EPA

Office of Emergency and Remedial Response

United States Air Force
Air Combat Command

United States Environmental Protection Agency

Office of Solid Waste and Emergency Response

Directive No. 9355.0-68FS
EPA 540-F-97-004
PB97-963501
April 1997

Presumptive Remedy:

Supplemental Bulletin Multi-Phase Extraction (MPE) Technology for VOCs in Soil and Groundwater

Quick Reference Fact Sheet

This Quick Reference Fact Sheet is issued jointly by the U.S. EPA and Air Combat Command (ACC) of the United States Air Force (USAF) to provide information on the Multi-Phase Extraction (MPE) technology for extraction of volatile organic compounds (VOCs) present in soil and groundwater. This fact sheet recommends MPE as a potentially valuable enhancement for the SVE option under the presumptive remedy for sites with VOCs in soils.

PURPOSE

This Fact Sheet will:

- Provide an explanation of the MPE technology;
- Explain how to determine if MPE is applicable to your site;
- Explain how to select between the three MPE applications;
- Discuss the advantages and disadvantages of the MPE applications;
- Provide contaminant extraction costs for MPE; and
- Provide references and points-of-contact (POCs) for more information on MPE.

BACKGROUND

Presumptive remedies are preferred technologies for common categories of sites based on historical patterns of remedy selection and U.S. EPA's scientific and engineering evaluation of performance data on technology implementation. By streamlining site investigation and accelerating the remedy selection process, presumptive remedies are expected to ensure the consistent selection of remedial alternatives and reduce time and costs required to clean up similar sites. Presumptive remedies are generally expected to be used at all appropriate sites; however, site-specific circumstances dictate whether a presumptive remedy is appropriate at a given site. The U.S. EPA has established presumptive remedies for sites with soils contaminated by VOCs. The U.S. EPA guidance documents on these presumptive remedies are *Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils, OSWER 9355.0-48FS* and *User's Guide to the VOCs in Soils Presumptive Remedy.*

This fact sheet is a supplemental bulletin for the VOC Presumptive Remedy. It is intended to provide site managers with recent information that may be useful in making decisions about the specific type of extraction technology to employ at a VOC, presumptive remedy site.

What is MPE Technology?

The MPE process was developed for the remediation of VOCs and other contaminants in low to moderate permeability subsurface formations. The process is a modification of the conventional soil vapor extraction (SVE) technology. Traditional SVE is the process of stripping and extracting volatile compounds from the soil by inducing air flow through the soil. Soil vapor flow is induced by applying a vacuum to extraction wells. Generally, SVE is applied to soil above the groundwater table.

MPE is an enhancement of the traditional SVE system. Unlike SVE, MPE simultaneously extracts both groundwater and soil vapor. The groundwater table is lowered in order to dewater the saturated zone so that the SVE process can be applied to the newly exposed soil. This allows the volatile compounds sorbed on the previously saturated soil to be stripped by the induced vapor flow and extracted. In addition, soluble VOCs present in the extracted groundwater are also removed.

MPE is a generic term for technologies that extract soil vapor and groundwater, simultaneously. Under this generic term, this fact sheet presents two technologies, the two-phase extraction technology (TPE) and the dual-phase extraction technology (DPE). Both technologies extract groundwater and soil vapor from a single well. You can consider MPE as a tool for VOC remediation as illustrated in Highlight 1.

The TPE technology employs a high vacuum (approximately 18 to 26 inches of mercury) pump to extract both groundwater and soil vapor from an extraction well. A suction pipe is lowered into the extraction well to extract the soil vapor and groundwater from the subsurface. A typical two-phase type system is illustrated in Figure 1.

For some TPE methods, turbulence generated within suction pipe facilitates the transfer of aqueous phase contaminants to the vapor phase (up to 98% stripping).

By comparison, the DPE technology employs a submersible or pneumatic pump to extract the groundwater, and a high vacuum (approximately 18 to 26 inches of mercury) or low vacuum (approximately 3 to 12 inches of mercury) extraction blower is used to extract the soil vapor as illustrated in Figure 2. For DPE wells using submersible pump, a sump is installed at the bottom of the well to prevent cavitation of the submersible pump. Under vacuum conditions, a net positive suction head may be maintained, to prevent cavitation of the submersible pump, using a standing water column. Under high vacuum conditions, a sump as deep as 20 feet may be required to provide proper water column at the pump intake.

Note that some specific hardware and well configurations associated with the MPE technologies are patented. In those cases, potential users should contact the patent owners about the patent owner's licensing

Highlight 1

Multi-Phase Extraction (MPE) - A remediation tool for simultaneous extraction of VOC contaminated soil vapor and groundwater.

The two types of MPE are:

- Two-Phase Extraction (TPE)
- Low or High Vacuum Dual-Phase extraction (DPE)

requirements. Description, or use of specific products, methods or companies does not constitute an endorsement by the USEPA or the U.S. Air Force's Air Combat Command.

Is MPE Appropriate at my Site?

Once you have determined that your site is a candidate for a presumptive remedy using the VOC User's Guide, you must determine if MPE can be implemented to treat the VOC contaminated media at your site. MPE is most cost effective for cleaning up low to moderate permeability sites with halogenated VOC contamination in the soil and groundwater. MPE is also effective at cleaning up sites contaminated with non-halogenated VOCs and total petroleum hydrocarbons (TPH). MPE may be particularly useful when expedited cleanups are necessary.

When considering use of MPE, it is important to choose an engineering firm that has experience implementing the MPE technologies. Prior to implementation, a treatability pilot study should be performed and the results evaluated to maximize the effectiveness of the MPE technology selected.

To determine if the MPE technologies may be effective at your site, compare your site conditions to the guidelines presented in Table 1. These guidelines provide a preliminary assessment of the basic site characteristics that relate to MPE treatment effectiveness. The MPE technologies are generally applied below the water table. They also may be applied above and below the water table simultaneously. Note that if you wish to apply MPE above the water table, your site should also meet the air permeability guidelines. If your site conditions meet these guidelines, then your site is a candidate for MPE. At this point you may wish to select one of the MPE technologies as the preferred technology for VOC remedial action at your site and proceed with a treatability pilot study. These guidelines are not a definitive screening test for MPE. So, even if one of your site conditions does not meet these guidelines, MPE may still be an appropriate technology for your site, but greater technical analysis may be warranted. An engineering evaluation, by experienced professionals, should guide your decision to proceed with an appropriate MPE treatability Pilot Study to confirm the applicability of the MPE technologies.

Table 1. MPE General Guidelines

Site Conditions	Guideline
Contaminant	1. Halogenated VOCs. 2. Non-Halogenated VOCs and/or Total Petroleum Hydrocarbons (TPH).
Contamination location	1. Below groundwater table. 2. Both above and below groundwater table.
Henry's Law Constant of majority of contaminants	> 0.01 at 20 C° (dimensionless)[a]
Vapor pressure of majority of contaminants	> 1.0 mm Hg at 20 C°
Geology below groundwater table	Sands to Clays
MPE application above the groundwater table	
Air permeability of soil above the groundwater table.	Moderate and low permeability (k< 0.1 darcy[b]) soils.

[a] Dimensionless Henry's Law Constant in the form: (concentration in gas phase) / (concentration in liquid phase)

[b] Soil Gas permeability (k): 1 darcy = 1×10^{-8} cm^2

The effectiveness of the MPE technologies are directly dependent on site characteristics including geologic, hydrogeologic, and contaminant characteristics. The MPE technologies tend to be less effective under conditions outside of the guidelines shown above. MPE has shown to be less effective for sites that have very high permeabilities and lithologies consisting primarily of gravels or cobbles. For effective MPE, the aquifer must be able to be dewatered. Sites with extremely high groundwater flow rates may be not as suitable for MPE. MPE is not recommended for sites where the target contaminants are not volatile compounds (i.e. inorganic and semi-volatile).

Which Type of MPE is Best for my Site?

Once you have determined that a MPE technology will be effective at your site, you must determine which variation of MPE will be most effective for contaminant removal. All of the MPE technologies; low-vacuum DPE (LVDPE), high-vacuum DPE (HVDPE), or TPE, have optimum site conditions where they are considered to be the most cost effective for VOC contaminant removal. To determine which MPE technology will be most effective at your site, compare your site conditions to the guidelines presented in Table 2. These guidelines provide a preliminary assessment of the basic site characteristics that relate to potential treatment effectiveness of LVDPE, HVDPE, and TPE.

Table 2. MPE Technology Selection Guide: LVDPE, HVDPE, or TPE

Site Conditions	LVDPE Guideline	HVDPE Guideline	TPE Guideline
Groundwater production rate[a]	not limited by typical groundwater production rate, however aquifer must be able to be dewatered.	not limited by typical groundwater production rate, however aquifer must be able to be dewatered.	< 5 gpm
Maximum depth of targeted contamination	not limited by depth of contaminant	Not limited by depth of contaminant	1. Up to 50± feet below ground surface bgs (for groundwater production < 2 gpm). 2. Up to 20-30 feet bgs (for groundwater production between 2 and 5 gpm).
Geology below groundwater table	Sands to silty sands	Sandy silts to clays	Sandy silts to clays
For MPE application above the groundwater table			
Air permeability of soil above the groundwater table.	Moderate permeability (greater than 1 x 10^{-3} darcy)	Low permeability (less than 1 x 10^{-2} darcy)	Low permeability (less than 1 x 10^{-2} darcy)

[a] For MPE, the aquifer must be able to be dewatered.

Generally, the high vacuum (approximately 18-26 inches mercury) applications, HVDPE and TPE, are most cost effective where the target geologic formations have low permeabilities (i.e., sandy silts to clays). Both HVDPE and TPE will be effective at depths less than 50 feet BGS with low ground water production rates (<5 gpm). However, HVDPE has a broader range of application and may also be applied at greater depths and higher flow rates.

The low vacuum (3 to 12 inches of mercury) application, LVDPE, is suitable for more permeable soils (i.e., sands to silty sands). LVDPE is not limited by depth of commitment or typical groundwater flow rates, however the aquifer must be able to be dewatered. Generally MPE is applied below the groundwater table. However, MPE may also be applied simultaneously above and below the water table. Where MPE is to be applied above the groundwater table, the air permeability must also be considered. Figure 3 presents a decision logic flowchart that may assist you in the selection of LVDPE, HVDPE, or TPE.

Prior to implementation of the chosen MPE technology, a treatability pilot study should be performed by an experienced engineering firm. Proper interpretation of the pilot study results are needed to maximize the effectiveness of MPE.

Case Studies and Costs

The MPE technology has been applied at dozens of low to moderate permeability sites and has consistently proven to be more effective at removing subsurface VOCs than conventional pump-and-treat or soil vapor extraction systems alone. This is due to the increase in groundwater and contaminated soil vapor removal rates, and the volatilization of contaminants in the previously saturated soils. The increased mass removal rates result in decreased total removal costs. Note that the effectiveness of the MPE technologies are directly dependent on site characteristics (geologic, hyrogeologic, and contaminant characteristics, etc).

Pilot study and/or full-scale MPE system field data, demonstrating the effectiveness of MPE at multiple military sites (including McClellan AFB, Travis AFB, Nellis AFB, FE Warren AFB, Offutt AFB, Ellsworth AFB, DDRW-Tracy Depot, and Air Force Plant-44 [AFP-44]) are currently available. Appendix A presents the results of selected case studies. Appendix A also includes estimated full-scale contaminant extraction costs, presented in dollars per pound of contaminant removed ($/lb), for each of the case studies. These costs are based on a single well extraction system operated for one year. They include capital costs, installation costs and operation and maintenance costs. The costs do not include design, well installation, or soil vapor/groundwater treatment costs. These costs also do not include any costs associated with patent requirements. As demonstrated in Appendix A, the contaminant extraction costs for MPE applications are highly site-specific. It is dependent upon the original and target clean-up level concentrations of contaminants, aquifer/vadose zone characteristics, groundwater and vapor flowrates, as well as the design and operation of the technology used.

LESSONS LEARNED

The key to designing an effective MPE system is experience and performing a treatability pilot study beforehand. Pilot study results provide key parameters, such as effective well vacuum, groundwater and vapor radii of influence, and groundwater and soil vapor extraction flowrates. These parameters are essential for the selection and design of vacuum pumps, submersible pumps, and eventually, groundwater and vapor treatment.

Because TPE and HVDPE application parameters overlap, other site parameters will also affect your decision on which MPE technology to use. The ability to use existing extraction wells at a site may be the key factor in deciding to use HVDPE or TPE.

Table 3 provides the advantages and disadvantages of HVDPE, LVDPE, TPE which may assist you in final selection of a MPE technology.

Table 3. Advantages and Disadvantages Between HVDPE/LVDPE and TPE

	HVDPE and LVDPE	TPE
Advantages	No limitation on depth of targeted contamination. Lower vacuum losses within extraction well. No limitation on groundwater production rate.	Groundwater stripping: up to 98% transfer of aqueous phase contaminants to vapor phase. No pumps or mechanical equipment required in well. Can be applied at existing extraction or monitoring wells.
Disadvantages	Where submersible pumps are used, a standing water column above the pump is required, therefore, installation of a new extraction well with a sump may be required. More controls required for pump as compared with TPE.	Limited to a maximum groundwater depth of approximately 50 feet below ground surface. Limited to a maximum groundwater flowrate of approximately 5 gpm. Higher vacuum losses due to lifting water from the well.

CONCLUSION

For sites with VOC-contamination in the soil and/or groundwater and appropriate site characteristics, MPE is a cost effective technology. MPE has been applied at dozens of low- to moderate-permeability sites and has consistently proven to be more effective at removing subsurface VOCs than conventional pump-and-treat or soil-vapor extraction systems alone. For further information or assistance on MPE applications, refer to Table 4 for points of contact or reference information.

Table 4. MPE Points-of-Contact and References

Points of Contact	Affiliation	Name	Title	Phone Number
Site Contacts	DDRW-Tracy	Marshall Cloud	Project Manager/ Environmental Specialist	(209) 982-2086
	Travis AFB	Mark Sandy	Remedial Program Manager	(707) 424-3172
	Nellis AFB	Jim Pedrick	Chief of Environmental Restoration Division	(702) 652-6103
	McClellan AFB	Kevin Wong	Remedial Program Manager	(916) 643-0830
	FE Warren AFB	Barry Mountain	Chief of Missile Engineering	(307)-775-2532
	Ellsworth AFB	John DeYoe	Remedial Program Manager	(605) 385-2675
	Offutt AFB	Phil Cork	Installation Restoration Program Manager	(402) 294-7621
	Wright-Patterson AFB (AFP-44)	Dennis Scott	Remedial Program Manager	(513) 255-0258 x417
EPA Contacts	U.S.EPA Headquarters	Scott Fredericks	Environmental Protection Specialist	(703) 603-8771
	U.S.EPA Headquarters	Michael Hurd	Chemist	(703) 603-8836
	U.S.EPA Headquarters	John Blanchard	P.E.	(703) 603-9031
ACC Contacts	ACC Headquarters	Margaret Patterson	Program Manager	(757) 764-6249
Existing U.S.EPA Guidance	"Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils," OSWER 9355.0-48FS.			
	"Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites," Final, October 1996, OSWER 9283.1-12.			
	"User's Guide to the VOCs in Soils Presumptive Remedy," April 1996.			

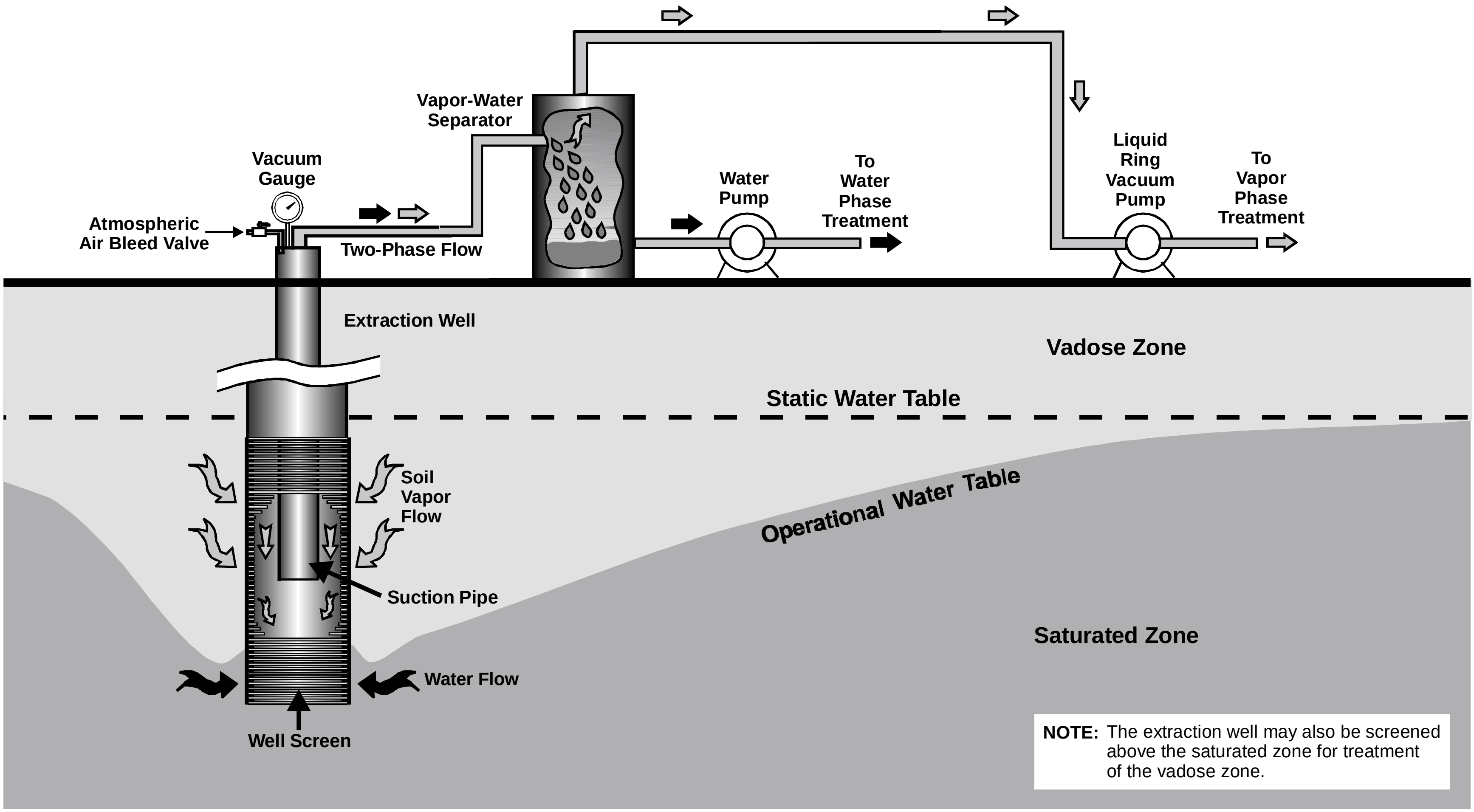

Figure 1. Schematic of a TPE System

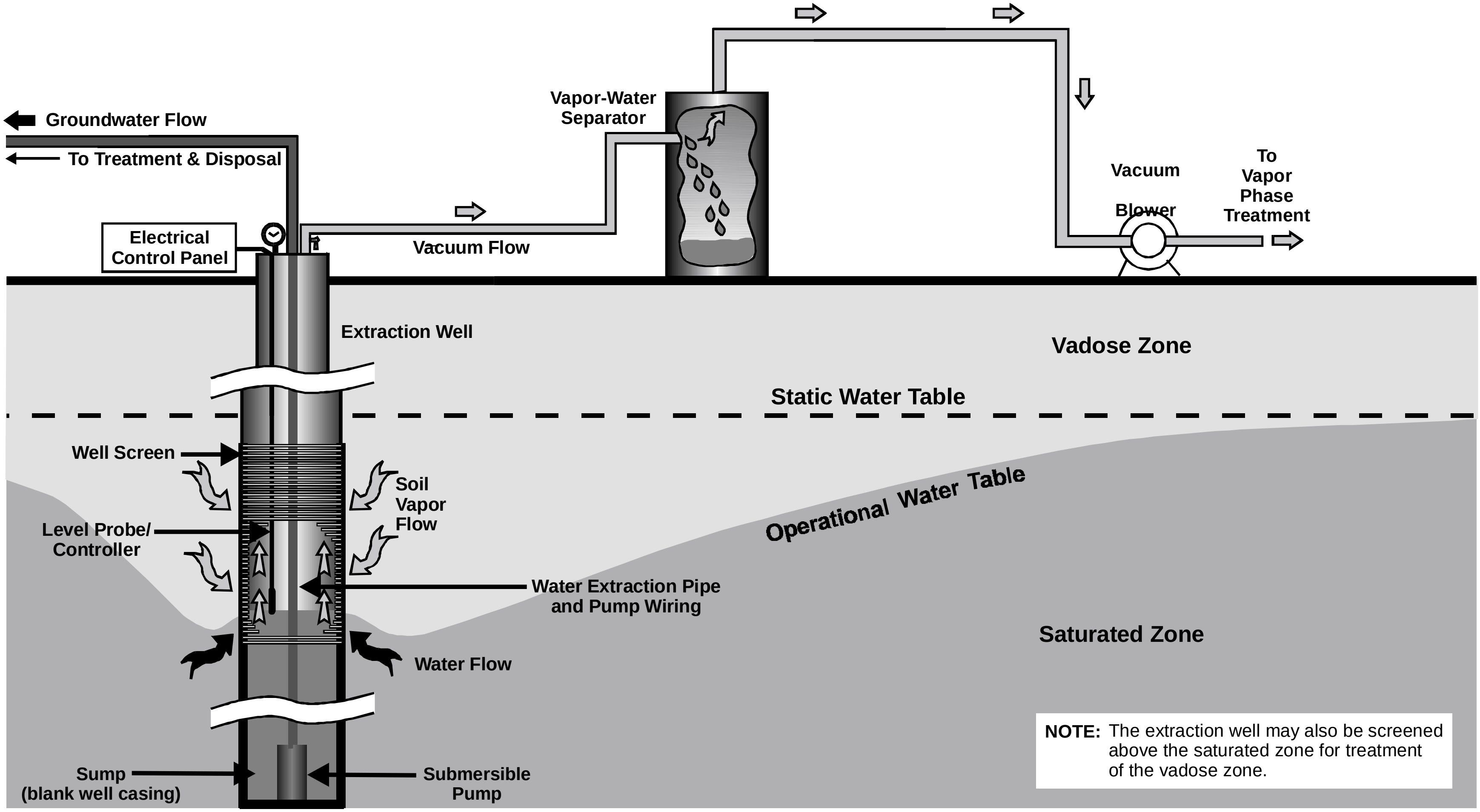

Figure 2. Schematic of a DPE System (Low Vacuum or High Vacuum)

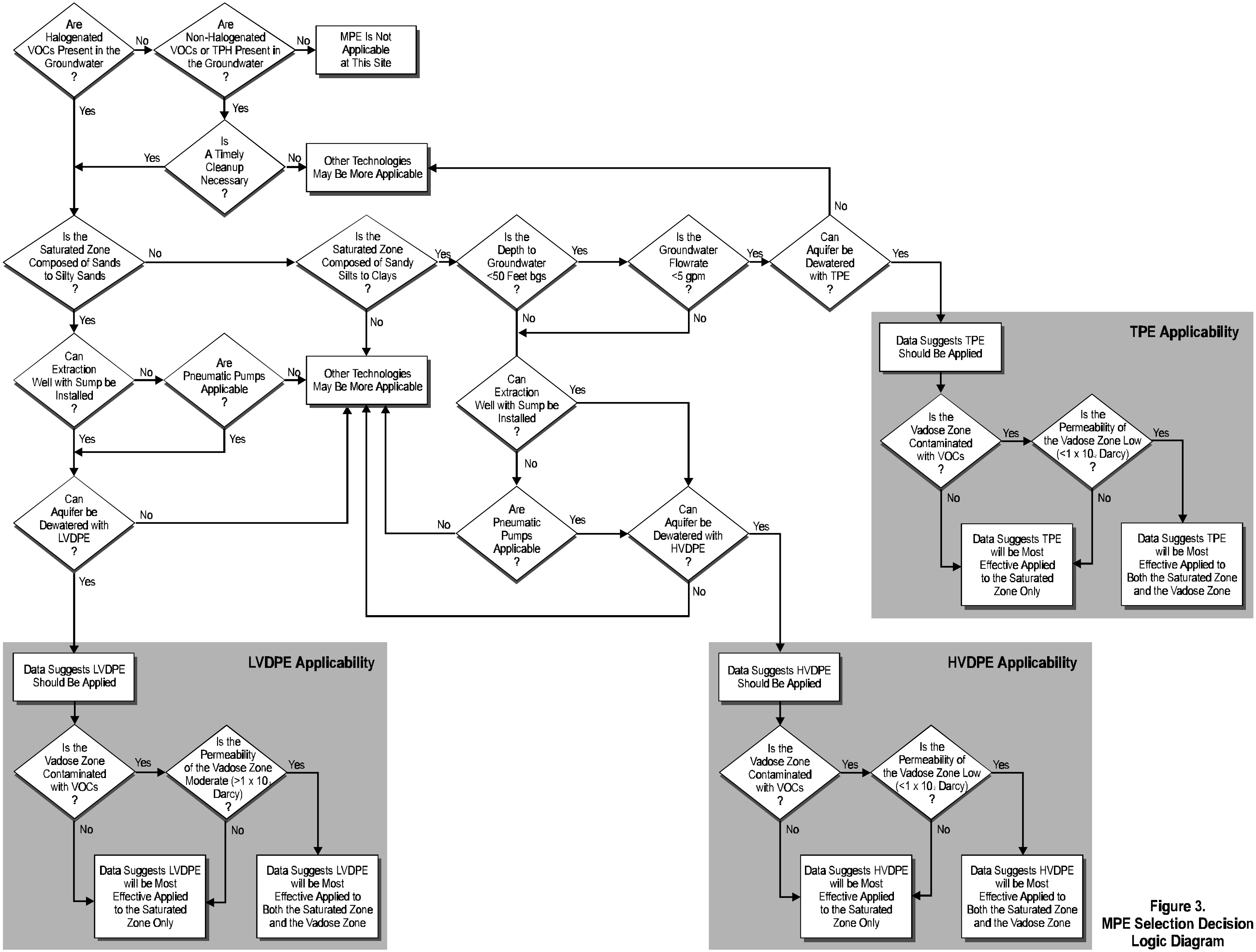

Figure 3. MPE Selection Decision Logic Diagram

Appendix A. Summary of Case Study Results

SITE	Treatment Type	Depth of Water (feet BGS)	Lithology		Targeted Contaminant	Groundwater Concentration (µg/L)	Number of Extraction Wells	Depth of Extraction Well (feet BGS)	Effective Well Vacuum (in. of Hg)	Screened Interval (feet BGS)	Initial Total Mass of VOCs Removed (lbs/day)		Groundwater Flow rate (GPM)		Vapor Flow rate (scfm)	Estimated Cost of Contaminant Extraction ($/lb)	Remarks
			Vadose Zone	Saturated Zone							MPE	P&T	MPE	P & T			
DDRW-Tracy OU1	TPE	24.0	silty clay	silty clay	TCE	3.5-6.5	1	31	18	15.5-30.5	2.5×10^{-3}	8.7×10^{-5}	3.5	0.5	13-17	38,000	a
Travis AFB, MW-269	TPE	13.7	silts, clays	silts, clays	TCE	1,030	1	22.5	19-22	11.7-21.7	0.113	0.008	3.72	0.8	6-10	848	
Travis AFB, Ragsdale & V, MW-7	TPE	10.0	silts, clays	silts, clays	TCE, TPH, Benzene	3,700	1	29	17	8.5-28.5	24	0.29	5	2	17	4	
Travis AFB, OSA	TPE	8.0	silty clay	silty clay	TCE, PCE	900	1	29	22.5	8-28	0.875	0.11	0.5	<0.25	3.5-5	110	
Nellis AFB, Site 44	TPE	45.0	silty clay	caliche, silty clay	TCE (VOCs)	1,760	1	60	6.5	30-60	0.39	0.012	1.7	0.8	87-97	351	b
McClellan AFB, Bld.666	TPE	109.0	sandy silt	sandy silt	TCE, PCE, Freon	8,400	1	124.5	20	105.5-124.5	9	0.36	5.2	4	94	58	c
FE Warren AFB, 0U2, EW1	TPE	10.0	clayey, gravely, silty, sands	clayey sands and clay	TCE	0-150	1	25	9-13	12.7-24.7	0.029	0.011	2.7-3.0	2-3	2-4	3,300	
Ellsworth AFB OU-11, BG-04	TPE	18	sandy silty clay, clayey sand	clayey gravel, pierre shale	TCE	40.5	1	33	9-14	13-23	0.003	0.001	2-3	<2 gpm (estimated)	15-30	32,000	a
Offutt AFB, Bld. 301	LVDPE	50.0	clay	silty sand	TCE	24,600	1	92	9-14.5	50-70	0.7	0.33	3.1	1.5	9-14.5	137	d
McClellan AFB, Bld. 360, EW - 321	LVDPE	112.0	clays, silts	sandy silts, silty sand	TCE (VOCs)	10,500	1	160	10	110-140	11.4	0.28	5.9	2.75	58	245	e
	HVDPE	112.0	clays, silts	sandy silts, silty sand	TCE (VOCs)	10,500	1	160	15	110-140	13.6	0.28	6.7	2.75	78	225	e
McClellan AFB, Bld. 360, MW-224	LVDPE	112.5	sandy silt	sandy silt	TCE (VOCs)	11,000	1	119.5	10	110-140	0.68	0.08	1.6	0.6	4.5	1,700	f
	HVDPE	112.5	sandy silt	sandy silt	TCE (VOCs)	11,000	1	119.5	24	109.5-119.5	2.54	0.08	1.8	0.6	11	1,290	f
Air Force Plant - 44, IRP Site 3,	LVDPE	132.0	interbedded sandy gravel & sandy clay	interbedded sandy gravel & sandy clay	TCE, DCE, TCA, Freon 113	190-510	1	175	6.5	42-184	177	0.21	58	47	231	3	
Air Force Plant - 44, IRP Site 2,	LVDPE	145.0	interbedded sandy gravel & sandy clay	interbedded sandy gravel & sandy clay	TCE	240-2,100	1	250	6	120-245	735	1.55	112	110	181	<1	
Air Force Plant - 44, IRP Site 5	LVDPE	118.0	interbedded sand	interbedded sand	TCE, DCE	25-58	1	180	6	120-150	23.5	0.032	69	64	220	12	

Remarks:

a. High contaminant removal costs are due to low groundwater concentrations.

b. Test results indicate that LVDPE would be more effective than TPE at this site.

c. Test results indicate that HVDPE would be more effective than TPE at this site.

d. Test results indicate that HVDPE would be more effective than LVDPE at this site.

e. HVDPE and LVDPE shown to be nearly equally cost effective for EW-321 at McClellan

f. HVDPE shown to be most cost effective for MW-224 at McClellan.

N/A = Not applicable

Note: Costs associated with any patent requirements are not included in the cost.