Paper Number:
DOE/MC/32109-97/C0791

Title:
Barometric Pumping with a Twist: VOC Containment and Remediation without Boreholes

Authors:
W. Lowry
S.D. Dunn
D. Neeper

Contractor:
Science & Engineering Associates, Inc.
1570 Pacheco, Suite D-1
Santa Fe, NM 87505

Contract Number:
DE-AR21-95MC32109

Conference:
Industry Partnerships to Deploy Environmental Technology

Conference Location:
Morgantown, West Virginia

Conference Dates:
October 22-24, 1996

Conference Sponsor:
Morgantown Energy Technology Center

Disclaimer

Barometric Pumping with a Twist: VOC Containment and Remediation without Boreholes

William Lowry (blowry@seabase.com; 505-983-6698)
Sandra Dalvit Dunn (sdunn@seabase.com; 505-983-6698)
Donald Neeper (dneeper@aol.com; 505-662-4592)
Science & Engineering Associates, Inc.
1570 Pacheco, Suite D-1
Santa Fe, NM 87505

Introduction

The majority of the planned remediation sites within the DOE complex are contaminated with volatile organic compounds (VOCs). In many instances the liquid contamination sources have not reached the water table, and do not pose an immediate threat. Volatiles emanating from these sources typically disperse over a soil volume much greater than the initial source. Containment of the volatiles is desirable to preclude vapor transport to the water table. For many remediated sites, residual contamination also exists which could not practically be removed by the applied remediation technology. These circumstances result in sites with contamination of limited risk, but by regulation they must still be controlled. These sites will ultimately require remediation of some type, either by active vapor extraction, bioremediation, or excavation and ex-situ soil treatment. The cost of remediating these sites can range from $50K to well more than $150 K, depending on site characteristics, contaminants, and remediation method. The remediation solution being developed in this project serves as an in-situ containment and extraction methodology for sites where most or all of the contamination resides in the vadose zone soil. The approach capitalizes on the advective soil gas movement resulting from barometric pressure oscillations, and is inherently inexpensive due to its passive design.

Oscillations in barometric pressure are both diurnal, corresponding to daily heating and cooling of the atmosphere, and of longer time periods, resulting from the passage of weather fronts. Daily variations will average about 4 to 5 millibars (one millibar is roughly one thousandth of an atmosphere) while those due to weather front passage can be 25 or more millibars. As the barometric pressure rises, a gradient is imposed on the soil gas which drives fresh surface air into the soil. As it drops, gas vents upward from the soil into the atmosphere. The pressure changes and resulting gradient are depicted in Figure 1, which shows data recorded in Albuquerque, NM [1]. The total movement of soil gas is dependent primarily on the magnitude and period of the pressure oscillations, the soil gas permeability, and the depth to an impermeable boundary. This boundary can be the water table, bedrock, or extensive layers of very low permeability material, such as caliche or clay. Since the fractional change in atmospheric pressure is small (typically 0.5 percent) the overall soil gas displacement during the daily cycle is also small (with an estimated range of centimeters to meters). Furthermore, the daily oscillations in atmospheric pressure always return to a mean value. Over time, no net soil gas displacement occurs in a homogeneous medium due to barometrically-induced advective forces alone.

Research sponsored by the U.S. Department of Energy’s Morgantown Energy Technology Center, under contract DE-AR21-95MC32109 with Science & Engineering Associates, Inc. 1570 Pacheco, Suite D-1, Santa Fe, NM 87505

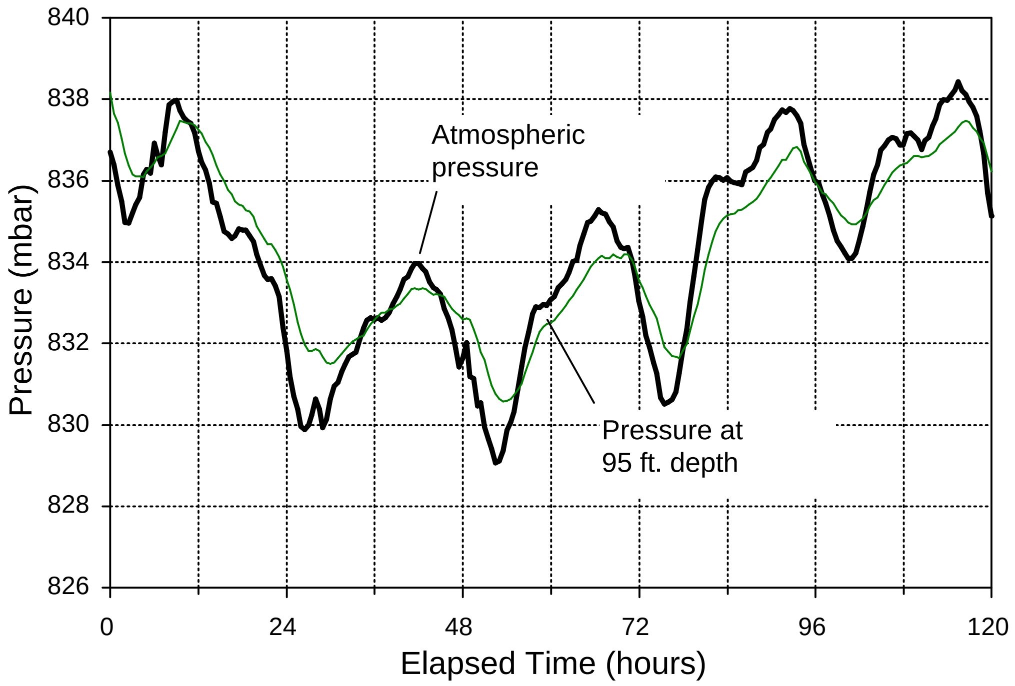


Figure 1. Barometric pressure, and soil gas pressure response at 95 ft. depth, recorded in Albuquerque, NM [1].

Displacement of soil gas can be controlled using surface features which impede the downward movement of vapors, but allow upward movement. The design evaluated in this project incorporates a surface seal, a plenum, and an extraction vent valve. These components are depicted in Figure 2.

Directly above the contaminant plume is a layer of highly permeable material, such as pea gravel, which forms a collection plenum for the upward-moving soil gas. A surface seal is placed outward from the collection plenum directly on the soil surface to form a buffer zone which controls the radial movement of air flowing into the soil during the high pressure periods. The surface seals an impermeable, rugged material (such as a geotechnical membrane) which forms a no-flow boundary at the ground surface. The plenum is connected to atmospheric pressure with a high volume vent valve, open only when soil gas is moving upward (during a drop in the barometric pressure). In operation the system ratchets the soil gas upward by allowing normal upward flow during barometric lows but restricting downward air flow during high pressure cycles. High pressure periods result in restricted downward gas movement because the vent valve is closed and soil gas flows around the plume ("inhaling"). When the atmospheric pressure is lower than the soil gas pressure at depth, soil gas flows upward and the surface seal forces the contaminated gas into the plenum, where the opened vent valve exhausts it to the atmosphere ("exhaling").

Objectives and Approach

The objective of the Phase I effort (completed November 1995) was to evaluate the feasibility of applying surface sealing and venting features to contain and remediate volatile organic compound (VOC) contaminated soils in the vadose zone. Using analytical and numerical porous flow models, flows of soil gas due to barometric processes were predicted. This included the geometric configuration of the surface seal design, plenum, and buffer zone dimensions. The modeling evaluated the sensitivity of the extraction rate to plenum areal extent, and buffer

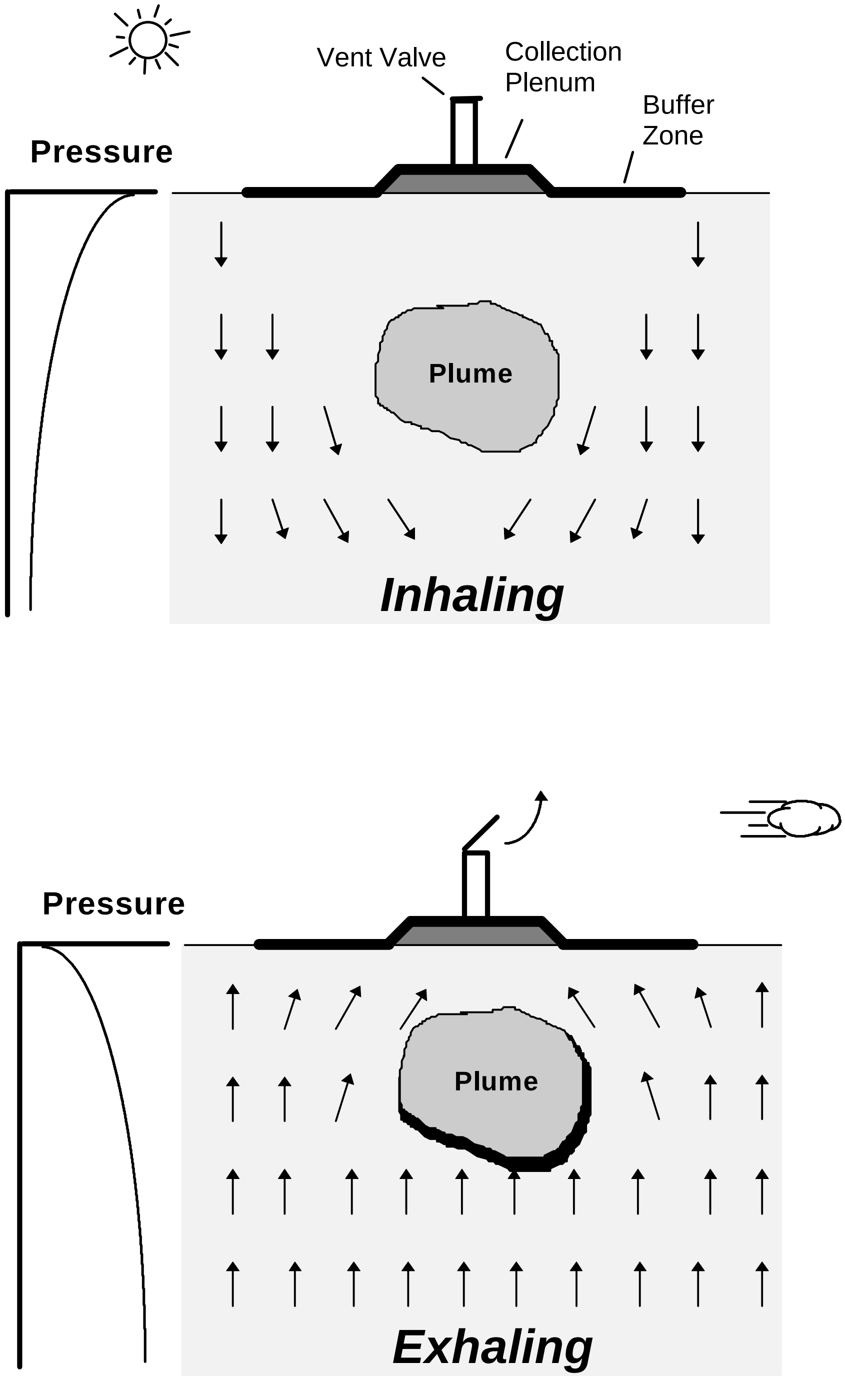


Figure 2. The surface treatment system controls the movement of soil gas due to barometric pressure changes.

zone size, particularly in relation to the depth and size of the plume. The analysis compared the advective gas flow caused by barometric pumping to the estimated diffusion rate of typical contaminants.

The following technical activities were completed in Phase I [2]:

- Meteorologic data for seven sites, selected based on their proximity to major DOE installations, was reviewed. This analysis established the magnitude, variability, and frequency of barometric pressure oscillations. Air temperature and wind speed data were also compiled.
- Transport and hazard characteristics of the major volatile contaminants found across the DOE complex were summarized.
- The naturally occurring soil gas displacement, due to an oscillatory surface pressure, was predicted for a range of geometric and flow conditions. This analysis defined the highest attainable upward soil gas velocities under ideal conditions.
- The opposing contaminant transport processes were analyzed to determine the net upward velocities required to overcome the opposing (downward) contaminant transport. These processes include diffusion and density-induced gravitational flow due to concentration and thermal gradients.
- A transient two-dimensional analysis was conducted of a typical installation to predict the system's performance. Using the Los Alamos FEHM code, the advective gas flow resulting from the oscillatory surface pressure was predicted throughout the soil volume of interest.
- Enhancements to the system operation, capitalizing on wind and solar heating, were studied to determine their potential boost to the system's performance.
- Costs of a typical system installation were compared to remediation costs using conventional techniques.

In Phase II the remediation system will be installed at the Radioactive Waste Management Complex (RWMC) of the Idaho National Engineering Laboratory. The system will cover an area of the landfill known to be contaminated with chlorinated hydrocarbons, deposited in shallow trenches. Operation will be monitored for a 12 to 18 month period to evaluate the degree of impact the installation has on soil gas displacement.

Technology Description

In its installed form, the typical barometric remediation system is depicted in Figure 3. The four key components are the surface seal, the plenum, the vent assembly, and the soil vapor monitoring points.

Surface seal

The role of the surface seal material is to contain soil vapors in the plenum region and prevent flow into or out of the soil in the buffer zone. Seal material must be resistant to soil moisture, organic contaminants, and sunlight (if exposed), and capable of multiyear emplacements. Fortunately, geomembranes have been developed for landfill installations to fill requirements more stringent than these, so a wide selection of candidate materials is available. EPDM (synthetic rubber), originally developed as a roofing material, is very rugged and resistant to exposure. In 45 mil thicknesses, EDPM costs \$0.45 to \$0.70/ft^2.

For simplicity and leak-tightness, the surface seal is one continuous sheet covering both the buffer zone and the plenum volume. It must be pliable enough to conform to the contours of the soil (the soil will be leveled to some degree before the seal is applied) and over the plenum. To minimize damage to the geomembrane from

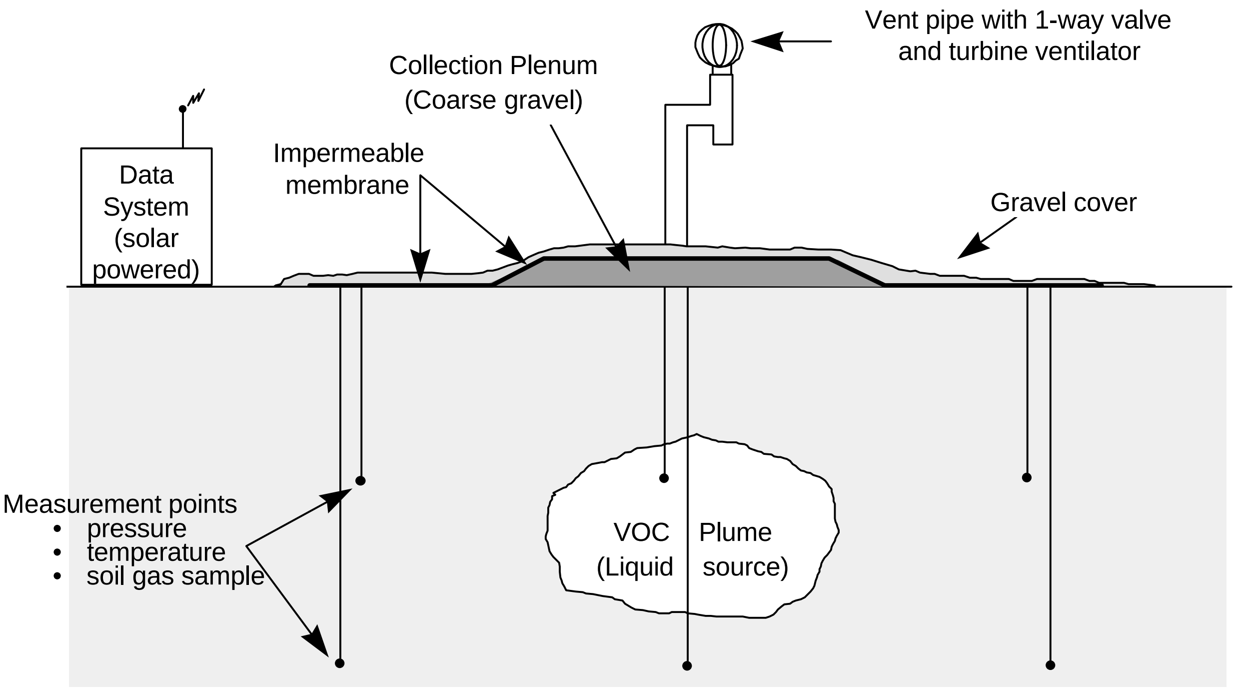


Figure 3. Typical field installation of barometric remediation system.

abrasion (due to foot traffic), exposure to the elements, or plant/animal intrusion, a shallow layer of gravel is placed over the membrane. This serves a secondary role of assuring the membrane is pressed firmly onto the soil to effect a good seal.

Plenum

The plenum serves as a collection manifold for the upward-flowing soil gas during the exhaling cycle of the system. Its basic requirements is that the plenum material have a permeability several orders of magnitude greater than the soil below. It must also be inexpensive, stable, and not pose a puncture threat to the membrane material (no sharp edges). Standard pea gravel fills these requirements with permeability in the range of 1000 to 5000 Darcies. Since it has such a high permeability, its thickness does not have to be great: six to twelve inches is adequate.

Vent assembly

The main role of the vent assembly is to allow only outward (exhaling) flow from the plenum volume. Its secondary role is to release the soil vapor high enough into the air to rapidly disperse the contaminants. The assembly consists of a vent pipe, a flapper valve, and a turbine ventilator. The surface seal membrane is clamped securely around the base of the vent pipe, which is free standing. The valve is a very low differential pressure relief valve, designed to release soil gas at overpressures less than 0.1 mbar and provide very little backpressure when open. The turbine ventilator is an enhancement which capitalizes upon the surface winds to increase the extraction vacuum in the plenum. The vent valve is designed to operate at a minimal differential pressure while maintaining a seal when no pressure differential exists allowing for flow in one direction. The approach to the design is to mount a light weight flapper valve inside the stack vent that will provide a seal by resting its mass on a sealing surface (Figure4). The valve is oriented at an angle off of vertical in the vent pipe designed to open at the lowest differential pressure attainable (less than 0.1mbar) yet still be strong enough to prevent backflow.

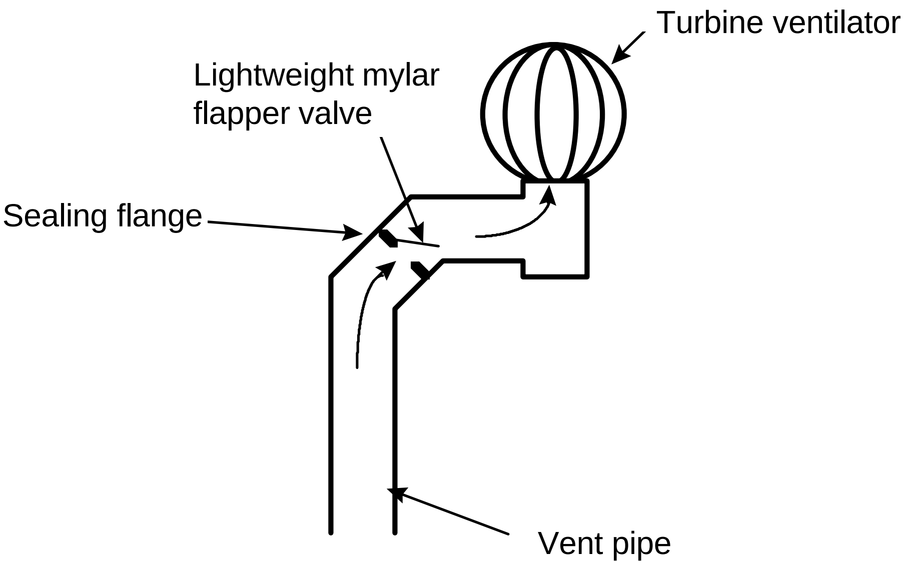


Figure 4. Relief (flapper) valve configuration

<u>Predicted Performance</u>

The role of this system design is to rectify, or minimize the downward sinusoidal component of the oscillatory soil gas movement as much as possible, to maximize the net upward velocity in the contaminated zone. The range of peak soil gas velocities attainable due to the naturally occurring variations in barometric pressure is determined analytically[2]. The average surface gas flux can be determined from the peak velocity by averaging the upward portion of the oscillatory velocity over a daily cycle. This is done by assuming that the velocity history is sinusoidal and we are only interested in the half of the sinusoid which results in positive upward flow (the one way vent valve prevents downward flow, hence resulting in a rectified flow out of the surface). Multiplying the peak velocity by $1/\pi$ yields the average velocity of the rectified sine wave over the entire period. Soil gas velocity is converted to flux by multiplying by the soil's connected, gas-filled porosity, and is presented in Figure 5. The

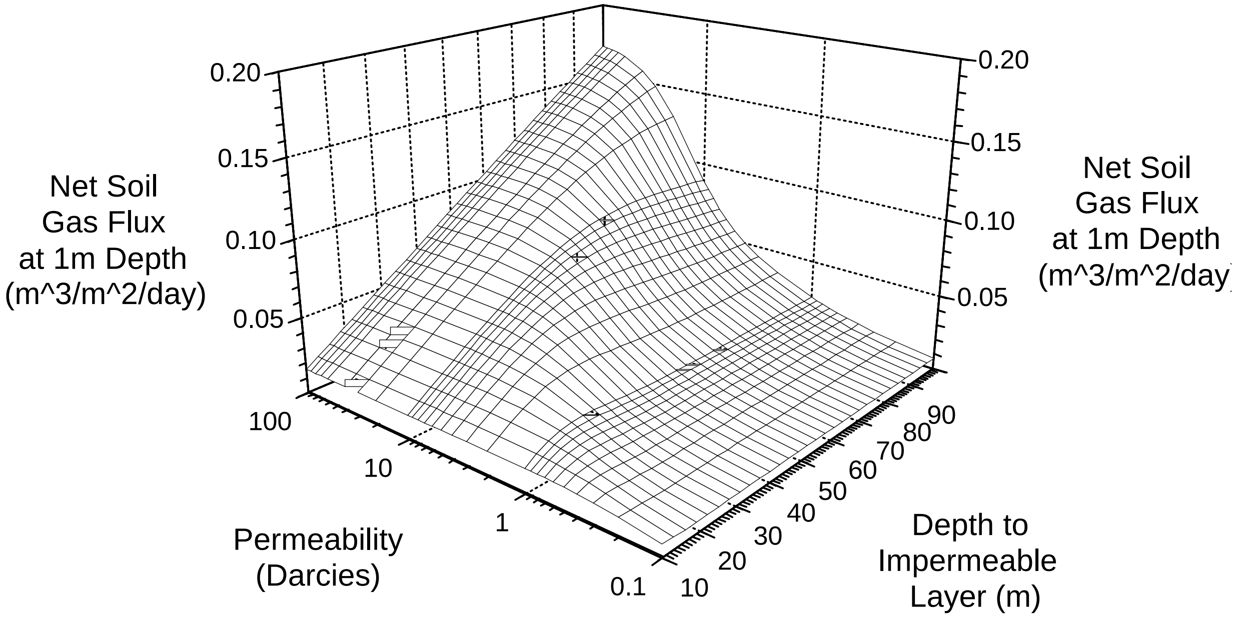


Figure 5. Maximum net upward soil gas flux attainable by the surface treatment system, given daily barometric pressure oscillations of 5 mbar and a soil porosity of 0.35.

maximum net soil gas flux attainable with the surface treatment system ranges from 0.03 to 0.07 m^3/m^2/day for 1 to 10 Darcy soil, with depths to the impermeable layer exceeding 30 m. For a 10 m diameter plenum, this yields a total soil gas extraction flowrate of 2.3 to 5.5 m^3/day. Given an air filled porosity of 0.35, 6.6 to 15.7 m^3 of soil is flushed per day.

Ideally, the surface treatment system results in a soil gas flux near the surface that is of a net magnitude equal to the upward-only component in the free field. This is attainable at the soil surface in the plenum zone. However, the gas is not constrained to flow only vertically in the soil, so the degree of rectification diminishes with depth. To determine the depth of influence of the surface treatment on soil gas flow, a transient numerical simulation was conducted with the Los Alamos National Laboratory FEHM code (Finite Element Heat and Mass transfer). FEHM is capable of modeling multiphase heat and mass transport in porous media [References 3, 4, and 5]. For this effort, gas flow only is modeled with an oscillatory surface pressure, a collection plenum connected to the atmosphere through a one way relief valve, an impermeable surface seal, an impermeable layer forming the model's bottom boundary, and a radial symmetric geometry. The geometry and properties are depicted in Figure 6. Atmospheric pressure is sinusoidal, with a period of 24 hours and a total variation of 5 mbar. The relief valve is modeled by allowing the plenum volume to have direct communication to the atmosphere when the gradient causes upward flow; the valve is closed at all other times. The soil permeability is set at 5 Darcies, and its air-filled porosity is 0.35 (these are typical properties of alluvial deposits). The depth to the impermeable layer is 100 m.

Velocity vectors at the two maximum flow times during the periodic cycle are depicted in Figure 7. Note that, as the barometric pressure drops, upward air flow occurs beneath the plenum at the same velocity as it does in the free field (away from the effects of the surface seal). Decreased vertical flow occurs beneath the buffer zone. As the barometric pressure rises, normal downward flow occurs in the free field but the scaled vectors indicate almost no downward vertical flow beneath the plenum (the vent valve is closed during this part to the cycle). It is this restricted downward flow that causes the net upward air flow over time.

The average vertical flow along the centerline of the plenum is plotted in Figure 8. At the surface inside the plenum region the average velocity is 0.2 m/day, meaning that 0.2 meters of soil gas is ratcheted up daily. This is converted to a gas flux by multiplying by the soil porosity (0.35), resulting in a surface flux of 0.2 m/day x 0.35 = 0.07 m^3/m^2/day. Note that this is equal to the flux predicted with the analytic model (see Figure 5) for similar conditions. The surface treatment effectively reduces to zero the downward flow immediately beneath the plenum, but allows unobstructed upward flow during the exhaling cycle.

The net velocity profile resulting from the numerical simulation is compared with the advective fluxes required to overcome the transport processes due to diffusion and density induced flow. Each will be summarized below (details are in Reference 2).

Diffusion

In the case of TCE evaporating and diffusing away from a one dimensional planar source, an advective upward velocity of 2x10^{-7} m/s (0.017 m/day) will overcome the diffusion rate at the source. Referring to Figure 8, the net upward velocity is above this value down to a depth of 10 m. This means that the surface treatment system, as modeled in this section, would effectively counter the diffusive transport of a liquid TCE source from the 10 m depth.

Temperature induced density gradients

Temperature induced gradients cause both upward and downward soil gas movement. However, their effects are small compared to the other processes considered. Considering normal variations of seasonal temperature in Albuquerque, for example, the density gradients resulting from cooling of the surface soil required advective upward velocities ranging from 3x10^{-7} m/s (0.026 m/day) at the soil surface. At a depth of 4 m, this drops to 1x10^{-7} m/s (0.009 m/day). The net velocity plot in Figure 8 shows 0.2 m/day at the surface and 0.08 m/day at 4 m. The temperature induced density gradients are insignificant under these conditions.

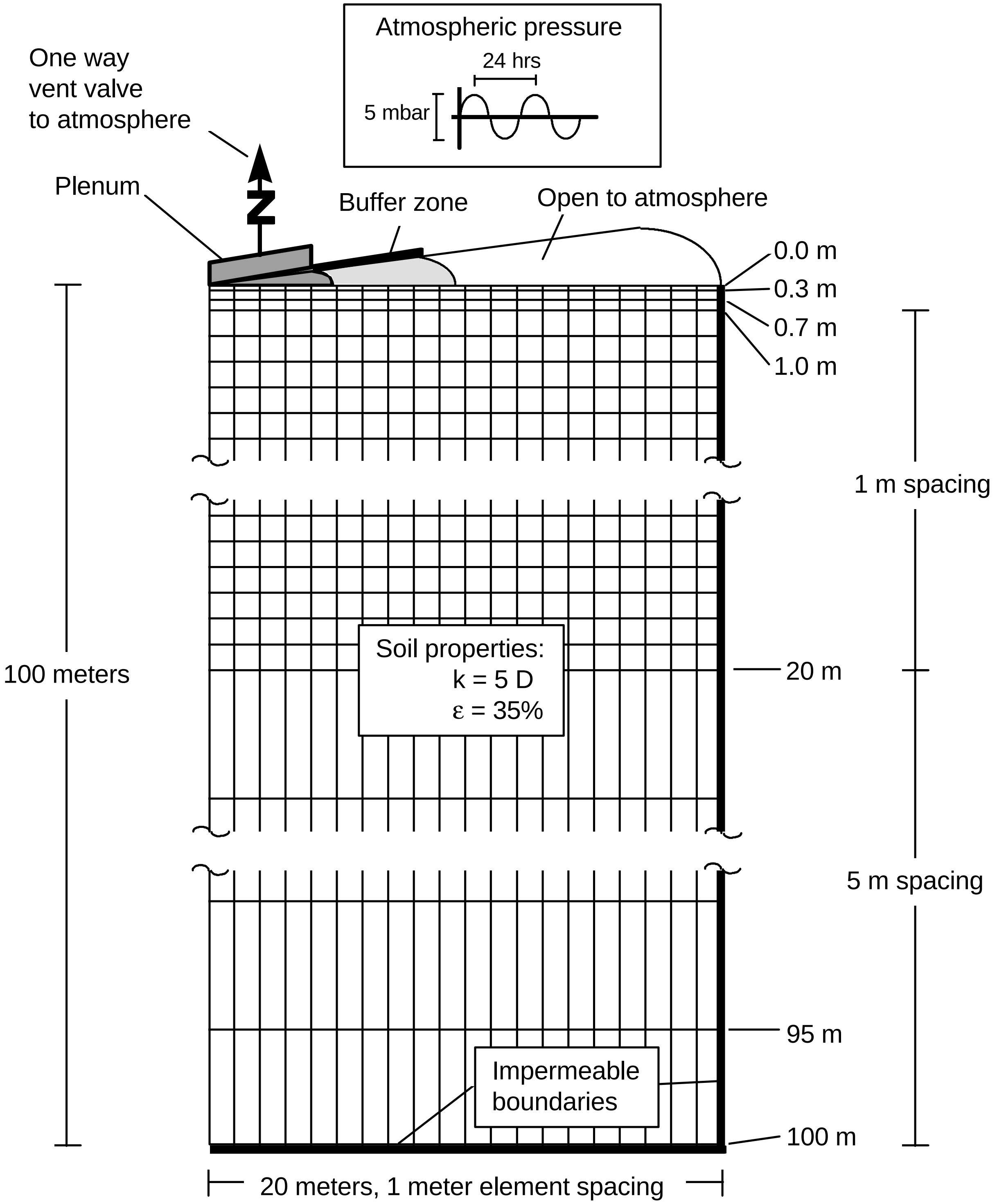


Figure 6. Geometry and properties simulated in the FEHM calculation

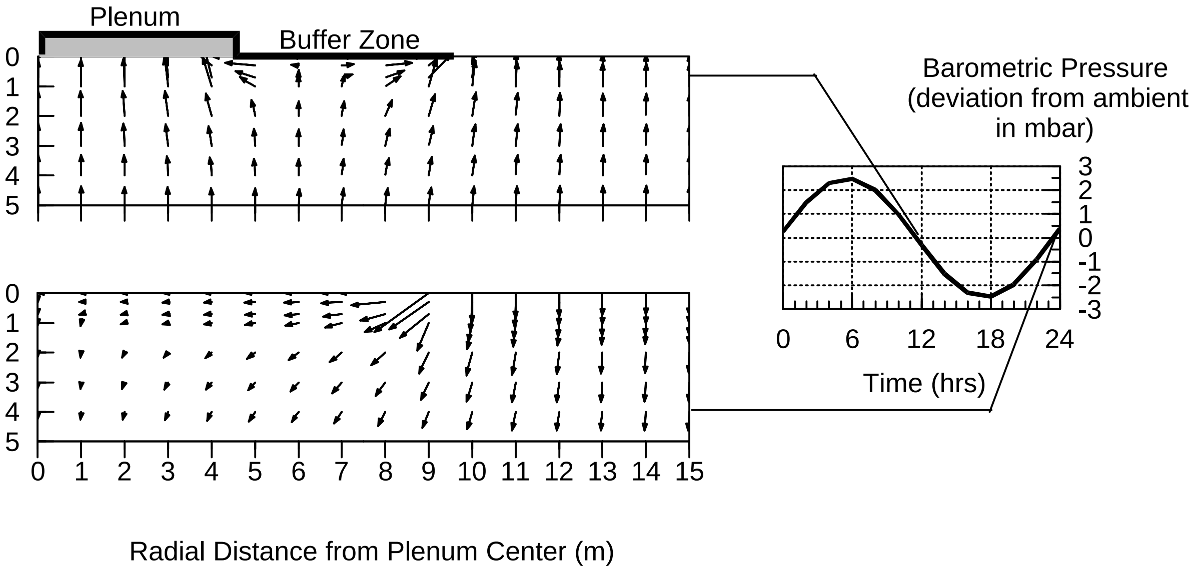


Figure 7. Resulting velocity fields due to the surface treatment.

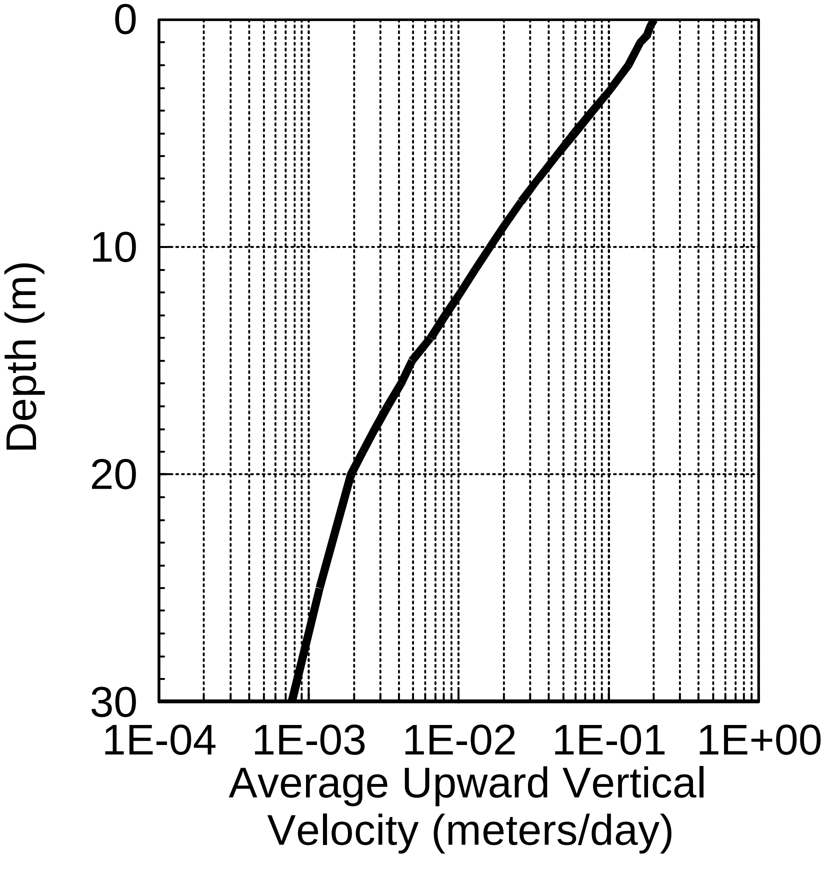


Figure 8. Net vertical velocity profile resulting from surface treatment.

Concentration induced density gradients

Since the density of TCE is 4.5 times the density of air, as it evaporates from a liquid source it results in a gas mixture that will tend to sink. This tendency will be greatest near the source and diminish with distance. The analysis showed that near a planar TCE source the diffusion will result in a concentration gradient (hence a density gradient) that requires advective velocities as high as $7x10^{-7}$ m/s (0.06 m/day). At a distance of 4 m below the TCE source, the required advective flowrate is $5x10^{-7}$ m/s (0.04 m/day). Comparing this to the net upward flows in Figure 8, we see that the surface treatment system overcomes this downward transport for a source buried as deep as 4 m in the soil.

Performance summary

The surface treatment system is capable of controlling the soil gas flows, with a maximum effect at the soil surface in the plenum region. Key performance features of the system are as follows:

- The **extraction flux**, under typical conditions, ranges from 0.03 to 0.07 m^3/m^2/day. For a 10 m diameter plenum, this yields a total soil gas extraction flowrate of 2.3 to 5.5 m^3/day.

- The **depth of influence** of the system is defined by the maximum depth at which it can overcome the other downward transport processes. The system can induce a net upward flow to counteract the concentration induced density gradient to a depth of 4 m. This is the most difficult process to overcome. Diffusion from a TCE source can be overcome with a source as deep as 10 m. Temperature induced density effects are not significant and can be overcome in all cases.

- The **maximum contaminant removal rate** is defined by how readily the source compounds volatilize and diffuse away from the source, given that the system can sweep all the contaminated vapors upward from a source. The maximum TCE transport rate from a planar source is 0.1 mg/s-m^2. If the source is 5 m in diameter and the TCE diffuses from both the top and bottom of the source, this translates to a daily removal rate of 0.34 kg, or 124 kg/year.

Applications and Cost Savings

The proposed system is applicable to VOC contamination in the vadose zone. By design, it assures that the vapors emanating from a contaminant source in the soil will not be transported downward and will, instead, be brought to the surface and released into the air in small concentrations. The process is slow but steady, and does not require excavation, boreholes, or site power for operation.

In general, this will be an attractive approach if one or several of the following conditions are met:

- The plume is not posing a significant, immediate threat to water contamination. The liquid source is not migrating downward at a rate which could not be counteracted by this system.
- The site has already been actively remediated (by vapor extraction, for example) but residual contamination exists. Incorporating this system can assure no residuals reach the water table, and it would remove residuals gradually over time.
- Usage of the site is not imminent. If, however, the site is a desirable location for a parking lot, the parking lot could perform the role of the surface seal.

The analyses presented in this document show that the surface treatment system will control and remediate volatile soil contaminants when the liquid contaminant source is as deep as 4 m in the soil. It will induce significant upward soil gas velocities in soils with typical gas permeabilities, and depths to an impermeable layer even as shallow as 20 to 30 m. These operating capabilities make it an attractive remediation technique for:

- Surface spills of fuels, solvents, and other volatile chemicals
- Buried pipe or drain line leaks

- Leaking underground storage tanks
- Shallow landfills containing hazardous volatile compounds.

Cost of a typical barometric remediation installation will be low, primarily due to the lack of earth removal and/or boreholes. The major components of an installation are listed in Table 1, which estimates the cost for installation and abandonment of the barometric extraction system. Characterization and monitoring costs are not included here because they are common to any remediation system application.

Table 1. Installation cost estimate

Cost Component	**Unit Cost**	**100 x 100 ft. Installation**
Materials:		
Sealant: 45 mil EPDM sheeting	$0.55/ft^2	$5.5
Plenum fill and seal cover gravel	$15/yd^3	9.2
Vent pipe, flapper valve, turbine ventilator, supports, vapor points	$1K/assy	1.0
Labor:		
Mobilization/demobilization	$1K	1.0
Surface grading and leveling	$45/hr	.72 (16 hr)
Installation (cover, plenum, vent)	$50/hr	3.2 (64 hr)
Abandonment (removal/reclamation)	$50/hr	3.2 (64 hr)
SUBTOTAL		23.8
Escalation (10%)		1.9
SUBTOTAL		25.7
Contingency and Proj. Mgmt. (@35%)		9.0
Total		$34.7 K

To compare with conventional techniques, the following cost estimates were produced using the Remedial Action Cost Engineering and Requirements (RACER) system developed by the U.S. Air Force. RACER includes a number of remediation technology models, several of which have been selected to illustrate costs associated with comparable methods of site remediation. These models include soil vapor extraction, in situ biodegradation, low temperature thermal desorption, and landfill disposal.

Each remediation technology model is designed to accept input from the user to define the contaminated site. For the purposes of this study, a number of assumptions were used to define a sample site. The sample site is based on a contaminated site with dimensions of 16 ft wide, 61 ft long, 16 ft deep for a total of 151 cubic yards. The contaminant is assumed to be a volatile organic compound (VOC) located in the vadose zone. The soil consists primarily of sand sized particles. Work is accomplished using safety level D. The start-up period is assumed to be 4 weeks with operation and maintenance for 24 weeks. Distance to the vendor from the site is assumed to be 200 miles. No characterization or monitoring costs are considered in these estimates.

<u>Soil Vapor Extraction</u>

Soil vapor extraction is designed to remove VOCs from the vadose zone. A soil vapor extraction system typically consists of a number of vapor extraction wells and an air handling system to draw air through the contaminated soil. This model is based on a single vapor extraction point installed to a depth of 50 ft using a hollow stem auger. As the air is drawn through the contaminated soil, VOCs are vented to the atmosphere.

In Situ Biodegradation

Biodegradation is a natural process involving the microbial transformation of organic constituents found in soil and ground water. The rate of natural biodegradation can vary between sites depending on the conditions. A number of factors influence conditions necessary for biodegradation to be an effective remediation method. These factors include soil moisture, oxygen content, pH, temperature, and nutrients. Each of these factors can be altered, as needed, to increase the rate of biodegradation of organic constituents. For example, this model relies on a vapor extraction point using one well connected to a blower to facilitate oxygen flow through the contaminated soil. This model also includes a sprinkler system to ensure adequate supply of moisture to the microorganisms. Finally, the model assumes the addition of nutrients to the site in the form of pulverized fertilizer.

Low Temperature Thermal Desorption

Thermal desorption is a method of remediation designed to remove the organic contaminants from the soil. Low temperature thermal desorption refers to the use of relatively low temperatures in the 300 to 600°Fahrenheit range. Prior to treatment, the contaminated soil is excavated from the site. Excavation includes the costs associated with handling and transporting contaminated soils from the site to the treatment facility.

Landfill Disposal

Contaminated soil must be disposed of in a permitted landfill facility designed and operated in accordance with current Federal and state standards. Primary costs associated with landfill disposal are trucking and disposal fees. Disposal fees can vary widely, depending on the type of facility and the regional location. For this model disposal fee of $99.99 was used, based on an average of regional fees from landfill facilities accepting contaminated soils considered to be hazardous waste. Prior to disposal, the contaminated soil is excavated from the site. Excavation includes the costs associated with handling and transporting contaminated soils from the site to the disposal facility.

Summary

This cost assessment indicates the relative scale of remediation costs using conventional techniques compared with the barometric pumping system. In general, any conventional techniques will cost in excess of $50K to remediate a contaminated site. The barometric pumping system, because it requires no earth removal or boreholes, will cost less than $35K. Costs are summarized in Table 2.

Table 2. Summary comparison of barometric pumping system cost with conventional remediation technologies.

Barometric pumping without boreholes	**$34.7 K**
Soil vapor extraction	$65 K
In-situ biodegradation	$82 K
Low temperature thermal desorption	$968 K
Landfill disposal	$190 K

Field Demonstration

The Idaho National Engineering Laboratory Radioactive Waste Management Complex (RWMC) has been selected as the candidate site for demonstration of the barometric pumping remediation system. The Subsurface Disposal Area (SDA) is a fenced disposal area inside the RWMC. During the 1960s and 1970s mixed wastes containing volatile organic compounds and radioactive wastes were buried at the SDA. Included in the SDA are numerous waste disposal pits, trenches, and soil vault rows. The pits are backfilled excavations with a variety of dimensions.

The geology of the SDA consists of surficial sediment deposits overlaying thick basalt deposits. Irregularities in the soil thickness (ranging from 1 to 23 ft.) reflect the surface undulations of the underlying basalts. The surface soils are typically less than 20 ft. thick and consist of gravely sand and fine-grained eolian deposits. The water table is at approximately 600 ft.

The volatile contaminant vapor plume is believed to extend vertically from the ground surface to the surface of the groundwater at the depth of the aquifer. Shallow soil gas surveys, obtained from samples taken 30” in the soil, are depicted in Figure9. The bulk of the contamination detected during soil gas surveys is in the form of chlorinated hydrocarbons, primarily carbon tetrachloride, trichloroethylene, chloroform, and tetrachloroethylene. Over the entire area of the SDA the peak concentration of any one component during the shallow soil gas surveys was about 1000 ppm (detected in a 1987 survey near Pit 9). A recent shallow survey (1992) is depicted in Figure 9, which shows the isopleths for carbon tetrachloride. The area chosen for this demonstration is identified as Pit 2. In the area of interest the peak contaminant concentration was 111 ppm of carbon tetrachloride (Figure 9). This disposal pit received barrels of sludge between 1954 and 1965. The records indicate that slightly over 1000 kg of sludge was deposited in this immediate area.

Active vapor extraction is underway at the SDA using three extraction units. These extraction units are concentrating on volatile contaminants which have accumulated in an interbed at approximately 100 ft., a relatively thin layer of silty material between basalt units. Chlorinated hydrocarbon contaminant concentrations as high as 6000 ppm have been detected in these zones, indicative of an accumulation of liquid contaminant. Unit C, the closest to the proposed demonstration site (approximately 250 ft. distant), extracts from a 10 ft. screened well interval centered on the 93 ft. depth.

This area is targeted for this demonstration because records indicate significant amounts of volatile contaminants were deposited in a well-defined area, soil gas surveys detected the presence of near-surface contaminant deposits, and the site has a deep water table to maximize barometrically-induced soil gas displacements.

In the course of the Phase I effort for this contract a set of criteria was developed to evaluate potential demonstration site candidates. In Table 3 those criteria are listed, and the specific attribute of the INEL RWMC listed in comparison.

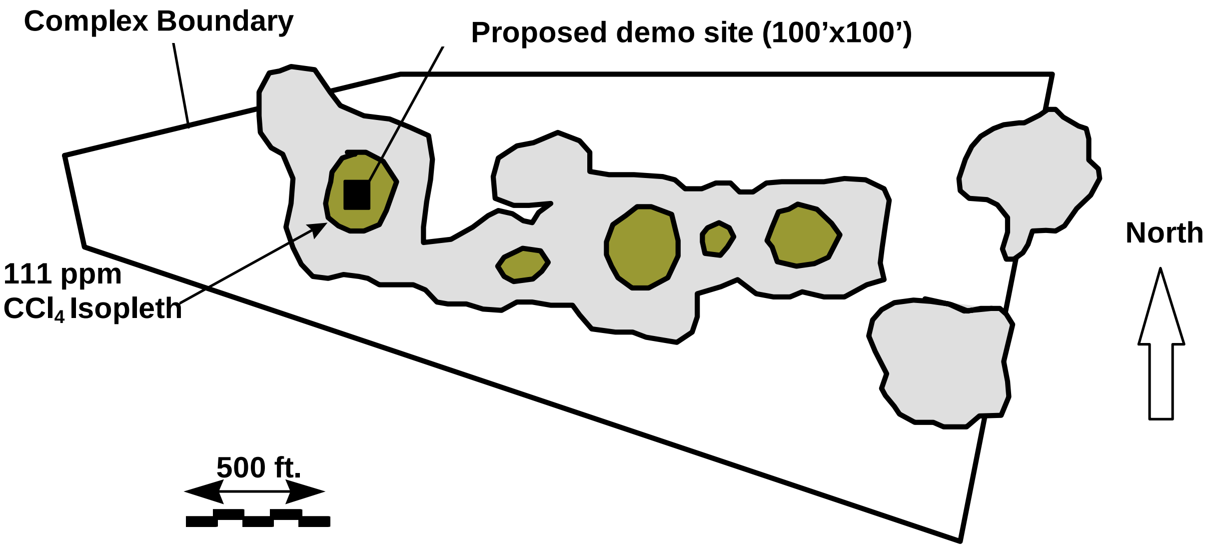


Figure 9. Barometric pumping installation at the INEL Radioactive Waste Management Complex (RWMC)

Table 3. Characteristics of the INEL Radioactive Waste Management Complex demonstration site.

	Attribute	INEL RWMC Characteristic
General setting:	Depth to water table > 20m	200m
	Low traffic area	No traffic
	Surface clear of complicated structures	No structures – very flat
Contaminant source:	Volatile	Yes – chlorinated hydrocarbons
	Concentrated source geometry (i.e., liquid or residual liquid deposit)	Buried, leaking drums of sludge
	Liquid source no deeper than 6 to 10 m	Drums deposited and covered with 3 to 6 m of backfill
Candidate sources:	Solvents, fuels, organic liquids	Chlorinated hydrocarbons (solvents)
	Shallow landfill or buried waste	Landfill
	Leaking underground storage tank	N/A
	Leaking buried pipeline	N/A
	Surface spill	N/A

This site meets virtually all of the demonstration requirements as to its technical suitability. It is also an attractive application because the site hosts may consider this design as an element of the final closure of the landfill, if it proves to control the VOC movement as desired.

The installation of the remediation system requires no excavation, although penetrations in the soil are required for soil vapor sampling. The site will need to be cleared of vegetation, rocks, and debris prior to installation of the surface components. The vapor monitoring system will require installation of soil vapor sampling points in the subsurface to quantify the performance of the system.

An impermeable membrane will be placed over the contaminated region of interest (see the plan view in Figure 10). In this case the membrane is 100 ft. square, and will be fabricated of a flexible geomembrane material. In the center of the membrane is a collection plenum formed with a coarse pea gravel layer (6” to 12” thick) beneath the geomembrane. In the center of the plenum is a vent pipe, which allows soil gas collected in the plenum to vent to the atmosphere (Figure 11). The area of the surface seal radially outward from the plenum is covered with a layer of pea gravel to provide a positive seal to the soil and prevent movement of the membrane due to high winds. Around the perimeter of the surface seal the membrane will be anchored to plastic pipe. This serves as a positive anchor for the membrane perimeter and also prevents water runoff from the surface seal during heavy rains. Water collected inside the perimeter of the surface seal will enhance the seal of the membrane to the soil. The cross section of the installation is depicted in Figure 12.

The monitoring system is a solar powered, autonomous soil gas sampling and data acquisition system with remote access capability (via cellular modem). At 45 minute intervals the system will record

- In-situ soil gas pressure
- Atmospheric and plenum air pressures
- In-situ temperature
- Wind speed
- Ambient air temperature
- Vent system outflow rate

On 12 to 24 hour intervals, the system will also sample soil gas and analyze for oxygen, carbon dioxide, and carbon tetrachloride (the dominant chlorinated hydrocarbon in the area). Manual gas samples will be collected bimonthly and analyzed for the balance of the anticipated contaminants (trichloroethylene and chloroform). Soil matric potential will also be measured at selected points with thermocouple psychrometers.

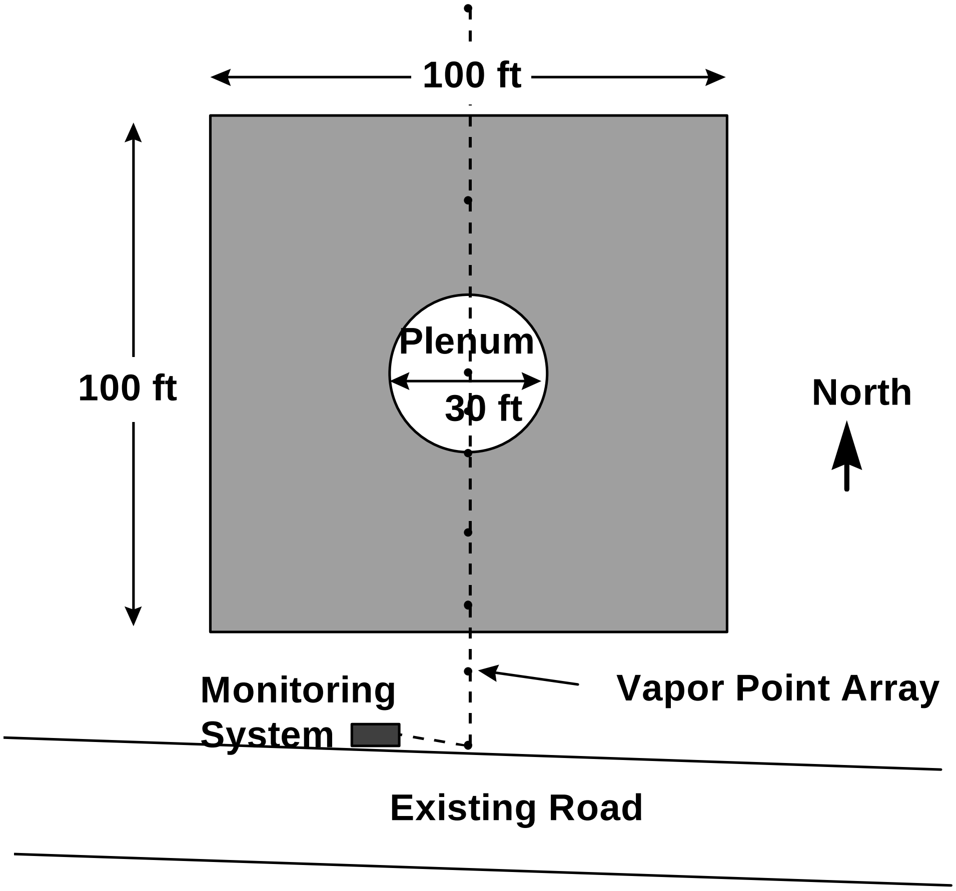


Figure 10. Plan view of installation

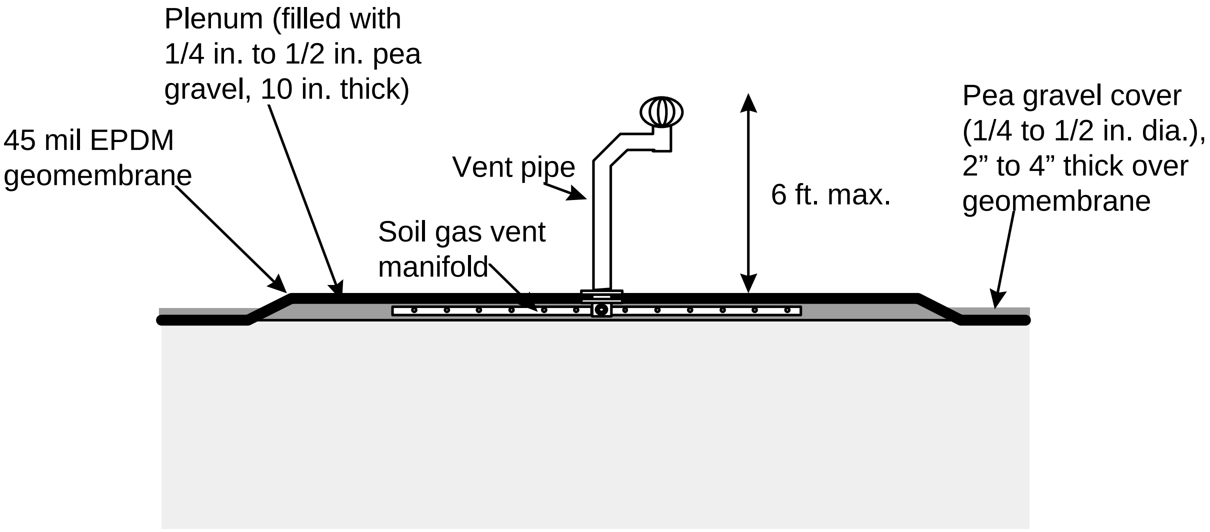


Figure 11. Vent pipe and plenum installation.

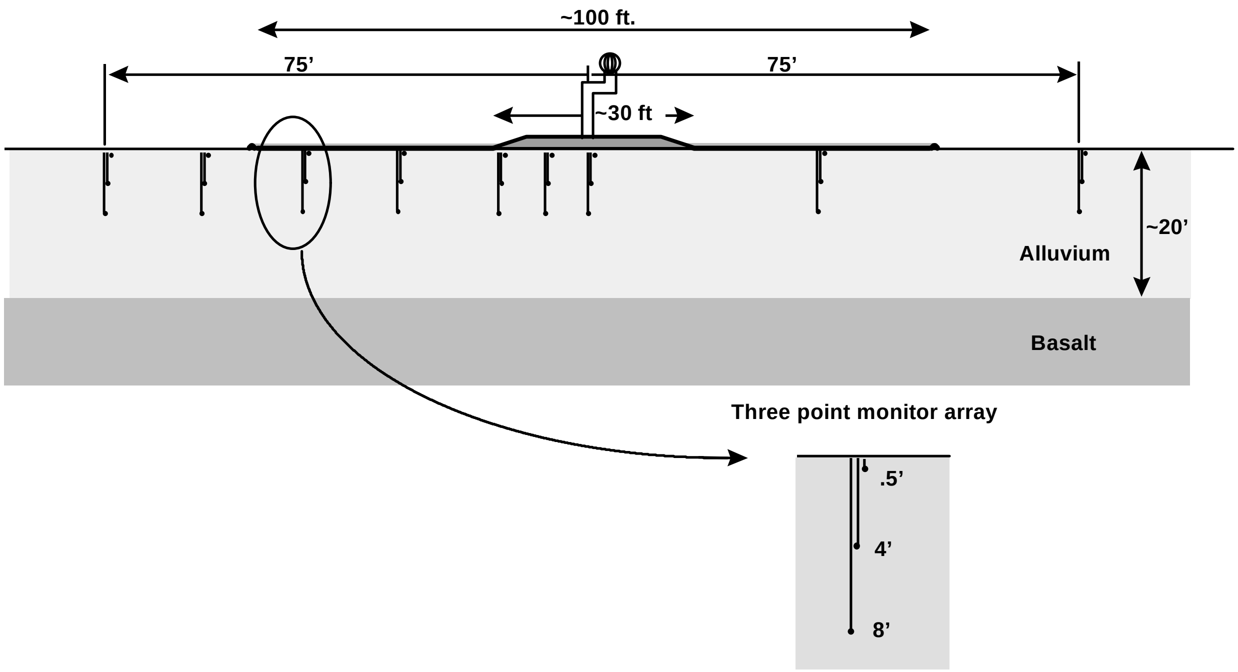


Figure 12. Vapor monitoring point installation design.

The demonstration schedule is depicted in Figure 13. Field installation is planned for start on November 10, 1996, with completion anticipated in under two weeks. Operation and monitoring will last 12 to 18 months.

Acknowledgments

The authors wish to acknowledge the project's METC Contracting Officer's Representative, Dr. Kelly Pearce, for his support throughout the effort. The project was initiated in March, 1995, and the field demonstration is planned for completion in December, 1997. We also acknowledge the field demonstration interest and support of Mr. Eric Miller and his associates with Lockheed Martin Idaho Technologies Company and Parsons Engineering Science, Inc. at the Idaho National Engineering Laboratory.

References

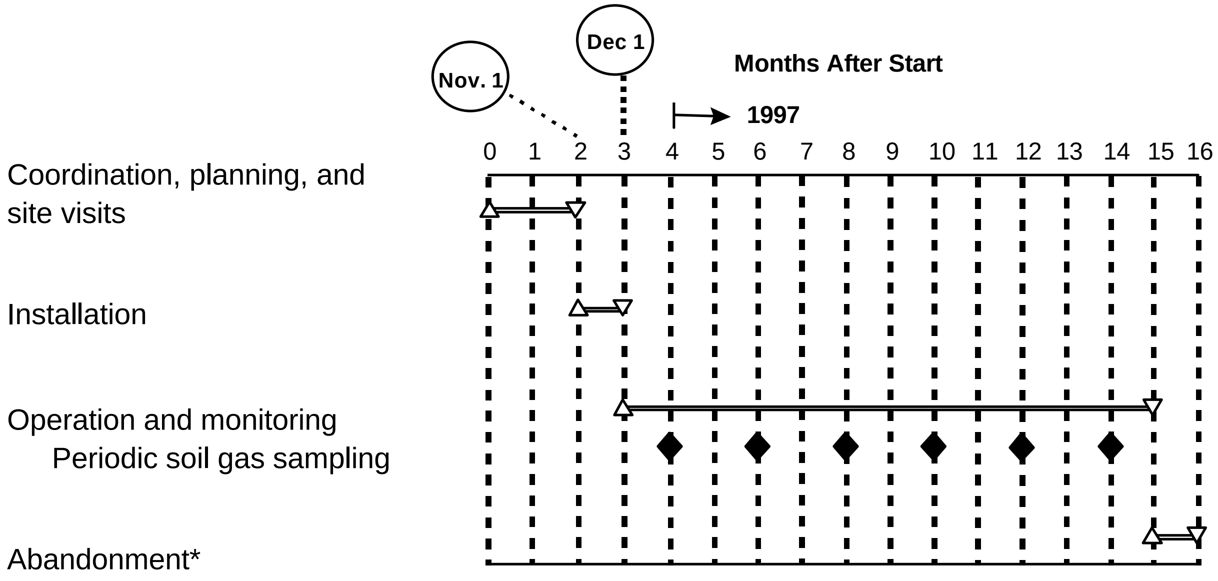
1 C. Williams, W. Lowry, D. Cremer, and S. Dalvit Dunn, "SEAMIST™ In-Situ Instrumentation and Vapor Sampling System Applications in the Sandia Mixed Waste Landfill Integrated Demonstration Program: Final Report," Sandia National Laboratories, SAND95-2060, September 1995.

2. W. Lowry, S. D. Dunn, R. Walsh, J. Burmester, P. Zakian, E. Cramer, "Barometric Pumping with a Twist: VOC Containment and Remediation without Boreholes Phase I Final Report" METC (in printing), August 1996.

3. G. A. Zyvoloski and Z. V. Dash, "Software Verification Report FEHMN Version 1.0," LA-UR-91-609, 1991.

4. G. A. Zyvoloski, B. A. Robinson, Z. V. Dash, and L. L. Trease, "Models and Methods Summary for the FEHMN Application," LA-UR-94-3787, Rev. 1, May 1995.

5. G. A. Zyvoloski, B. A. Robinson, Z. V. Dash, and L. L. Trease, "Users Manual for the FEHMN Application," LA-UR-94-3788, Rev. 1, July 1995.



*System could be left in place if desired by host

Figure 13. 1996 INEL RWMC test schedule.