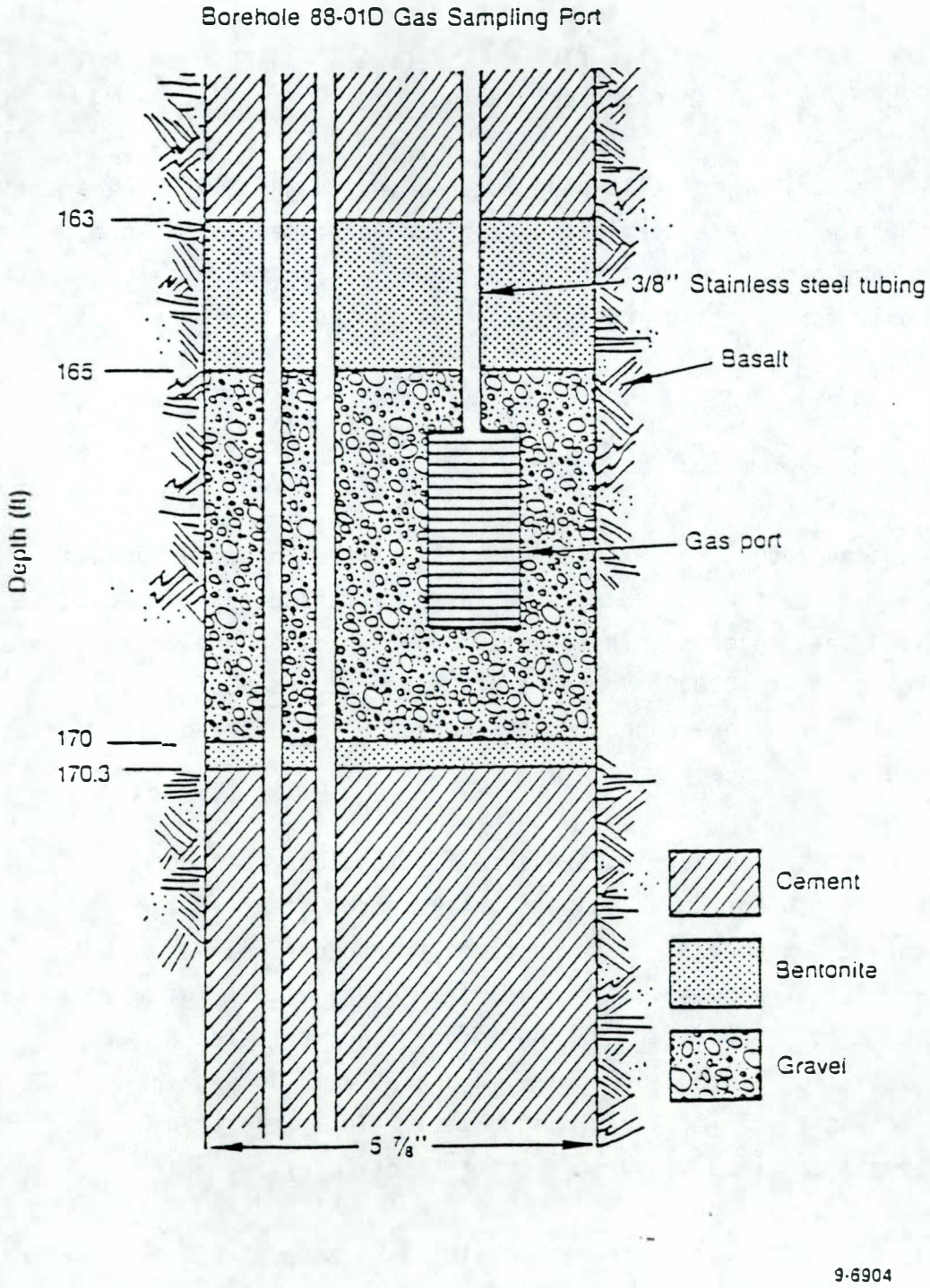


Figure 4. Construction of typical sample port.

five to nine different sampling ports. All sample ports were constructed by centering a short length of stainless steel well screen at the desired depth and packing a 5-ft section of the wellbore with gravel. The gravel pack was capped with a bentonite plug and the wellbore was filled with cement to the elevation of the next sample port. Each well screen was connected to the ground surface by 3/8-in stainless steel tubing.

Three of the monitoring wells were located inside the SDA. The sampling ports within those wells were terminated at ground surface using a pressure transducer and sample-pump connection. The two wells located outside the SDA were used only for gas sampling purposes due to their distance from the extraction well.

2.3 Data Acquisition System

Data were acquired at the extraction well and the three surrounding monitoring wells inside the SDA using a variety of transducers connected to WaveTek Model 52A data loggers. These data loggers have an analog to digital conversion resolution of ±0.0001 V, and a stability accuracy of ±0.005% of range. The data loggers were connected to Compaq SLT/286 portable computers for data storage.

For the purpose of measuring pressure fluctuations both downhole and at ground surface, the monitoring wells were instrumented with Setra Model 270 absolute pressure transducers. These pressure transducers have a measurement range of 600 - 1100 mbar and a voltage output of 0 - 5 V dc. This output is specified by the manufacturer to have operational uncertainties of ±0.1% of range for its set zero reading (600 mbar), a preset gain uncertainty of ±0.1%, and a voltage linearity of ±0.5% for output data. Thus, the transducers and data loggers have a combined measurement uncertainty of ±0.60 mbar.

The extraction well was instrumented with a Kurz Model 555 flow meter for measuring stream flow; a Setra Model C239 differential pressure transducer for measuring the vacuum generated in the system by the extraction process;

and three type T thermocouples for monitoring ambient temperature, stream temperature, and DAS enclosure temperature. An uncertainty analysis was performed on the system as a whole.

2.4 Gas Sampling and Analysis System

A Scentograph Plus PC portable system gas chromatograph (GC) was used to measure concentrations of the contaminant. The GC was calibrated to 225 ppm benzene; response factors relative to benzene were established to identify target compounds stored in an internal industrial solvent library. The GC was equipped with a 6-ft, 3% SP-1000 packed column and an argon ionization detector (AID) (Rauen, 1990).

A sample was introduced to the column by connecting the Tedlar sample bag to an external GC sample port with Teflon tubing and a Tygon nipple. The sample was pumped to a sample loop (approximately 3 in) and valved to the column. The excess sample was automatically purged from the system. Each Tedlar sample bag was purged and used a maximum of five times. Random blanks were run on a daily basis as a quality control (QC) measure to assure system memory or carryover contamination did not occur. Further, CCl_4 standards (i.e., Scott Specialty Gas, certified $\pm 2\%$) of 205 ppm and 1000 ppm were run on a daily basis to ensure a linear CCl_4 response from approximately 100 ppm to 1000 ppm (Rauen, 1990).

3. TEST SCALE VAPOR VACUUM EXTRACTION SYSTEM OPERATIONS

The operating principle of the TSVVE system was to apply a vacuum to the extraction well head and adsorb the VOCs on an activated charcoal bed (See Figure 2). The soil gases removed by the vacuum system are displaced by clean air entering across the ground surface. Appendix A provides a calendar of pump events based on DAS data sets and the hand written operations log kept at the RWMC.

3.1 Gas Sampling and Data Collection

Gas analyses were performed on three types of samples:

- Tedlar bag samples from the extraction well (8901D) process stream
- Tedlar bag samples from monitoring wells 8801D, 8902D, D02, WWW-1, and 78-4
- Continuous samples of the stack effluent.

At the extraction well Tedlar bag samples were collected through a Swagelok quick connect located 15 ft downstream from the wellhead. The three monitoring wells located within the SDA (8801, 8902, and D02) were sampled on a weekly basis while the outlying wells (WWW-1 and 78-4) were sampled on a biweekly basis. Gas samples from all monitoring wells were collected following the same procedures. Each sample port was purged three volumes. A 1-L, 2-mil Tedlar sampling bag (SKC Inc., Part #232-01) was connected to a Xitech Vacuum Sample Collection Box. A Swagelok quick connect connected a sample line from the box to the purged well sampling port. The sample pump created a vacuum in the sample box forcing well gas into the sample bag without contaminating the pump. The bag was labeled in conjunction with the procedures outlined in the Sample and Analysis Plan (Rauen, 1990). When samples from each sampling port of a well were collected, they were

transported, for analysis, to the GC located at the RWMC Stored Waste Examination Pilot Plant (SWEPP) facility.

A process stack effluent stream was continuously sampled by a panel mounted HNu-201 gas analyzer. In accordance with manufacturers recommendation, the system was calibrated at least weekly with certified 92.7 ppm isobutylene. If a concentration of 25 ppm gross VOCs was detected and maintained for five seconds, the HNu-201 gas analyzer was programmed to shut down the TSVVE system. The HNu-201 gas analyzer was equipped with an 11.7 eV lamp which was capable of ionizing the chlorinated VOCs of interest. Each photoionization lamp had a life expectancy of approximately 300 hours, which created a need for frequent maintenance (Rauen, 1990).

All sampling and maintenance work was conducted in accordance with the Health and Safety Plan (Spang, 1990).

3.2 Data Acquisition System

All points of data were collected by the DAS at 2 min intervals. Data were time stamped for each scan and kept in chronological order in a large file on the Compaq portable computer. Every three or four days the data were transferred to a floppy disk for processing and storage (Rauen, 1990). There were some intervals of data lost due to a programming error in the software on the WaveTek data loggers. These losses occurred infrequently, but did result in the loss of 24 hours of data each time they occurred. There were a total of 72 hours of data lost by the DAS for wells 8801D and 8901D, 48 hours of data lost for well 8902D, and 48 hours of data lost for well D02. These losses had no significant impact on the analyses of the data because:

- An adequate number of barometric cycles were found in other intervals of data.

- Pump on/off events occurred during intervals when DAS was operational.

3.3 Data Analysis

3.3.1 Extraction Well

Data acquired by the DAS for extraction well points were used to calculate the following parameters for the TSVVE four month test:

- Average flow
- Average vacuum/pressure
- The relationship between flow and vacuum
- Average extraction stream temperature.

Over the four months of operation the TSVVE system operated at two flow rates, 492 and 678 scfm. The 678 scfm flow rate was attained following the installation of a larger vacuum pump. The TSVVE system operated a total of 2088 hours. If the two week shut down required for new pump installation was not considered, the TSVVE system ran more than 80% of its planned schedule. Figure 5 summarizes the flow rates over the four month test.

Appendix A contains a record of TSVVE system pump events and causes for system shut down. While there are 20 shut down events listed as unknown, these events were later attributed to a faulty HNu-201 gas analyzer ionization tube. Overall the system performed reliably and with low maintenance while removing a total of 65 million ft^3 of soil gas, 53 million ft^3 at 492 scfm and 12 million ft^3 at 678 scfm.

During the four month test, a wellbore flow test was carried out in the extraction well. The results are shown in Figure 6. It was determined that approximately half of the soil gas extracted came from above the 110 ft interbed and the remaining gas was extracted from a basalt rubble zone

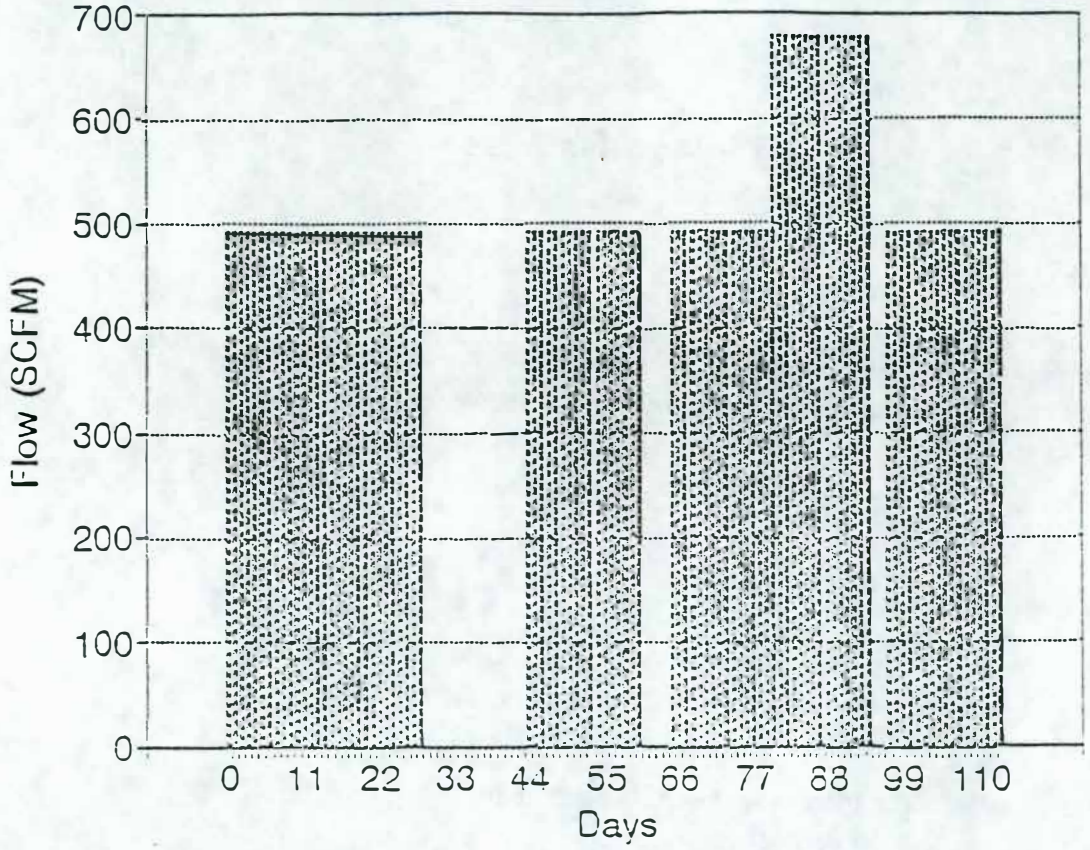


Figure 5. Extraction flow rate vs time for TSVVE test.

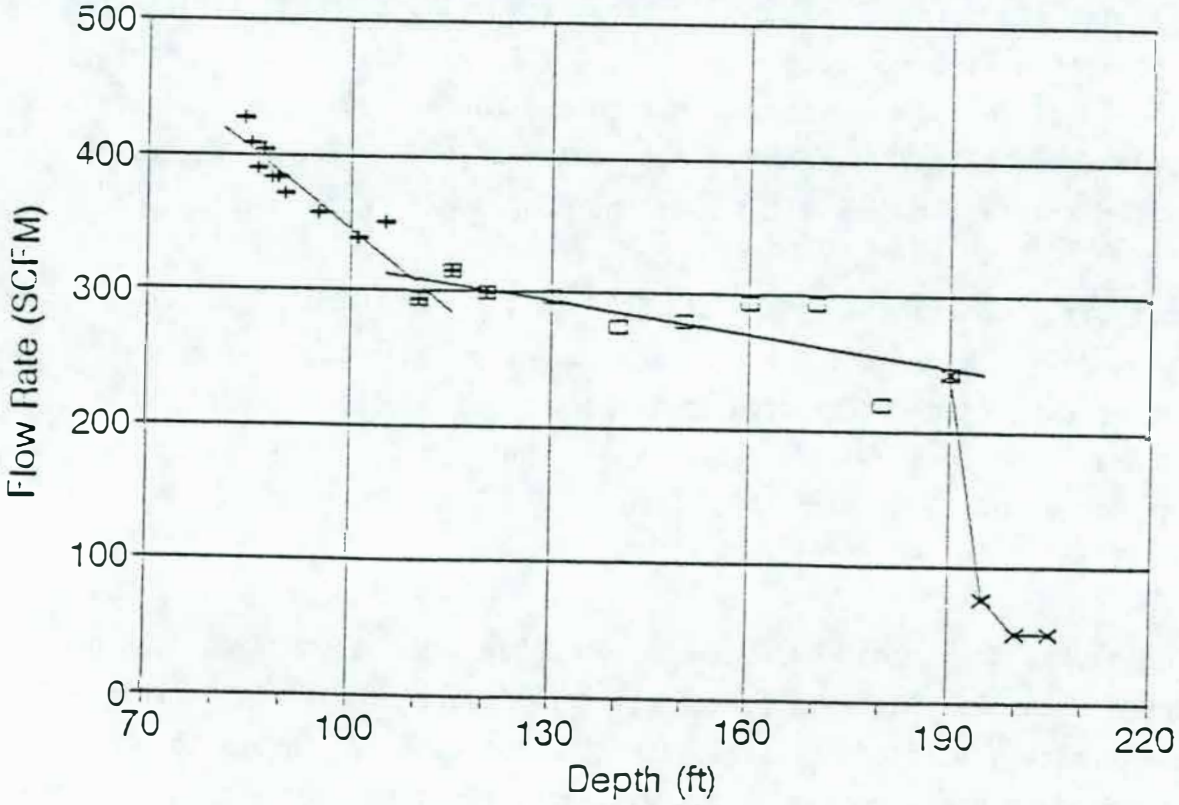


Figure 6. Wellbore flow test in the extraction well.

at 190 - 195 ft. While the precision of the wellbore flow test was limited by the presence of the well screen, it indicates that the rubble zone strongly affected soil gas flow patterns. Removal of the well screen would allow a more precise evaluation.

A test comparing pressure and flow was developed from operations data by pairing flow rates with vacuum pressures while the TSVVE was running. The results of this test are shown in Figure 7 and indicate that only 0.6 psi of vacuum developed in the wellbore at 678 scfm. These results indicate that 2,000 - 3,000 scfm flow rates are achievable with the existing well. All data were considered analytical support II data.

3.3.2 Downhole Pressure Analysis

The downhole and barometric pressures obtained during the four month test are shown in Figure 8. As can be seen, the downhole pressures lagged the barometric pressure and were more pronounced at greater depths. Also, the downhole pressures appear to be smoother than the barometric pressure and again the effect is more pronounced at greater depths. Figure 8 also indicates that it will be difficult to see any pressure changes in the downhole pressure caused by the TSVVE system. Thus, the barometric pressure effects must be removed before an accurate evaluation can be made. The barometric pressure effects can be removed by Fourier analysis.

A Fourier series was fitted to the barometric and downhole pressures using standard techniques. The resulting Fourier series had a different amplitude at each frequency and the ratio of the downhole to barometric amplitudes are shown in Figure 9. Figure 9 shows that the higher the frequency the lower the ratio of downhole to barometric amplitudes. Figure 9 is also referred to as the real part of the transfer function that relates downhole to barometric pressure. The phase angle or lag can also be plotted versus frequency and is known as the imaginary part of the transfer function. Once the real and imaginary parts of the transfer function are known, a downhole pressure can be estimated from the barometric pressure. The estimated pressures were subtracted from the measured values and the differences are shown in Figure 10.

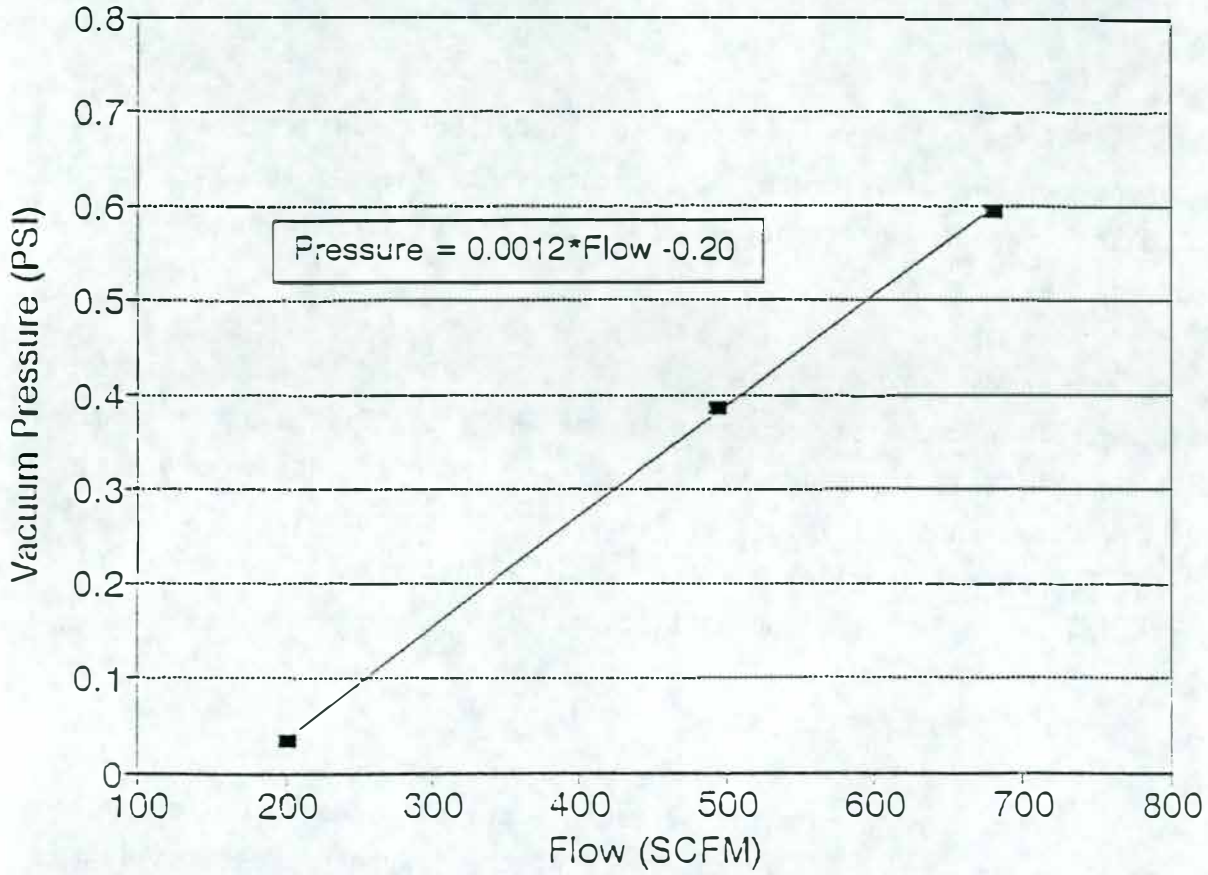


Figure 7. Vacuum pressure in the extraction well as a function of flow rate.

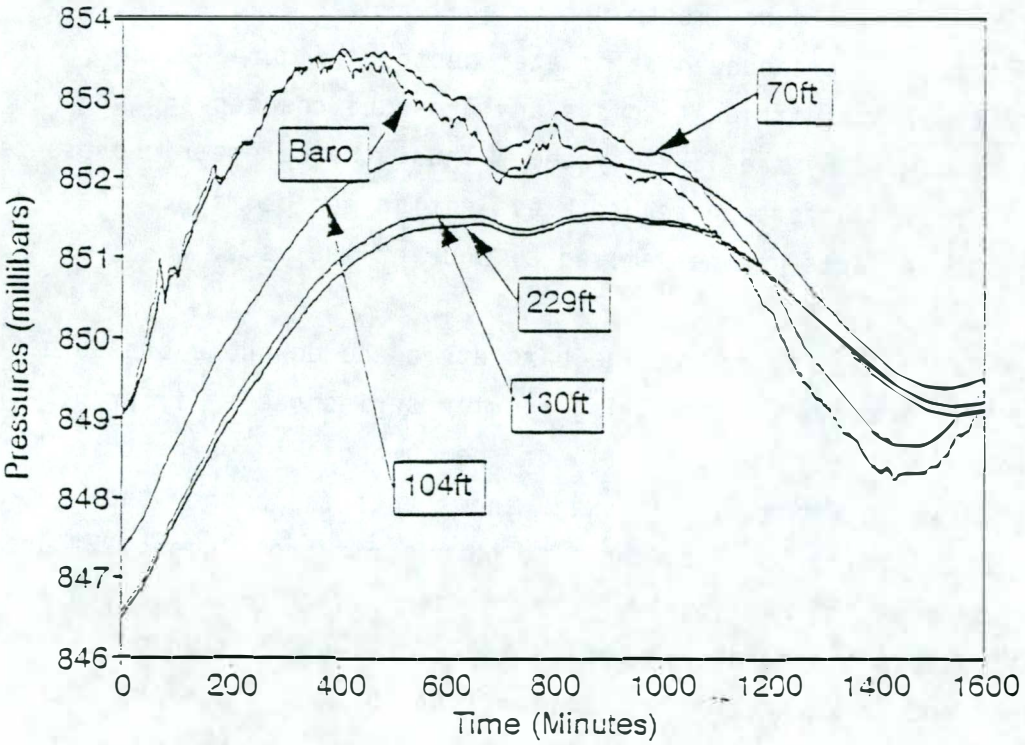


Figure 8. Barometric and downhole pressures from selected depths.

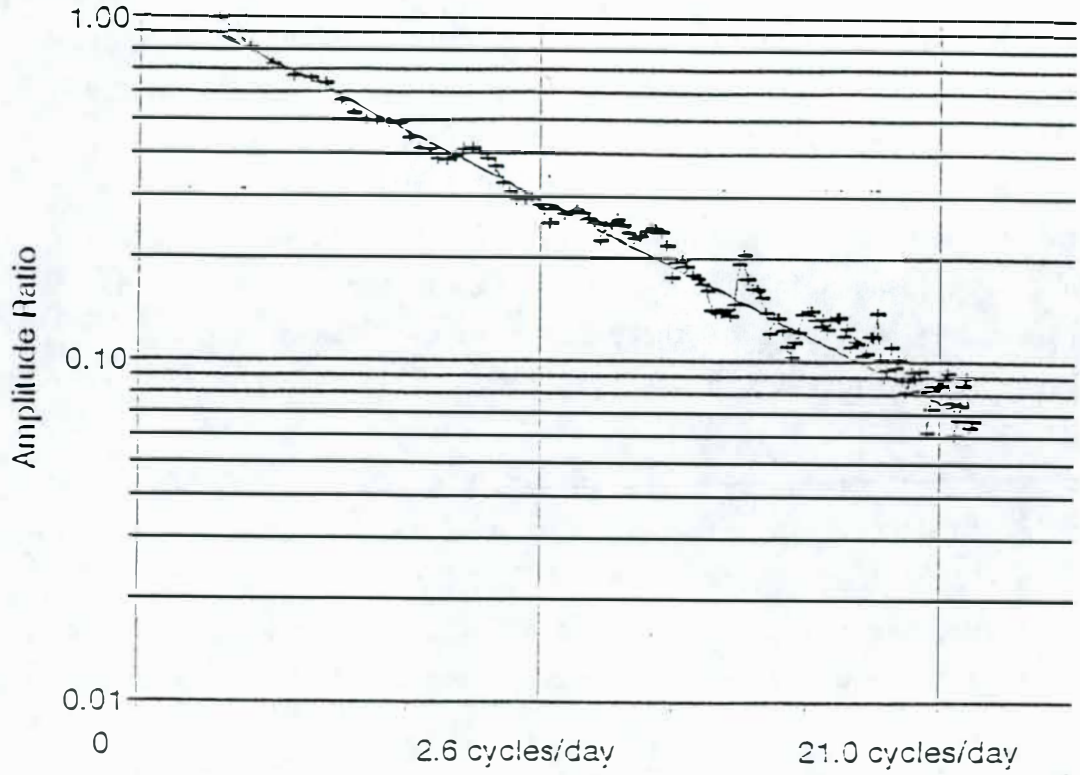


Figure 9. Real part of transfer function.

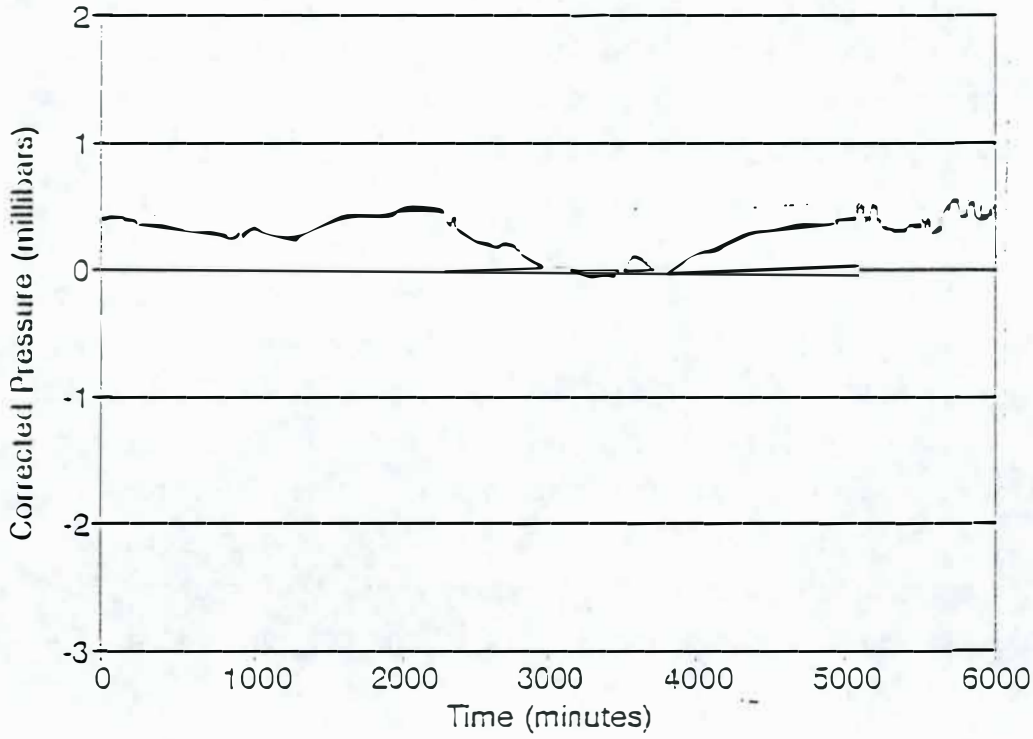


Figure 10. Downhole pressure after correcting for barometric effects.

While the curve shown in Figure 10 deviates from the ideal level line, it does indicate that most of the barometric effects have been removed from the downhole data. Although the uncorrected downhole data ranged over 10 mbar, the corrected data had a range of about 0.6 mbar. The transfer function methodology was applied to an interval of data that spanned a pump startup event. This is shown in Figure 11. The pump startup event is now clearly visible and the magnitude of the pressure change can be used to estimate the large scale hydraulic properties required in the modeling effort.

An added benefit of computing the transfer functions is that the vertical hydraulic conductivities can be estimated from the slope of the transfer function (Carslaw and Jaeger, 1959). The conductivities estimated from the transfer function ranged from 0.1 to 4.5 m/d. Vertical conductivities are also required by the transport model.

3.3.3 Gas Sampling Data

Concentrations of VOCs were estimated from gas samples obtained from the extraction stream while the TSVVE system was operating. Concentrations of CCl_4 obtained over the four month test period are shown in Figure 12. The concentrations averaged from 232 $\pm$ 81 mg/m^3 for CCl_4 and 87 $\pm$ 25 mg/m^3 for TCE.

Cumulative totals of CCl_4, TCE, and CCl_4 + TCE removed from the basalts over time are shown in Figure 13. Only the CCl_4 and TCE concentrations are shown because they accounted for 94% of the VOCs extracted. The cumulative values were computed using the flow rates shown in Figure 5 and the four month concentration average. Figure 13 indicates that the extraction process resulted in 429 Kg of CCl_4, 164 Kg of TCE, for a total of 593 Kg of combined CCl_4 and TCE being removed from the basalt. Further, using the results of Walton et al (1988), the TSVVE system removed 9.5% of the CCl_4 and 16% of the TCE present in the vapor phase.

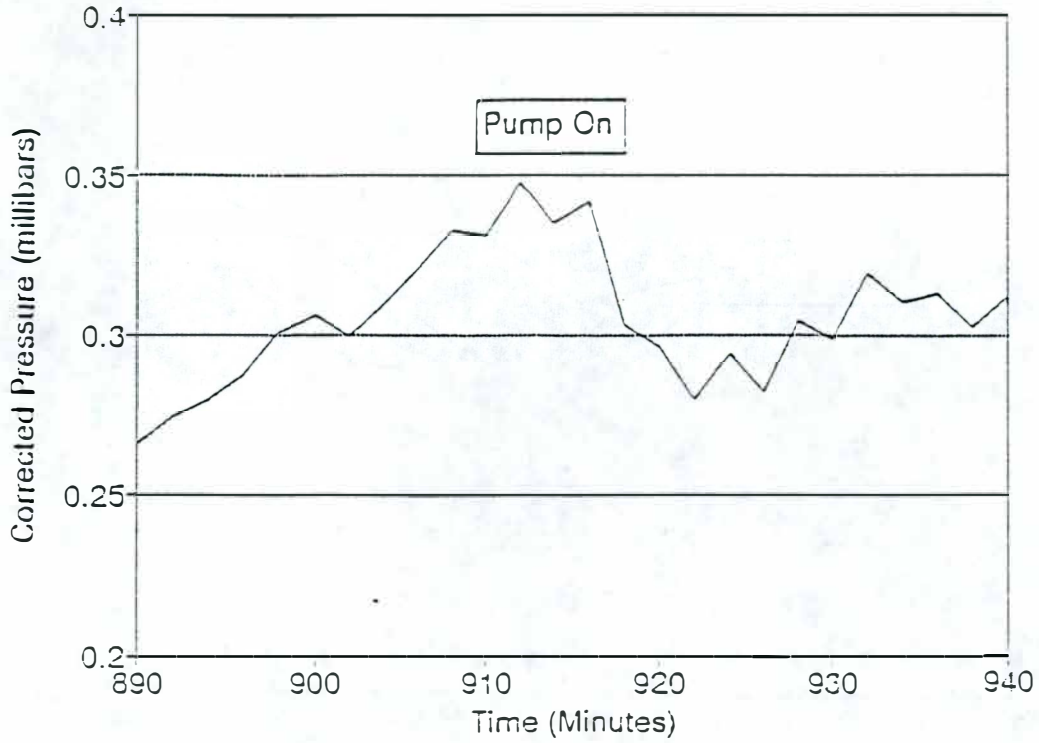


Figure 11. Corrected downhole pressures with pump startup event.

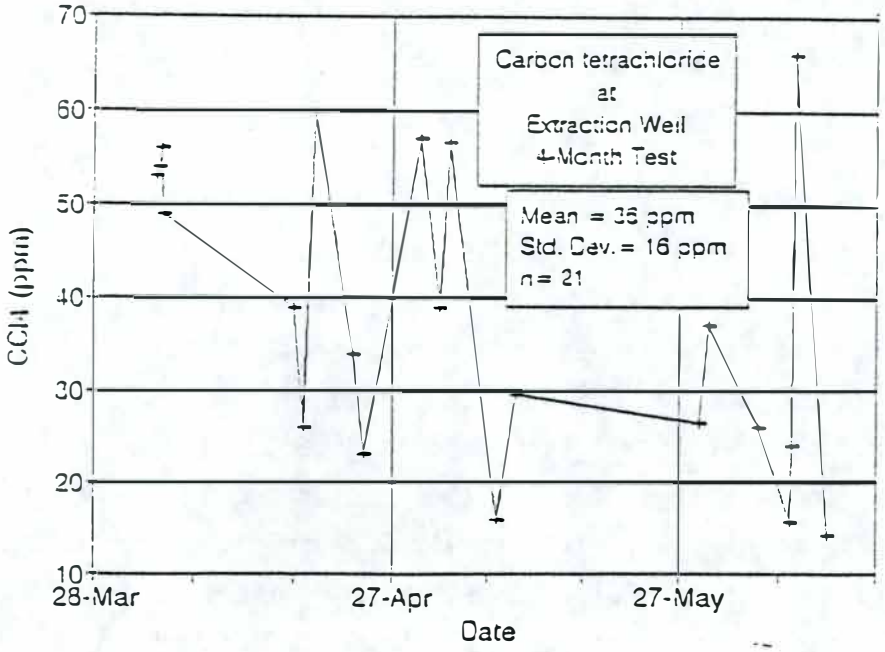


Figure 12. Concentration of CCl_4 in the extraction stream.

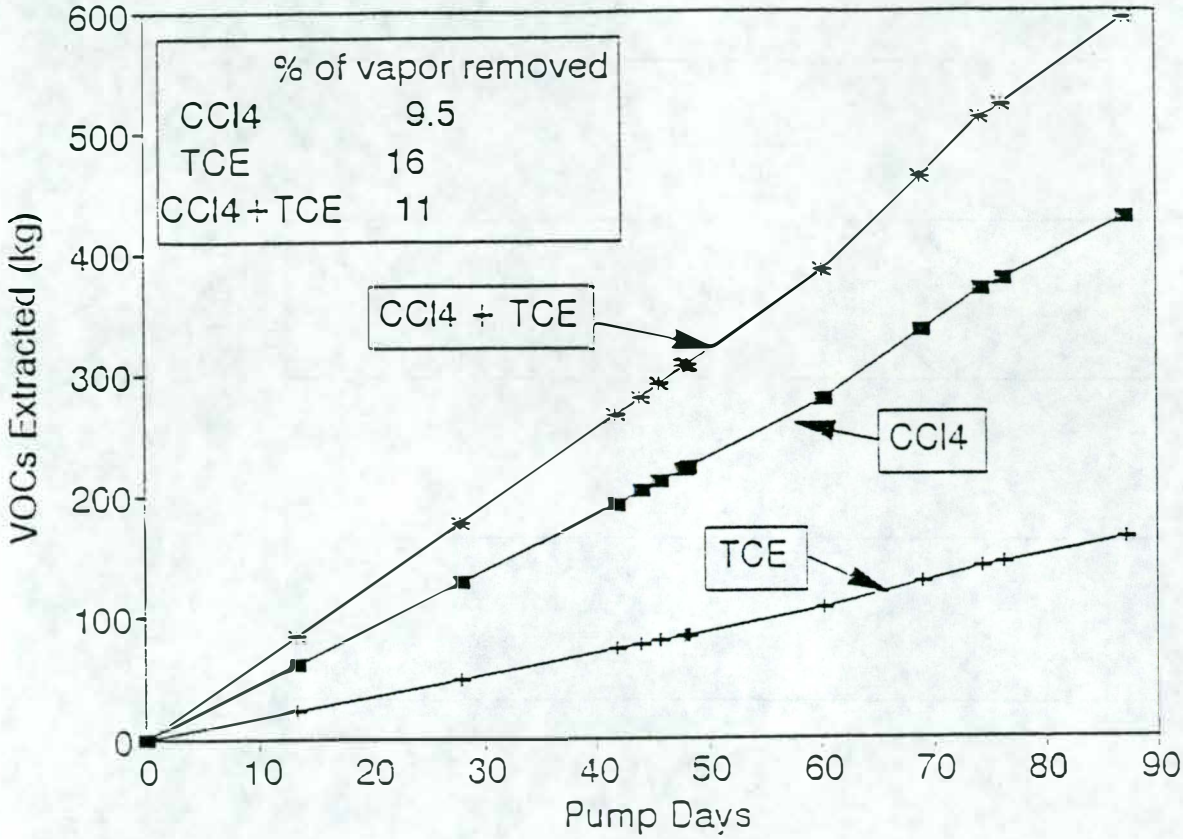


Figure 13. Cumulative CCl_4, TCE and CCl_4 + TCE extracted.

The VOCs in the vapor phase represent 3% of the total VOC disposed, 13% remains in the original disposal containers, and 84% of the VOCs have diffused to the atmosphere.

The four month average concentration of CCl_4 was plotted versus depth for each monitoring well inside the SDA (i.e., 8801D, 8902D and D02) and is shown in Figure 14. In general, the concentration of CCl_4 increases with depth to about 100 ft then decreases toward 240 ft. The general features of these plots (i.e., the large bulge at depth) were predicted with numerical transport models and referred to as the dying source term effect. The dying source term effect results from very high concentrations occurring in the waste pits and trenches following disposal of VOCs. As CCl_4 diffuses from the trenches, depleting the buried wastes of CCl_4, concentrations in the upper regions are reduced. As diffusion continues CCl_4 is transported toward deeper depths and upward through the soil surface. Thus, the high concentration bulge develops and appears to move downward although total VOCs in the vadose

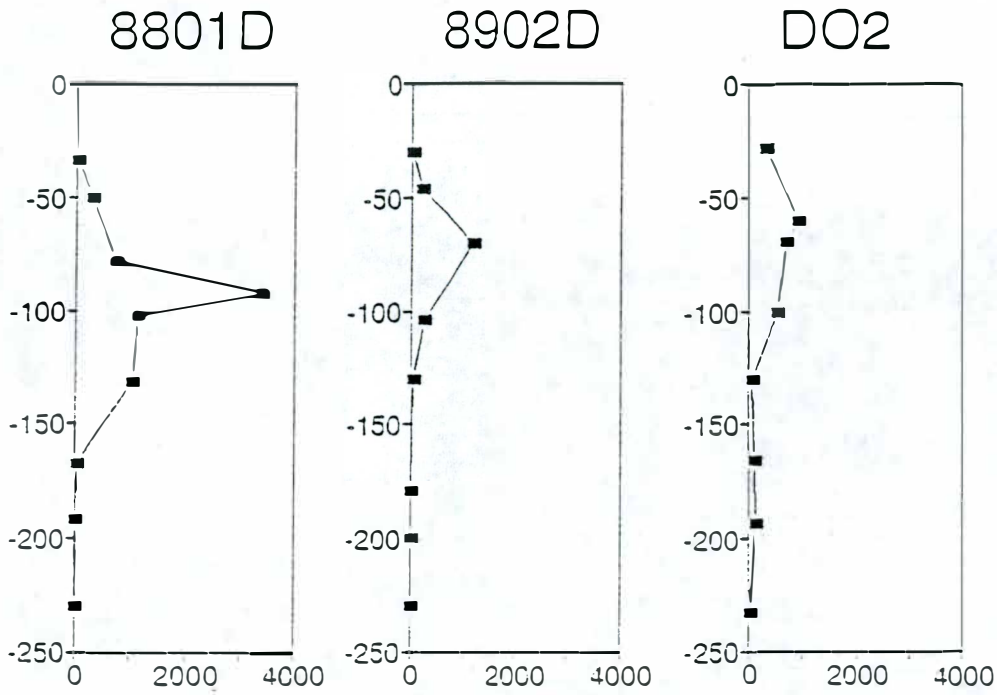
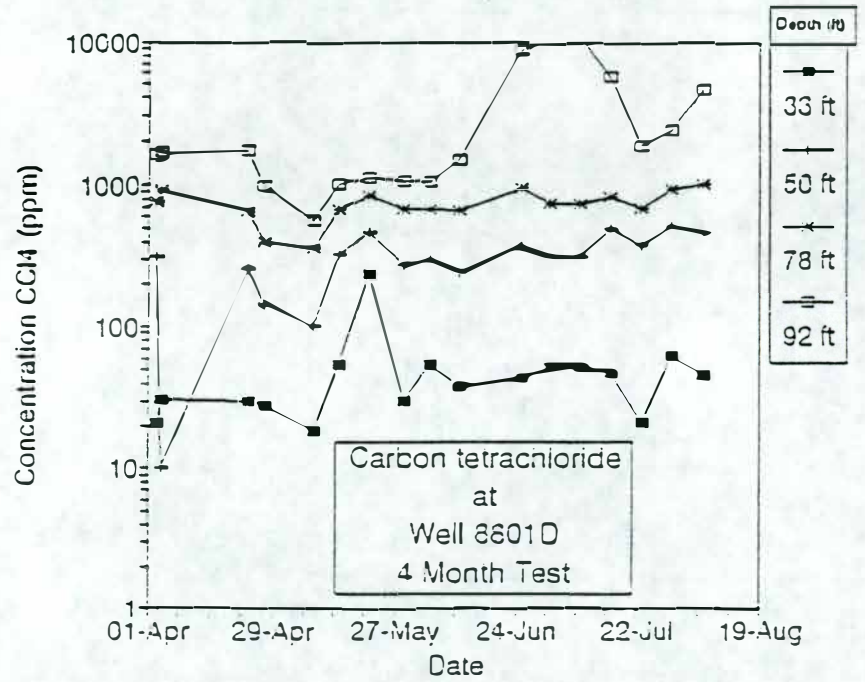


Figure 14. Concentration of CCl_4 as a function of depth in the monitoring wells.

zone decrease with time (Walton et al, 1988). The CCl_4 concentration in well 8801D at 92 ft is greater than 3000 ppm. These high concentrations may also be occurring in wells 8902D and DO2, however, since there are no ports located at 92 ft in 8902D or DO2; this high concentration would be missed. These results indicate that placement of ports, based on logs of the wellbore, should be enhanced with actual concentration measurements at each proposed sampling port location. Figure 14 was constructed using the average values shown in Figures 15, 16, and 17. The upper portion of Figure 15 shows CCl_4 concentration values below 92 ft. The concentrations at and above 92 ft do not indicate any clear trend with time. The CCl_4 concentrations at 102 and 131 ft show an increase with time, possibly indicating the bulge in the plume is migrating downward with pumping operations. Since half the extracted volume of gas was found to be coming from the 192 ft rubble zone, the downward movement of the plume would be expected. Also, the large volume of gas being obtained from the rubble zone at 190 to 195 ft indicates upward movement that would account for decreasing concentrations of CCl_4 seen at 192 and 230 ft.



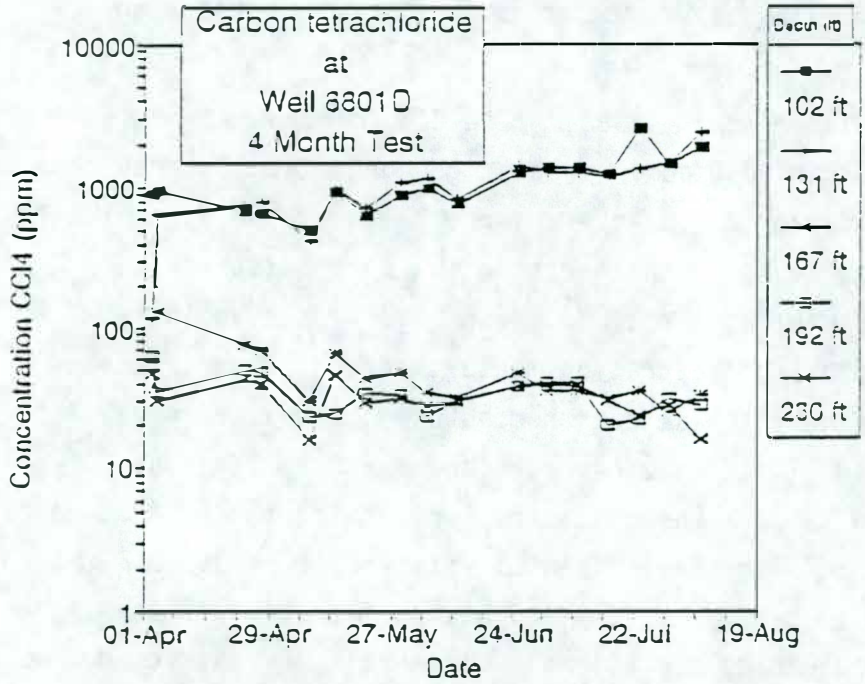


Figure 15. Concentration of CCl_4 in monitoring well 8801D as a function of time.

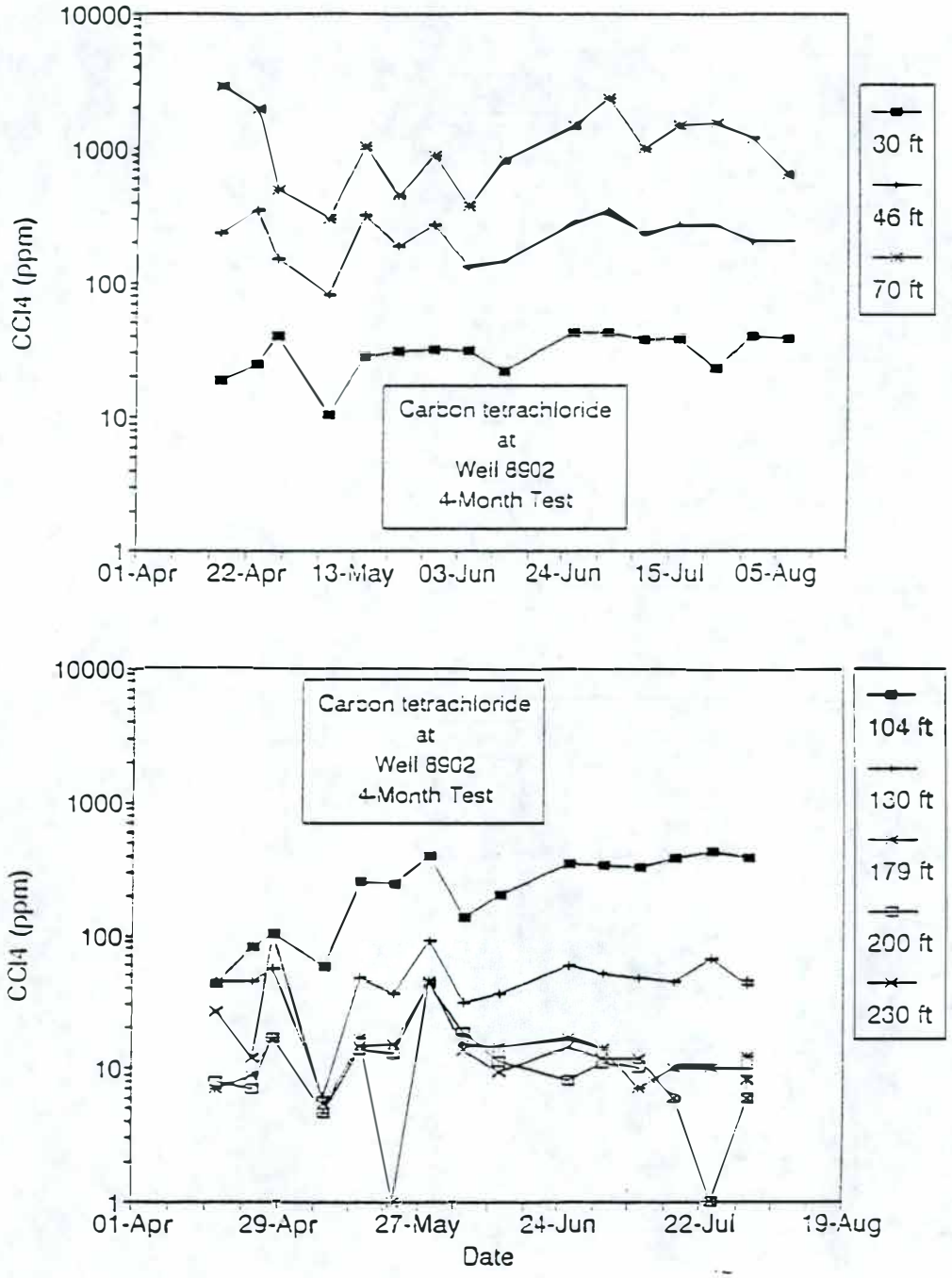


Figure 16. Concentration of CCl_4 in monitoring well 8902D as a function of time.

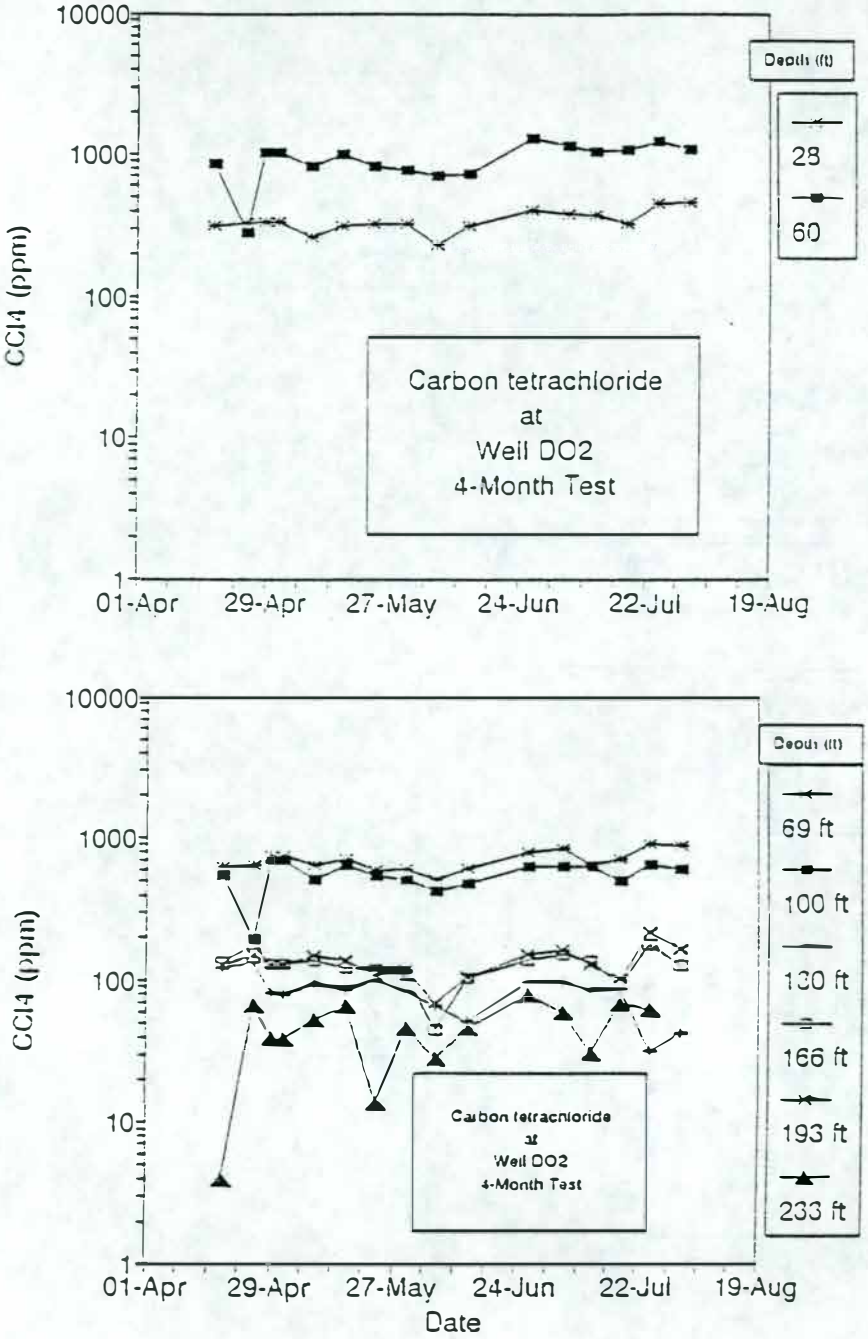


Figure 17. Concentration of CCl_4 in monitoring well DO2 as a function of time.

Extended operation of a year or more at the 500 scfm extraction rate, would yield verifications of these explanations. Also, numerical modeling would serve to validate these findings. While the trends at 102, 131, 192, and 230 ft are easily explained, the decreasing concentration at 167 ft over time does not fit well with this model of system behavior.

Figure 16 shows the CCl_4 concentrations at well 8902D over time. The only possible trend occurring at this monitoring well was found at 104 ft. The apparent increase in CCl_4 concentrations over time is the result of relatively low CCl_4 concentrations found for the first four samples analyzed. Thus, the apparent trend could have resulted from sample port purging effects following installation of the monitoring ports.

Figure 17 is the result of CCl_4 analysis done at well D02.

4. GEOLOGICAL PROPERTIES, SYSTEM VARIABLES, AND OPERATION

The volume of soil gas that can be removed from beneath the SDA is directly proportional to porosity. Thus, more accurate estimates of the underlying basalt porosity will lead to an improved estimate of the amount of VOC contaminant to be removed by VVE. Also, the time needed for remediation will be better determined if the total volume of contaminated gas to be processed is known. While porosity is a geological controlling variable for total volume of soil gas to be extracted, hydraulic conductivity is the geological control determining the rate the extraction process can be carried out. Thus, improved estimates of hydraulic properties will contribute to sizing of future extraction equipment.

Estimates of the porosity of the basalt can be substantially improved through the analyses of carefully executed tracer tests. Both small and large scale tests can be performed. Small local scale tests will establish an improved correlation between basalt type and porosity. Large scale tests will establish the effective porosity of the layered system under the SDA. The small scale local test can be carried out within single boreholes by injecting a tracer gas into one sample port and monitoring its concentration in adjacent sample ports. This test would also lead to improved estimates of the diffusion coefficients of VOCs in the basalt. While the TSVVE system is in operation, large scale porosities can be estimated from data obtained while injecting a tracer into a sampling port and monitoring concentration at the extraction well. In addition to large scale porosity, estimates of dispersion coefficients can be computed from data sets obtained during this test.

As new wells are added to the extraction system, pump tests, using open boreholes, should be conducted prior to installing gas ports to ensure the pumping rates are adequate for the permeability estimates. Also, using inflatable packers to construct the monitoring sampling port systems would allow the borehole to be converted to an extraction well should that be desired at a later date. Convertible wells would lead to a more flexible

design in that cleanup of high concentration zones could proceed before cleanup of large volumes of basalt contaminated with relatively low concentrations of VOCs.

At present, there is little information regarding vacuum pressure relative to flow rate through the basalt at high Reynolds numbers. A significant amount of this information is readily obtainable from packer tests conducted on the existing well (8901D) while operating the TSVVE system over a wide range of flow conditions. These results would support the feasibility of using very large extractors and only a few wells to achieve rapid cleanup.

4.1 Testing

4.1.1 Tracer Tests - Cross Hole and Cross Port

Improved estimates of the travel times from point to point in the subsurface would enhance our understanding of transport phenomena. Based on the small pressure difference observed between the wells during pumping, the travel times between well 8801D and the extraction well are believed to be short. Thus, if a tracer were injected at well 8801D, it would arrive within the extraction stream in a few days (perhaps hours). Deviation from this pattern would indicate sorption to be a significant factor. If this were true, rapid cleanup would be impacted. Conversely, if the travel times were found to be more rapid than current expectations, the effective porosity could be less than current estimates and lead to accelerated cleanup. The tracer test can be done from monitoring well to extraction well and also from sample port to sample port within a monitoring well. These tests will improve the current estimates of the volume of soil gas that will be pumped, provide verification of current models, and thus improve the design of a PSVVE system.

4.1.2 Sample Port Tests

The sample port tests conducted at the monitoring wells were intended to provide data for horizontal conductivity estimates. Results of these tests were inconclusive due to the pressure drop generated by flow through the 3/8-in tubing connecting the sample port to the ground surface. This was particularly true for gas ports located in areas of high permeability. In order to eliminate the effects of this head loss, the pressure must be monitored in the sampling port.

To further determine properties of the basalts, pump tests using inflatable packers need to be carried out. These tests will provide data for conductivity estimates and data for improving estimates of the plume distribution under the RWMC.

4.1.3 Flow Tests

Flow tests performed in the extraction well identified two intervals dominating the extraction process. However, the presence of the well screen in the extraction well prevented precise measurements of flow. Thus, to better quantify the properties of the intervals dominating the extraction process, flow tests with the well screen removed are required. The test procedure used should also provide the use of inflatable packers to permit isolation of dominating intervals. Thus, allowing larger pressure changes to be seen at the monitoring well.

5. TRANSPORT MODELING STATUS

The transport modeling effort will provide information to enhance the PSVVE system design and eventual cleanup of the organic contaminants. Further PSVVE system design considerations are given in Appendix B. The current modeling effort involves a full three-dimensional transient simulation beginning from the growth of the VOC plume upon emplacement of the wastes to the cleanup of the subsurface using various VVE configurations. This model incorporates the most recent and up-to-date information regarding subsurface geometry, source term strength and locations, and hydraulic and transport properties.

Preliminary to the three-dimensional model, a two-dimensional axisymmetric model was developed for calibration purposes. This preliminary model includes laterally continuous basalt layers, sedimentary interbeds, and the 190-ft rubble zone. In addition to being used to obtain large-scale estimates for soil properties, this model has also provided insights into the possible flow patterns that exist around the current extraction well. The calibration process was initiated by using the vertical conductivity estimates from barometric data and then adjusting these to match the observed flow rates from the extraction well flow test. The flow pattern and corresponding travel times resulting from the calibration process (assuming a 500 scfm pump rate) are shown in Figure 18. The flow lines indicate that for intervals extending several feet above the 110-ft interbed, flow is nearly horizontal toward the well. One reason why concentration changes could not be seen above 110 ft is that the plume is moving horizontally in this region. Thus, as soil gas is being removed it is replaced by gases of nearly the same concentration.

The effect of the 190-ft rubble zone on the flow of soil gas can also be seen in Figure 18. The figure indicates a strong upward pattern in flow toward 190 ft. This vertical flow suggests soil gases of low VOC concentration are being drawn from depths below 240 ft. Thus, concentrations in the monitoring wells from below 190 ft should decrease with pumping. This

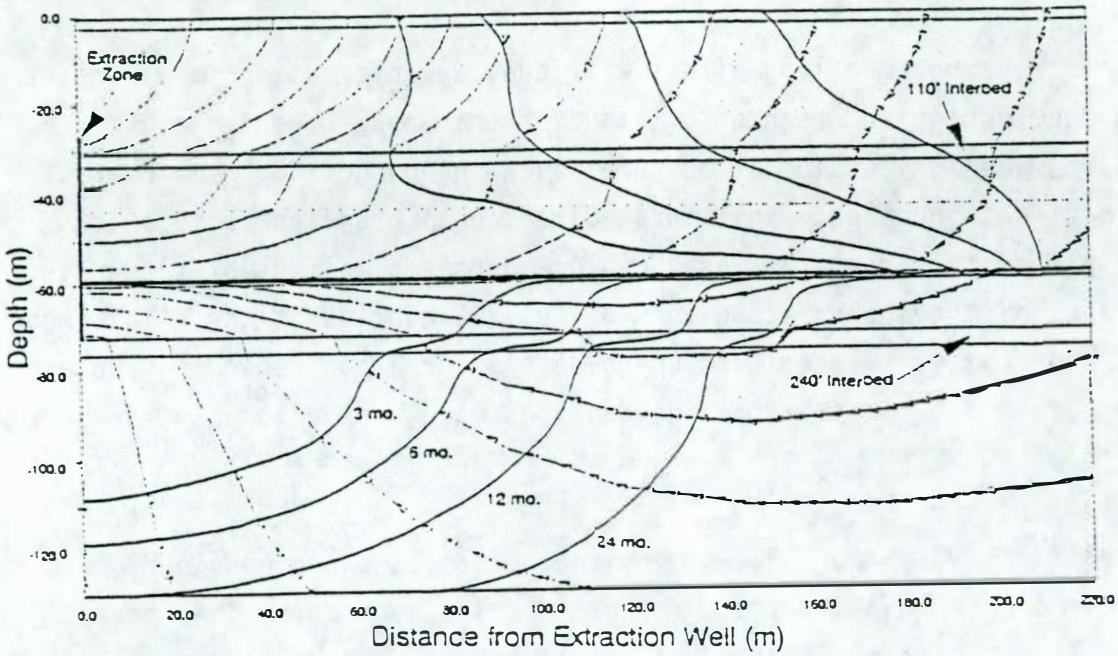


Figure 18. Soil gas flow pattern around the extraction well as a function of depth and radius.

was evident in the field data as decreasing concentrations at depths below 167 ft were noted in well 8801D.

The estimated travel times from various points in the basalts to the extraction well are imposed on the flow patterns shown in Figure 18. Upon examination of these, it is possible that soil gas extracted from the 190-ft rubble zone during the four month test could have come from monitoring well D02 (150 m away). These travel times can be substantiated using cross bore hole tracer tests.

The VOC transport model will be calibrated based on concentrations observed in the monitoring wells over time, pressure drawdowns in nearby monitoring wells, and the use of tracer tests. Once calibrated, the transport model will provide VOC concentration distributions over time, extraction rates, and eventual cleanup times. These transport model results can be used to optimize future extraction well spacing, depth, and pump rates.

6. TEST SCALE VAPOR VACUUM SYSTEM OPERATION PROBLEMS AND CORRECTIVE ACTIONS

The problems encountered during the operation of the TSVVE system included a HNu-201 gas analyzer spiking problem, HEPA filter failures condensation in the HNu-201 gas analyzer sample lines, problems encountered during data collection, and DAS operation.

The spikes generated were indicated by the HNu-201 gas analyzer or when gross VOC concentration exceeded the 25 ppm alarm limit on the exhaust side of the carbon beds when, in fact, concentrations did not exceed the alarm limits. The problem was overcome with the installation of a five second time delay relay which required the HNu-201 gas analyzer to generate the alarm trigger for at least five seconds to cause a shut down. The spiking problem was later attributed to a defective ultraviolet ionization tube. If a more maintenance free gross VOC detector can be identified, it should be considered as a replacement instrument for the HNu-201 gas analyzer.

The HEPA filter failed following the installation of the new extraction pump. While it is possible that condensation accumulated on the filters during the period of inactivity, rust particulate, welding slag, and quartz grains were found in the filter housing. The purpose of the cyclone separator was to prevent particulate from reaching the HEPA. Thus, particulate in the filter housing indicates that the cyclone separator did not perform as expected and should be replaced with a more reliable particulate trap.

Following detection of condensation in the HNu-201 gas analyzer sampling lines, heat tape was applied to the exposed tubing, and no further condensation problems were encountered.

Lab test results obtained during the last week of the test were compared to the Field GC and the differences were noted. A more stringent comparison using standard gases will be conducted to identify and resolve differences. Another problem has been the large fluctuations seen in reported

concentrations. A QC procedure was put in place and has reduced the problem, but continuing effort needs to be expended in this area. One improvement would be to provide formal training to the GC operators in addition to the informal training conducted by Field team leader.

During the operation of the DAS, a software problem was encountered that caused the DAS to lose data over 24 hour periods in an intermittent fashion. The DAS vendor has provided new software and preliminary tests indicate the problem has been solved.

7. CONCLUSIONS

During the four month test, the TSVVE system operated a total of 2090 hours; 65 million ft^3 of soil gas was extracted, and 429 kg of CCl_4, and 163 kg of TCE was removed from the basalts beneath the RWMC. Thus, VVE should be considered a viable remedial technology for removal of VOC from the RWMC.

Since 50% of the soil gas extracted originated from the rubble zone at 190 ft, the rubble zone dominated the gas movement pattern near the extraction well. The presence of the rubble zone acted to increase the effective radius of the extraction well by producing a more vertical soil gas movement pattern. Thus, the rubble zone at 190 ft will be an important consideration in the design of future systems.

A numerical model was formulated to match flow rates in the extraction well flow test. The preliminary modeling effort showed a strong pattern of vertical flow toward the rubble zone at 190 ft. A similar pattern was observed in soil gas concentration data. The model also indicated that travel times from the closest monitoring well to the extraction well ranged from one to several months. These model and field results indicate that concentrations as far as 50 ft from the extraction well were affected. Extended operation would impact a larger region and trends in concentrations would become more clearly defined. These results together with pump test data indicate that extraction rates in the order of 2000 - 3000 scfm can be achieved. Thus, TSVVE can be considered a viable interim remedial action.

8. REFERENCES

Baca, R. G., J. C. Walton, and A. S. Road, 1988, "Organic Contaminant Release from a Mixed Waste Disposal Site: Analysis of Vapor Transport Through the Vadose Zone and Site Remediation," Proceedings of the Tenth Annual DOE Low-Level Waste Management Conference, Denver, CO. 1988.

Carslaw, H. S., and J. C. Jaeger, 1959, Conduction of Heat in Solids, Oxford University Press, pp. 510.

EG&G Idaho, Inc., 1990, Remedial Investigation/Feasibility Study Work Plan for the Subsurface Disposal Area, Radioactive Waste Management Complex at the INEL, Draft, Idaho National Engineering Laboratory, EGG-WM-8776.

Leenheer, J. A., and Bagby, J. C., 1982, Organic Solutes in Ground Water at the Idaho National Engineering Laboratory, IDO-22061, U.S. Geological Survey, Water Resources Investigation 82-15, Idaho Falls, Idaho.

Rauen, C. D., 1990, Sampling and Analysis Plan for the Radioactive Waste Management Complex Subsurface Disposal Area RECRA Facility Investigation/Corrective Measures Study Task: Vapor Vacuum Extraction, Rev. 2, EGG-WM-8381.

Spang, N. W., 1990, Health and Safety Plan for Operations Performed for the Environmental Restoration Program Task: Vapor Vacuum Extraction, Rev. 2, EGG-WM-8689.

Walton et al., 1989, "Model For Estimation of Chlorinated Solvent Release from Waste Disposal Sites" Journal of Hazardous Materials, 21.

APPENDIX A

THE FOUR MONTH TEST
START/STOP TIMES

APPENDIX A

THE FOUR MONTH TEST START/STOP TIMES

Start	Stop	Cause
04/12 07:28	04/25 14:54	unknown
04/25 15:36	05/10 07:53	absorber swap
05/24 16:21	05/24 16:23	restart testing
05/24 16:37	05/24 16:43	restart testing
05/24 17:01	06/07 08:35	absorber sampling
06/07 08:51	06/07 12:13	HNu-201 Gas Analyzer
06/07 13:33	06/07 16:11	use other absorber
06/07 16:13	06/09 19:11	unknown
06/09 19:23	06/09 19:41	storm
06/10 13:41	06/11 13:18	check radon ports
06/11 13:32	06/11 13:38	install radon ports
06/11 13:40	06/12 08:04	unknown
06/12 08:14	06/13 10:52	unknown
06/13 11:48	06/13 12:40	unknown
06/13 13:18	06/13 18:20	unknown
06/13 19:18	06/13 20:30	unknown
06/13 22:26	06/13 23:22	unknown
06/14 00:12	06/14 00:46	unknown
06/14 00:58	06/14 10:41	planned work
06/14 13:54	06/14 13:58	same work
06/14 16:29	06/14 16:34	same work
06/18 10:00	06/18 13:14	check zero flow reading
06/18 13:16	06/18 16:54	HNu-201 Gas Analyzer spike
06/19 14:34	06/19 15:08	HNu-201 Gas Analyzer spike
06/19 15:10	06/19 15:12	HNu-201 Gas Analyzer spike
06/21 10:34	06/21 12:52	HNu-201 Gas Analyzer spike
06/21 13:00	06/21 14:26	R5 relay work
06/21 14:28	06/21 15:22	R5 relay work
06/28 13:18	07/10 14:35	install lab flowmeter
07/10 16:00	07/12 08:08	flow meter calibration
07/12 11:06	07/12 11:44	flow tests
07/12 13:56	07/12 13:58	reset HEPA alarm
07/12 14:08	07/12 14:10	flow tests
07/12 14:20	07/12 14:24	flow tests
07/12 14:28	07/12 14:40	flow tests
07/12 14:48	07/16 13:17	unknown
07/16 13:19	07/16 13:23	unknown
07/16 13:27	07/16 13:43	unknown
07/16 13:47	07/16 13:49	unknown
07/16 14:15	07/16 14:23	unknown
07/16 14:29	07/19 09:26	unknown

Start	Stop	Cause
07/19 10:10	07/19 10:14	unknown
07/19 10:18	07/19 10:22	unknown
07/19 10:26	07/19 10:32	unknown
07/19 10:42	07/19 11:04	unknown
07/19 11:10	07/19 19:40	unknown
07/20 09:18	07/24 16:03	end of 2 week hi flow test
07/25 13:47	07/25 13:55	DOP test failed
07/25 15:15	07/25 15:27	no smoke in generator
07/25 15:35	07/25 15:37	DOP test failed
07/31 09:27	07/31 09:37	DOP test passed restore system
07/31 09:41	08/02 05:41	unknown
08/02 06:55	08/03 20:47	unknown
08/03 20:51	08/06 08:05	unknown
08/06 08:07	08/07 13:17	to reset HEPA alarm
08/07 13:19	08/11 12:37	unknown
08/11 12:43	08/13 08:27	end of 4 month test

APPENDIX B

PRODUCTION SCALE VAPOR VACUUM EXTRACTION SYSTEM CONSIDERATIONS

B-1. PRODUCTION SCALE VAPOR VACUUM EXTRACTION SYSTEM CONSIDERATIONS

Implementation and system design enhancements can be achieved through further testing to delineate active sources of VOCs, better define the hydraulic properties of the underlying basalts, and more accurately determine the extent and mass of the contaminant plume. The design optimization requires tradeoffs between extraction zone depth; number, size, and depth of wells; extractor life expectancy; and operating costs.

B-1.1 PSVVE Recommendations

The number of extraction wells is an important design parameter because site cleanup requires the contaminant plume to be displaced with atmospheric air and a large number of wells would accelerate this process. A two level cleanup system that consists of shallow wells to extract the high concentration zones above the 110-ft interbed and a few wells used to extract the low concentration zones found below the 190-ft rubble zone should be considered.

A few wells that extract soil gas from the 190-ft rubble zone would remove VOCs from the basalts, but could have the effect of drawing the contaminant plume above the 110-ft interbed toward the Snake River Plain Aquifer. If the risk of moving the plume to deeper depths were deemed too high, a large number of shallow wells could be used to remove VOCs from the shallow depths prior to pumping the 190-ft rubble zone.

Man-made radionuclides were not detected at the extraction flow rates used during the four month test. Therefore, if man-made radionuclides are not detected at proposed higher flow rates, removal of the HEPA filter should be considered to improve efficiency of the VVE process.