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Stakeholder Acceptance Analysis:

**Passive Soil Vapor Extraction
Using Borehole Flux**

T.S. Peterson

December 1995

Prepared for the U.S. Department of Energy's
Office of Technology Development
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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STAKEHOLDER ACCEPTANCE ANALYSIS

PASSIVE SOIL VAPOR EXTRACTION

Prepared by

**Todd Peterson
Battelle Seattle Research Center**

for

**U.S. Department of Energy
Office of Technology Development**

December 1995

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INTRODUCTION

This report presents evaluations, recommendations, and requirements concerning passive soil vapor extraction (PSVE) derived from a three-year program of stakeholder involvement. PSVE takes advantage of the naturally occurring tendency of soil vapor to leave the subsurface during periods of low barometric pressure. PSVE seeks to expedite the release of volatile contaminants through the use of boreholes and technological enhancements. This report is for technology developers and those responsible for making decisions about the use of technology to remediate contamination by volatile organic compounds. Stakeholders' perspectives help those responsible for technology deployment to make good decisions concerning the acceptability and applicability of PSVE to the remediation problems they face.

The report provides:

- Stakeholders' final evaluation of the acceptability of PSVE in light of the technology's field test.
- Stakeholders' principal comments concerning PSVE.
- Requirements that stakeholders have of any remediation technology. Technology decision makers should take these conclusions into account in evaluating the effectiveness and acceptability of any remedial method proposed for their site.

In addition, the report presents data requirements for the technology's field demonstration defined by stakeholders associated with the Hanford site in Washington State, as well as detailed comments on PSVE from stakeholders from four other sites throughout the western United States.

STAKEHOLDER INVOLVEMENT PROCESS

The Volatile Organic Compounds in Arid Soils Integrated Demonstration (VOC-Arid ID) extensively involved stakeholders in the evaluation of innovative technologies to remediate contamination by VOCs. The stakeholder involvement program identified data requirements and issues at five arid sites. Data requirements are needs for specific information about a technology and its performance. They derive from questions about a technology's demonstration and operation. Issues and concerns are requirements and conditions for the acceptability of a technology. An example is "Technologies should be versatile in application and not transfer contaminants from one environmental medium to another."

A goal of the VOC-Arid ID was to test a technology once and then be able to deploy it broadly by ensuring that test plans for technologies to be demonstrated at one site included the issues, concerns, and data requirements of stakeholders from other sites where the technology was likely to be used. Ultimately, the process was designed to expedite deployment of effective and acceptable remedial technologies by determining what stakeholders required of these technologies.

Stakeholder involvement proceeded in three phases. Throughout, innovative technologies were evaluated in comparison to technologies in current use ("baseline" technologies). In the first phase, through individual interviews, Hanford site stakeholders

contributed to the development of criteria by which technologies would be evaluated. In focus groups, these stakeholders defined data requirements and posed questions to be addressed in technology demonstrations. An integrated workshop was then held to augment the demonstration plans for six technologies. The workshop included all of the Hanford stakeholders and the scientists and engineers developing and testing the technologies. The six technologies were:

- Passive Soil Vapor Extraction Using Borehole Flux
- Tunable Hybrid Plasma
- ResonantSonic Drilling
- In-Situ Bioremediation
- In-Well Vapor Stripping
- Membrane Separation

In the second phase of the technology evaluation program, 75 stakeholders from four other DOE arid sites accomplished two goals through individual interviews. First, they validated and further refined the data requirements, issues, and concerns identified by Hanford stakeholders. Second, they defined requirements specific to their site and region.

Demonstrations were subsequently completed for Passive Soil Vapor Extraction Using Borehole Flux, ResonantSonic Drilling, and Tunable Hybrid Plasma.

In the third phase of the technology evaluation program, principal investigators were interviewed to obtain answers to stakeholders' data requirements and questions in light of completion of technology demonstrations. These answers were recorded in the fourth column of a four column matrix (please see Appendix A). Demonstration results were provided to Hanford stakeholders, who used them to make final evaluations.

This report presents Hanford stakeholders' final evaluation of Passive Soil Vapor Extraction Using Borehole Flux.

STAKEHOLDER EVALUATION OF PASSIVE SOIL VAPOR EXTRACTION

This section contains four parts:

1. A summary of stakeholder evaluation of PSVE,
2. An overall evaluation of PSVE by Hanford stakeholders,
3. Interview comments that form the basis for Hanford stakeholders' final evaluation, and
4. A narrative of stakeholders' principal comments about PSVE.

Summary of Stakeholder Evaluation of PSVE

Stakeholders generally found PSVE to be an acceptable remediation method because of its basis in a natural process, its low cost, and because it is simple and logical to operate.

Stakeholders consistently called for definition of where PSVE should best be applied. Most stakeholders felt PSVE should be used as a secondary remediation method in conjunction with active soil vapor extraction. They see PSVE as particularly applicable with low concentrations of contaminants and when long (20-40 years) cleanup schedules are acceptable. There is significant stakeholder interest in the use of PSVE to control the expansion and migration of contaminant plumes. Some see this as PSVE's best use.

Overall Evaluation of Acceptability

Most of the regulators participating in the final evaluation rated PSVE as acceptable, with one saying it does not coordinate with long-term cleanup objectives for the Hanford site. All of the Public Interest Group Representatives found the technology acceptable. One Technologist strongly supported the use of PSVE, one recommended applying the technology where cost-effective, and a third felt that the data available were insufficient to warrant an endorsement. The tribal representatives did not endorse the use of PSVE. The table on the following page lists specific comments.

Overall Evaluation: Comments

Comment	Stakeholder Categories
<ul style="list-style-type: none"> Based on incomplete data concerning effect of radionuclides and chemical co-contaminants, PSVE is acceptable. 	<ul style="list-style-type: none"> Public Interest Group Rep
<ul style="list-style-type: none"> PSVE is worthy of continued investment. It has real utility. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> PSVE is a valuable tool after active extraction has done its work. But the method needs to continue to develop. It is not far enough along. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> PSVE does not coordinate with Hanford cleanup milestones for 2018. Doesn't carry high priority with the public. PSVE doesn't fit protection of river measures. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Apply where it is cost-effective 	<ul style="list-style-type: none"> Technologist
<ul style="list-style-type: none"> An expensive scheme for not doing much. 	<ul style="list-style-type: none"> Tribal Rep
<ul style="list-style-type: none"> Use active systems. Get the contaminants out before the money runs out. 	<ul style="list-style-type: none"> Tribal Rep
<ul style="list-style-type: none"> The technology is not ready to go. What's holding up the data? 	<ul style="list-style-type: none"> Technologist
OTHER ISSUES AND COMMENTS	
<ul style="list-style-type: none"> PSVE's principal investigators need to educate and present the method's potential to regulators and potential customers. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> The four-column matrix does not provide enough information. "Field test results expected in September." Provide that information. 	<ul style="list-style-type: none"> Public Interest Group Rep Technologist

Final Evaluation Interview Comments

In focus groups during the initial phase of the stakeholder involvement program, Hanford stakeholders identified data requirements and questions to be addressed in technology field demonstrations. The demonstrations provided answers to these data requirements and questions, with results recorded in a four-column matrix (please see Appendix A). The results were subsequently provided to Hanford stakeholders, who used them to develop final evaluations of the technology. The following table records their interview comments concerning PSVE.

Comment	Stakeholder Categories
BENEFITS AND DRAWBACKS	
<ul style="list-style-type: none"> PSVE's drawback is the long time it requires to extract contaminants. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Its benefits are its low cost (particularly when able to use existing wells) and minimal equipment. However, since time is a critical issue, expect it will be hard to sell. Additionally, if you add enhancements such as solar powered wind system, then the features of simplicity and low cost that make it attractive are reduced. The long time that PSVE requires needs to be described to stakeholders. The timeliness of cleanup is critical to stakeholders. Stakeholders want cleanup now. 	<ul style="list-style-type: none"> Regulator Public Interest Group Rep Technologist
<ul style="list-style-type: none"> Its benefits are low cost and maintenance after the removal of high concentrations of contaminants. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Its benefit is that it's environmentally benign. 	<ul style="list-style-type: none"> Regulator Public Interest Group Rep
<ul style="list-style-type: none"> Proven effective given performance criteria. No irreversible problem if used and fails. Has a place among group of technologies. 	<ul style="list-style-type: none"> Public Interest Group Rep
<ul style="list-style-type: none"> There are minimal negative environmental impacts - PSVE is good for the future environment. 	<ul style="list-style-type: none"> Public Interest Group Rep
<ul style="list-style-type: none"> A big drawback is regulatory uncertainty caused by the unpredictability of the rate of release of sorbed contaminants. 	<ul style="list-style-type: none"> Public Interest Group Rep
<ul style="list-style-type: none"> PSVE can achieve lower contaminant levels than otherwise possible at low price. 	<ul style="list-style-type: none"> Technologist
PERFORMANCE	
<ul style="list-style-type: none"> Can PSVE's rate of performance be measured, and will the slowness of the technology prevent containment? Tests incomplete so evaluation is as well. 	<ul style="list-style-type: none"> Regulator

Comment	Stakeholder Categories
PERFORMANCE (CONTINUED) <ul style="list-style-type: none"> • Neat science, but no definitive results yet. The remediation method needs to continue to develop. It is not far enough along. Need volume estimates and cost effectiveness studies. Public will find release into air unacceptable, must capture off gases. Concern about PSVE's ability to achieve cleanup levels. 	<ul style="list-style-type: none"> • Regulator
<ul style="list-style-type: none"> • Questions remain on the possible effects of co-contaminants. It is important to establish the ability to meet regulatory requirements. 	<ul style="list-style-type: none"> • Regulator
<ul style="list-style-type: none"> • Determine how much contaminant it pulls out and the time required to do so. The long time PSVE requires to extract contaminants may be an issue for Native Americans looking ahead to the future use of ancestral lands. Determine the best place to install PSVE: ahead of the leading edge of a plume? Right at the edge? Determine if the best use is polishing or preventative. 	<ul style="list-style-type: none"> • Regulator
<ul style="list-style-type: none"> • Contaminant movement should be fully known. Doesn't want PSVE used if some contaminant escapes into groundwater due to the technology's slow pace. 	<ul style="list-style-type: none"> • Public Interest Group Rep
<ul style="list-style-type: none"> • Don't have enough information to evaluate the technology. 	<ul style="list-style-type: none"> • Public Interest Group Rep
<ul style="list-style-type: none"> • Are you going to be required to monitor PSVE wells in order to meet air permit standards? There will be a regulatory cost with this method. Determine the percentage difference in extraction of contaminant between surface flux and borehole flux if you put money in new wells and enhancements. Is PSVE effective enough to warrant drilling new wells? 	<ul style="list-style-type: none"> • Public Interest Group Rep
<ul style="list-style-type: none"> • Not comfortable with quality of data and lack of detail provided in the demonstration process. 	<ul style="list-style-type: none"> • Public Interest Group Rep
<ul style="list-style-type: none"> • PSVE should have been evaluated after test results came back. 	<ul style="list-style-type: none"> • Technologist
<ul style="list-style-type: none"> • Can use CPT wells at a fraction of the cost of other wells due to flow expectations. Remaining challenge is how far apart to space the wells. 	<ul style="list-style-type: none"> • Technologist
<ul style="list-style-type: none"> • Where does PSVE stand in relation to air emission standards? Does it need an air permit? What contaminants can it handle? Is it applicable to TCE?; applicable at the Horn Rapids landfill? 	<ul style="list-style-type: none"> • Tribal Rep
<ul style="list-style-type: none"> • Concern about PSVE's slowness and the resulting high cost of monitoring. It would be necessary to periodically monitor PSVE wells and, over the long periods of the method's operation, this would get expensive. 	<ul style="list-style-type: none"> • Tribal Rep

Comment	Stakeholder Categories
COST <ul style="list-style-type: none"> Challenge is marketing, particularly to hydrogeologists. When selling to technology developers, they need to be educated on the process; when selling to customers, expect few concerns; when selling to regulators, focus on tail of restoration. Determine cost in terms of \$/lb/day. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Need more specific cost estimates. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Give cost scenarios with and without the cost of well drilling. Cost information is needed to show industry and DOE that PSVE should be used. 	<ul style="list-style-type: none"> Public Interest Group Rep Tribal Rep
<ul style="list-style-type: none"> Will DOE's internal orders complicate and raise the cost of using PSVE? 	<ul style="list-style-type: none"> Public Interest Group Rep
<ul style="list-style-type: none"> Didn't get clear picture on costs. 	<ul style="list-style-type: none"> Public Interest Group Rep
APPLICATION <ul style="list-style-type: none"> Use after active system, not as main method of remediation. Consider a cyclic application of active and passive systems. 	<ul style="list-style-type: none"> Regulator Public Interest Group Rep Technologist
<ul style="list-style-type: none"> Works well enough to be considered. Has a niche application. Enhancements should be used with PSVE to increase flow and efficiency. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> EPA is evaluating PSVE carefully. EPA is studying where on the contaminant concentration curve active systems are no longer economically efficient. The work going into PSVE will help EPA's work on presumptive remedies. That may be the place for PSVE to step in if it can handle expected rebound effect which occurs between 6 months and 2 years after stopping active systems. PSVE is a valuable complement to active system, a valuable tool after active extraction has done its work. Make GAC use mandatory with PSVE. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> PSVE doesn't coordinate with cleanup milestones at the Hanford Site. Technologies must be targeted at priorities. At Hanford the priorities are protecting the Columbia River and addressing high concentration plumes. PSVE is applicable after high concentration plumes have been cleaned up. PSVE is applicable at Superfund sites with long cleanup timelines and at gas stations. There will be a 60-70% budget reduction at Hanford over the next three years. Technologies are needed that are cheap, fast, and aggressive. 	<ul style="list-style-type: none"> Regulator

Comment	Stakeholder Categories
APPLICATION (CONTINUED)	
<ul style="list-style-type: none"> Niche is converting observation and characterization wells. PSVE's prime use is at the end of active extraction. It is advantageous to use monitoring wells for PSVE because well construction is so expensive. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Don't see PSVE being used in a manner in which you have to meet milestones. Use at low priority sites to get ahead of the game, before you even investigate the site, or use after milestones have been met. Use also to prevent the migration of contaminant plumes. Use PSVE and active systems in different circumstances. Finish with active, and then decide if passive is appropriate. Message to PIs - define location of optimal installation. More information is needed to determine effectiveness and performance. 	<ul style="list-style-type: none"> Regulator
<ul style="list-style-type: none"> Makes huge sense to use. PSVE is cost competitive with active vapor extraction especially at Hanford. The two technologies are complementary. Provide cost when used in conjunction with an active system. 	<ul style="list-style-type: none"> Technologist
<ul style="list-style-type: none"> Use at edges of contaminant plumes. Method seems applicable to a wide range of contaminants. The speed of extraction is important, so use as a secondary treatment. 	<ul style="list-style-type: none"> Public Interest Group Rep Technologist
<ul style="list-style-type: none"> Use as the last step in a system - GAC, THP, PSVE. Concerned that the technology will be used for primary remediation. Most applicable with low concentrations of contaminants and when long (20 - 40 years) cleanup schedules are acceptable. 	<ul style="list-style-type: none"> Public Interest Group Rep
<ul style="list-style-type: none"> If proven cost effective, then use as long-term maintenance technology. Use at the edge of plumes. 	<ul style="list-style-type: none"> Public Interest Group Rep Technologist
<ul style="list-style-type: none"> Use cone penetrometer to install PSVE wells. 	<ul style="list-style-type: none"> Technologist

Stakeholder Principal Comments Concerning PSVE

Stakeholders defined the following issues as conditions for the acceptance of PSVE:

No release of contaminants. Off gas from PSVE must be captured and managed in an environmentally sound manner.

Rate of performance. The use of PSVE, because of its relatively slow rate of performance, must not allow the migration of VOCs from the vadose zone into groundwater to become dense non-aqueous phase liquids (DNAPLs). Stakeholders who opposed the use of PSVE did so largely out of concern that the method is too slow and unpredictable. Trading time for money is reasonable only when health or environmental

risks are not incurred. A drawback of the method is the regulatory uncertainty caused by what is at this time an unpredictable rate of release of VOCs sorbed onto subsurface soil particles.

Application. Most stakeholders recommend using PSVE after active extraction has done its work. A number of stakeholders saw plume containment as the best use of the remediation method. One said, "If PSVE is sufficient to keep a contaminant plume from growing, then it should be used. Attainment of milestones will not be so important if you can show that PSVE can contain contaminant plumes."

Stakeholders recommended using PSVE in areas of lower concentrations of contamination, below 500 ppm. They suggest using PSVE at low priority sites to get ahead of the game in situations where you don't have to meet milestones, or after they have been met. One stakeholder recommended not putting a lot of time and money into technological enhancements because "the advantage of PSVE is its simplicity."

Some stakeholders believe PSVE's best application is at Superfund sites with long cleanup timelines and at small scale sites, such as abandoned gas stations, contaminated by petroleum products. PSVE, some believe, does not coordinate with cleanup milestones and the priorities at Hanford of protecting the Columbia River and addressing high concentration plumes.

Ability to deal with co-contaminants. Stakeholders are not satisfied with the level of information currently available about PSVE's ability to deal with co-contaminants, particularly radionuclides.

Cost. Stakeholders evaluate PSVE's relatively low cost favorably. However, with federal budgets for cleanup declining, some stakeholders commented that only technologies that are fast, aggressive, and cheap would likely be supported for further development and use.

Lifecycle costs including the cost of treating off gas must be quantified and provided to stakeholders, particularly regulators, as well as the cost of PSVE when used in conjunction with active extraction. Stakeholders judge cost information, as currently presented, inadequate.

It is necessary to address the cost of the long-term monitoring and periodic maintenance PSVE requires.

Regulatory issues/track record. The regulatory standards (e.g. MCLs and air permit requirements) against which PSVE will be judged must be determined. It is necessary to clearly demonstrate the level to which PSVE can reduce contamination, and PSVE's ability to meet regulatory requirements. Some stakeholders see PSVE's lack of a track record as a drawback at a time when the public and regulators are demanding clear evidence of progress in cleanup.

Future land use/ Environmental impact/ Effect on cultural resources. For reasons of expense, possible redistribution of contamination, and permanent environmental impact, stakeholders advocate limiting the number of new wells drilled. They recommend using existing wells and, after remediation, returning well sites to as natural a condition as possible.

Comments Concerning PSVE from 75 Stakeholders at Four Arid Sites Other Than Hanford

These assessments were recorded before the remediation method's field demonstration.

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Remaining Contamination</p> <ul style="list-style-type: none"> Determine if PSVE will induce a temperature gradient causing VOCs to change from vapor phase to liquid phase, thus condensing NAPLs in the subsurface. Will PSVE require so many boreholes that they will serve to redistribute contamination? Define the effectiveness of the technology with co-contaminants, including radioactive co-contaminants, and the potential effects on non-target contaminants (e.g., co-precipitation, co-vaporization, co-reformation and release, and effects on animal or human uptake). Release of contamination to the air is unacceptable; contamination needs to be totally destroyed. It is better to keep it in the vadose zone and monitor it than to release it to the air. Assess the ability of the technology to stop contaminant migration so that there is not seepage into uncontaminated areas. Define estimated results in advance of demonstration. Assess time and efficiency compared with active systems, and evaluate whether gains outweigh loss of efficiency. Consider natural biodegradation as a contributor to decreases in concentrations of VOCs in soils. 	<ul style="list-style-type: none"> INEL INEL INEL Rocky Flats Los Alamos Rocky Flats Rocky Flats Rocky Flats Rocky Flats 	<ul style="list-style-type: none"> Regulator Regulator Tribal Rep Public Interest Group Rep Tribal Rep Public Interest Group Rep Public Interest Group Rep Regulator Public Official Regulator

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
Remaining Contamination (Continued) <ul style="list-style-type: none"> Assess whether there will be residual contamination. The levels of acceptable residuals depend on future land use. Consider injecting air into the subsurface to increase the flow of the contaminated air stream. Evaluate whether the technology will change the characteristics of the contaminant. 	<ul style="list-style-type: none"> Rocky Flats Rocky Flats Rocky Flats 	<ul style="list-style-type: none"> Technologist Technologist Technologist
Process Waste <ul style="list-style-type: none"> Evaluate the effects of tritium exhausting in vapor form. Consider a 1-pound/hour limit for VOCs in off gas in Clean Air Act non-attainment areas. 	<ul style="list-style-type: none"> Los Alamos Sandia 	<ul style="list-style-type: none"> Technologist Regulator
Practicality <ul style="list-style-type: none"> This is an appropriate technology for areas with dilute concentrations of VOCs in the vadose zone. Assess the ability to control and predict performance of a passive system, and define the time frame over which confident predictions are possible. Demonstrate what is gained by not making the system active. Assess the ability of PSVE to work in combination with other technologies. Consider using perimeter PSVE wells with active soil vapor extraction (ASVE) at the center, or using the ASVE in a pulsed mode to accomplish additional extraction. 	<ul style="list-style-type: none"> INEL INEL Rocky Flats Rocky Flats INEL Rocky Flats 	<ul style="list-style-type: none"> Public Interest Group Rep Regulator Public Official Regulator Public Interest Group Rep Technologist

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Practicality (continued)</p> <ul style="list-style-type: none"> Define optimum borehole sizes in varying strata, the number of borings needed, the details of well construction needed, and the desired zone of influence. Evaluate the ability to use with existing wells and define the requirements for those wells. Define the range of site conditions in which the technology will be effective, the effect of these conditions on flux rates, and the upper limit for effective operation of the process. Evaluate the effect of moisture on contaminant transfer and measure whether the well is adding or removing moisture from the soil at different depths and in different soil types. Evaluate the mass transport rate in different circumstances, and relate the data to general conditions so that it can be modeled. Incorporate predictability into designs. Measure pressure drop with distance from wells, and the contaminant concentrations at the borehole and at various locations over time. Assess the technology's ability to control migration and to capture methane and dense chlorinated hydrocarbons in the vapor phase in the vadose zone. Evaluate the level of air exchange needed to make this technology practical. Assess its usefulness as a soil drying technique should there be a spill. 	<ul style="list-style-type: none"> INEL Los Alamos INEL Sandia INEL Los Alamos Rocky Flats Sandia Los Alamos Los Alamos Sandia Los Alamos 	<ul style="list-style-type: none"> Regulator Technologist Technologist Technologist Technologist Regulator Technologist Technologist Regulator Technologist Technologist Technologist Technologist

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Practicality (continued)</p> <ul style="list-style-type: none"> • Evaluate the limits of functionality in complex mixtures (e.g., BTEX) and how PSVE interacts with ongoing biodegradation. • Evaluate the levels of VOC that are captured on GAC when using PSVE, and define the needs for change out of the GAC. Define extraordinary situations, such as surges that fill the GAC unpredictably. • Consider using an interlocked valve that closes off the well when GAC breakthrough occurs; consider other off-gas treatments, as GAC can be a management problem. • Define monitoring and controls needed to measure and control flux. • Evaluate the suitability of PSVE for early stages of cleanup. • Assess its effectiveness in late-stage remediation where chlorinated solvents are contained in tight silts and clays that don't respond well to ASVE. • PSVE will be a secondary treatment method; it may not be an effective primary technology for source removal. It will never meet ARARs. • Define the meteorological conditions, including wind, temperature, and high-pressure systems, under which the technology will work most effectively, and the role of wind in affecting natural soil vapor extraction. 	<ul style="list-style-type: none"> • INEL • INEL • INEL • INEL • Rocky Flats • INEL • Sandia • INEL • Los Alamos • INEL • Los Alamos • Rocky Flats 	<ul style="list-style-type: none"> • Regulator • Technologist • Technologist • Technologist • Public Official Public Interest Group Rep • Technologist • Regulator • Technologist • Regulator • Technologist • Regulator • Pubic Interest Group Rep Regulator

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Practicality (continued)</p> <ul style="list-style-type: none"> • Define if housing the extraction area in a building or tent would be needed to protect the equipment from snow or extremes in temperature. Determine how maintenance would be done in these circumstances. • Watch for removal correlations with phases of the moon and tidal effects. • Evaluate security and maintenance needs. • Define the need for any in-situ equipment to operate the technology and its function. • Evaluate the effectiveness of the technology. It could be useful for landfill gases. • This is an attractive technology because it is inexpensive and no power is needed. • Evaluate the ability to obtain the technology from multiple vendors; there appear to be multiple suppliers. 	<ul style="list-style-type: none"> • INEL • Los Alamos • Sandia • Rocky Flats • Sandia • Sandia • Sandia 	<ul style="list-style-type: none"> • Technologist • Technologist • Regulator Technologist • Public Interest Group Rep • Public Official • Technologist • Technologist

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Works as Intended</p> <ul style="list-style-type: none"> Consider demonstrating PSVE in an area where ASVE has been carried out so that the zone is at a realistic place on the contaminant removal curve. Try two demonstrations, one after ASVE and one before, but only when the risk to other environmental media is low. Consider forcing air into the formation as a mechanism to control plumes, and using a plastic surface cover over certain areas to enhance and direct flow. Determine whether VOCs diffuse out of mesa sidewalls. Assess the effects of subsurface fracturing and permeability on PSVE performance. Evaluate previous uses and successes of the technology. It has been used at gas station sites. Define the radius of influence of the technology, the number of wells needed, the distance between them, the configuration of borehole arrays, and the time required for the technology to function effectively. Assess the ability of the technology to handle large plumes. Calculate mass removal over time. Define how gradients and pressure fluctuations will be used to achieve cleanup and how they will be controlled. Evaluate the volume of VOCs released from the soil by pressure changes as compared to just moving entrained VOCs up and down a little in the soil. 	<ul style="list-style-type: none"> INEL INEL Los Alamos Los Alamos Rocky Flats Los Alamos Los Alamos Sandia Sandia Rocky Flats Los Alamos 	<ul style="list-style-type: none"> Regulator Regulator Regulator Regulator Regulator Regulator Public Interest Group Rep Technologist Public Interest Group Rep Technologist Technologist Public Interest Group Rep Technologist

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Works as Intended (continued)</p> <ul style="list-style-type: none"> • It is important to understand the limiting factors for the technology and the bases for those limitations. • Use peizometers at radial distances to determine the zone of influence of the wells. Expect nonsymmetric zones of influence based on discontinuities in the subsurface. • Demonstrate that heavy vapors will actually move to the surface from 100 feet below grade. • To measure the success of PSVE, assess how much natural biodegradation of VOCs is occurring and has occurred. • Define the barometric changes needed to bring contaminants to the surface. • Evaluate requirements for attaching treatment systems while still retaining pressure differentials. • Define flux rates and the mobility of contamination. Consider the effects if migration moves contamination faster than PSVE can remove it. Use ASVE in these situations. • Evaluate taking advantage of subsurface stratigraphy to use natural flux most effectively. 	<ul style="list-style-type: none"> • Los Alamos • Los Alamos • Sandia • Rocky Flats • Rocky Flats • Rocky Flats • Sandia • Sandia 	<ul style="list-style-type: none"> • Technologist • Technologist • Regulator • Regulator • Regulator • Regulator • Technologist • Public Interest Group Rep • Technologist
<p>Cost</p> <ul style="list-style-type: none"> • Evaluate the system costs and cost per pound of contaminant removed. Low cost is an advantage. • Define the cost effectiveness of the technology, and compare cost effectiveness with a trench system or horizontal collector pipes. • Evaluate startup costs, including the cost of drilling wells. Startup costs for the technology appear to be low. 	<ul style="list-style-type: none"> • INEL • Sandia • Los Alamos • Sandia • Sandia 	<ul style="list-style-type: none"> • Technologist • Public Interest Group Rep • Technologist • Regulator • Technologist

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
<p>Time</p> <ul style="list-style-type: none"> Address both the effectiveness and the time required for cleanup to specified levels. Speed is important to regulators. Evaluate the extremely long cleanup time needed to reach regulatory standards and to address ground water contamination. There is no mechanism for faster operation. Will cleanup deadlines prevent this technology from being used? Evaluate the ability to couple PSVE with ASVE to maximize removal as quickly as possible. 	<ul style="list-style-type: none"> INEL Sandia INEL Los Alamos Rocky Flats Sandia 	<ul style="list-style-type: none"> Public Interest Group Rep Public Interest Group Rep Regulator Technologist Technologist Public Official Technologist Public Interest Group Rep
<p>Public Health and Safety</p> <ul style="list-style-type: none"> Subsurface VOCs released at the surface through PSVE must be captured and treated. Evaluate off-gas production and the portion captured. Define whether the off gas is acceptable to diffuse. Evaluate emissions from the technology, plans for recovering vapor or venting it to the atmosphere, and effects of this venting on human health. Evaluate the ability to control well venting when wells are no longer monitored. 	<ul style="list-style-type: none"> INEL Los Alamos Rocky Flats Sandia Rocky Flats Sandia Sandia 	<ul style="list-style-type: none"> Public Interest Group Rep Technologist Public Interest Group Rep Public Official Regulator Technologist Regulator Public Interest Group Rep Regulator Technologist Public Interest Group Rep Public Interest Group Rep Regulator

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
Public Health and Safety (Continued) <ul style="list-style-type: none"> Consider PSVE's potential to encourage migration of dissolved contaminants toward the water table. Assess whether the pressure dynamics induced by PSVE will push contaminants in unanticipated directions. Evaluate the potential for VOC flammability in an open system and the potential for explosion. 	<ul style="list-style-type: none"> Sandia Rocky Flats Sandia 	<ul style="list-style-type: none"> Regulator Public Interest Group Rep Technologist Regulator Technologist
Environmental Impacts <ul style="list-style-type: none"> Assess the environmental impacts of the technology. Evaluate the potential for penetrating an impermeable layer at depth and creating a contaminant pathway, particularly into the Snake River aquifer. Pressure differentials could spread contamination in unpredictable directions. PSVE is a "nice but crude idea." Assess the use of solar energy with PSVE. Use ASVE when contamination threatens imminent damage. Assess subsurface impacts from the influx of air, temperature changes, etc., and evaluate the effect on natural degradation, and stimulation of microbes. Investigate odors from the system; this could be a problem in urban areas. 	<ul style="list-style-type: none"> INEL INEL Rocky Flats Sandia Sandia Sandia 	<ul style="list-style-type: none"> Public Interest Group Rep Public Interest Group Rep Public Interest Group Rep Public Interest Group Rep Technologist Technologist

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
Public Perception <ul style="list-style-type: none"> • The simplicity and low cost of the technology are positive attributes. Taxpayers will like its low cost, but will the public be patient with the slow rate? • A low-technology solution will likely be acceptable to the public since it is understandable. • This technology is less of a concern because it is a natural phenomenon. 	<ul style="list-style-type: none"> • INEL • Los Alamos • Sandia • Sandia 	<ul style="list-style-type: none"> • Technologist • Regulator • Public Interest Group Rep • Public Interest Group Rep
Regulatory Infrastructure and Track Record <ul style="list-style-type: none"> • Independent, third-party verification of success and reference to historical use of the technology are important, especially to federal and state regulators. • The technology is unpredictable in terms of regulator approval due to the time and rate of mass removal, and the uncertainty of the risks. • Evaluate regulators' familiarity with the system. There may be problems in deployment decisions for regulators involved with hazardous wastes; however, PSVE is currently used by EPA for radon control. 	<ul style="list-style-type: none"> • Los Alamos • Sandia • Sandia 	<ul style="list-style-type: none"> • Regulator • Regulator • Technologist

ISSUES BY CATEGORY	SITES WHERE ISSUES RAISED	STAKEHOLDER CATEGORIES
Regulatory Compliance <ul style="list-style-type: none"> Assess off-gas concentrations produced by PSVE and the technology's ability to meet state air quality regulations and Clean Air Act requirements. A permit will be required in New Mexico; the regulatory limit for hazardous constituents is zero, so off-gas control is essential. Evaluate technology's ability to produce sufficient results for CERCLA five-year review. There is a need for more information on use in permeable zones to convince regulators of the speed of cleanup. Regulators may be satisfied with direct venting, since it is acceptable to wind row UST contaminated soil. 	<ul style="list-style-type: none"> Los Alamos Sandia Rocky Flats Sandia Sandia 	<ul style="list-style-type: none"> Regulator Technologist Technologist Regulator Technologist Technologist
Other <ul style="list-style-type: none"> This is an attractive technology. Understanding this phenomenon may give a more realistic view of what subsurface and contaminant conditions really exist. 	<ul style="list-style-type: none"> INEL Rocky Flats 	<ul style="list-style-type: none"> Technologist Regulator

Appendices

Appendix A presents the four-column matrix developed by Hanford stakeholders and PSVE's developers. Appendix B presents the general comments of Hanford stakeholders concerning PSVE, recorded before the technology's field demonstration. Appendix C presents comments applicable to the development of any innovative technology. Appendix D offers a fact sheet describing the operation of the technology.

APPENDIX A

FOUR-COLUMN MATRIX

PASSIVE SOIL VAPOR EXTRACTION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS ADDRESSING DATA REQUIREMENTS	RESULTS
<p>1. Determine if passive soil vapor extraction (PSVE) may be used best as a long-term maintenance technology; for example, to provide containment at the edge of contaminant plumes, or as a secondary approach to be used in conjunction with other technologies, such as active soil vapor extraction.</p>	<p>1. Design field demonstration to determine PSVE's effectiveness in containing contaminant plumes or as a secondary remediation method.</p>	<p>1. Test various wells for VOC concentrations and flow rates to determine PSVE's removal rate and cost efficiency compared to Active SVE.</p>	<p>1. PSVE wells with flow rates of 10 standard ft³/min were shown to be more cost effective than active systems at CCl₄ concentrations of 500 ppm, or lower. PSVE wells with 5 standard ft³/min flow rates were shown to be more cost effective than active systems at 200 ppm, or lower. Active systems are more cost effective at high contaminant concentrations. Plume edge containment and use as a secondary system seem to be two good applications for PSVE.</p>
<p>2. Define the varying depths of the vadose zone at which this technology will work (e.g., will it operate at 200-250' depths in the Hanford formations).</p>	<p>2. No further comment.</p>	<p>2. The field demonstration includes testing system operation at various depths.</p>	<p>2. Pressure differentials below the caliche (and other low permeability layers) cause PSVE to be most effective, but it is also effective above the caliche. For such low pressure difference areas, GAC treatment unit design must provide for lower head loss.</p>
<p>3. Analyze the flow characteristics of air under different conditions. Determine the flow rate of contaminated air from PSVE wells, and factors affecting intake of clean air into the earth. Define what pressure changes are needed for the technology to succeed.</p>	<p>3. Determine efficiencies and predict performance of wells bored in specific soil classes.</p> <p>The demonstration will provide information about the flow characteristics of air from the surface and in the subsurface.</p> <p>Overall air-flow can be predicted and VOC concentrations measured so that total mass of contaminant removed can be calculated.</p>	<p>3. Basically one type of soil is found at the Hanford demonstration site, above and below the caliche layer. Various other PSVE test sites will provide data on other soils. Measurements of pressure at depths from 5' to 210' are ongoing. Flows are measured from wells open above and below the caliche (generally depths range from 120' to 200'). Graphs from resulting data have been produced. Mass removal can be calculated based on this information.</p>	<p>3. The average differential pressure above the caliche layer at Hanford is 0.5 inch water or less; the average differential below the caliche is greater than 1.5 inches water. Thus, there is usually, at the Hanford demonstration site, sufficient differential pressure to allow air flow. The PSVE system must have pressure drops less than the available differential pressure.</p>

PASSIVE SOIL VAPOR EXTRACTION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS ADDRESSING DATA REQUIREMENTS	RESULTS
<p>4. Define the subsurface radius of influence of PSVE wells, in terms of different soil types, moisture content, and contaminant concentrations.</p> <p>Define any local conditions that may affect the effectiveness of the technology (e.g., major subsurface fractures, nearby active soil vapor extraction, etc.).</p>	<p>4. Assess the effect on the method's radius of influence of placing plastic sheeting on the surface.</p>	<p>4. Testing with and without plastic sheeting covering the ground surface is ongoing. Tracer technology is also being employed. With tracer technology known, sulfur hexafluoride an inert nontoxic compound is added to the air so as to exactly "trace" its flow path and rate.</p>	<p>4. A portion of the field demonstration area has been covered with plastic sheeting.</p> <p>Data is pending as the test is ongoing.</p> <p>Any local conditions that inhibit the effectiveness of ASVE also inhibit the effectiveness of PSVE.</p>
<p>5. Determine the effect of surface temperature on the remediation method. Measure temperatures at the subsurface depths being assessed.</p>	<p>5. No further comment.</p>	<p>5. Measurement of temperature at 10 feet and at well maximum depth is planned to determine if temperature has an effect on the technology's performance.</p>	<p>5. When wells are blowing out, air temperatures reflect ambient subsurface temperatures. When wells are sucking in air, temperatures are similar to those of ambient surface air. These temperatures will be correlated with concentrations of CCl_4 measured.</p>
<p>6. Define active soil vapor extraction's point of diminishing returns in site conditions similar to those where PSVE would be used.</p>	<p>6. Formulate the demonstration test plan so as to provide this information.</p>	<p>6. See Element #1</p>	<p>6. See Result #1</p>
<p>7. Define the applicability of the technology to a full range of VOCs (especially those that are heavier than air).</p>	<p>7. Design the test plan and carry out the demonstration to determine the behavior of VOCs that are heavier than air.</p>	<p>7. Behavior of various compounds can be extrapolated based on partial pressures and composition and concentrations of these in air.</p>	<p>7. Current data indicate that when gases are dissolved in air at low concentrations they act like air.</p> <p>PSVE works with any contaminant that is dissolved in air, in concentrations that are usually encountered.</p>

PASSIVE SOIL VAPOR EXTRACTION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS ADDRESSING DATA REQUIREMENTS	RESULTS
8. Assess the effects of radioactivity or other VOCs as co-contaminants.	8. PSVE encounters the same co-contaminants at Hanford as active systems. HEPA filters are an option in the PSVE system conceptual design. HEPA filters are used to capture radioactive particulates. Monitor PSVE emissions to determine if and when HEPA filters are necessary.	8. All Hanford PSVE work is done in a non-radioactive area; the only radionuclide present is naturally occurring radon. The test is measuring for chloroform, methylene chloride, and MEK in addition to CCl ₄ .	8. The co-contaminants (chemical) present are not having a physical effect on PSVE, but they are affecting the concentration of CCl ₄ in the air. All other VOCs are captured on GAC and have typically been measured at lower concentrations than CCl ₄ .
9. Develop information on diffusion rate limitations of sorbed carbon tetrachloride and TCE in various soils, including information on soil chemistry and partitioning coefficients. Determine the relationship of mass removal to desorption kinetics.	9. Characterize the exchange between the aquifer and the vadose zone in terms of VOC contamination and diffusion in and out of ground water. Site by site assessment is necessary to determine if PSVE works rapidly enough to prevent VOCs from migrating into and dissolving in ground water. Another concern was that dense non-aqueous phase liquids (DNAPLs) in the vadose zone migrate to become DNAPLs in the ground water, which are difficult to remediate. Some data on these issues developed through work with active soil vapor extraction (ASVE) are being used to plan and verify the PSVE demonstration. PSVE is effective in the same conditions and geologic formations as ASVE.	9. A soil chemistry and partitioning coefficient study is underway. The ground water/vadose zone contaminant interaction is being calculated based on Henry's law constant, and known ground water concentrations. It is then compared to actual soil gas measurement. There has not been very good correlation to date.	9. Results are expected by September 1995.
10. Assess whether there are sites that will "clean themselves up" without enhancing the natural phenomenon.	10. No further comment.	10. Data are being collected to allow this to be determined.	10. Once sufficient data are available this can be calculated. In theory, sites will clean up over time, but the time is probably long. For example, current calculations indicate that approximately 21% of CCl ₄ contamination at Hanford's 200 West Area was lost to the atmosphere between 1955 and 1990 (this percentage includes CCl ₄ vented by soil surface flux).

PASSIVE SOIL VAPOR EXTRACTION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS ADDRESSING DATA REQUIREMENTS	RESULTS
11. Define pre-characterization activities needed to construct networks of passive soil vapor extraction wells.	11. The demonstration report will evaluate needed pre-characterization.	11. Some characterization has been done, but further characterization of soil types and viability of PSVE is planned for 1996.	11. Some general knowledge of favorable conditions is in hand now. Some of these are: <ul style="list-style-type: none"> ● Permeable soil is best. ● Confining layers help extraction. ● Ice and pavement covers may help extraction. ● High moisture content inhibits air flow. ● High organic matter inhibits contaminant removal. <p>Other factors are also being evaluated.</p>
12. Assess cost of operation and maintenance over the long periods potentially necessary to use this technology. Include drilling costs.	12. Define the breakpoint, in terms of cost, between ASVE and PSVE. Define the long-term costs of PSVE alone and in combination with ASVE. Early evaluations indicate that at less than 1000 ppm of VOC extracted, the economic advantage may turn from ASVE to PSVE.	12. Studies to date have not included drilling cost but all other factors for comparison to ASVE are being measured .	12. See Result #1.
13. Define monitoring needs and costs of the remediation method, including fencing, signs, and ecological monitoring.	13. No further comment.	13. No ecological monitoring is now part of the test. Fencing and signage cost are known but not yet factored into cost comparisons.	13. Long-term maintenance costs are currently uncertain.
14. Determine the costs of off-gas treatment. Compare the cost for treating GAC with the cost of direct release, including the cost for obtaining air permits.	14. Determine the cost of PSVE's operation with and without off-gas treatment. The demonstration will compare the cost of treatment with the cost of direct release, including permitting costs.	14. Hanford demonstration operates with GAC. The Savannah River PSVE demonstration operates without GAC and without air permits because the low quantity of VOC released requires no permits. Comparisons can be calculated.	14. Cost results reported in #1 are for Hanford and would be more favorable to PSVE without GAC.

PASSIVE SOIL VAPOR EXTRACTION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS ADDRESSING DATA REQUIREMENTS	RESULTS
15. Define the costs of enhancements. Define cost/benefit ratios in terms of incremental benefit for added costs (capital, operation, and management).	15. The demonstration will provide this information.	15. The work plan will check the rate and amount of VOC removal and relate this to the costs of enhancements.	15. Results due September 1995.
16. Define the flux with varying atmospheric pressures, soil types, soil moisture, and depths. Define how this remediation method's performance will be measured. Monitor so that the effect of active soil vapor extraction will not be attributed to the passive approach.	16. Demonstration results will present and analyze this data.	16. The test is measuring pressure differentials with various depths, levels of moisture and soil types. The Hanford PSVE testing is not near an ASVE area. The effectiveness of PSVE enhancements will be measured by the total VOC removed.	16. Results due September 1995.
17. Assess whether captured contaminants are classified as mixed waste if radionuclides are present.	17. No further comment.	17. At this time the test plan does not address this.	17. The PSVE field test is being conducted in an area free of radionuclides. If the PSVE wells were to vent naturally occurring radon along with VOCs, this would not be considered mixed waste under RCRA regulations, but it might be in terms of DOE policies.
18. The release of contaminants to the air from passive soil vapor extraction is a significant issue, potentially requiring regulatory attention. For many stakeholders, uncontrolled release is not acceptable, they believe that off-gas must be captured and managed.	18. The demonstration will provide data on off-gas quantities and concentrations of contaminants in relation to regulatory limits and risk levels. Hanford concentrations of VOCs have been measured between the 100s and 10,000s of parts per million. Off-gas capture and treatment associated with PSVE must be designed to accommodate low pressure differentials.	18. At Hanford, off-gas is being captured during the field test.	18. Contaminants are not being released to the atmosphere during the field test at Hanford.

PASSIVE SOIL VAPOR EXTRACTION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS ADDRESSING DATA REQUIREMENTS	RESULTS
19. Assess potential health and safety concerns related to venting contaminants, including VOCs, radon, tritium, and carbon-14 at the surface, addressing long-term fate and transport as well as atmospheric breakdown of these contaminants.	19. Radon is sorbed on GAC. Correlate radon extracted with carbon tetrachloride extracted.	19. At this time the test plan does not address this.	19. These elements are not being evaluated during this test.
20. Assess the need for personnel protective equipment (PPE) to guard against contact with carbon tetrachloride and other contaminants during well maintenance and monitoring.	20. The demonstration will examine and report on contaminant flux and exposure.	20. Site Safety officer has authority to require PPE based on contaminant levels exiting the wells.	20. Procedures and action levels have been established for personnel protection at Hanford.
21. There are disadvantages to drilling new wells, including potentially creating subsurface conduits for contamination, high costs, and future problems with abandoned wells. The number of new wells drilled should be minimized.	21. The demonstration will provide data on the number of wells needed for various applications and how both existing and new well networks can be used.	21. Radius of influence of PSVE wells is being determined. This data will be used to determine the appropriate number of wells.	21. The PSVE field test at Hanford is using only existing wells.
22. Determine the need to grout wells after use of the technology. (Some stakeholders see grout as permanently damaging.) Assess the possibility of complete well removal or other well-closure methods.	22. Wells must be closed in accordance with Washington Administrative Code (WAC) regulations. Closing usually entails grouting and sealing. There is a concern that even closed wells may cause environmental damage. Formulate the test plan so as to determine the effect of closed wells.	22. In some cases, pulling wells out may be more environmentally damaging than grouting. Evaluation of this issue is not part of the test at this time.	22. The PSVE test is not putting in new wells and is not planning any well abandonment at this time.
23. Assess this technology's potential impacts on future land use.	23. Assess the impacts of the technology on future land use given that permanent covers are not planned, but temporary covers may be used.	23. Not included in the test plan at this time.	
24. Define any effects on climate resulting from use of the technology.	24. Determine, if off-gas is treated, the technology's effect on climate. Examine the possible effects of soil surface flux.	24. Not included in the test plan at this time.	24. Measuring possible effects on climate is beyond the scope of the current field demonstration at Hanford.

PASSIVE SOIL VAPOR EXTRACTION

FOCUS GROUP DATA REQUIREMENTS	WORKSHOP COMMENTS	TEST PLAN ELEMENTS ADDRESSING DATA REQUIREMENTS	RESULTS
25. Determine whether this remediation method, relying as it does on variable rates of soil vapor flux, will be able to meet regulatory requirements and cleanup milestones.	25. Determine how this approach to remediation fits in with deadlines established.	25. Total soil flux is being measured, as is rate of removal, time to achieve goals can be calculated.	25. The ability of PSVE to meet regulatory requirements and cleanup milestones remains to be determined. Field tests results will be used to compare PSVE to ASVE.
26. Define the types of well construction appropriate to support PSVE (i.e., what is the ideal well construction; is it consistent with existing well regulations?). Assess the availability of wells that fit those criteria, since drilling new wells is expensive.	26. PSVE does not have unique well-installation requirements. Determine if existing small wells can be used for PSVE. (Determine how small).	26. The Hanford demonstration is successfully using 2 inch to 8 inch diameter, existing wells.	26. The usability of 1 inch wells will be determined. Some usability of 1 inch wells has been demonstrated with ASVE. The Savannah River PSVE test includes some 1 inch wells.

APPENDIX B

HANFORD STAKEHOLDERS' COMMENTS CONCERNING PSVE PRIOR TO THE TECHNOLOGY'S FIELD TEST

GENERAL COMMENTS ON PASSIVE SOIL VAPOR EXTRACTION

1. A low-cost, slow technology such as this may be appropriate as long as there is no additional exposure in the interim (e.g., contaminants moving into ground water from the vadose zone, which would warrant using active soil vapor extraction or other techniques that work more quickly). In some cases, it is reasonable to trade time for money, but only when health or the environment are not put at risk. A specific argument for using a faster, more active method is the need to capture VOCs in the vadose zone, so that they do not reach ground water and become Dense Non-Aqueous Phase Liquids (DNAPLs) in the aquifer, a difficult problem to remediate.
2. The release of contaminants to the air from passive soil vapor extraction is a significant issue, potentially requiring a specific regulatory framework. Some stakeholders perceive a higher risk from contaminants in the air than from those in the ground. For many people, uncontrolled release is not acceptable; they believe that off-gas must be captured and managed.
3. There are disadvantages to drilling new wells, including potentially creating subsurface conduits for contamination, high costs, and the problems of abandoned wells. The drilling of new wells should be minimized. The oil and gas industry should be consulted for information on well networks and interconnection effects.
4. The technology is attractive, as it speeds up a natural process, has a low cost, and is simple and logical to operate. However, the questions related to off-gas releases are critical. It is not clear whether this remediation method, relying as it does on variable rates of soil vapor flux, will be able to meet regulatory requirements and cleanup milestones.
5. This VOC extraction method needs to be predictable in its results in order to be selected by remedial project managers.
6. "Better, faster, cheaper" is a motto for new technology evaluation at Hanford. This method is not faster.

APPENDIX C

STAKEHOLDER COMMENTS APPLICABLE TO ANY INNOVATIVE ENVIRONMENTAL TECHNOLOGY

An analysis of the stakeholders comments collected during the focus group meetings and individual interviews revealed concerns and data requirements that apply to all of the technologies evaluated. Those making decisions about the use of any environmental technology should take these perspectives into account. Comments are sorted into the following categories: performance, cost, environmental health and safety, regulatory issues, and socio-political issues.

PERFORMANCE

Potential to increase contaminant mobility. Stakeholders require that a technology not increase the mobility of contaminants it is designed to remediate.

Subsurface injection. Some technologies inject substances ranging from water to microorganisms into the subsurface. This injection raises stakeholders' concerns related to regulation (e.g., Washington State's non-degradation standard for groundwater), effects on groundwater levels, effects on indigenous microorganisms, or the ability to monitor and control the consequences of subsurface injection.

Transfer of contaminants from one environmental medium to another. Stakeholders oppose removing contamination from one area or environmental medium only to transfer it to another, for example from the subsurface to the atmosphere. Technologies that do not immobilize or destroy contaminants on-site will raise these concerns.

Ability to deal with co-contaminants. Stakeholders clearly express concern about a technology's ability to remediate all the contaminants it is likely to encounter. They are concerned about technologies that do not take care of the entire problem, leaving or mobilizing other contaminants. This is a particular concern with mixed radioactive and hazardous contaminants and important for in-situ technologies facing the challenge of residual co-contaminants.

Versatility. In a related issue, stakeholders prefer technologies that deal with a range of contaminants and that are effective in varying conditions of soil, temperature, climate, and other site conditions. Stakeholders will challenge the wisdom of investing in a technology with narrow application.

Process/Secondary waste. Although almost all remediation methods produce some type and quantity of process waste, there is significant stakeholder concern about how that waste will be treated, stored, transported, disposed of, or otherwise managed. Therefore, stakeholders will likely be critical of any innovative technology that generates secondary waste that concentrates toxicity or is more difficult to dispose of or recycle than secondary waste generated by a baseline technology.

Complexity. A technology's complexity of design and operation raises questions for stakeholders. There is a common belief that the more complex a technology, the more expensive it is, the more likely it is to fail, and the more costly and difficult it is to repair.

Maintenance and operation. Technologies that local labor can operate and maintain are preferable to those that require complicated, expensive, off-site maintenance.

Auxiliary technologies. Stakeholders evaluate a technology within the context of the entire system within which it operates. In order to assess one component of the system, stakeholders point out that it is necessary to evaluate the benefits and drawbacks of the entire system. Technologies that require auxiliary components raise issues if the supporting technologies are not completely described, understood, or reliable.

Off-site treatment/transport. Off-site transport, treatment, or disposal of contaminants concern stakeholders. These considerations include the complexities of dealing with varying jurisdictional authorities, possible environmental and health exposure, and accidents, as well as the impact of treatment and disposal facilities.

Timeliness. A technology may have significant benefits in terms of effectiveness, cost or other attributes, but may operate more slowly than a baseline technology. In evaluating technologies, stakeholders take into account rate of performance and time required to complete the job. Many believe that time is of the essence in remediation, particularly in relation to blocking the migration of contaminated plumes.

COST

In evaluating technology, cost is important to stakeholders without taking precedence over certain other considerations, especially health and safety. Stakeholders are concerned about the following aspects of cost:

Cost greater than baseline. Stakeholders will be interested to know if the cost to develop, operate, or decommission a new technology is greater than for the baseline technology. A particular point of concern to stakeholders is life-cycle cost, including startup, operations, maintenance, and decommissioning. Stakeholders will ask to see a complete accounting of life-cycle costs.

Reduced budgets. Stakeholders point out that many decisions about technology development and deployment now have to be made in light of reduced budgets.

ENVIRONMENTAL HEALTH AND SAFETY

Stakeholders are interested in the effect any new technology may have on the health and safety of workers and the public. Specifically they will be concerned about the following:

Failure, and emissions or releases. This is a critical issue with stakeholders. Effects on the environment, the public, or on workers from the failure of a technology — which may range from release of contaminants to mechanical failure and injury — must be carefully considered. Stakeholders require that the ability to control and mitigate failure be built into any technology.

They are very concerned about any uncontrolled emissions or releases of contaminants or other hazardous materials resulting from installation, operation, or removal of a technology. Stakeholders require detailed information about the possible impact of releases on people, wildlife, vegetation, air, water, and soil.

Energy demand. The use of large amounts of energy, for example electric power, to construct, operate, remove, and decommission a technology will matter to stakeholders. A projected energy demand greater than for baseline will raise concern as will the possibility that using the technology and supplying it with energy will place an inordinate demand on or damage natural resources.

REGULATORY ISSUES

Track record. A technology with no history of approval within the federal, state or local regulatory system will raise stakeholders' concerns. Regulatory track record refers to the regulations and regulatory guidance needed to evaluate a technology's compliance. Regulators' familiarity with a technology reduces regulatory uncertainty. Stakeholders will also have concerns about a technology that requires many complex regulatory approvals.

SOCIO-POLITICAL ISSUES

Future options. Stakeholders evaluate unfavorably technologies they see as foreclosing future options for remediation or land use. They will likely prefer methods that promote unrestricted future use of currently contaminated sites, including spiritual, traditional, and practical uses. Stakeholders are critical of technologies that change the physical nature of the land itself, or that preclude future waste processing or other remediation.

Potential to impact natural or cultural resources. Any potential impact from a technology on resources valued by a particular community or region will raise significant concern among stakeholders. These resources include clear air and scenic vistas, drinking water/groundwater supplies, important habitats, open space, and tribal resources and traditional land uses.

Hanford stakeholders identified the following data requirements as necessary for inclusion in the test plan and demonstration of any innovative technology.

DATA REQUIREMENTS - ALL TECHNOLOGIES	
1.	Demonstrate the technology considering differing geological conditions and with a broad range of contaminants and contaminant mixtures to measure its versatility.
2.	Define the demonstration assumptions and expectations about the production, storage, treatment, and disposal of secondary waste from the technology.
3.	Define the specific elements of risk and the risk management strategy to be used in the demonstration and in subsequent deployment of the technology.
4.	Define the elements of and process for assessing operational readiness for the demonstration of the technology.
5.	Define the liability implications and insurance requirements for the deployment of the technology.
6.	Define the control mechanisms and methods of response to all potential technology failures.
7.	Define the methods and equipment necessary to monitor the effectiveness of the technology both as an operating unit and with respect to effects on the environment.
8.	Demonstrate that further cleanup action is not foreclosed by the technology's use.

APPENDIX D

FACT SHEET

Fact Sheet: PSVE-Borehole Flux

Category: Retrieval

NEED:

This technology can be complementary to active soil vapor extraction. (Active soil vapor extraction uses non-renewable power to create a vacuum. That vacuum is applied to a subsurface soil area through a well or wells.) When the point of diminishing returns in removing a volatile contaminant is reached with active soil vapor extraction (because of mass transfer and energy cost limitations), there may still be significant contamination left in the ground. To remove the residual contamination efficiently, the removal process must be tailored to the physical and chemical limitations of the situation. Passive soil vapor extraction offers a lower cost method to remove the residual contamination.

DESCRIPTION:

Fluctuations in atmospheric pressure occur due to weather and seasonal changes. These fluctuations create differential pressure between the atmosphere and air entrained in unsaturated subsurface soils. This approach to remediation uses these differences in air pressure. If the two zones are connected (by a well or borehole), air flow results. If the subsurface contains a volatile contaminant, this contaminant will be carried with the air flow to the surface. Since the driving force (atmospheric pressure fluctuations) of this removal process occurs naturally, this remediation method is inherently inexpensive. The key to its effective use is an understanding of the pressure relationship between the surface and subsurface at a given site under various atmospheric conditions. This knowledge can be used to accurately install pathways (e.g., vadose zone boreholes and wells) to effect contaminant removal. The flow through these pathways can then be controlled or enhanced to facilitate contaminant removal. The following table presents potential enhancements that will

be part of the demonstration, and describes their expected effects.

PSVE Potential Enhancements Projected Effect/Benefit

Wind-driven turbines on the off-gas stack
 Amplify volume of air extracted by passively increasing the pressure differential in the well.

Venturi on off-gas stack
 Amplify volume of air extracted by passively increasing the pressure differential in the well.

Windmill on the off-gas stack
 Amplify volume of air extracted by passively increasing the pressure differential in the well.

One-way flow valve
 Control air flow direction through borehole which will lead to contaminant plume migration control and increased extraction efficiency.

Hot air, steam, or nutrient injection
 Contaminant plume migration control, increased extraction efficiency, or degradation of contaminants in place.

Off-gas treatment: Collection on GAC or other absorbent
 Reduced VOC in off gas.

Off-gas treatment: Destruction by photocatalytic or energy process
 Reduced VOC in off gas.

Interconnected or systemically controlled well networks
 Control of contaminant plume migration rate and direction.

ADVANTAGES:

This remediation method is significantly less

expensive than the baseline of active soil vapor extraction (ASVE). Once a low removal rate is reached with the baseline technology, then the passive removal technology is more cost effective. The demonstration will attempt to quantify advantages and limitations.

CHALLENGES:

Understanding the dynamics of the atmospherically driven removal process

requires measurement over a period of time sufficient to characterize the broad range of atmospheric changes and conditions that can occur. These measurements must then be understood and compared with contaminant removal rates. After gathering and understanding these measurements, the process must be designed, and the parameters of operation must be set and controlled, both in general and at a specific particular site.

Passive Soil Vapor Extraction Using Borehole Flux