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LUST Remediation Technologies

Part III
Options for Ground Wate Corrective Action

Parino Techical Service, Inc.

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Hazardous Waste Research and Information Center
One East Hazelwood Drive
Champaign, Illinois 61820

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LUST Remediation Technologies

Part III
Options for Ground Water Corrective Action

by

Perino Technical Services, Inc.

Illinois Department of
Energy and Natural Resources

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ABBREVIATIONS

ADL	acceptable detection limit
APEG	alkaline metal hydroxide/polyethylene glycol
ATEG	alkaline metal hydroxide/tetraethylene glycol
ATAG	Alternative Technologies Assessment Group
BCD	base-catalyzed dechlorination
BTEX	benzene, ethylbenzene, toluene and xylenes
B.P.	boiling point
cm/sec	centimeters per second
DAPC	Division of Air Pollution Control
°F	degrees Fahrenheit
°C	degrees Centigrade
DLPC	Division of Land Pollution Control
DNAPL	dense non-aqueous phase liquid (hydrocarbons)
DOE	Department of Energy
DRE	destruction/removal efficiency
DWPC	Division of Water Pollution Control
EDTA	ethylene-diamine tetra-acetic acid
GAC	granular activated carbon
HWRIC	Hazardous Waste Research and Information Center
IEPA	Illinois Environmental Protection Agency
IEMA	Illinois Emergency Management Agency
IESDA	Illinois Emergency Services and Disaster Agency
ISV	in-situ vitrification
KOH	potassium hydroxide
KPEG	potassium hydroxide/polyethylene glycol
LPH	liquid petroleum hydrocarbons
LUST	leaking underground storage tank
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
NAPL	non-aqueous phase liquid (hydrocarbons)
NaOH	sodium hydroxide
NPDES	National Pollutant Discharge Elimination System
OFSM	Office of the State Fire Marshall
PEG	polyethylene glycol
PCB	poly-chlorinated biphenyl
PCP	poly-chlorinated phenols
PNA	poly-nuclear aromatic hydrocarbons
POTW	publicly-owned treatment works
ppm	parts per million
ppb	parts per billion
RCRA	Resource Conservation and Recovery Act
SVE	soil vapor extraction

ABBREVIATIONS
(Continued)

TCLP	target compound leaching procedure
TEG	tetraethylene glycol
TPH	total petroleum hydrocarbons
TSDF	treatment, storage or disposal facility
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound
yd^3	cubic yards

ABSTRACT

Leaking underground storage tanks (LUSTs) are recognized as a major potential source of ground water contamination in the U.S. Current state and federal regulations require the remediation of sites where the soil and/or ground water has been contaminated by materials leaking from underground storage tanks. This document summarizes information on technologies for the recovery of liquid petroleum hydrocarbons (LPH) and the remediation of petroleum-contaminated ground water at LUST sites. A companion volume, *LUST Remediation Technologies: Part II - Soil Corrective Action Descriptions*, presents information on technologies for the remediation of contaminated soil at LUST sites. *LUST Remediation Technologies: Part I*, is a question and answer comparison of selected characteristics of remediation technologies.

Currently, the most common method to remediate ground water at LUST sites is removal of the contaminated water by pumping from recovery wells or trenches, treatment of the contaminated ground water by one of several technologies, and discharge or reinjection of the treated ground water. Commonly called "pump and treat", this method has traditionally been readily accepted by regulatory officials.

The ground water pump and treat method is of limited effectiveness in some circumstances, and cleanup objectives may not be reached at some sites for many years, if ever. Because of this, several alternative technologies are being pursued. The alternative technologies described in this document include:

- in-situ bioremediation;
- aquifer air sparging; and
- vacuum vaporization.

Regulatory and permitting requirements for ground water remedial actions in Illinois are also summarized.

SECTION 1
INTRODUCTION

Leaking underground storage tanks (LUSTs), which comprise about twenty-five percent of all underground storage tanks (USTs) in the U.S. are generally discovered during tank testing activities. The major release products are petroleum hydrocarbons, including gasoline, diesel fuel, aviation fuels, kerosene, used motor oil, and fuel oils.

The release of petroleum hydrocarbons from a LUST results in contamination of the surrounding soil and generally the underlying ground water as well. Ground water becomes contaminated when the released hydrocarbons migrate through the soil to the water table. In some cases, when sufficient quantities of liquid petroleum hydrocarbons (LPHs) have been released, the LPHs may pool in a layer floating on top of the water table. LPH is also referred to as "free product." Hydrocarbons that are light enough to float on water (i.e., they have a specific gravity or density less than that of water) are also referred to as light non-aqueous phase liquids (LNAPLs). Gasoline, diesel fuel, and kerosene are examples of LNAPL hydrocarbons. Hydrocarbons that are too heavy to float on water (i.e., they have a specific gravity or density greater than that of water) are referred to as dense non-aqueous phase liquids (DNAPLs). Number 6 fuel oil and the solvent trichloroethylene are examples of DNAPL hydrocarbons.

Concern over the impact of releases from USTs on ground water resources and public and domestic water supplies prompted Congress to initiate protective and corrective measures through the passage of Subtitle I of the Hazardous and Solid Waste Amendments of 1984 (PL 98-616). Under this legislation, the U.S. EPA and the states have developed regulations requiring mitigation of the immediate dangers posed by a release. Corrective action is also required when the release threatens public health and the environment, whether the release is in the form of LPH in the soil or floating on the ground water, or dissolved LPH constituents such as benzene in the ground water.

This handbook describes basic techniques for recovering LPHs and remediating contaminated ground water at LUST sites. A companion volume, entitled *LUST Remediation Technologies: Part II - Soil Corrective Action Descriptions*, describes techniques for treating and/or removing contaminants from unsaturated soil at LUST sites. LUST Remediation Technologies: Part I, is a question and answer comparison of selected characteristics of remediation technologies.

1.1 Free-Product Recovery and Ground Water Remediation Technologies

Several free-product recovery and ground water treatment techniques have been developed or are under development. These cleanup techniques vary in effectiveness and cost. Some are generally accepted and widely used; some are innovative and not yet fully proven, or have not yet seen widespread use; while still others are emerging and have yet to be fully developed for commercial use.

Free-product recovery is commonly included in the early stages of ground water cleanup projects. As long as LPHs remain in the ground they remain a continuing source of contamination of soils and ground water, and can pose a serious fire or explosion hazard. Free-product recovery methods can recover significant proportions of the initial spill volume. However, no free-product recovery system can remove all of the released product. In order to meet cleanup objectives, other soil and ground water cleanup methods must be employed.

Historically, the most common approach to cleaning contaminated ground water has been to pump the water from the ground through wells. The contaminated ground water is then treated at the surface to remove or destroy the contaminants. The cleaned ground water is then typically discharged to a stream, discharged to a sewer system, irrigated on the land, or reinjected into the ground. This cleanup approach is commonly referred to as "pump and treat."

In recent years, the effectiveness of pump and treat technologies has been questioned. Although it is often possible to significantly improve the quality of ground water at a release site, it can be extremely difficult to achieve cleanup objectives at some sites. One article indicated that as of 1990 there were no sites where cleanup objectives had been met using pump and treat technology (Travis and Doty, 1990).

Because of the questions over effectiveness, many ground water professionals have come to think of pump and treat as a containment technology, rather than a treatment technology. Containment-based approaches isolate or immobilize contaminants to keep them from migrating and adversely impacting human health or the environment. Treatment-based technologies remove or destroy the contaminants from the contaminated soil or ground water.

Pump and treat approaches can be extremely effective at preventing ground water from migrating and spreading contamination off site. However, alternative treatment technologies are being sought to eliminate the contaminants from the ground water.

At this time, there are two broad classes of alternative technologies that are being applied in efforts to remediate contaminated ground water: biological technologies and aeration technologies. Biological technologies rely on microorganisms to biologically degrade the contaminants. Aeration technologies remove contaminants from ground water by volatilization, air stripping, and increasing dissolved oxygen, to increase natural biodegradation.

These technology groups can be applied in various configurations, singly or in combination. Unfortunately, few rigorous guidelines exist for the optimal design, installation, and operation of ground water remediation systems. Design of alternative ground water remediation systems has been largely empirical. Designing a specific remediation system, and even determining whether or not a particular technology can be applied, is highly dependent on the specific features of the site, the characteristics of the contaminants present, and the nature of the soils and ground water system to be remediated. Ensuring that a remedial action will achieve its objectives in a cost-effective and timely manner depends on adequate site characterization and design efforts. Pilot testing and/or treatability studies are usually needed to establish design parameters.

Five cleanup technologies are described in the following sections of this volume:

- free-product recovery technologies;
- removal, above ground treatment and disposal of contaminated ground water (conventional pump and treat);
- in-situ bioremediation of contaminated ground water;
- aquifer air sparging and soil vapor extraction; and,
- vacuum vaporization (a patented, emerging technology relying on aspects of all of the above approaches in a unique configuration).

1.2 Contaminants and Contaminant Characteristics

Before selecting and designing a remediation system, the contaminants of concern and their chemical characteristics must be determined. The contaminants of concern are those which are present in levels above the IEPA cleanup levels and must be dealt with in the remediation plans. These contaminants differ for releases of gasoline and for those of other petroleum hydrocarbons and are discussed below.

Characteristics such as vapor pressure, solubility, Henry's Law constant, and soil adsorption coefficient of the chemical(s) released into the subsurface from a LUST are very important. These characteristics govern the behavior of petroleum hydrocarbons and the potential for success in attempts to remediate the ground water. They are described later in this section.

Gasoline

USEPA and IEPA have determined that the contaminants of primary concern at LUST sites which involved a release of gasoline are benzene, ethylbenzene, toluene, xylene (total), and total BTEX. Total BTEX is the sum of the benzene, toluene, ethylbenzene, and total xylene concentrations. Hundreds of chemical constituents are present in gasoline besides the BTEX constituents.

When gasoline is released to the environment, its composition changes. Some constituents volatilize, others are naturally biodegraded, while others are chemically altered. This change in composition is often referred to as "weathering". Typically, as it weathers, gasoline becomes relatively depleted in the lower molecular weight constituents such as isopentane and benzene, and relatively enriched in the higher molecular weight constituents such as ethylbenzene and m-xylene.

The four BTEX constituents are highly volatile and have chemical properties enabling them to be successfully recovered by air stripping, bioremediation, aquifer air sparging, vapor extraction, and vacuum vaporization, although not necessarily with equal ease. For example, benzene has a relatively high vapor pressure. It is relatively easy to recover using aeration technologies such as aquifer air sparging and vacuum vaporization. The xylenes, however, have much lower vapor pressures and moderately high soil adsorption coefficients. Complete remediation using aeration technologies is more difficult for xylenes than for benzene.

The Illinois generic cleanup objective for ground water is much lower for benzene than for other BTEX constituents (which are included in the objective for total BTEX). Thus, cleanup objectives for BTEX constituents can often be met at gasoline sites by meeting the more strict benzene standard. Section 7 presents information on the IEPA cleanup objectives for ground water contaminated with various chemicals released from LUSTs.

Other petroleum products

In cases where middle or heavy end petroleum products (e.g., diesel fuel, kerosene, fuel oil, lubricating oil) or other organic substances (e.g., solvents, pesticides, transformer oil, waste oil) are released, the contaminants of concern may not be easily remediated with aeration technologies such as air stripping and aquifer air sparging. At these sites, remediation may be driven by the cleanup objectives for high molecular weight compounds such as naphthalene or other poly-nuclear aromatic hydrocarbons (PNAs). These compounds are less likely to be successfully remediated using Soil Vapor Extraction (SVE). Bioremediation or thermal treatment may be more effective.

Gasoline and other petroleum products

Some of the physical and chemical properties important to successful remediation are listed in Table 1 for chemicals typically found in petroleum products. The physical and chemical characteristics that most influence the behavior of organic contaminants in the subsurface are vapor pressure, water solubility, Henry's Law constant, and soil adsorption coefficient. A discussion of why they are important follows.

Table 1. Chemical Properties of Hydrocarbon Constituents of Petroleum Products

Chemical Class	Representative Chemical	Liquid Density (g/cm^3) @ 20°C	Henry's Law Constant (dim.)	Water Solubility (mg/ℓ) @ 25°C	Pure Vapor Pressure (mm Hg) @ 20°C	Vapor Density (g/m^3) @ 20°C	Soil Sorption Constant (K_{oc}) (L/kg) @ 25°C
n-Alkanes							
C4	n-Butane	0.579	25.22	61.1	1560	4960	250
C5	n-Pentane	0.626	29.77	41.2	424	1670	320
C6	n-Hexane	0.659	36.61	12.5	121	570	600
C7	n-Heptane	0.684	44.60	2.68	35.6	195	1300
C8	n-Octane	0.703	52.00	0.66	10.5	65.6	2600
C9	n-Nonane	0.718	N/A	0.122	3.2	22.4	5800
C10	n-Decane	0.730	N/A	0.022	0.95	7.4	13000
Mono-aromatics							
C6	Benzene	0.885	0.11	1780	75.2	321	38
C7	Toluene	0.867	0.13	515	21.8	110	90
C8	m-Xylene	0.864	0.12	162	6.16	35.8	220
C8	Ethylbenzene	0.867	0.14	167	7.08	41.1	210
C9	1,3,5-Trimethylbenzene	0.865	0.09	72.6	1.73	11.4	390
C10	1,4-Diethylbenzene	0.862	0.19	15	0.697	5.12	1100
Phenols							
Phenol	Phenol	1.058	0.038	82000	0.529	2.72	110
C1-phenols	m-Cresol	1.027	0.044	23500	0.15	0.89	8.4
C2-phenols	2,4-Dimethylphenol	0.965	0.048	1600	0.058	0.39	N/A
C3-phenols	2,4,6-Trimethylphenol	N/A	N/A	N/A	0.012	0.09	N/A
C4-phenols	m-Ethylphenol	0.037	N/A	N/A	0.08	0.53	N/A
Indanol	Indanol	N/A	N/A	N/A	0.014	0.1	N/A
Di-aromatics	Naphthalene	1.025	N/A	30	0.053	0.37	690

Source: USEPA, 1991a, Table 1.

Vapor Pressure is a measure of the compound's tendency to evaporate. Vapor pressure increases dramatically with temperature. Heating with warm air (eg., off-gas treatment system exhaust) will enhance the volatilization of contaminants in technologies involving aeration, such as air stripping or aquifer air sparging. Chemicals with vapor pressures greater than 0.5 millimeters of mercury (mm Hg) can be expected to volatilize readily and therefore be amenable to treatment with aeration technologies. Many of the constituents of gasoline, including benzene, ethylbenzene, toluene, and xylenes, have vapor pressures well above 0.5 mm Hg. Thus, these contaminants can be effectively removed from soil and ground water with aeration technologies.

Water Solubility controls the degree to which the compound dissolves in ground water and in pore water in the vadose zone (i.e., the unsaturated zone).

Henry's Law constant is a dimensionless coefficient describing the tendency of a compound to volatilize from the dissolved state. It is analogous to the vapor pressure, which describes the tendency of the compound to volatilize from its liquid state. Like the vapor pressure, Henry's Law constant is highly temperature dependent. Remediation of ground water containing compounds with high Henry's Law constants (greater than 0.01) may be achieved with aeration technologies such as air stripping and aquifer air sparging.

Soil Sorption Coefficient, K_d, describes the tendency of the compound to adsorb on soil or organic matter particles. Larger, more carbon rich molecules have much higher sorption coefficients than smaller, lower molecular weight compounds. This helps account for the relative immobility of heavy fuels in soils.

1.3 Site Characteristics

In order to design an efficient, cost-effective ground water remediation system, data on the environmental conditions of the site must be acquired. The site characterization activities must define the direction and rate of ground water flow, contaminants of concern, the horizontal and vertical extent of contamination, the depth to ground water, and the thickness of the unsaturated zone. The physical and chemical characteristics of the soil environment both above and below the water table (e.g., the vertical and horizontal permeability with respect to air, hydrocarbon liquids, and water; the moisture content of the soil in the unsaturated zone; the organic matter content; and the soil structure) must be determined.

Identifying and quantifying the contaminants of concern leads to the definition of cleanup goals, which fundamentally control the subsequent remedial design. Defining the contaminants of concern takes place both prior to site characterization by examining records of fuels and chemicals known and suspected of having been used at the site, and during site characterization by sampling and analyzing the soil and ground water at the release site.

It is not sufficient to rely solely on knowledge of the substance known or presumed to have been released. Samples from the site must be taken and analyzed. The date of the release, the properties of the site, and the properties of the substance released, will influence the contaminant concentrations in the soil, determine what cleanup objective(s) will apply, and determine what remediation technologies will be effective.

For example, at a very old gasoline spill, much of the lighter gasoline constituents (especially benzene and toluene) may have dissipated or degraded. Polynuclear aromatic hydrocarbons from waste oil and lead from leaded gasoline may be the primary constituents of concern. In such a case, above-ground aeration technologies (air strippers) would be relatively ineffective in removing the organic constituents and completely ineffective at removing dissolved lead. In-situ technologies might be very effective at treating the organic constituents by stimulating biological activity and biodegradation, but would similarly be ineffective at removing the lead. It would likely be more effective to conduct multi-stage above-ground technologies employing biological treatment of the organic contaminants followed by inorganic treatment for lead removal.

The vertical distribution of contaminants in the soil and the position of the water table are key factors affecting design. Often, contaminant concentrations are highest in the soil zone through which the water table fluctuates. Liquid phase contaminants may be floating on the ground water. Seasonal variations in the water table must be identified to ensure that all of the contaminants are captured by the remediation system. Treatment of contaminated ground-water may never achieve cleanup objectives if nearby or overlying sources of contamination in the unsaturated zone are not cleaned. Fluctuating water levels can produce zones of highly variable contaminant concentrations.

The characteristics of the site and the soil control the inherent effectiveness of a remediation system for a particular site. The physical and chemical characteristics of the soil that are most important in the design of remediation systems are:

1) Soil Permeability (Hydraulic Conductivity): the permeability of the soil is the single most important variable controlling the feasibility and the design of in-situ and ground water extraction remediation systems. Permeability is a measure of the ability of fluids (air, liquid hydrocarbons, or water) to flow through the soil. The permeability of the soil with respect to water in the saturated zone below the water table is also referred to as the hydraulic conductivity. Permeability can vary both vertically and horizontally over a site. These variations in permeability have a major influence on the direction and speed of ground water and liquid hydrocarbon flow.

2) The Soil Moisture Content: the moisture content of the unsaturated soil above the water table affects the behavior of contaminants in the subsurface in several ways. Soil moisture occupies soil pore space, thereby reducing the gas volume, reducing the air permeability, and interfering with volatilization. Some of the contaminants in the unsaturated zone will dissolve in the soil moisture making removal more difficult or complex.

3) Soil and Ground Water Temperature: several of the chemical characteristics of contaminants (e.g., the vapor pressure and the Henry's Law constant) are temperature dependent. In general, higher temperatures enhance the desorption, volatilization, and flow of contaminants through the subsurface to extraction wells and their removal using aeration technologies. The soil temperature is seldom a decisive factor in determining whether to employ a particular treatment technology. However, if a treatment system is to be operated in the winter, provision for heating the system and possibly heating injection air to warm the subsurface may be incorporated in the design.

4) The Soil Organic Matter and Clay Content influences the capacity of the soil to adsorb organic contaminants. Soils with a high proportion of clay and/or organic matter have relatively high adsorption capacities. Therefore, they are less likely to be completely remediated by vapor extraction techniques. Desorption of strongly adsorbed VOCs in organic or clay rich soils may not be possible without excavation and thermal treatment or incineration. Biological treatment may be effective, however. High organic matter and clay content also decrease permeability. Clean sands and gravels adsorb contaminants much less strongly than organic-rich soils. They also transmit air and water far more easily. These factors improve the potential for successful remediation using in-situ techniques.

5) The Soil Structure affects the way in which liquid, free-product, vapor phase contaminants, and contaminants dissolved in the ground water from a LUST release migrate through the soil. The presence of zones of higher permeability, and of preferred flow paths such as utility trenches, root channels, improperly sealed wells, and desiccation cracks, influence the design and performance of the ground water extraction and in-situ treatment systems.

SECTION 2
RECOVERY OF LIQUID PETROLEUM HYDROCARBONS

Liquid petroleum hydrocarbons (LPH) in the ground can pose two potentially serious threats: the threat of ground water contamination; and, if the LPH or hydrocarbon vapors migrate into sewers or basements, the threat of explosion and fire. If liquid petroleum hydrocarbons are detected during tank removal actions or at any point during site investigations, the Illinois EPA requires that free-product recovery be initiated as soon as possible. It may also be necessary to control the flow of both the LPH and ground water underlying the site to keep the contaminants from migrating off-site, and posing a threat to nearby drinking-water supplies, or possibly a risk of fire or explosion.

The amount of LPH that can be recovered after a spill will always be less than the total amount released. A fraction of the LPH will remain as a residual between and adhering to the soil particles. This fraction cannot be recovered as a liquid. In the vadose zone, remediation techniques such as excavation and land disposal or soil vapor extraction must be used (see the companion volume to this report, *LUST Remediation Technologies: Part II - Soil Corrective Action Descriptions*).

Residual hydrocarbon droplets can also be trapped below the water table if the release occurs from a pipe or tank below the water table, or as a result of seasonal water level fluctuations. Generally, LPH trapped below the water table cannot be recovered as a free liquid. It must be remediated by removing the dissolved constituents in the ground water, using a technique such as air sparging (see Section 5.0), or by artificially lowering the water table to enable the use of a soil corrective action technique.

Determining the depth to LPH and the thickness of LPH contamination or plumes are important in determining how much can be recovered, identifying an effective recovery method, and estimating the time for recovery to be completed. The distance to the top of LPH in a well and to the oil-water interface can be measured using a weighted tape with oil and water sensing pastes, with an electronic oil-water interface probe, or with a clear bailer.

Detection, monitoring, and recovery of floating LPH are complicated by the different behaviors of organic liquids and water. These differences in behavior result from the immiscibility of hydrocarbons and water and differences in the physical properties of the two liquids. Testa and Winegardner (1991) present a more detailed discussion of the geochemistry of petroleum hydrocarbons, their occurrence and behavior in the environment, and methods for detecting and measuring them in the subsurface.

The thickness of free liquid hydrocarbons in a monitoring well does not directly correspond to the actual thickness in the surrounding formation. The difference between apparent thickness in a well and the actual LPH thickness is dependent on the specific gravity of the hydrocarbon; and on the grain size distribution, hydraulic conductivity, and porosity of the formation. The apparent thickness is generally greater than the actual thickness, as shown in Figure 1.

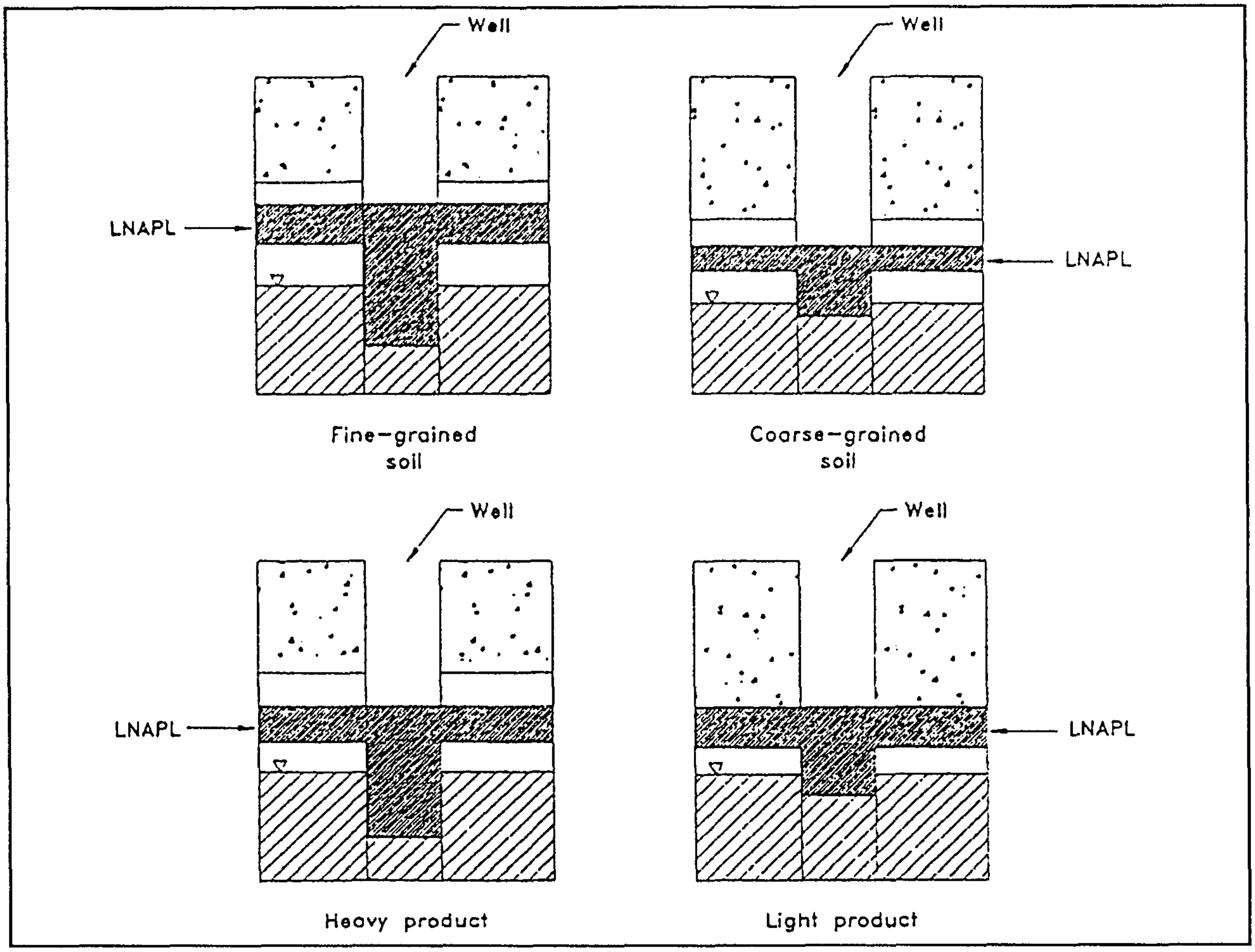

Figure 1: Apparent LPH Thickness in a Well and Adjacent Formation

Testa and Winegardner (1991) provide a detailed discussion of the principals which determine the actual differences observed between apparent LPH thickness and actual LPH thickness, and the practical aspects of estimating actual LPH thickness from measurements of the apparent thickness in a well. As a general rule of thumb for gasoline, the apparent thickness of free LPH measured in the well can be roughly estimated at 4 times the actual formation thickness (de Pastrovich, et al, 1979). The apparent thickness may be as much as five to ten times greater than the actual thickness for heavier hydrocarbons and fine-grained soils, or as little as two to three times the actual thickness for light LPH in coarse sands or gravels (Testa and Winegardner, 1991).

2.1 Recovery Methods

There are two basic approaches to recovering free LPH from the water table: linear interception systems (trenches and drains) and recovery well systems (Testa and Winegardner, 1991; U.S. EPA, 1992). Each approach has advantages and disadvantages which are discussed in the following subsections.

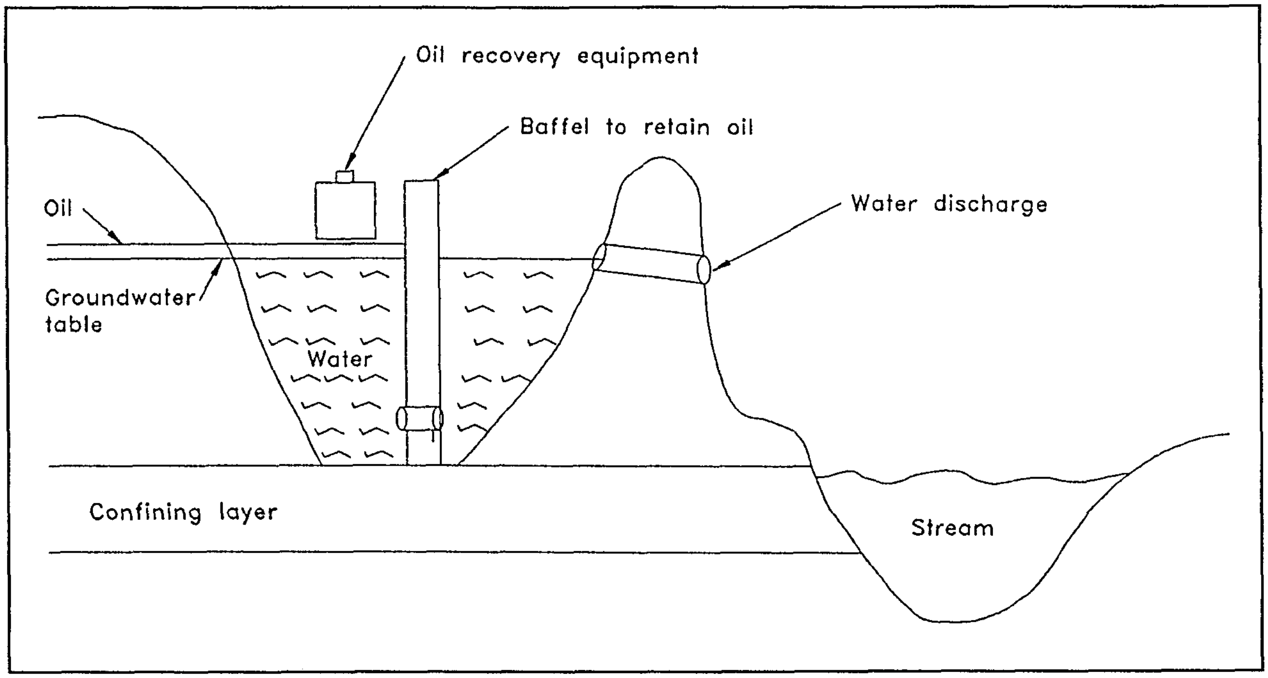

Figure 2: **Schematic Showing a Typical Recovery Trench System**
(Testa and Winegardner, 1991)

2.1.1 Linear Interception Systems

Linear interception systems include ditches, trenches, and hydraulic troughs. These systems are also referred to as line sinks. They rely on the creation of a linear area of low hydraulic head to direct subsurface water and free LPH to a collection point. The use of trenches is suitable at sites where there are no restrictions on excavation resulting from under-ground utilities or space limitations, and where the depth to ground water and LPH is 25 feet or less (Testa and Winegardner, 1991). A schematic of a typical recovery trench is shown in Figure 2.

Linear interception systems typically have relatively large surface areas exposed to the atmosphere. Evaporation of LPH can be considerable. Thus, the use of open trenches is only appropriate at sites where odor and/or air quality concerns are minimal (Testa and Winegardner, 1991).

Linear interception systems can be either passive or active. In passive systems, there is no external stimulation of flow to the recovery system. In active systems, flow to the recovery point is stimulated by pumping of ground water/product to increase the hydraulic gradient and thus the rate of flow (Testa and Winegardner, 1991).

Passive systems rely on natural hydraulic gradients to transport free product to the collection trench or ditch. The flow of LPH is generally quite slow. However, they are relatively easy and inexpensive to install. They can often be installed quickly as an initial recovery and containment method, and can be very effective at preventing the migration of free LPH from the site (Testa and Winegardner, 1991).

Active systems stimulate flow to increase the rate of LPH recovery. In order to enhance recovery from a trench, pumping may be used to lower the water level and stimulate flow into the trench. In such a system, considerable water may be collected which may need to be treated to remove dissolved contaminants before being disposed, discharged, or reinjected. However, recovery of LPH is accelerated. In addition, protection of downgradient receptors may be enhanced since water flows into the trench from both sides and establishes a hydraulic barrier to ground water flow (Testa and Winegardner, 1991).

Different configurations of linear systems may also be employed to enhance LPH recovery or containment of contaminants. For example, collection trenches may be extended throughout the LPH plume, as illustrated in Figure 3. Trenches may be backfilled with permeable material such as gravel, then capped with a clay or synthetic liner to reduce air emissions. Collection pipes may be installed in a classic French drain configuration (Testa and Winegardner, 1991). A schematic of such a system is shown in Figure 4.

The amount of water entering a trench recovery system can be estimated using Darcy's equation:

$$Q = KAI,$$

where Q = the discharge, I = the hydraulic gradient on either side of the trench, K = the permeability of the soil, and A is the area of the trench sides (Testa and Winegardner, 1991).

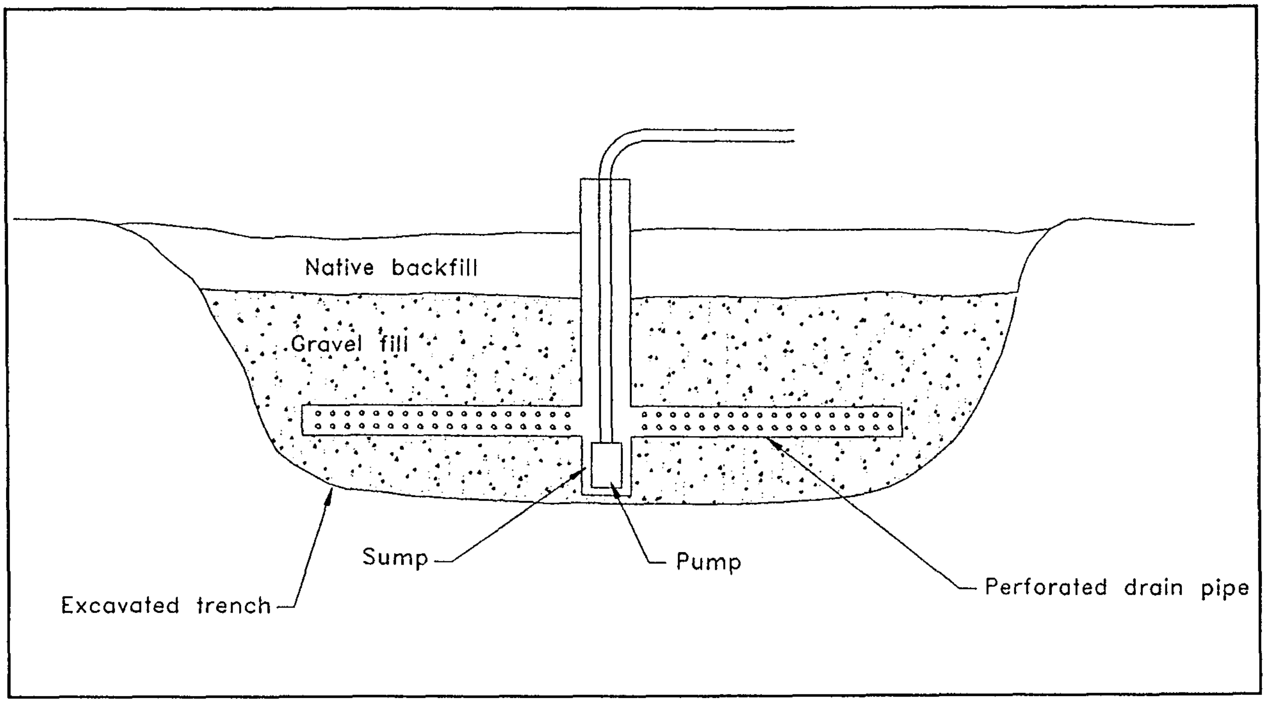

Figure 3: Collection Trenches in the LPH Plume

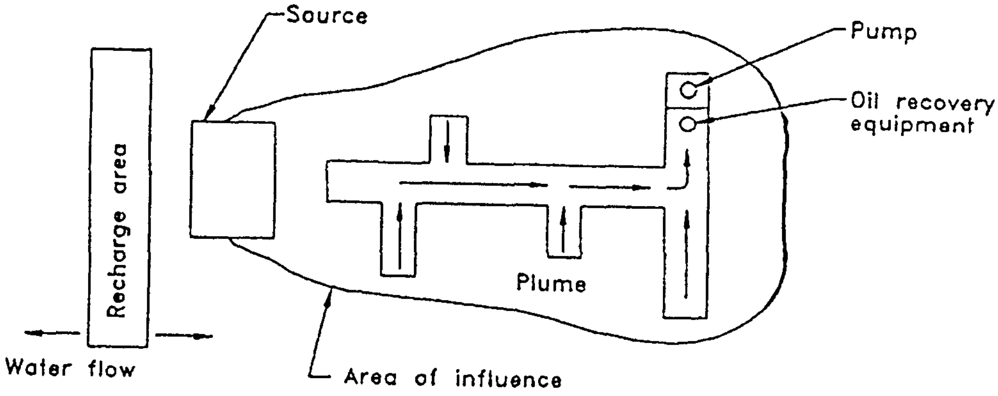

Figure 4: **A Backfilled Trench Recovery System in a Classic French Drain Configuration**

2.1.2 Well-Point Systems

Wells are point features rather than linear features. Their use in recovering LPH is indicated when there are surface or subsurface restrictions or obstructions to constructing trench systems, when the depth to the LPH and water table is too great to enable excavation of a trench system, or when there are regulatory, safety, or nuisance factors limiting the uncontrolled release of hydrocarbon vapors.

LPH recovery wells differ from monitoring wells and ground water recovery wells in several important details of their designs. Most critically, the screened interval must overlap the hydrocarbon - water interface and must accommodate seasonal fluctuations in water levels. Several variations on the basic concept of recovery wells are possible. Variables include the size, number, and spacing of wells, and also the methods by which the LPH is collected and removed from the well. LPH collection equipment is discussed in Section 2.2 below.

Well points are shallow (<20 feet), often small diameter (2 - 4 inch diameter) pipes attached to short (2 - 3 feet) lengths of well screen. They are commonly used for lowering the water table below construction excavations. Fluid (water and/or LPH) is commonly removed using a suction pump, although other approaches are possible. A typical well point is shown in Figure 5. Well points should only be used where the hydrocarbon-water interface elevation does not move above or below the screened interval.

Well points may be linked together in a network to recover LPH from a larger area or to mimic an interception trench, as shown in Figure 6. In this way they can serve as effective barriers to migration of contaminants from the site, and LPH recovery can be accelerated.

Well points are generally installed using conventional hollow-stem auger-drilling techniques, or they may be simply driven into the ground if the soils are soft and the depth to the water table is shallow. The hydraulic properties of the soil must be conducive to fluid movement to the well point.

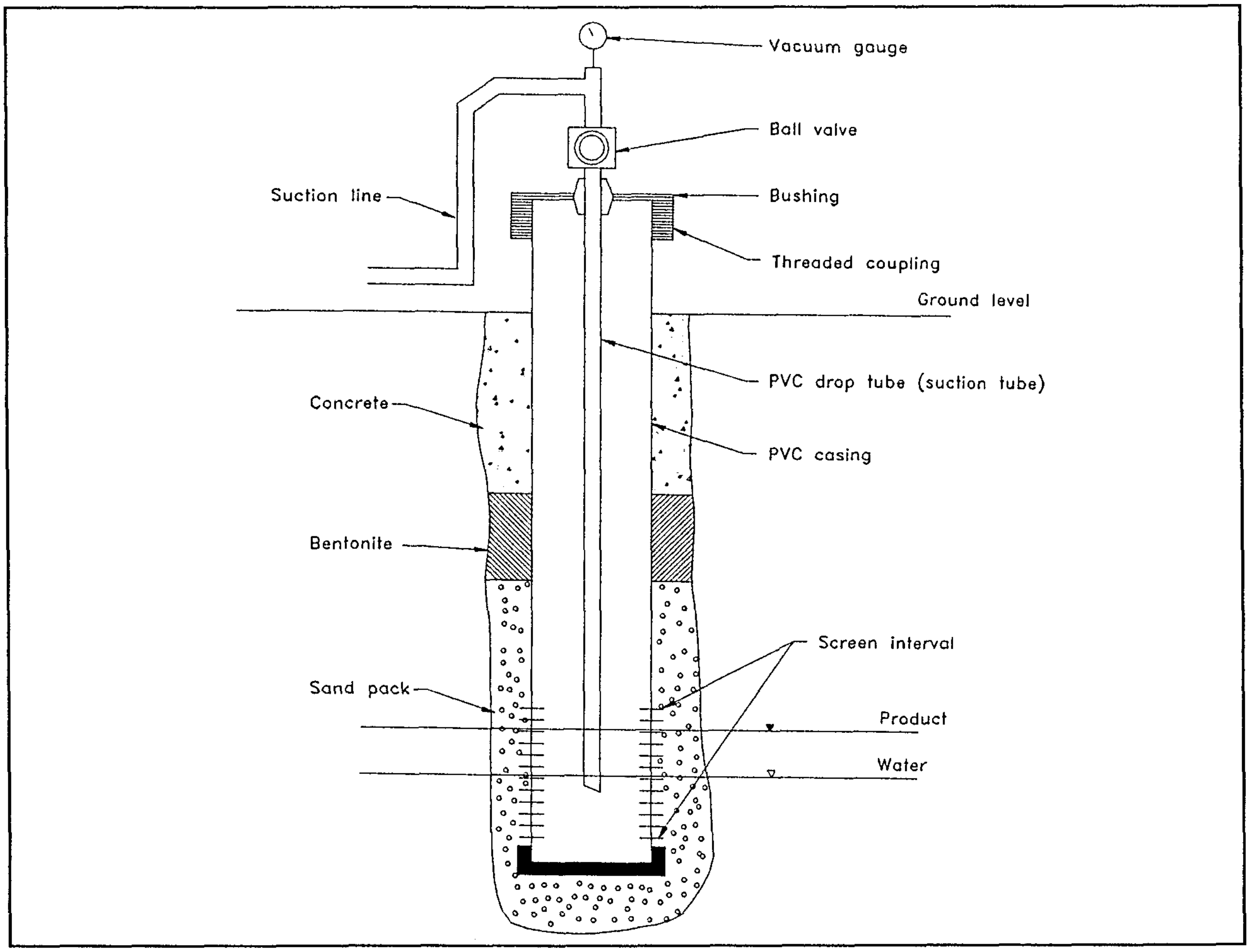

Figure 5: Typical Well Point

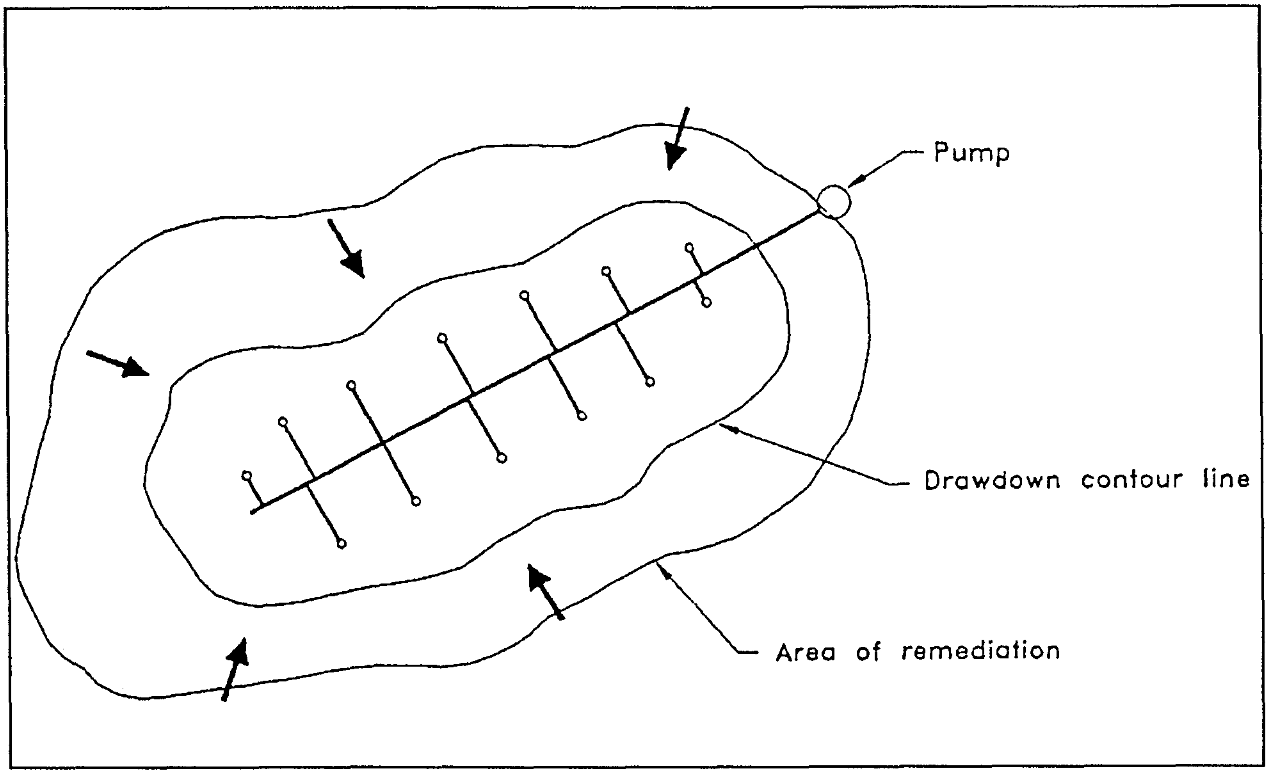

Figure 6: **Example Layout for a Well Point Recovery System**

2.2 Recovery Equipment

There are several different kinds of equipment that can be used to remove LPH from trenches or recovery wells. Passive and manual techniques do not require a power source, and may be adequate for sites where the LPH is thin and/or comes into the well or trench very slowly. Active and automated systems may be more appropriate for sites where large volumes (100 gallons or more) of LPH are to be recovered, the thickness is greater, and/or the LPH flows readily into the well or trench.

2.2.1 Manual Bailing

If the LPH in a well is thin and moves into the well slowly, the simplest removal is to periodically manually bail it from the well. The frequency of bailing is determined by the rate that product reenters the well after it is bailed. This is generally considered an interim measure, since the time required to remove a significant volume of product is very long. In clays or tills with low permeabilities, it may be possible to remove only a few ounces or pints of product every few days. Care should be taken when bailing to remove as little water as possible to reduce disposal costs. In general, however, a more pro-active approach to corrective action is dictated, either by regulatory authorities or concerns over safety and potential liability for the spill.

2.2.2 Sorbent Wicks

Sorbent wicks are similar to the adsorbent booms used to contain and adsorb oil spilled into surface waters. They are made of oil-attracting (oleophilic), water repelling (hydrophobic) materials. When suspended in a well at the hydrocarbon level, they soak up the LPH much like a candle wick. Periodically they are removed and disposed. Like manual bailing, they are suitable only for thin layers of LPH or very low permeability soils. However, they can be left unattended in a closed well while recovering LPH, requiring only periodic visits for replacement as they become saturated.

2.2.3 Skimming Units

Skimming units are well-suited to the removal of thin layers (fractions of an inch thick) of floating LPH from either wells or open trenches. They are available in a variety of forms and configurations.

Rope and belt skimmers employ a continuous loop of oleophilic rope, cord, hose, or belt to pick up floating hydrocarbon from the surface of a trench. Narrow (4-inch) belt systems are also available for use in wells. Figure 7 shows the basic configuration of a belt skimmer.

Rope and belt skimmers operate by continuously passing the oleophilic rope or belt over a drive pulley system. Floating hydrocarbons adsorb to the rope or belt as it passes through the oil layer. The loop is drawn through wipers or scrapers to remove the oil and returned to the surface of the oil layer. When a rope or tube is used on the surface of a recovery trench, excess length floats on the surface to provide additional contact time over a larger surface area, to improve collection. The collected LPH is channeled to a storage drum or tank for recycling or disposal.

Belt and rope skimmers require significant operating attention. Periodically, the collection drum or tank must be emptied. They can collect up to a few hundred gallons per day of LPH. Heavier hydrocarbons such as fuel oil or diesel fuel adsorb more effectively to the oleophilic material than light products such as gasoline. Volatilization may inhibit their use at active retail gasoline locations where odor or flammability may be concerns.

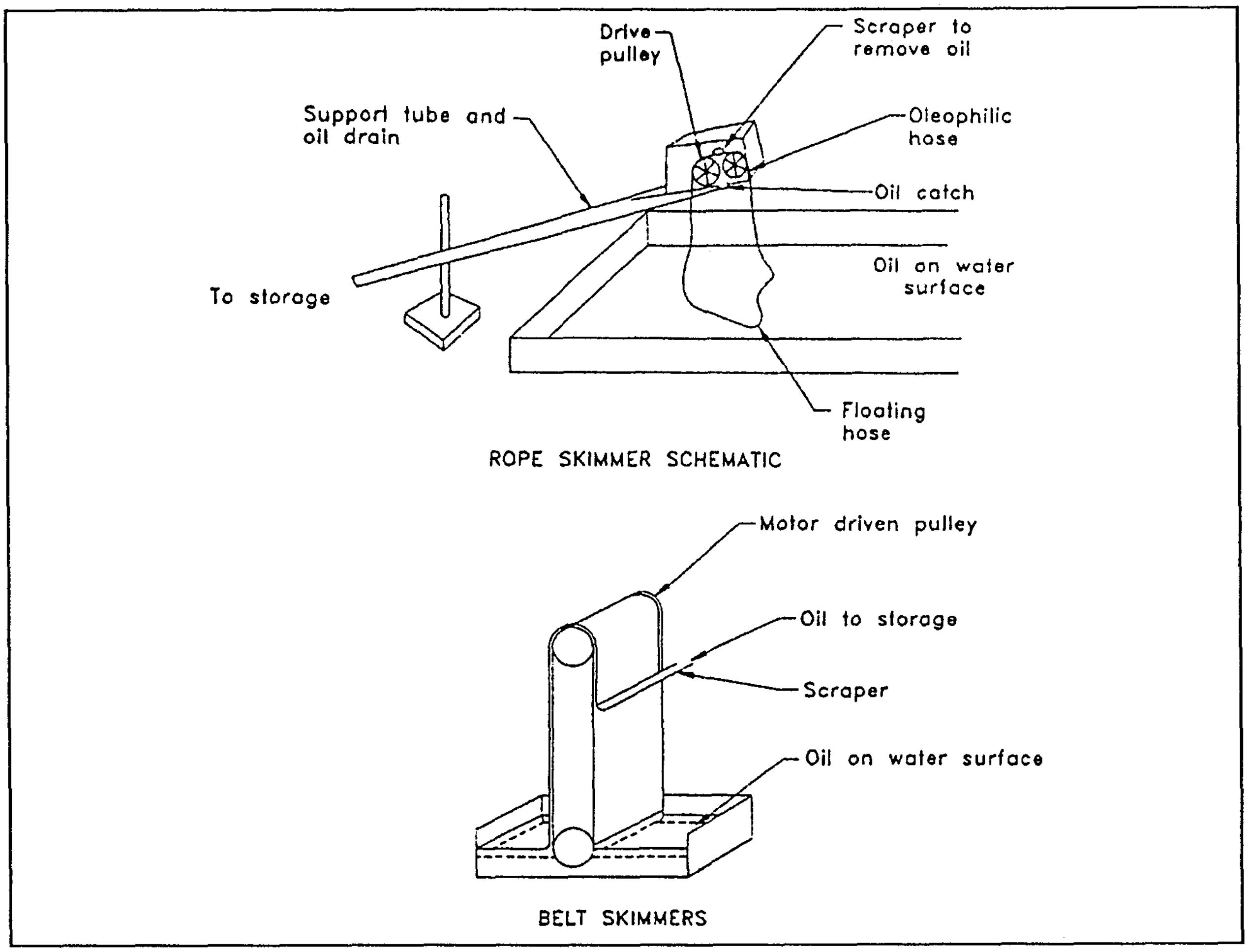

Figure 7: **Basic Principles of Belt Skimmer Operation**
(Testa and Winegardner, 1991)

Floating skimmers have been designed primarily for use in wells but can be used in trenches or sumps as well. Both passive and active versions have been developed. The basic operating principles of a passive canister skimmer are shown in Figure 8. The skimmer floats freely on the surface of the water in the well, adjusting to fluctuations in the water level. Typically, the intake is screened with a hydrophobic filter to minimize the collection of water.

Passive skimmers are essentially floating, top-loading bailers. As the skimmer fills, it gradually settles deeper into the water table. The intake is sized to span the hydrocarbon/water interface as the skimmer settles. Water is excluded with a hydrophobic filter over the intake. The skimmer is prevented from sinking to the bottom of the well with a length of line, which is used to periodically retrieve the skimmer for emptying.

Floating skimmer pumps are used to recover mainly product with little or no water from the well. The floating skimmer adjusts automatically with the changes in the fluid levels in the well. A selective oleophilic filter separates the hydrocarbon liquids from the water and product is allowed to accumulate in a small vessel. When sufficient fluid has been collected, it is pumped to an above-ground storage drum or tank. The pumps used are generally suction lift or pneumatic and may be controlled by a timer, float switches, or electronic sensors (Testa and Winegardner, 1991).

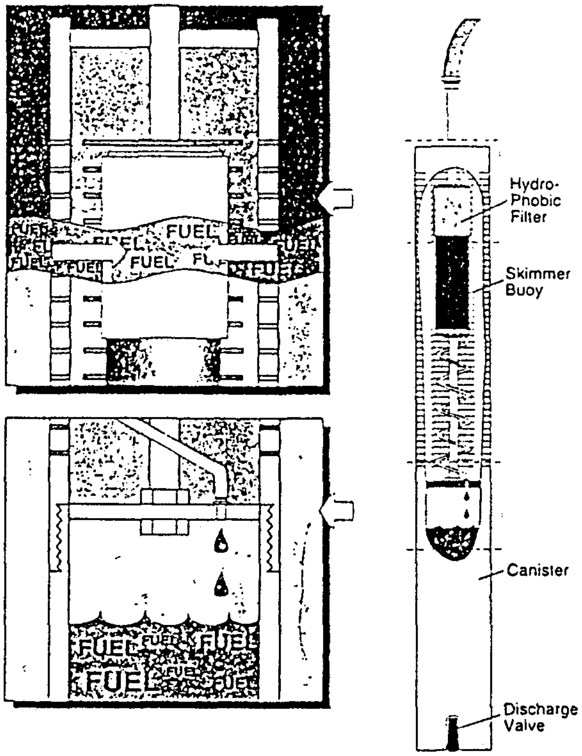

Figure 8: Schematic of a Passive Floating Canister Skimmer
(EnviroTech Services Co., 1991)

2.2.4 Single Pump Systems

Single pump systems will deliver water and/or product, depending on placement in the well. Air/product/water levels can be monitored using simple float switches, air-bubble pressure switches, amperage controls, or interface probes to control pump operation as shown in Figure 9. These devices will switch the pump on and off to protect the pump from running dry and allow time for the well to recharge. If the goal is to recover only floating product, the pump intake should be set at the product/water interface and installed with some type of hoisting mechanism to accommodate fluctuations in product level. Single pumps can also be placed deeper in the well to recover mainly water or both water and product. Water and product mixtures recovered from the well must be separated or treated using an oil/water separator or other means. Whether the pump is a turbine, mechanical lift, bladder type, pneumatic, or electrical, operation should be explosion proof if petroleum vapors or free product exist (Testa and Winegardner, 1991).

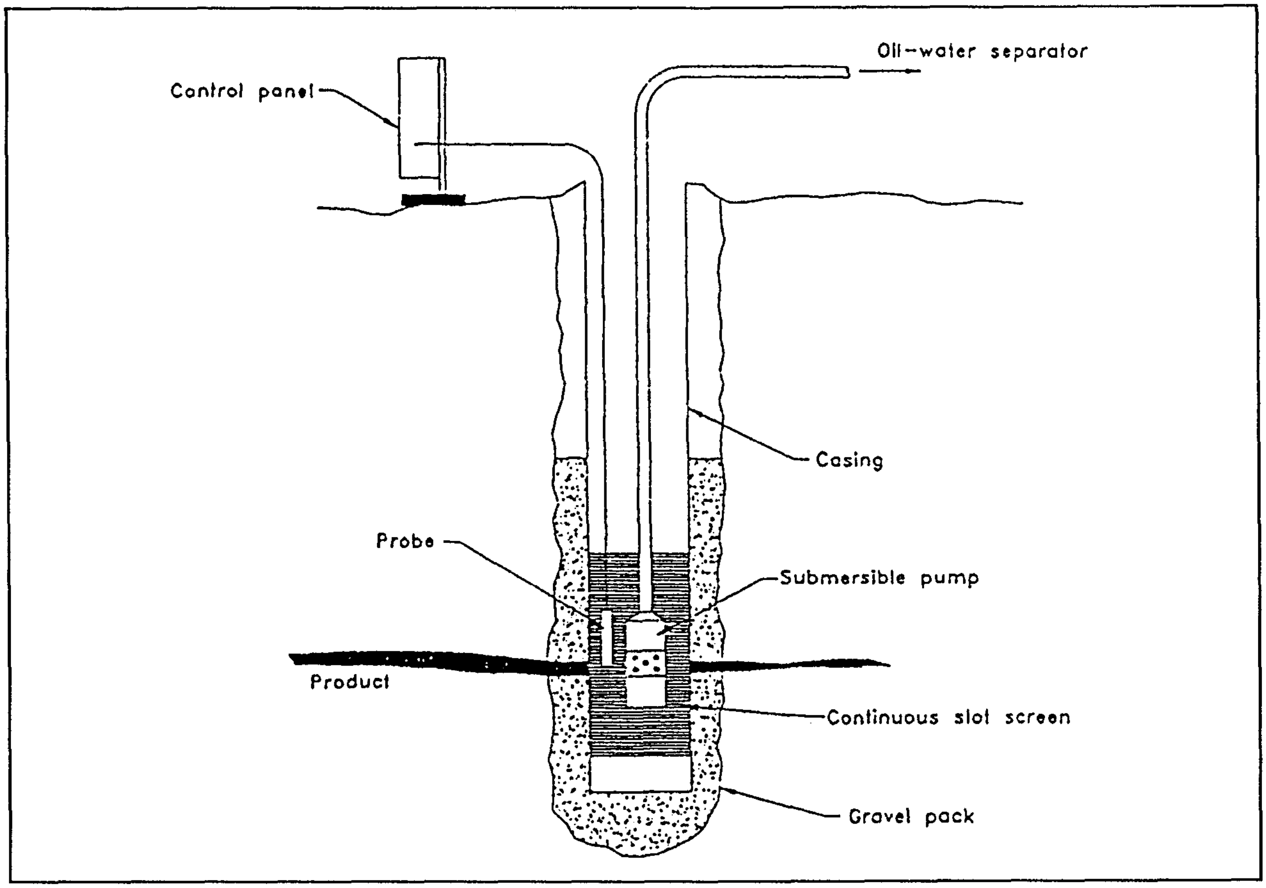

Figure 9: **Single Pump System in Recovery Well**
(Testa and Winegardner, 1991)

2.2.5 Dual-Fluids Pumps

Two-pump or dual-fluids pump systems are used where significant quantities of free product must be recovered. This system incorporates a water pump and a product pump together in a single well as shown in Figure 10. The water pump is used to lower the water table, creating a cone of depression and enhancing LPH flow to the recovery well. The second pump is located at the LPH/water interface to recover floating product. Interface detection probes control the operation of both pumps. The probe for the water pump is set to detect a product/water interface so that the pump will stop before it reaches the product phase. The probe for the product pump detects the air/product/water interfaces so this pump only pumps product and doesn't run dry (Testa and Winegardner, 1991). Advantages to the dual-fluids pump system include product separation in the well which reduces the need for above-ground separation. Dual-fluids pump systems also reduce mixing of the oil and water phases which results in less or lower additional dissolved contamination in the water phase. Due to their size and complexity, dual-fluids pump systems will require larger recovery wells and more routine maintenance for the pumps and probes.

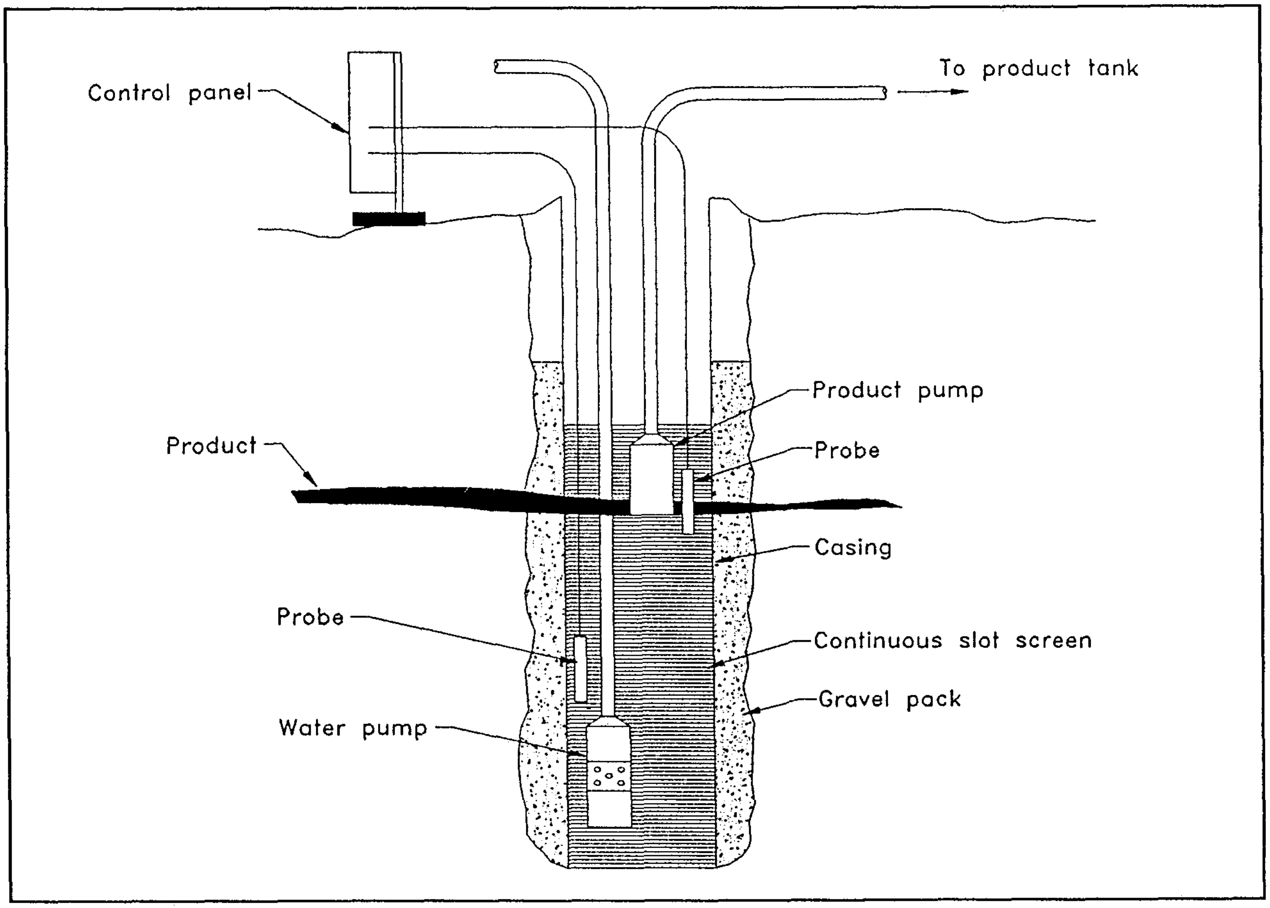

Figure 10: **Dual Fluids Pump System in Recovery Well**
(Testa and Winegardner, 1991)

2.3 Cost

Current prices for LPH recovery equipment can be obtained from manufacturers' representatives, specialty suppliers, and some local suppliers. Disposable bailers are less than $10 each. Sorbent wicks for a 2 inch or larger well cost about $150 for a stainless steel canister and 15 spare wicks. Floating-skimmer pumps cost around $2,500 for an electric model. Single submersible well pumps can cost $500 but may require a pump controller $1000 to $1500, and a compressor for pneumatic systems, $750 to $4,500.

SECTION 3
CONVENTIONAL PUMP AND TREAT SYSTEMS

3.1 Description of Technology

Pump and treat systems have been used for several years to remediate some Superfund sites contaminated with TCE's, and other volatile organic compounds. The initial reaction towards these technologies was overwhelming due to the fact that there were few technologies available to treat contaminated ground water sites. Pump and treat technology was able to treat some contaminants to below detection levels. For example, at the Emerson Electric site in Altamonte Springs, Florida, contaminants in the 100 ppb to 1000 ppb range were reduced to below detection levels in two years with the pump and treat method.

Initially, pump and treat was recognized as the most viable technology in treating ground water. Recently, this view has changed due to the fact that the technologies have failed or frequently fail to meet the stringent drinking water standards. It is now recognized that pump and treat alone will often not be able to meet these goals at most sites but can be used as a containment technology to control the contaminants from spreading in the subsurface and in meeting the cleanup standards other than those for drinking water. The problem with pump and treat is not that the treatment fails for what is pumped out but that the contaminants are slowly leaking into the water, so the treatment continues for extended periods.

Pump and treat methods involve pumping contaminated ground water to the surface through a recovery well or an extraction well, treating it on the surface at the site using physical, chemical, or biological treatment methods, and recharging the aquifer with treated water or discharging the treated water to the surface. Some of these ground water recovery systems, water treatment systems, disposal methods, and costs of the pump and treatment technologies are discussed in the following sections.

3.2 Site Characterization

Before considering pump and treat for ground water clean up, the site must be thoroughly evaluated in terms of the nature and extent of contamination in the ground water. Then, all geologic or hydrogeologic parameters, such as depth to bed rock, type of water-bearing formation, type of geologic formation, porosity, existence of structures, and hydraulic conductivity should be considered in the site characterization. Ground water modelling should be performed to determine the ground-water flow regime and subsequent contaminant transport (U.S. EPA, 1991d) and to identify potential locations for well placement at the site. Table 2 presents favorable and unfavorable conditions for the use of pump and treat technologies.

The contaminant should be characterized physically, chemically and biologically. This, in turn, helps to identify the appropriate treatment technology for the contaminated ground water. Some of the properties include density, volatility, solubility, biodegradability, and chemical structure. Proper characterization is necessary for successful treatment.

Table 2: Favorable and unfavorable conditions for pump and treat technologies
(Mercer et al, 1990)

Favorable Conditions		Unfavorable Conditions
Source removed	<u>SOURCE TERM</u>	NAPLs at residual saturation
Mobile chemicals	<u>CHEMICAL PROPERTIES</u>	Chemicals adsorbed or precipitated
High hydraulic conductivity (e.g., K > 10^{-5} cm/s) Homogeneous	<u>HYDROGEOLOGY</u>	Very low hydraulic conductivity (e.g., K < 10^{-7} cm/s) Highly heterogenous

The following sections focus on different methods of ground water removal, water treatment methods, disposal methods, and costs involved in pump and treat technologies.

3.3 Ground Water Removal Systems

The ground water removal systems commonly used for pumping ground water to the surface include: linear interception systems and horizontal and vertical recovery well systems. The linear interception systems are categorized as laterals, trenches, and drains. The most common types of pumps are also discussed. Some of these systems are compared and discussed in detail in the following sections.

3.3.1 Laterals, Trenches, and Drains

The use of laterals, trenches, and drains is uncommon for ground water removal, but can be quite effective for contaminated aquifers which lie close to the surface. These methods are better used for containment of the contaminant rather than as a recovery system. They can be effectively employed to contain the spread of contamination due to accidental spills. The most important factor for use of these systems is that the area surrounding the site be of low permeability so the soil will act as a barrier, keeping the contaminant from spreading. This technology is described in more detail in Section 2.1.1 which deals with LPH recovery systems, the more common use for laterals, trenches, and drains.

3.3.2 Vertical and Horizontal Recovery Wells

The vertical recovery-well system is the most commonly used method to remove contaminated ground water. High-pressure drills are used to bore vertical wells into the contaminated zone. Ground water is pumped from these wells to the surface for treatment by one of the water treatment technologies described later in this report. Figure 11 shows the typical construction details for a vertical recovery well.

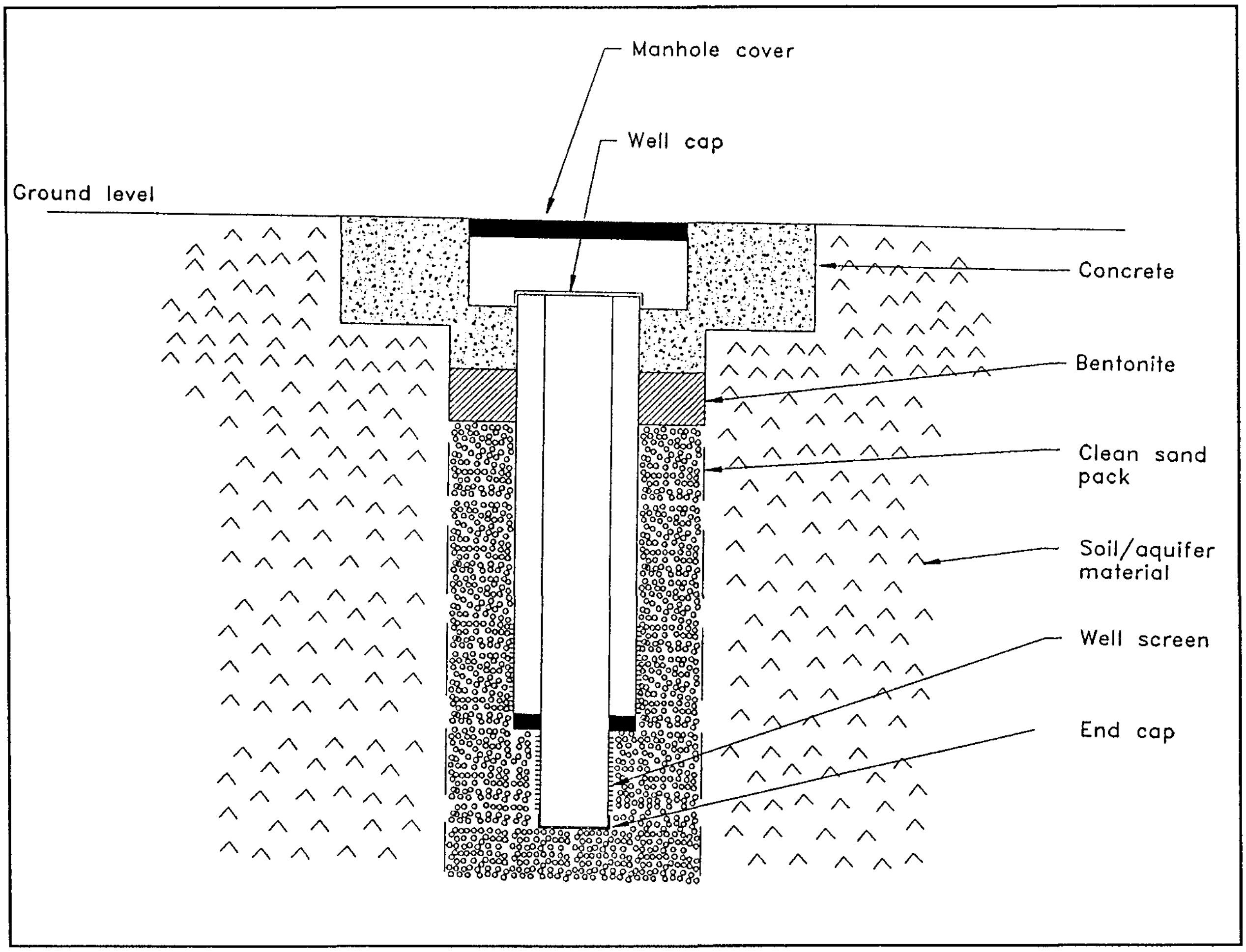

Figure 11: Schematic of a Vertical Recovery Well

Horizontal wells are also used. Some, which use a computer-guided horizontal drill bit, were originally developed by the oil industry for petroleum extraction. This special type of horizontal well is used primarily for deep consolidated formations, such as that commonly encountered when drilling for oil. This is basically an enhancement of the vertical recovery well. Horizontal wells work for deep contaminated ground water and collect contaminants in greater volume than vertical wells, due to the greater surface area of extraction. Horizontal wells can pump water up to 100 times faster than vertical wells (Farrell, 1993).

For an aquifer less than 20 feet deep, with contaminants of specific gravity less than one, a different type of horizontal well configuration would be used. A shallow trench is dug to below the water table and below the contamination level. In this trench, a horizontal recovery screen and recovery pipe are placed and covered with a filter gravel pack; then, a vertical well with a submersible pump is installed. The whole trench is then backfilled with the original dirt. The completed trench acts as a contamination barrier to prevent further spread of the contaminant. Lengths of trenched area can be greater than 2000 feet. Contaminated ground water flows to the horizontal well screen and to the vertical well. From there it is pumped to a treatment system (Farrell, 1993).

The main advantage of using a horizontal recovery-well system is that it can pump water at a faster rate than that of a vertical recovery well. Horizontal trenched well systems are difficult to install in areas with underground pipelines or cables, under landfills or buildings, or in bedrock, due to problems with trenching in these places. Horizontal drilled well systems can avoid these problems but the costs are higher.

3.3.3 Pneumatically-Driven Vacuum Pumps

Pneumatic (suction-lift) pumping is probably the most versatile of the methods. It has a wide range of pumping rates, making it effective for both low and high-permeability soils. In addition, the suction-lift method has another advantage; the well can be pumped dry without damaging the pump. Dry pumping also induces a vacuum on the wells which, in turn, induces vacuum-enhanced fluid entry into the wells (Hayes et al., 1989). One more advantage is that suction-lift pumps are pneumatically-driven and are intrinsically safe. They have no parts that would spark during operation of the system.

Suction-lift pump systems consist of a pneumatically-driven, double-diaphragm, suction-lift pump, which creates the vacuum for the recovery system. Figures 12 & 13 show a typical recovery well and typical double-diaphragm pump controls. As many as 4 wells may be connected to one pump. These pumps are self-priming to 22 feet, after which, they can pump effectively up to 27 feet if suction is not broken.

The pneumatic pump system is constructed in much the same fashion as a normal vertical well but has enhanced capabilities.

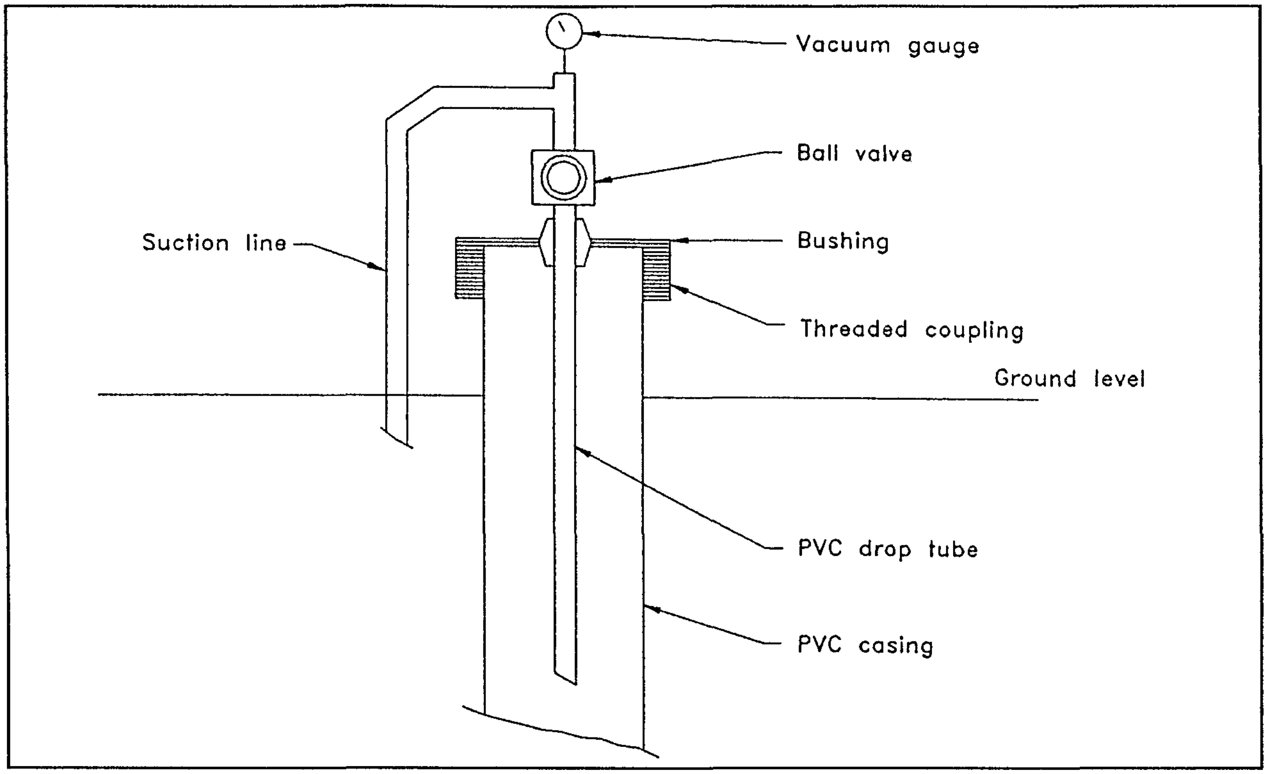

Figure 12: Typical Recovery Well Construction

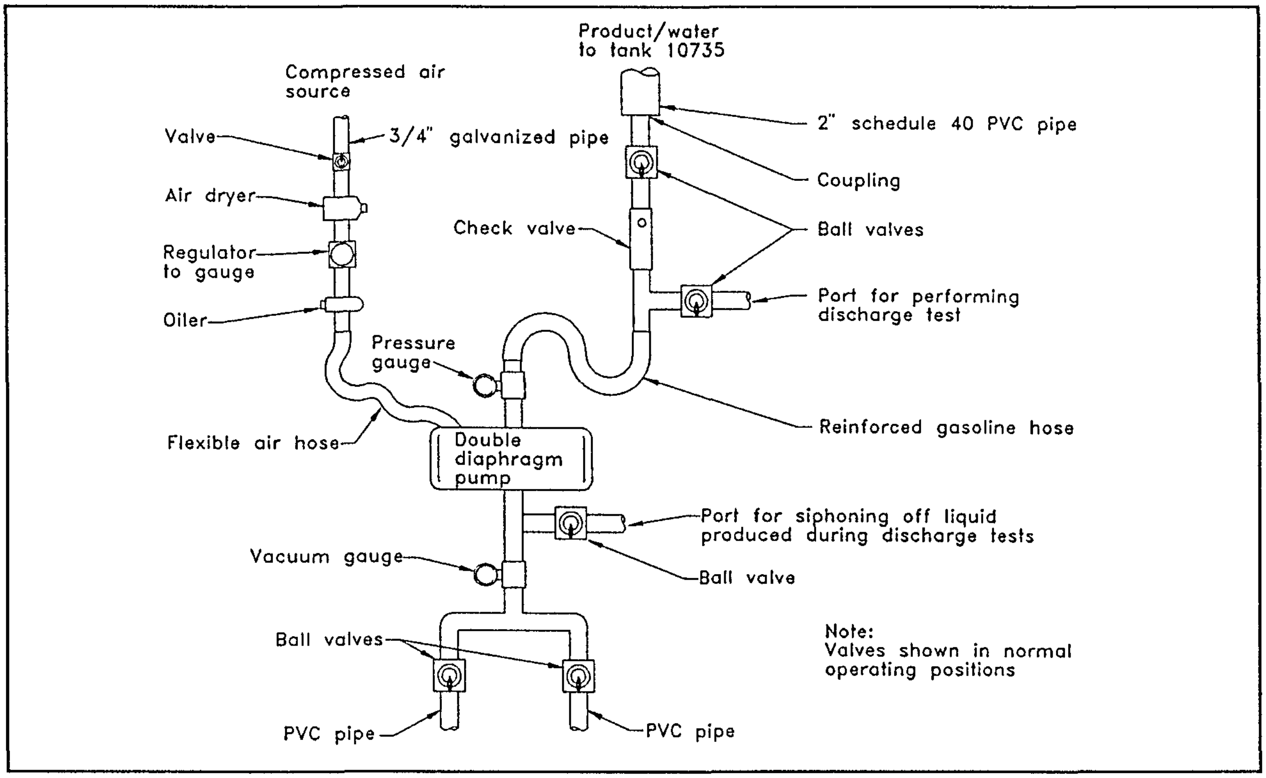

Figure 13: Double-Diaphragm Pump Controls
(Hayes et al, 1989)

3.4 Water Treatment Technologies

Once the contaminated ground water is brought to the surface, it can be treated using one or more combinations of physical, chemical, or biological treatment technologies. Selection of the treatment technology depends mostly on the type of contamination and the cost associated with the treatment. This report discusses technologies that are generally used to remove organics from the ground water.

3.4.1 Organics Removal

Several methods exist for organics removal from the retrieved ground water. The following sections will discuss the five most commonly used methods: air stripping, activated carbon adsorption, chemical oxidation, UV oxidation, and biological treatment.

3.4.1.1 Air Stripping

Air stripping is a process by which volatile contaminants are removed from the aqueous phase by passing air through the water. This process has been applied directly in removing trichloroethylene (TCE), trihalomethane, (THM), and hydrogen sulfide. Contaminants are removed from the aqueous phase to the gaseous phase, at which point they are collected by vapor recovery equipment or allowed to disperse in the air if permissible. The mass transfer depends on the vapor pressure or Henry's Law constant. Generally, air stripping is feasible if Henry's Law constant, K_h > 10^-3 atm - m^3/mole.

Air stripping is commonly accomplished in a packed tower equipped with an air blower. The packed tower works on the principle of counter-current flow. The water stream flows down through the packing while the air flows upward, and is exhausted through the top to the atmosphere or to emission control devices. The four basic equipment configurations used for air stripping are diffused aeration, counter-current packed columns, cross-flow towers, and coke tray aerators. The column configuration is most widely used because (Stover, 1989):

- it provides the most liquid interfacial area;
- high air-to-water volume ratios are possible due to the low air pressure drop through the tower; and,
- the counter-current tower can be readily connected to vapor recovery equipment when emission of organics to the atmosphere is unacceptable.

The column configuration will be the main focus of this section. Figure 14 shows examples of all four configurations that can be used.

The design of an air stripping process for removing volatile organics from contaminated ground water is accomplished in two steps. The cross-sectional area of the column is determined first; then, the height of the packing is determined. The cross-sectional area of the column is determined using the physical properties of the air flowing through the column, the characteristics of the packing, and the air to water flow ratio. A key factor is the establishment of an acceptable air velocity. A general rule of thumb used for establishing the air velocity is that it should be 60% of the velocity that causes flooding. Flooding is the condition in which the air velocity is so high that it holds the water in the column to the point where the tower becomes water logged and transfer efficiency is reduced. Generally, a ratio of 6:1 for height of the packing material to diameter of the tower is used (Stover, 1989).

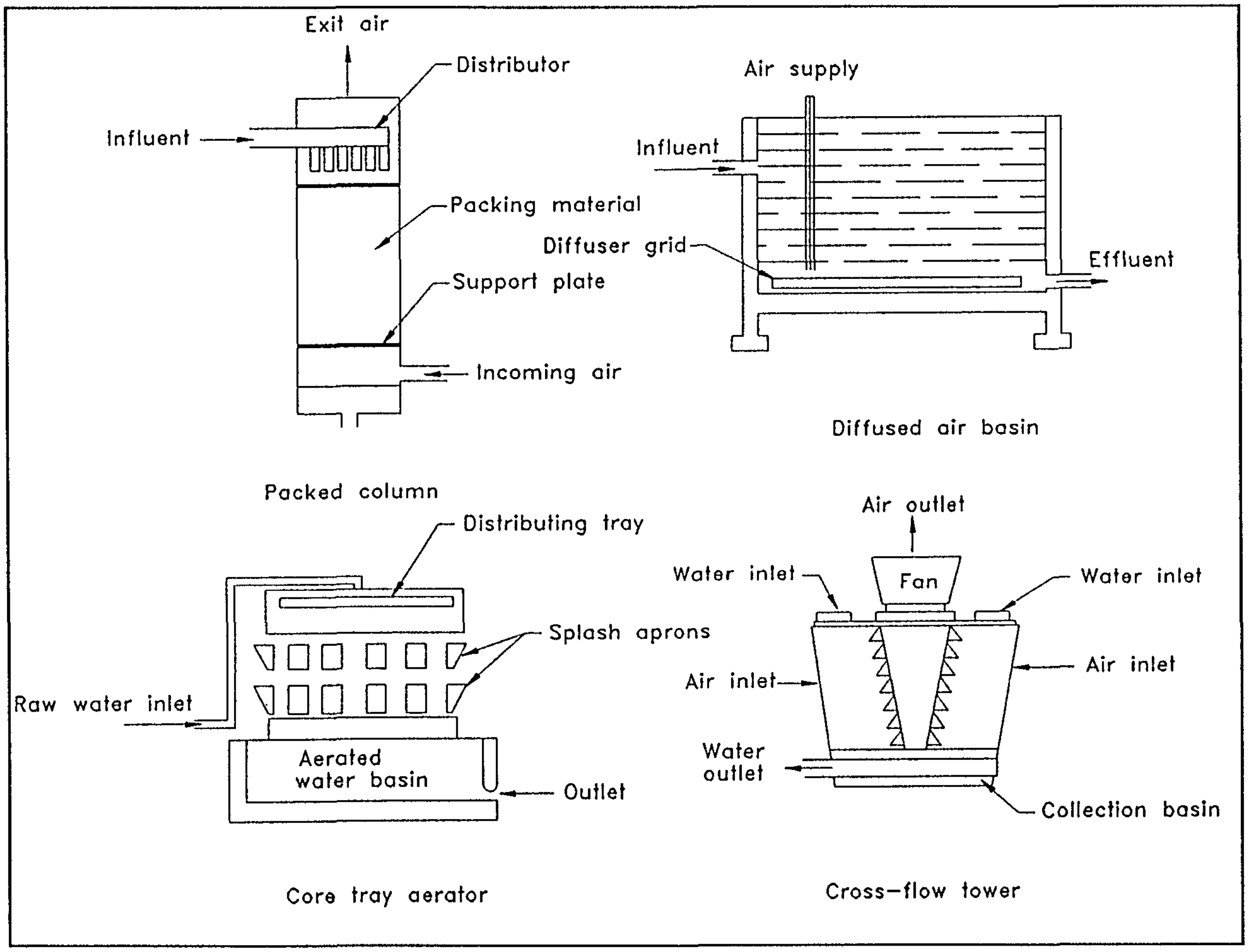

Figure 14: Typical Air Stripper Configurations

Two main expenses should be considered when determining the feasibility of an air stripper. One is the capital cost of the equipment which is a function of the diameter and the height of the tower. The smallest tower is about 10 inches in diameter and 5 feet tall. The other main expense is the operating cost, primarily the cost of operating the blower and system oversight.

3.4.1.2 Activated Carbon Adsorption

Activated carbon adsorption is a process in which contaminants in the aqueous phase are carried through a carbon bed and are adsorbed on the surface of the carbon. This results in a decrease in the concentration in the aqueous phase. In the adsorption process, the contaminant acts as an adsorbate and carbon as an adsorbent. The carbon provides the necessary sites for the cation or anion exchanges, complex formation, and surface precipitation for the removal of the contaminants from the liquid phase. The quantity of contaminant adsorbed is a function of both the concentration of contaminant in the water and presence of potential sites for adsorption.

Three types of adsorbents currently used are granular activated carbon, (GAC), powdered activated carbon, (PAC), and synthetic resin. All three remove dissolved contaminants from ground water. GAC is the most commonly used. Synthetic resin can be relatively expensive. PAC usually has more operational and maintenance problems. Typical adsorption systems consist of a large vessel (column) partially filled with adsorbent, an inlet for contaminated ground water, and an outlet for the treated water. Influent water enters the column and is in contact with the adsorbent for a specified period of time and then exits for collection, recharge, or further treatment.

Many different factors affect the feasibility and reliability of carbon adsorption. These include:

- contaminant solubility in water: as this increases, adsorptivity decreases;
- chain length of contaminant: as this increases, adsorptivity increases;
- benzene ring quantity: as number of benzene rings increases, adsorptivity increases; and,
- polarizability: as polarizability decreases, adsorptivity increases.

Isotherm tests are performed for a range of contaminant concentrations in solution at a constant temperature to determine whether a particular contaminant is well suited to carbon adsorption.

The two main types of carbon adsorption systems are fixed bed and counter-current moving bed. These are shown in Figure 15. The fixed bed is operated in either down flow or up-flow mode. With the counter-current moving bed, the water moves in the up-flow mode and the carbon moves in the down-flow mode. The reason for the down-flow of carbon is because it can be more easily removed from the column by gravity.

A typical fixed-bed carbon column consists of an inlet distributor, an underdrain system, and a surface wash. During operation, the contaminated ground water enters through the inlet distributor at the top of the column and flows downward through the carbon filled bed where the removal of contaminants takes place. Finally, the treated water exits through the underdrain system. The column is usually operated at a hydraulic rate of 2 - 5 gpm/sq. ft. (Testa & Winegardner, 1991).

The counter-current moving bed system is usually operated with two or more columns in series. The influent contaminated ground water enters the bottom of the first column by means of a manifold system that uniformly distributes the flow across the bottom. It then flows upward through the column.

Some design parameters that must be taken into account are:

- influent characteristics, discharge requirements;
- contact time (15 min. minimum);
- pretreatment or backwash requirements; and,
- temperature.

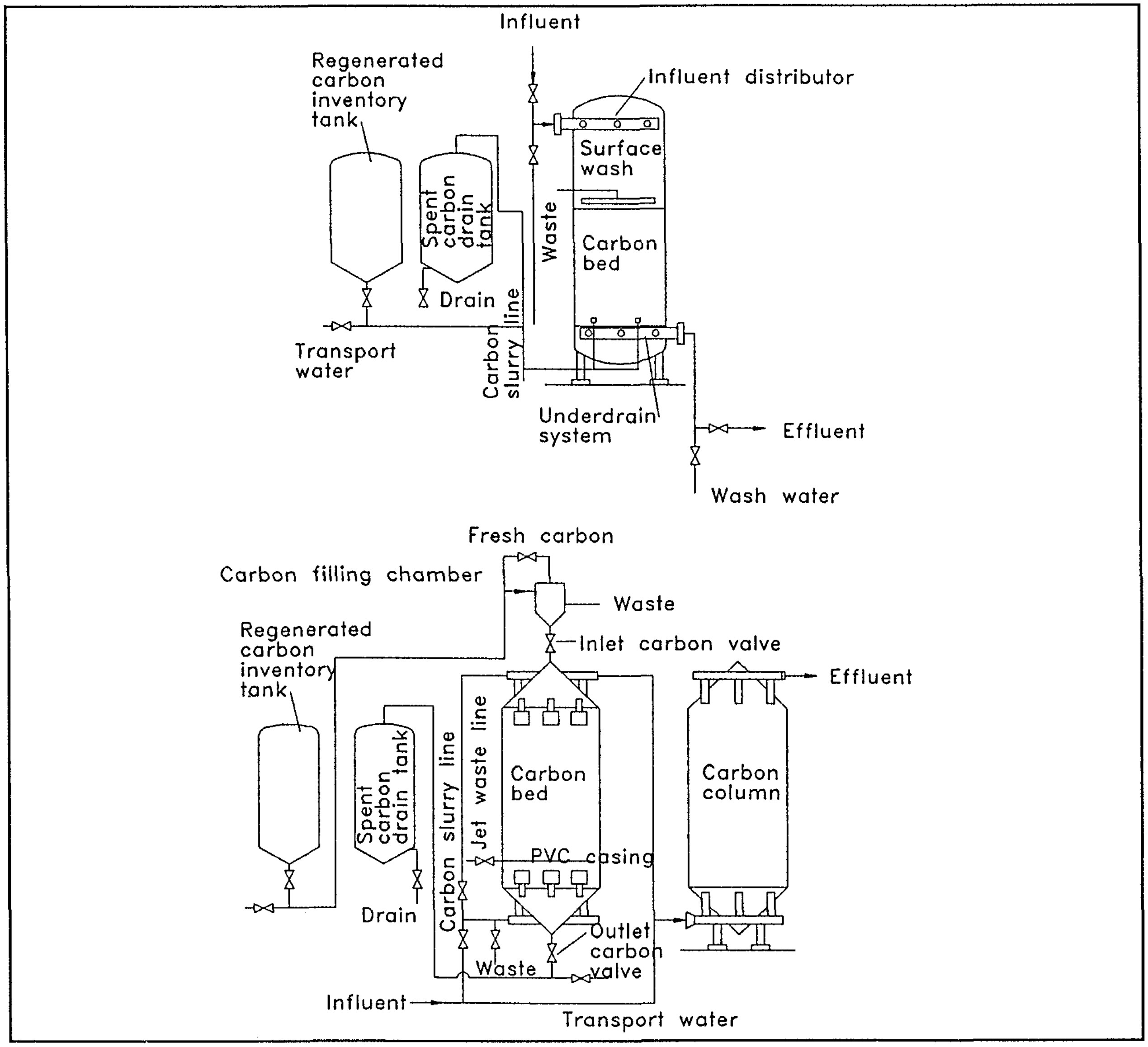

Figure 15: Typical Fixed-bed and Counter-current Moving Bed Carbon Adsorption Systems (Testa and Winegardner, 1991)

Once these parameters are known, the amount of carbon needed is determined. The amount of spent or exhausted carbon that will be generated and what will be done with it should be considered. Currently, two basic options are available: disposal or regeneration/reactivation. This is one of the two major operating costs for this type of system (the other is carbon replacement). Disposal to a landfill is generally the less attractive of the two for liability reasons; the spent carbon may be a hazardous waste (Fu, 1993). Landfill disposal of spent carbon classified non-hazardous special waste costs from $12 to $20 per ton and when classified hazardous costs $120 to $150 per ton (Advertised Costs, Central Illinois Landfills, 1994). The trend is to regenerate and reuse the carbon to make the process more economically feasible. Frequently this option is offered by the carbon supplier.

3.4.1.3 Chemical Oxidation

Chemical oxidation processes raise the oxidation state of the contaminants, which reduces their solubility or toxicity and transforms the contaminants into a form which can be more easily disposed of as non-toxic wastes. Chemical oxidation has found extensive use in treatment of organic wastes. The commonly used oxidants are air, oxygen, ozone, ozone with ultraviolet light, chlorine gas, hypochlorites, chlorine dioxide, and hydrogen peroxide.

In the oxidation process, the compound supplying the oxygen, (or chlorine or other negative ion) is called the oxidizer or oxidizing agent while the compound accepting the oxygen, (supplying the positive ion) is called the reducing agent. The oxidation reaction can be enhanced by catalysts, electrolysis, or irradiation.

The major practical limitation of the oxidation process is that the process is nonspecific; any oxidizable compounds will be oxidized. Also, some reactions are explosive in nature, specifically reactions with hydrogen peroxide.

Some oxidation processes and their limits of applicability are discussed below:

- *Oxidation by Hydrogen Peroxide (H_2O_2)*: Hydrogen peroxide is used as an oxidizing agent to treat contaminated ground water. Hydrogen peroxide is not a stable oxide of hydrogen since it easily gives up its extra oxygen. However, it is an excellent oxidizing agent. The major drawbacks of the process are that the reaction is nonspecific and it is explosive in nature. Oxidation by hydrogen peroxide is not applicable for in-situ treatment. However, it is commonly used for the surface treatment of ground water.

- *Oxidation by Ozone (Ozonation)*: Ozone is an oxygen molecule containing three oxygen atoms. It is relatively unstable and dissociates into the oxygen gas and an extra oxygen ion; thus, it is an ideal oxidizing agent. Ozone can be used to pretreat wastes to break down refractory organics or as a polishing step after biological or other treatment processes to oxidize the untreated organics. Ozone has been used for the treatment of hazardous wastes and to destroy cyanide and phenolic compounds.

- *Alkaline Chlorination*: Chlorine can be added to contaminated ground water under alkaline conditions to oxidize the contaminants. This oxidation process is widely used to treat cyanide wastes but can also be used to treat petroleum hydrocarbon wastes. Cyanides can be oxidized with chlorine to less toxic cyanates or completely oxidized to nontoxic nitrogen gas, carbon dioxide, and bicarbonates. Limitations of this technology include the exothermic heat of reaction and additional chlorine demands due to other reactions. The pH in the reaction vessel must be maintained in the range of 7.5 - 9.0 to avoid the release of toxic volatile gases during the process. It is a commercially available process.

- *Oxidation by Hypochlorite*: This process consists of adding sodium or calcium hypochlorite to oxidize organics present in the ground water. This method produces some toxic chlorinated organic by-products and is best done under controlled conditions (i.e., in batch reactors). It is not applicable to in-situ treatment but can be used to treat contaminated ground water on the surface. It is a commercially available process.

- *Electrolytic Oxidation*: In this oxidation process, cathodes and anodes are immersed in a tank containing contaminated ground water. A DC current is applied to the system to oxidize the contaminants. This process is used for cyanide removal, some metals removal, and some petroleum hydrocarbon removal. Limitations include the physical form of the influent (solids must be dissolved) and long process times.

3.4.1.4 UV Oxidation

UV oxidation takes chemical oxidation one step further by adding ultraviolet light to the system in order to increase the rate of the reaction. Two basic ways in which UV-oxidation is applied are UV-ozone and UV-peroxide systems. Figure 16 shows typical configurations for each of these systems.

Ozone and hydrogen peroxide are both strong oxidizing agents by themselves but their effectiveness dramatically increases when used in conjunction with UV light. Some field application problems with this method have been identified. The worst of these occurs when the UV light source becomes dirty in contact with influent ground waters. This reduces the effectiveness of the UV light very quickly (Nyer and Bitter, 1991).

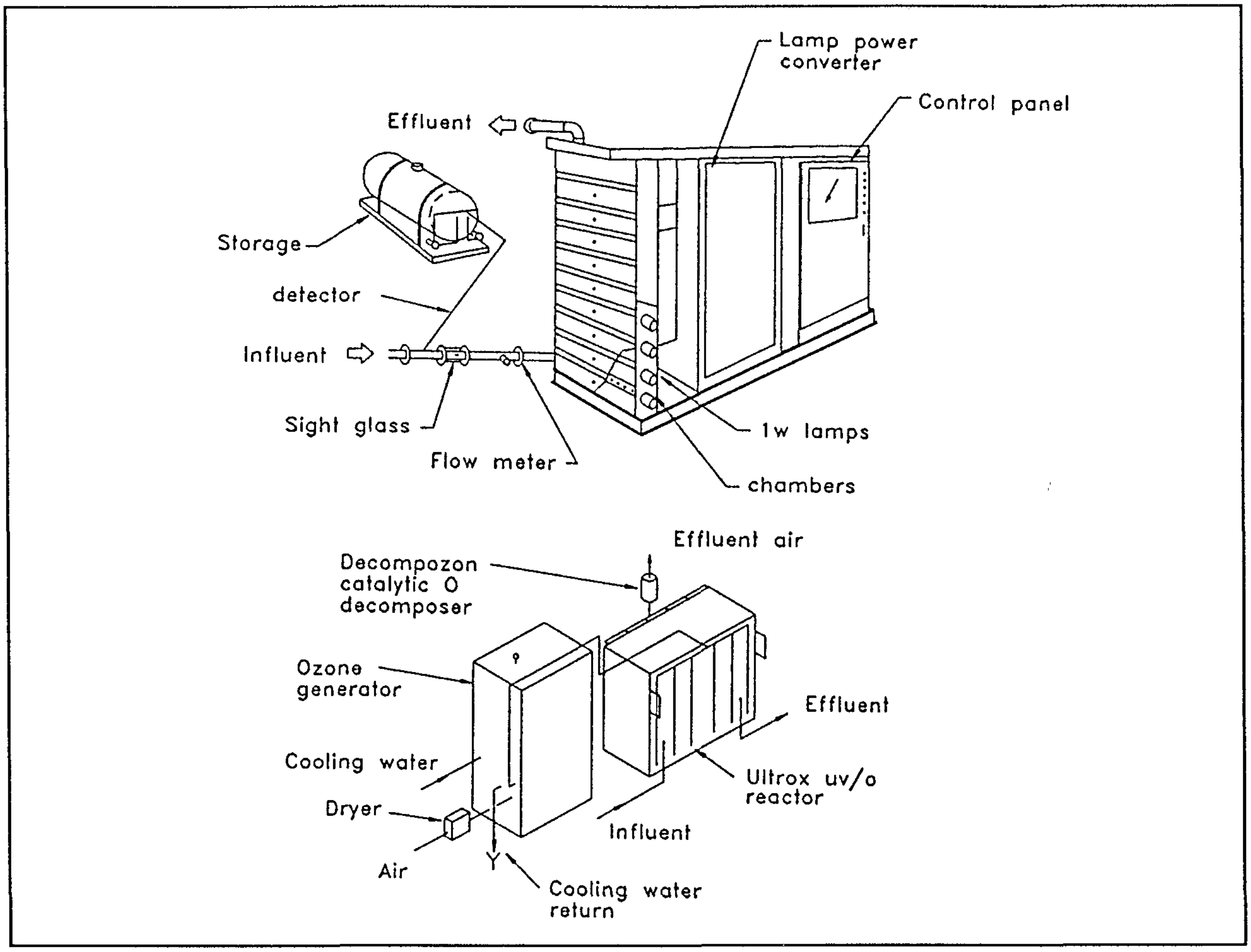

Figure 16: **UV-Oxidation Treatment Methods**
(Nyer and Bitter, 1991)

3.4.1.5 Biological Treatment

Biological treatment uses microbial organisms to metabolize organic chemicals. The two main types of biological treatment systems for contaminated ground water are suspended-growth systems (activated-sludge processes) and fixed-film systems.

The basic activated-sludge process generally consists of a large basin into which both contaminated water and air or oxygen are introduced. Microorganisms are present in the system as suspended material. The contaminants are adsorbed by the biological suspension, which is then separated by gravity from the water. To keep a constant biomass, the mass increase due to synthesis is discarded before the process repeats itself. Without the proper amount of biomass, the system will fail (Stover, 1989).

In the fixed-film system, microorganisms are present on a fixed substrate, such as PVC, instead of suspended in the mixture. The system is in tower form with the contaminated water being sprayed down from the top of the tower. As the water passes over the medium, the microorganism layer that has formed will remove the organic waste. The fixed-film system is potentially lower in cost than the activated-sludge process due to the absence of aeration equipment and its ease of operation (Stover, 1989).

3.4.2 Metals Removal

When removing metals, different techniques than those used for organic materials are usually employed. The next few sections will focus upon three metals removal techniques: chemical precipitation and flocculation, ion exchange, and reverse osmosis.

3.4.2.1 Chemical Precipitation and Flocculation

Chemical precipitation is a physio-chemical process whereby a substance (heavy metal) in solution is transformed to solid phase. It can be accomplished by:

- adding a chemical which changes the solubility equilibrium of the waste to reduce the solubility of specific contaminants;

- adding a chemical that will react with the contaminant in a solution to form a sparingly soluble compound; or,

- changing the temperature to decrease the solubility of the contaminants.

Removal of metals as carbonates, hydroxides, or sulfides is the most common application of precipitation in waste water treatment. Many precipitation reactions (i.e., metal sulfides) do not readily form floc (large fluffy precipitates) particles, but rather precipitate as very fine and relatively stable colloids. Sometimes, flocculating agents such as alum and polyelectrolyte are used to cause the flocculation to occur. The effectiveness of these agents is based upon the nature and concentration of the contaminants and upon the process design.

The optimum chemicals and dosages, suitable chemical addition systems, optimum pH and mixing requirements, sludge production, sludge flocculation, settling and dewatering characteristics must all be considered when designing the system.

This technology is used to treat aqueous wastes containing metals. The limitations of this process include the fact that not all metals have a common optimum pH at which they can precipitate. Chelating and complexing agents can interfere with the process.

3.4.2.2 Ion Exchange

Ion exchange is a process in which toxic ions are removed from the aqueous phase by being exchanged for relatively harmless ions present in the exchange material. Ion exchange can be used to remove a broad range of ionic species from water. These include:

- all metallic elements in the dissolved state either as anions or cations;

- inorganic ions such as halides, sulfates, nitrates, Cyanides, etc.;

- organic acids such as carboxylics, sulfonics, and some phenols; and,
- organic amines.

Ion exchange effectiveness depends upon the electrochemical potential of the ion to be recovered versus that of the exchange ion and also upon the concentration of the ions in solution. After a critical, relative concentration of recoverable ion is exchanged, the resin is said to be 'spent'. This is usually determined by the concentration of metal in the effluent from the ion exchange. Little more contaminant will be removed until the resin is recharged. Spent resin is usually recharged by exposing it to a very concentrated solution of the original exchange ion so that a reverse exchange takes place, resulting in regenerated resin and a concentrated solution of the removed ion which can be further processed for recovery and reuse.

Ion exchange systems are used to treat metal wastes, including cations (e.g., Ni^{2+}, Cd^{2+}, Hg^{2+}), and anions (e.g., $CrO^{2-}{}_4$, and $SeO^{2-}{}_4$, etc.). Ion exchange systems function well in dilute waste streams of variable composition, provided the effluent is monitored constantly to determine when exhaustion of the ion exchange resin bed has occurred.

3.4.2.3 Reverse Osmosis

Reverse osmosis is a treatment process in which the water in a solution of dissolved contaminants is forced by pressure to pass through a membrane against the natural osmotic pressure to accomplish separation of clean water and concentration of the dissolved contaminants in a much smaller volume of water. Reverse osmosis is commonly used to treat saline water and obtain purified water in areas where fresh water is scarce. Reverse osmosis has been extended to industrial applications for separating chemical and metallic salts from industrial waste streams. Osmotic membranes are semi-permeable. The membrane can be tubular or flat in shape and functions more like a filter due to pressure difference. Pore size and type of membrane can be varied for the specific application. In application, the waste stream flows past the membrane while the solvent, water, is forced to pass through the membrane's pores. The remaining inorganics and organics do not pass through and are enriched to high concentrations in the effluent side of the membrane. Several passes through a series of membranes can be used to achieve the desired concentration.

The rate of flow across the membrane is directly proportional to the effective pressure, the difference between the applied and osmotic pressures. The operating pressures vary anywhere between 350 - 1500 psi, with a typical range of 600 - 800 psi (Viessman, Jr. and Hammer, 1985).

Reverse osmosis membranes are available in spiral or hollow fiber forms. The membranes are usually made of cellulosics, polymides, and composites consisting of a thin polymide film on a porous structure. The major drawback of reverse osmosis is that it is usually not cost effective with non-ionic and particulate substances that can be treated by other membrane technologies, such as microfiltration and ultrafiltration (Vembu, 1994). The physical and chemical properties of the semi-permeable membrane must be compatible with the contaminant's physical and chemical characteristics in order to make the process cost effective and efficient.

3.5 Treated Water Disposal Methods

There are four basic disposal methods employed to deal with the water treated at LUST sites:

- re-injection into the ground to increase the velocity of the contaminated water flowing to the wells in order to contain the plume;
- discharge to surface waters;
- discharge to a sewer for treatment at a Publicly Owned Treatment Works (POTW); and,
- discharge to a commercial waste water treatment facility or haul off-site to such a facility.

3.5.1 Re-injection

Treated ground water from an extraction well can be re-injected to help increase the ground water velocity in the vicinity of the well and facilitate the desorption of contaminants from soil to speed the cleanup. At the same time, dewatering of ground water resources can be reduced or avoided. This approach increases the local gradient near the extraction well, thereby increasing the capture rate of the well and speeding the attainment of cleanup goals (Hoffman, 1993).

Design and placement of the re-injection wells is important. The wells can be placed upgradient or downgradient of the plume depending on the containment objective. Also, well redevelopment should be considered. Eventually, wells will have to be redeveloped or they will become clogged. Costs of redevelopment and potential, adverse plume migration are two of the main limitations of this disposal method. (Testa and Winegardner, 1991)

3.5.2 Discharge to Surface Waters

Discharge to surface waters must be done under the National Pollutant Discharge Elimination System (NPDES), which is administered by the IEPA (with authorization from the U.S. EPA).

In order to be granted a permit, the detailed design for a pretreatment system must be submitted. This process usually takes at least 180 days; so, submittal time must be planned accordingly.

3.5.3 Discharge to POTW

Discharge to a POTW through a sewer system is relatively easy and cost-effective. It is necessary to obtain approvals from the intermediate sewer system owners and the receiving treatment plant. These approvals take the form of permits from the IEPA Bureau of Water. Sometimes permits are also required from the local sanitary districts or public works departments.

The POTW may refuse the discharge if it is operating at maximum capacity or if there are contaminants in the water that are not usually treated at that facility. The POTW may also accept the discharge only after pretreatment. A permit must be obtained from the IEPA for construction and operation of the pretreatment facility.

3.5.4 Haul to Off-Site Facility

The easiest disposal method for small volumes of contaminated water is hauling the water to an off-site, treatment facility. As this water is considered a special waste because it is a pollution control waste, the transport vehicle and the treatment facility must be licensed/permitted to handle such wastes before the waste is transported off site. The owner/operator of the LUST site must also obtain a special waste Generator ID Number.

In addition, an Illinois Special Waste Manifest must be completed prior to shipment of the water and the IEPA Bureau of Land special waste regulations must be followed.

3.6 Cost

Pump and treat costs will vary greatly with the different options that are available depending on site-specific conditions. No "average" cost has been estimated. IEPA estimates for pump and treat and other remediation efforts are provided in Appendix A.

SECTION 4
IN-SITU BIOREMEDIATION

4.1 Description of Technology

Bioremediation of contaminated soils and ground water has been gaining recognition and acceptance among regulators and the regulating community. Compared with conventional ground water treatment technologies such as pump and treat, in-situ bioremediation provides a potentially cost-efficient and time-saving remediation technique. Biological treatment techniques have long been used in municipal waste-water treatment. New biotreatment methods are emerging to handle industrial waste waters with higher concentrations of contaminants that are more difficult to degrade. Releases of petroleum hydrocarbons into the soil and ground water create a complex biological challenge. Developing a successful biotreatment system requires controlled experimentation and judgement to optimize performance (Morski and Griffin, 1993).

Bioremediation utilizes naturally occurring microorganisms or specially cultured organisms such as bacteria, fungi, and yeast, to transform harmful substances (hydrocarbons) into nontoxic compounds, mainly carbon dioxide, water, and fatty acids. In order to make the process effective, the microorganisms need a proper mix of nutrients, such as nitrogen, phosphorus, trace metals, carbon, and energy. The engineered bioremediation process introduces the required nutrients and oxygen to enhance the natural process and to enable an acceptable remediation level to be achieved. The main advantage of bioremediation over other treatment methods is that bacteria use these organic contaminants as a substrate for growth and convert them into safe end products. However, without proper care, the hydrocarbons may be only partially metabolized or may be converted to more harmful chemicals.

In-situ bioremediation is the treatment of organic contaminants without removing the contaminated soil or water from the site. It promotes the growth of microorganisms to degrade and/or detoxify hazardous constituents in the soil at a contaminated site (IEPA, 1991). In-situ bioremediation can be applied to treat contamination in both soil and ground water. The concept of in-situ bioremediation is simple; it relies on the natural biodegradation that occurs spontaneously in the subsurface. But, its successful implementation requires careful consideration of parameters such as site hydrogeology, microbiology, and nutrient levels.

Generally, site characteristics and contaminant type control the design and implementation of in-situ bioremediation. Some of these characteristics are summarized in Table 3, which provides a scoring system that indicates whether in-situ bioremediation is feasible for a particular site.

Table 3: Screening Criteria for In-Situ Bioremediation

PARAMETERS	SCORE
1. Contaminant Characteristics	
A. Structure	
Simple Hydrocarbon C1 to C15	0
C12 - C20	-1
> C20	-2
Alcohols, phenols, amines	0
Acids, esters, amides	0
Ethers, monochlorinated, nitro	-1
Multichlorinated	-2
B. Sources	
Well defined point sources	+1
Under defined multiple sources	-1
2. Hydrogeology	
A. Aquifer Permeability (cm/sec)	
> 10^-3	0
10^-3 to 10^-4	-1
10^-4 to 10^-5 or less	-2
B. Aquifer Thickness, (feet)	
> 20	+1
5 - 20	0
< 5	-1
C. Depth to Aquifer (feet)	
> 20	+1
5 - 20	0
< 5	-1
D. Homogeneity	
Uniform	+1
Non Uniform	-1
3. Soil and Ground water Chemistry	
A. Ground water pH	
> 10	-2
8 - 10	-1
6.5 - 8	0
4.5 - 6.5	-1
< 4.5	-2
B. Ground water Chemistry	
High NH4 and Cl	-0.5
Heavy metals (As, Cd, Hg)	-0.5

Interpreting the Total Score

0 or greater	Site Appears Suitable
-1 to -2	Possible Areas of Concern
-2 to -4	Areas of Significant Concern or other options advantageous
less than -4	Success is Unlikely

4.2 Site Characterization

Site characterization is usually performed to describe the environmental setting for in-situ bioremediation. Considerable site drilling and sampling is often required. This helps determine the potential migration of contaminants and information for the design and implementation of the process.

The design of an in-situ bioremediation system is very site specific. Each application requires a thorough understanding of the target contaminants, the site geology and hydrogeology, and the microbial factors.

4.2.1 Site Geology

The geologic parameters that affect contaminant transport, oxygen and nutrient supply, etc. include: bedrock depth, thickness, inclination, porosity, and fracturing (U.S. EPA, 1991d). Some of these parameters influence biodegradation that occurs in the soil, particularly, the porosity. The porosity of soil affects the ability to provide oxygen and other nutrients for microorganisms in the soil. Knowledge of these geologic and hydrogeologic conditions helps in designing extraction and recovery wells utilized in bioremediation.

4.2.2 Soil Characteristics

Soil parameters that influence microbial action in the soil are: soil stratification, depth, texture, hydraulic conductivity, soil moisture, and organic matter content. The presence of various horizontal layers of different chemical composition will affect biodegradation and movement of the contaminants. Figure 17 illustrates the relative difference between rates of biodegradation for gasoline and diesel in various types of soil. The less porous the soil type, the longer the treatment takes and the higher the cost involved. Soil texture generally influences other parameters, such as porosity, and hydraulic conductivity. Soil hydraulic conductivities of $6.94 * 10^{-5}$ - $6.94*10^{-3}$ cm/s are favorable for adding or removing materials. Soils with conductivities above this range may require careful design to prevent excessive drainage or contaminant mobility. Soils with conductivities below this range may be difficult to add water and nutrients to or to remove by-products from. The conductivity may be enhanced by hydrofracturing techniques (Murdoch, 1994). Microbial activity is usually optimum at soil moisture of 60 - 80 percent of field capacity (U.S. EPA, 1991c).

4.2.3 Contaminant Characteristics

The nature of the contaminant and its biodegradability are two main determining factors in evaluating the feasibility of in-situ bioremediation at a given site. The most readily degraded contaminants are the ones similar in molecular structure to natural substrates the microorganisms already use. Chemical contaminants with no natural counterpart are much more difficult and require longer periods of time to degrade. The complexity of the molecular structure is directly related to its biodegradability. While a simple benzene ring is readily degradable, complex long-chain compounds with multiple rings or rings with substituted chlorines, etc. are more slowly degraded, as illustrated in Figure 18. Table 4 presents different biodegradabilities for various contaminants.

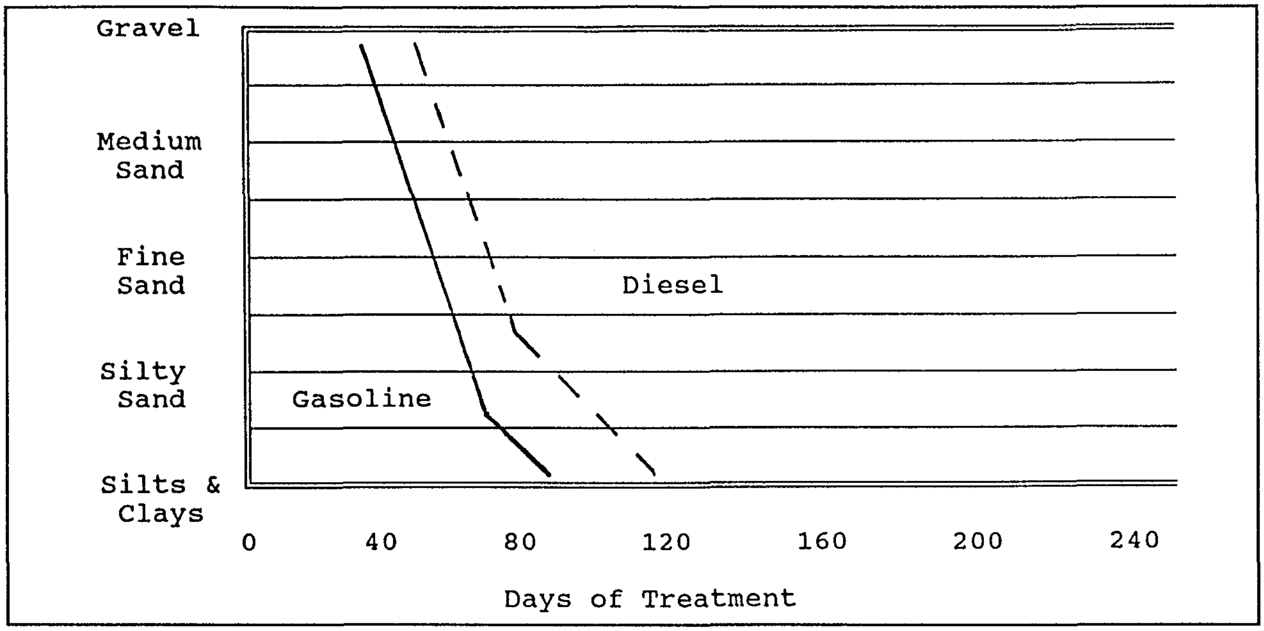

Figure 17: Rates of Biodegradation as a Function of Product and Soil Type

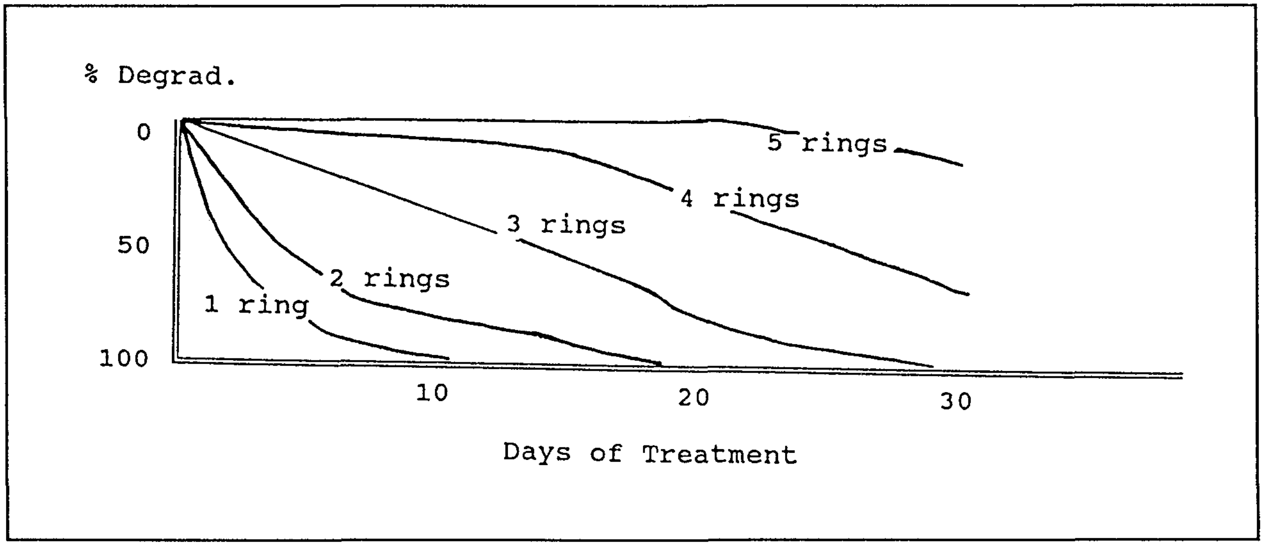

Figure 18: Degradation of Aromatic Compounds in Soil as a Function of Number of Benzene Rings

Table 4: Biotreatability of Various Contaminants
(Groundwater Technology, Inc., 1992)

CONTAMINANT AVAILABILITY

High (Soluble)	Low (Strongly Sorbed)
HIGH TREATABILITY Gasoline Diesel Jet Fuel Petroleum Solvents: BTEX, Naphtha, Mineral Spirits Phenols	**MODERATE TREATABILITY** PAHs API Separator Sludge No. 6 Fuel Oil Crude Oil PCBs < 1242 Lo-Cl Pesticides Phthalates
LOW TREATABILITY Chlorinated Solvents Fuel Additives: MTBE, TBA Ethers	**VERY LOW TREATABILITY** PCBs > 1242 Hi-Cl Pesticides

4.3 Design Parameters

4.3.1 Microbial Addition

The most common metabolic mechanism for in-situ biodegradation of petroleum contamination is aerobic respiration:

$$\text{Hydrocarbon} + O_2 \text{ ---> } CO_2 + H_2O + \text{cell material} + \text{energy}$$

Although a variety of both aerobic and anaerobic organisms are capable of metabolizing petroleum hydrocarbons, anaerobic degradation is generally slower and less complete. The requirements for aerobic respiration include:

- microorganisms acclimated to the contaminant and environment;
- nutrients; and,
- favorable environmental conditions.

Engineered biological cultures utilize bacteria which readily degrade organic chemicals. Some naturally occurring microorganism populations may be genetically engineered, adapted, or stimulated to degrade specific compounds. Several companies market developed or genetically engineered strains that can be used to inoculate soils and/or supplement the natural population. Local bacteria already adapted to the environment tend to perform better than non-indigenous bacteria, especially when natural environmental conditions seem extreme (Groundwater Technology, Inc., 1993).

Bioremediation can combine soil treatment with ground water treatment, remediating contamination in both the unsaturated and saturated zones. Within the unsaturated zone, microbes are combined with a nutrient solution and introduced to the subsurface soils through percolation or injection. Within the saturated zone, ground water is recovered, enriched with biomass and/or nutrients, and reintroduced through injection wells or infiltration galleries.

4.3.2 Environmental Growth Factors

Naturally occurring microorganisms which are acclimated to natural compounds similar to the contaminant of concern will adapt readily to the new substrate, provided suitable environmental conditions exist. The oxygen concentration, temperature, pH, moisture, nutrients, soil permeability, and absence of toxins will control the rate and success of biodegradation. Table 5 lists potentially limiting environmental factors to biodegradation.

Table 5: Potentially Limiting Environmental Factors
(Groundwater Technology, Inc., 1993)

Temperature	Alkalinity
pH	Salinity
Osmotic Pressure	Redox Potential
Hydrostatic Pressure	Presence of other organic materials
Free Water	Inorganic Nutrients (N,P, Trace minerals)
Radiation	Oxygen

When considering bioremediation designs, the most essential ingredient is oxygen followed by moisture, nutrients, and microbes. Oxygen is the controlling factor in aerobic respiration. Without a supply of oxygen, aerobic biodegradation ceases and anaerobic conditions prevail. Nutrients necessary for microbial growth include carbon (contaminant or added source), nitrogen, phosphorus, and trace elements (Fe, Mg, Ca, S, Mn, etc.).

4.3.3 Oxygen Supply

Oxygen is the principal rate-limiting factor in aerobic biodegradation and also the most critical operational parameter. It must be supplied in adequate quantities. As the rate of biodegradation increases, oxygen is depleted quickly in the soil, particularly in the saturated zone. In order for degradation to continue, a fresh supply of oxygen must be constantly provided. Sources of oxygen for in-situ bioremediation include air, pure oxygen, and hydrogen peroxide.

Oxygen is introduced to the system either by injection or extraction. Within the saturated zone, oxygen may be added either by injecting hydrogen peroxide or by installing an air sparging system. Within the unsaturated zone, oxygen is usually supplied in connection with a vapor extraction system which can move large volumes of air through the subsurface from the surrounding clean soils. Vacuum extraction systems were originally designed to remove volatile organic compounds but have also proven very useful in supplying oxygen for microbial degradation.

The efficiency of oxygen transfer will depend on the type of carrier media: aerated water, oxygenated water, hydrogen peroxide, or air. The amount of carrier medium required to deliver one pound of oxygen appears in Table 6. The optimum rate of oxygen introduction can best be determined by evaluating oxygen utilization rates of the bacteria in a laboratory or field test (Groundwater Technology, Inc., 1992).

Table 6: Pounds of Carrier to Deliver One Pound of Oxygen
(Groundwater Technology, Inc., 1993)

CARRIER	POUNDS
Aerated Water	100,000 lbs
Oxygenated Water	25,000 lbs
Hydrogen Peroxide (at 500 ppm)	10,000 lbs
Atmospheric Air	4.5 lbs

4.3.4 Well Placement

Placement of injection and extraction wells is based on the nature and extent of the contamination plume, geologic and hydrogeologic conditions, and a model of ground water flow. Computerized ground water flow models can be used to predict water-level responses to injection and extraction for specified parameters such as boundary conditions, aquifer geometry, hydraulic properties, initial water-level conditions, well locations, injection rates, and extraction rates. A preliminary pilot-scale evaluation will also help in determining the most appropriate location for injection or extraction wells. When evaluating placement of vacuum extraction wells to supply oxygen for aerobic biodegradation, one central vapor extraction well may be placed where the geologic and contaminant conditions are representative of conditions throughout the site. The total well depth should correspond to the top of the capillary fringe in the unsaturated zone (minus a couple feet to allow for upwelling of the water table that occurs when a vacuum is applied to a well). The screened interval in the well should span the depth of the unsaturated zone from the capillary fringe to several feet below the ground surface to prevent short circuiting. Above this depth the annular space around the well should be sealed to the ground surface.

A vacuum can be applied across the entire length of the screened interval or a discrete-level extraction device can be lowered into the well to focus the applied vacuum only on the most contaminated soils. Vacuum monitoring points positioned at varying distances and depths from the extraction well can be used to measure the vacuum influence. Based on pressure readings at the vacuum monitoring points, the radius of influence and the soil gas permeability can be determined. The vacuum monitoring points are also useful for collecting soil vapor samples to evaluate the influence of venting on oxygen supply and biodegradation.

Soil gas permeability is a key design parameter in determining proper spacing between vapor extraction wells. Soil permeability to air flow can be determined by using an equation described by Johnson et al., (1990). This equation involves such parameters as the radius of the well, its radius of influence, the absolute ambient pressure, the absolute pressure at the well, and the screened interval length. A k value (value of soil permeability to air) of 10^{-8} cm^2 is typical for fine to medium sands (Johnson et al., 1990).

Depending on the contaminant type, the aeration system should be designed to displace a specified pore volume of air through the contaminated soil zone in a specified period of time. Table 7 lists the oxygen uptake and exchange rates for in-situ bioremediation of petroleum contaminants.

Table 7: Air Pore Volume Exchanges Required for Treatment
(Groundwater Technology, Inc., 1993)

CONTAMINANT TYPE	OXYGEN UPTAKE (lb O_2 / yd^3/ day)	EXCHANGE RATE (pore volume/day)
Light Hydrocarbons:		
Gasoline, Jet Fuel	2.45	20.7
Diesel, Fuel Oil	0.33	2.80
Waxy Cake	0.026	0.22

4.4 Cost

In-situ bioremediation techniques are generally considered more cost effective than other remediation techniques. There is no containment, capture, or removal involved. However, the tendency to be expensive is present as treatment can be unpredictable, may not always be complete, and may take an unexpected length of time. The major cost involved with in-situ bioremediation is the supply of air and nutrients, which usually involves pumping the contaminated groundwater out of the aquifer, seeding with acclimated microorganisms and or nutrients, and recycling it through the system until satisfactory remediation is achieved. According to IEPA statistics (2-16-94), the average cost for in-situ bioremediation was $25 per cubic yard. This estimate was derived from cost data for an average site of 5,000 cubic yards with a total remediation cost of $491,000. For more cost information on in-situ bioremediation, see Appendix A. Table 8 shows cost effectiveness of bioremediation for various case studies with different levels of contamination.

Table 8: Costs of Treating Various Contaminants by Bioremediation

Contaminant	Reduction	Cost
Chlorinated Phenolic Herbicides	2800 ppb to 100 ppb	in excess of $ 150,000 verses carbon treatment
Nitroaromatics	90 %	30 - 50 % of landfill disposal cost
Pesticides, Phenols, Alcohols	6000 ppm to < 100 ppm	$ 350,000 less than previous activated carbon treatment
Gasoline	> 1000 ppm to below detection limits	$ 500,000 less than landfill cost
Phenols	350 ppm to < 100 ppm	30 % less than landfill cost
Polycyclic Aromatic Hydrocarbons	80 %	50 % cheaper than other technologies

SECTION 5
AQUIFER AIR SPARGING

Aquifer air sparging (soil/ground water aeration) is an in-situ, innovative process of ground water treatment. It is one of two in-situ aeration approaches to treat VOC contaminated areas (the other method, vacuum vaporization will be discussed in Section 6 of this report). Air sparging involves the injection of air directly into a saturated zone to treat VOCs and petroleum hydrocarbons in ground water through volatilization and biodegradation.

As a remediation technology, air sparging has an advantage over pump and treat because it volatilizes contaminants adsorbed on solids in the saturated zone. Ground water contamination is generally a result of soil contamination. Due to the low solubilities of most oily phase hydrocarbons, less than five percent of the total exists in the dissolved phase. The rest is adsorbed onto the soil and/or aquifer solids. Traditional pump and treat simply treats the ground water contamination (dissolved phase contaminants), ignoring the contaminants in the soil (Brown, 1994).

Air sparging has several engineering and economic advantages over conventional pump and treat methods including (Barrera, 1993):

- higher or greater VOC removal rates;
- simplicity and ease of operation;
- reduced capital costs due to the lower power requirement of moving air and not ground water;
- elimination of the need for above-ground air treatment systems (low-profile and stripper towers, activated carbon, etc.) it is essentially an in-situ air stripping system; and,
- reduced need for ground water discharge permits due to minimal amounts of water transported to the surface.

5.1 Description of Technology

Air sparging is an in-situ aeration process that emulates an air stripping system and removes VOCs from the saturated zone. The saturated soil acts as the packing. Injected air flows through the water and over the soil, where the air bubbles contacting dissolved/adsorbed-phase contaminants cause VOCs to volatilize. The organics are then carried by the air bubbles into the vadose zone, where they can be captured by a vapor extraction system, or if permissible, allowed to escape through the ground surface. The injected air supplies oxygen to the ground water, which enhances natural biodegradation. Air sparging also elevates the oxygen level in the vadose zone (by increasing the air flow), stimulating the indigenous bacteria. These bacteria, in turn, enhance biodegradation of the VOCs, which further increases the remediation rate. Air sparging is often used in conjunction with in-situ bioremediation (Angell, 1992).

Air sparging creates turbulence and increases mixing in the saturated zone. This increases contact between the ground water and soil, which in turn increases the desorption of contaminants from soil particles. Contaminants freed from their adsorbed state move into the dissolved state, where there is a greater chance for volatilization (Angell, 1992).

A typical air sparging system consists of three parts: an injection system, an air flow system, and an off-gas treatment system. These systems are briefly described in the following subsections.

5.1.1 Injection System

The injection of hydrocarbon-free gas, usually air, into the saturated soil zone is achieved using a series of injection wells manifolded to a compressor(s). Several types of compressors can be used. The most common type is an oil-free air compressor rated for continuous duty. Reciprocating and rotary-screw (not oil-free) compressors are also widely used in this application. Coalescing and particulate filters, and air dryers are available and can clean injection air to less than 3 parts per billion total hydrocarbons. These filtration systems, however, add complexity and maintenance costs. The possibility of a filtration failure should also be considered and alternatives or replacements made available (Marley et al., 1992).

The well itself is constructed much as a ground water monitoring well. A typical sparge well is shown in Figure 19.

Air flow rates typically used in the field are in the range of 3 - 10 standard cubic feet per minute per sparge point. This is a site specific parameter governed by the air-to-water flow ratio, which produces the desired contaminant mass removal ratio for a given volume (Marley, et al., 1992).

5.1.2 Air Flow System

Air flow in the subsurface is controlled by the configuration of the injection system (i.e., the placement of the extraction wells, injection wells, or surface seals) and the natural soil conditions, including the soil type (sand, clay, etc.), the soil moisture content, and the distribution of air permeability in the soil. The air sparging system itself consists of a compressor (generally, oil-free) connected to one or more sparging, or injection wells, which are completely in the saturated zone. This system is usually teamed with soil vapor extraction (SVE) for capture of the produced vapors.

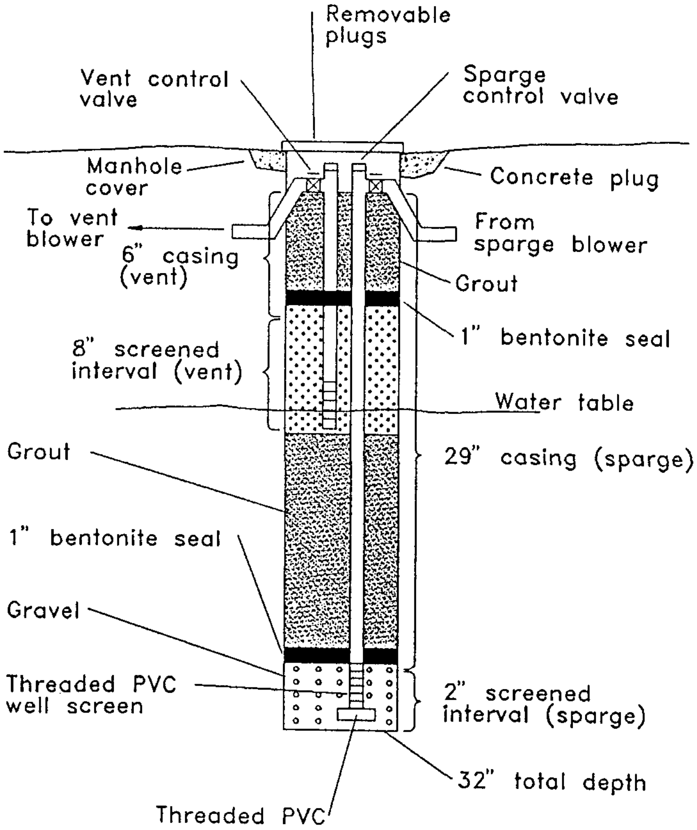

Figure 19: **A Typical Air Sparging Vent Point Construction**
(Angell, 1992)

5.1.3 Integration with SVE Systems

Soil vapor extraction is a proven, in-situ remediation technology for removing VOCs from the vadose zone in the soil. This technique involves the controlled application of an air pressure gradient to induce an air flow through soils contaminated with VOCs. As soil gas is drawn toward the vacuum source (vapor extraction well), the equilibrium between the VOC phases (free-phase product, adsorbed phase, vapor phase, and the dissolved phase) is upset, causing enhanced partitioning into the vapor phase. VOCs in the vapor phase are subsequently removed from the subsurface and treated using one of several available off-gas treatment systems. One of the limitations of SVE is that it does not adequately address remediation of contaminated soil below the water table (Marley et al., 1992).

A few techniques have been developed and employed to expand upon SVE to achieve remediation in the saturated soil zone. These include artificial water table drawdown and air sparging. With air sparging, the VOCs dissolved in ground water and adsorbed onto or trapped in the soil can partition into the advective gaseous phase, effectively simulating an in-situ, saturated-zone air-stripping system. The stripped contaminants are then transported in the gaseous phase to the vadose zone within the radius of influence of an operating SVE system

(Marley et al., 1992). Figure 20 illustrates a typical SVE/air sparging system.

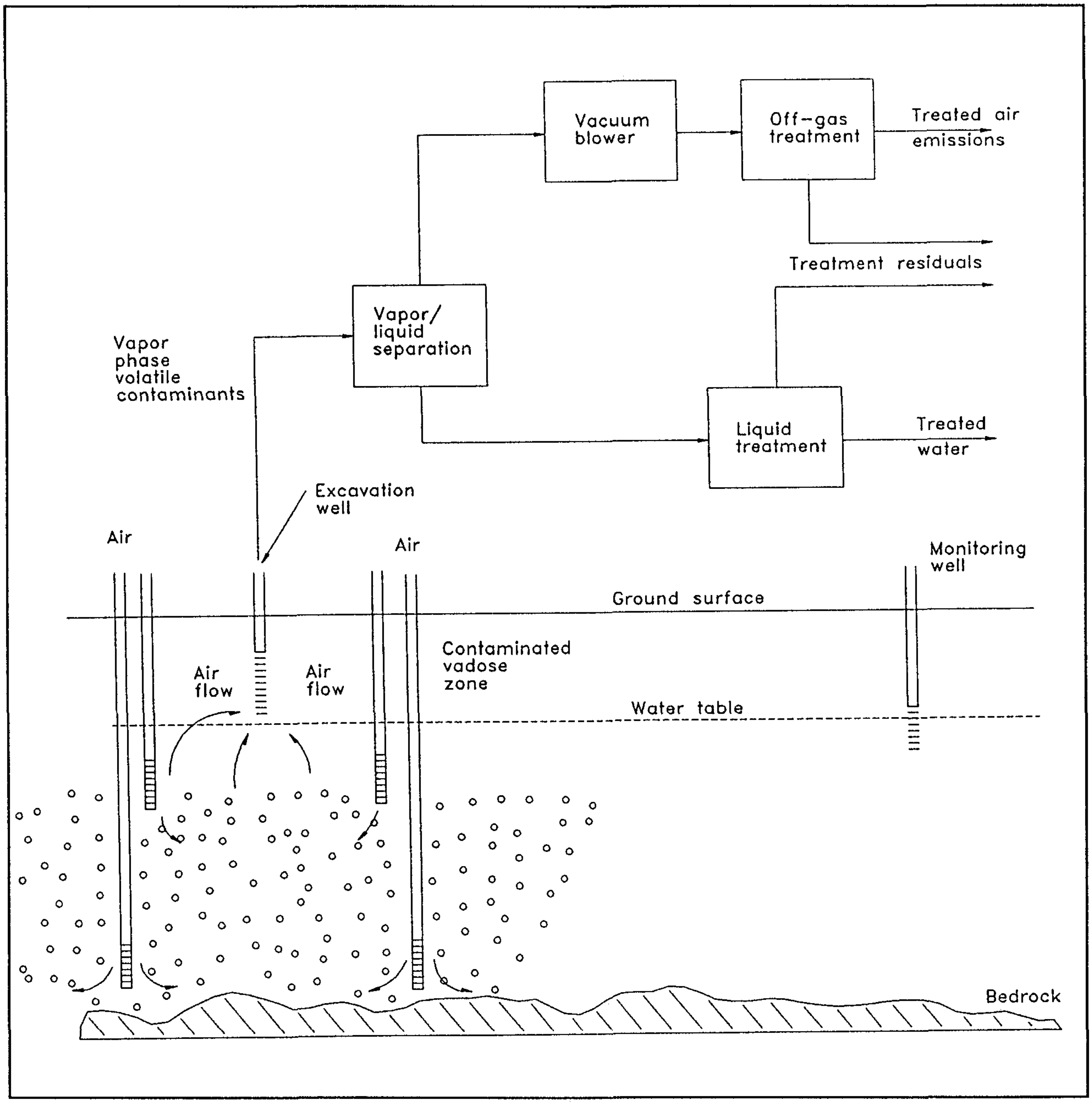

Figure 20: A Typical SVE/Air Sparging System

5.1.4 Off-Gas Treatment

Direct discharge of extracted vapors to the atmosphere without treatment for the removal of VOCs may be acceptable if concentrations of contaminants are within regulatory limits. Otherwise, an off-gas treatment system must be employed to remove the VOCs prior to discharge to the atmosphere.

In most of Illinois, emissions to the atmosphere are allowed by IEPA at rates up to eight pounds of total VOCs per hour. Ozone non-attainment areas exist in the Chicago and St. Louis metropolitan areas. In these areas, VOC emissions are more limited. The local air quality compliance status must be verified for each site to determine allowable emissions before an air sparging/SVE system can be designed.

In some cases, the need to control emission rates may arise from a potential fire/explosion hazard, or aesthetic considerations (odors). In such cases, it is necessary to treat the off-gas to remove the VOCs prior to discharge.

Several vapor treatment technologies are available, including:

- granular activated carbon (GAC) adsorption;
- thermal oxidation (incinerator and packed-bed thermal processor);
- catalytic oxidation;
- internal combustion engine;
- biodegradation; and,
- direct discharge with operational controls to limit emission rates.

Soil gas removed by the air sparging/SVE system contains water vapor in addition to the vapor phase hydrocarbons. This water vapor increases wear on blowers and other equipment, can cause problems with rust, decreases the adsorption efficiency of GAC off-gas treatment systems, and increases the energy consumption of thermal off-gas treatment systems. Therefore, water vapor is typically removed from the off-gas before any other treatment. Both the water and the vapor are then treated. Removal of the water for treatment is accomplished using demisters or condensers.

5.1.5 Operation and Maintenance

The initial operation phase following construction and installation of an air sparging system involves balancing the injection/extraction ratio. This involves a system start-up test and generally takes about five days to regulate. A 1:10 ratio of injection:extraction is recommended by Barrera (1993) to introduce adequate air flow into the aquifer but to prevent any potential off-site transport of contaminants.

Weekly sampling of ground water and off-gas for the first month and monthly thereafter is recommended. The operational parameters to monitor include: temperature, pressure, and airflow; extraction - temperature, pressure, airflow, and concentrations of VOC's in the extracted air (PPMv).

All mechanical equipment should be carefully monitored during winter months to avoid freeze up and down time. In the midwest, flooding has also created down time and intermittent operation, reducing the efficiency of the system (Barrera, 1993). Contingency plans must be implemented in this case.

5.2 Design Parameters

As air sparging is essentially a physical/chemical treatment process (with potential biological enhancements), the compounds that are amenable to remediation are easily identifiable. Generally, chemicals with high vapor pressures that are easily removed from contaminated ground water through traditional air stripping towers are considered optimal for application of in-situ air sparging. Site geology is also an important parameter. Air sparging is generally more effective in coarse-grained soil (Marley, et al., 1992).

5.2.1 Site Characterization

Based on the mechanics of air and water flow in soils, the following assumptions can be made in conceptualizing the in-situ air sparging process (Marley et al., 1992):

- entry of air into a saturated soil requires pressures greater than the resisting head pressure due to capillary forces. This is known as the "air entry pressure" which is required to displace water from a saturated soil;
- as air entry pressures are overcome, the injected air phase displaces water along paths of least resistance. These paths, or channels, are the result of differences in air entry pressures in the medium caused by micro and macro-scale heterogeneities; and,
- once a continuous air phase channel through the saturated soil is established, it will maintain its integrity as long as the air entry pressure is maintained within the channel.

The most important design parameter is site geology. The soils most amenable to air sparging are coarse-grained uniform soils, which allow for a lower air entry pressure and more even air distribution. Other soils can also be amenable to air sparging, with less efficiency, as long as certain inhibitors (for example, heterogenous soil pockets) are avoided.

Fine grained soils, such as silts and clays can be used, although a higher air-entry pressure must be used to ensure the distribution of air to the contaminants. Gas pockets are easily formed in fine grained soils, which reduce effectiveness of sparging and cause lateral displacement of ground water and contaminants.

In air sparging, air flow is both horizontal and vertical. Non-uniform, vertical channeling is a significant drawback of air sparging in heterogeneous soils, which can be found by performing field pilot testing. A complete lithological profile of the air sparging system should be developed before the system is implemented. The geological nature of the contaminated soil should be given careful consideration because channeled air flow may cause uncontrolled spread of contamination. Thus, in-situ air sparging is not generally recommended for use in fine grained or heterogeneous soils (Brown, 1994).

The type of contaminant to be removed is another very important design parameter. Those compounds which are easily removed in ground water using air stripping are optimal for removal by air sparging. Such compounds include lighter petroleum compounds (C_3-C_{10}) and chlorinated solvents (Marley et al., 1992).

Interactions and geochemical changes in the subsurface environment must be accounted for because they may decrease the efficiency of the removal process. These may influence the choice of the sparging gas, or even the choice of air sparging as a removal method.

Field pilot tests can determine whether a site is amenable to air sparging before a full-scale system is introduced to a site. The best sparge system design requires a field test that includes monitoring the following parameters (Angell, 1992):

- pressure vs. distances: this indicates the radius of influence of the sparging well;
- VOC concentrations in ground water: these indicate what is being removed, what areas are being affected, and what should be done before, during (with and without the system running), and after testing;
- CO_2 and O_2 levels in soil vapor: these indicate biological activity and should be done before, during, and after the test for petroleum contamination sites, under static as well as pumping conditions;
- dissolved oxygen levels in water: may be slower to see than air flow;
- water levels before and during test: this indicates air flow, which can cause some mounding; and,
- iron precipitation: which can clog the system.

5.2.2 Well Placement and Design

Pressurized air is supplied to the sparging wells via a manifold network. Metal pipe or rubber air hose may be used depending on site-specific conditions. The use of rigid PVC pipe in air sparging manifold lines should be avoided as the heat generated during air compression can damage the pipe. Where multiple sparging wells are used, a header-type distribution system is used. A pressure gauge and a regulator should be provided at each sparging well as a means of measuring and controlling air flow rates and maximizing system flexibility (Marley et al., 1992).

Air-sparging wells may be constructed of rigid PVC or metal casing and screen. The installation of air-sparging wells may be the most costly and difficult aspect of system installation. The presence of running or heaving sands may require the use of drilling fluids to maintain borehole integrity during installation. The well screen or air diffuser must be sealed within a sand filter pack at the design depth. The well's annular seal may be constructed of bentonite pellets or a thick, non-shrinking, neat cement grout. Any cracks or bridging in the seal will allow short circuiting of air flow through the borehole and can greatly reduce the effectiveness of the sparging well (Marley et al., 1992).

The ease and affordability of installing small-diameter air-injection points allow considerable flexibility in the design and construction of a remediation system. The ability to install a dense grid of injection points without major site disruption or expense means that many of the problems associated with stagnation zones in well-fields may be avoided simply by completely covering the contaminated zone with injection points (Angell, 1992).

5.2.3 Air Flow System

Inlet air flow is generally controlled by a pressure gauge and regulator at each well. For intermittent use, pulsing of air is sometimes used. Pulsing of air is considered, by some, due to potential mass transfer limitations, to provide an energy-efficient and cost-effective approach to remediation (Marley et al., 1992).

There is a wide variety of available sparging and SVE equipment. Many companies provide modular air-handling pump stations. Air injection can be accomplished by positive displacement blowers or standard air compressors. Typical pressure requirements range from 1 to 3 PSIG (in addition to the pressure required to overcome hydrostatic head) with airflow rates up to 15 CFM (Barrera, 1993).

Air sparging systems can be designed and installed to operate in conjunction with existing pump and treat and bioventing systems. Ex-situ treatment can be employed for trench soils and drill cuttings. Steam injection, heated air injection and nutrient addition can be used to remove semi-volatile compounds and heavier petroleum hydrocarbons. Air sparging has proven to be an excellent cost-effective alternative to conventional pump and treat technology (Barrera, 1993).

5.2.4 Off-Gas Treatment

The parameters relating to selection and design of off-gas treatment systems include:

- the contaminants of concern;
- the anticipated contaminant concentrations, gas flow rates, and contaminant mass loading;
- the time in which remediation is to be completed;
- cost, including both capital expenditure or lease cost and the cost of supplementary fuel (if required); and,
- ease of maintenance.

The off-gas is extracted from the vadose zone by using a positive-displacement blower. The off-gas undergoes heating from compression in passing through the blower. Cooling may therefore be required prior to off-gas treatment (Pendersen and Curtis, 1991).

Prefabricated SVE systems are available with a variety of off-gas treatment systems integrated into the unit. Available treatment options include:

- granular activated carbon (GAC) adsorption;

- thermal oxidation (incinerator and packed-bed thermal processor);
- catalytic oxidation;
- internal combustion engine; and,
- biodegradation.

GAC, thermal oxidation, and catalytic oxidation units are most frequently employed. The selection of one form of off-gas treatment over another is based on the combined criteria of cost and technical applicability. For example, very high concentrations of contaminants are needed for self-sustaining internal-combustion engines to operate. Granular activated carbon is effective at low contaminant concentrations, but the costs of replacement or regeneration become prohibitive at high concentrations. The capital cost of a catalytic oxidation unit can be accommodated at these high concentrations because its operating costs are less than the replacement costs of activated carbon.

Granular Activated Carbon (GAC) Adsorption

Adsorption on granular activated carbon (GAC) is the most common method for treating SVE off-gases (Penderson and Curtis, 1991). GAC is easy to handle, is readily available, can be regenerated for reuse, and is effective in adsorbing a wide variety of contaminants. Package systems are available for purchase or lease in many sizes.

The adsorption efficiency of GAC depends on the constituents present, their concentrations, and the temperature and humidity of the gas stream. Isotherms showing the mass of specific contaminants that can be adsorbed per unit mass of carbon are available for many contaminants. GAC has a high affinity for the contaminants most commonly associated with LUST sites.

The mass loading associated with many LUST site SVE systems may make GAC treatment cost-prohibitive, at least in the initial stages of cleanup when VOC concentrations in the off-gas are high. In this case, the adsorptive capacity of the GAC may be quickly reached and the costs of regeneration/replacement may be prohibitive (Penderson and Curtis, 1991).

Thermal Oxidation

Thermal oxidation employs direct incineration of the VOCs, generally in a combustion chamber. Several commercial vendors supply units suitable for SVE systems. Very high temperatures (1000 to 1400 degrees F) are employed to achieve complete destruction of the contaminants. This complete destruction is the major advantage of incineration over GAC adsorption, where the contaminants must still be disposed of following collection on the carbon. Fuel costs to maintain the required temperature may be quite high. However, if the concentration of VOCs produced by the SVE system is high, the contaminants will help sustain combustion. Off-gas concentrations above 50,000 ppm may be capable of supporting combustion without additional fuel.

A variant on thermal oxidation is the packed-bed thermal processor. In this type of unit, a packed bed of ceramic beads is heated to 1,800 degrees F. The off-gas is passed through the packed bed and the contaminants are oxidized. Initial heating of the packed bed is done electronically. If contaminant concentrations exceed about 2,000 ppm, combustion of the contaminants maintains the temperature and no supplemental fuel is needed. This system is somewhat unique among incineration techniques in its ability to process chlorinated compounds without degradation of the packed bed (Penderson and Curtis, 1991).

Catalytic Oxidation

Catalytic oxidation systems employ a catalyst, generally a precious metal mesh or packed bed, to accelerate oxidation of the contaminants. These systems operate at much lower temperatures than thermal incineration units and therefore have lower fuel requirements. Care must be exercised to keep the concentration of contaminants in the extraction gas below about 3,000 ppm to prevent overheating, which deactivates (or melts) the catalyst (Penderson and Curtis, 1991).

Internal Combustion Engine

Internal combustion engines have been used for many years to destroy landfill gas and have recently been applied to the destruction of VOCs from SVE systems. This application has mainly been employed in southern California. Virtually any automotive or industrial engine can be used. Carburetor modifications are required to enable the engines to run on a gaseous fuel. Supplemental fuel (usually propane) may be required, and ambient air must be provided to supply oxygen to sustain combustion. A standard automobile catalytic converter is typically employed as a final cleaning step.

Internal combustion engines are portable, relatively easy to maintain, and can handle a very wide range of contaminant concentrations. Experience in California indicates removal efficiencies comparable to other off-gas treatment systems. In addition, it is possible to harness some of the engine's power to other uses, such as powering vacuum pumps or a generator. However, they require considerable attention during operation, can handle only limited flow rates, and are noisy (Pendersen and Curtis, 1991).

Biodegradation

Biodegradation of vapor streams may be accomplished in a soil bed. Laterals of perforated pipe are buried in the soil bed to distribute the exhaust gas. In passing through the soil bed, contaminants are adsorbed on soil particles and degraded by the resident microbial population. Since the bed is constructed, careful control of the environment (particularly with respect to moisture and nutrient content) in the soil is possible. If large amounts of water are added, a leachate collection system may be required. Soil beds have been used at sewage treatment and industrial plants for odor control for many years. Their use at remediation sites is recent (Pendersen and Curtis, 1991).

Moisture Removal

The air flow from the subsurface may contain considerable moisture in both the liquid and vapor phases. Dust and silt particles may also be entrained in the air flow. The amount of water in the air flow depends on the moisture content of the soil, the soil permeability, the proximity of the screen to the water table, the amount of infiltration, and the configuration and operating conditions of the system.

Removal of entrained liquid water, water vapor, and particulates is important to minimizing equipment wear (and therefore maintenance costs) and extending equipment life. Water removal is essential if GAC treatment is employed. Water decreases the capacity of the carbon to remove contaminants and carbon replacement/regeneration costs can soar.

Demisters, knock-out drums, and condensers are used for moisture removal. The collected water must be treated and disposed. If ground water is being remediated at the site, the water can be added to the ground-water treatment system influent stream. If the rate of water production is low, collection and disposal at a commercial industrial waste water treatment facility is simple, and it may be the most economical disposal method.

Direct Discharge

Instead of treating off-gasses, one simple way that hydrocarbon emission rates can be limited is through operational controls. There are two basic approaches:

- bleeding fresh air into the system to reduce air flow from the subsurface and dilute the off-gas stream prior to discharge; and
- limiting the amount of time the system operates during the day, based on the monitored concentrations of total organic vapors in the off-gas.

Since these control methods reduce the rate of VOC removal from the subsurface, the time required to complete remediation can be substantially lengthened. Off-gas treatment may be necessary if cleanup time requirements are to be met.

5.3 Cost

An average cost of air sparging (with SVE) given by the IEPA (1992) is $65 per cubic yard. This technology, as most others, is site specific so costs can vary greatly with each site. For more specific cost information, see Appendix A.

SECTION 6
VACUUM VAPORIZATION

Vacuum vaporization is an in-situ technology which can be used to remediate subsurface contamination present in the ground water, the capillary fringe area, and the unsaturated zone. This technology was first developed and applied in the field in Germany. It is commonly referred to as Unterduck-Verdempfer-Brunnen (UVB). UVB is recommended for sites that are contaminated with volatile and semi-volatile hydrocarbons.

The UVB process involves in-situ treatment of ground water by aeration in a negative pressure field. The strippable contaminants are removed from the ground water and treated with activated carbon on the surface. The advantages of this technology include short remediation periods, low costs, and good mixing of air and dissolved contaminants through vertical circulation flow in the saturated zone. Also, this technology can be used in conjunction with in-situ bioremediation.

6.1 Description of Technology

The UVB system consists of a specially-adapted ground water well, a negative-pressure stripping reactor, an above-ground mounted vacuum pump, and a waste-air decontamination system such as an activated carbon filter. A typical UVB system is shown in Figure 21.

The vacuum pump creates a negative pressure inside the well that exhausts contaminants stripped from the water causing the water to rise in the well and inducing fresh air flow through draft tubes to the stripping zone. Rising air bubbles increase the suction at the bottom which, in turn, speeds up the transfer of contaminants from the aqueous phase to the gaseous phase.

A pump draws contaminated water from the lower portion of the aquifer and pumps it to the stripping zone. In the stripping zone fresh air goes through a pinhole plate in the stripping reactor and mixes with the water. Contaminants in the water escape due to the intermixing with air. The air bubbles have a considerable surface area for the contamination to strip onto. The air is removed and passed through the vacuum pump and an activated carbon filter.

The stripped water exits at the top of the stripping reactor and is recirculated into the aquifer. Ground water is circulated within the sphere of influence (part of the aquifer affected by the UVB). The water which re-enters at the top of the aquifer circulates extensively through the aquifer before it again enters at the bottom of the well. Not all of the water will re-enter the well; some of it will flow downgradient. However the sphere of influence of this technology is limited so larger contaminated plumes may require a series of UVBs.

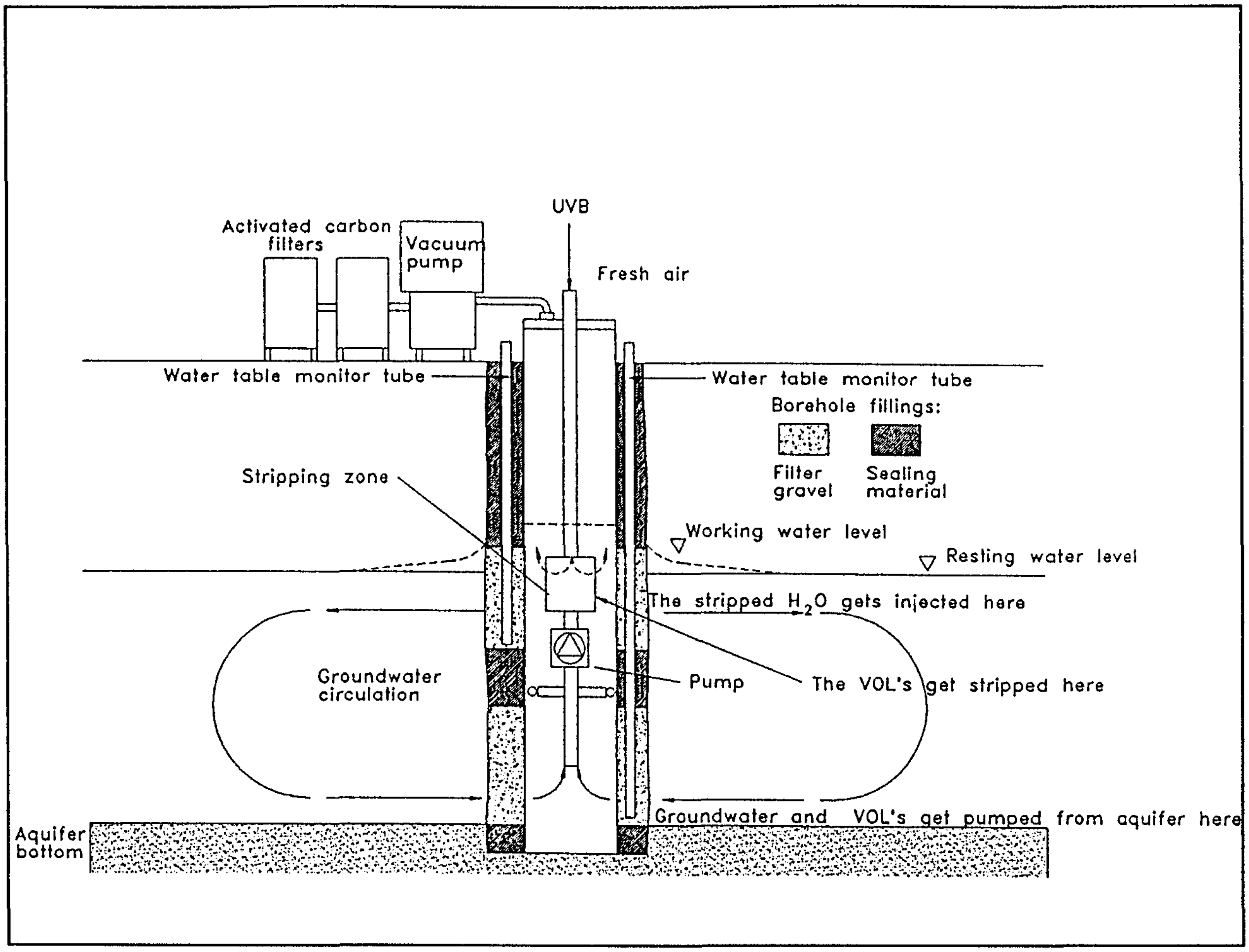

Figure 21: **Typical UVB (Vacuum Vaporization) System**
(Alesi et al.)

One advantage of this system is that clean water is never introduced into the contaminated aquifer from outside. The water is treated in situ and that water is released and recirculated in the aquifer. There is also no ground water extraction or surface run-off water as it is treated and released in situ. This makes permitting easier. Also, the ground-water table is not lowered; so, structural damage can be avoided.

Some of the advantages of the UVB method over the other remediation technologies are:

- it is not necessary to pump and treat the ground water on the surface;
- no waste water is generated; and,
- compared to other hydraulic stripping units, the UVB method requires a much lower air to water ratio, i.e., 10 : 1. This becomes very significant when large amounts of ground water are to be treated.

6.2 Design Parameters

The important parameters that are considered in the use of UVB include: site geology, hydrogeologic conditions, and contaminant delineation. The site geology involves soil zones, such as the vadose and saturated zones, soil texture, soil porosity, etc. The hydrogeologic conditions include hydraulic conductivity in vertical and horizontal directions, depth to bedrock, type of aquifer, and structural features, such as fractures, faults, and folds. The contaminant must be characterized before any remedial action is planned. The type and extent of contamination should be determined in both the vadose and saturated zones. Once the contaminant plume is delineated, the number of wells required, spacing between wells, and location of wells can be determined. Other parameters like contaminant volatility, density, and chemical makeup will also help in the design of the remediation system.

6.3 Cost

The costs involved in the UVB process were estimated from German market prices because the UVB method was initially developed and field tested in Germany. Costs of the UVB method can not be directly compared to USA market prices. However, a rough estimate indicates that the total cost is about $ 352,000 dollars for installation and operation of 2 remediation wells. This cost includes remediation planning, organization, and project management, site investigations, sample analyses, and supervision of the remediation process. Table 9 shows the typical costs for various activities involved in the UVB method.

Table 9: Typical Costs for Various Activities Involved in the UVB Remediation Method

Compilation of Costs	%	US $
planning, organization, project management, provision of the UVB units	21.8	77,000
remediation monitoring, field work	21.5	76,000
laboratory analytical work	8.2	29,000
boring of two remediation wells, equipment installation	15.3	53,000
activated carbon unit and disposal of the recovered contaminants	24.1	85,000
total electrical energy cost	9.1	32,000
total	100.0	352,000

SECTION 7
PERMITS AND REGULATIONS

The discovery of a leaking underground storage tank initiates a process of reporting and interaction with three state agencies: the Office of the State Fire Marshall (OSFM); the Illinois Emergency Management Agency (IEMA), formerly known as the Illinois Emergency Services and Disaster Agency (IESDA); and the Illinois Environmental Protection Agency (IEPA). Other agencies may also become involved such as the local POTW depending on the remediation options that are selected.

Each of these agencies plays a different role. The IEMA serves as a clearinghouse for notifications when a release is discovered. The IEMA assigns an Incident Number to the release incident and forwards notification of the release to the IEPA. The Incident Number is used to track the subsequent remediation efforts and to cross-reference correspondence, permitting, and LUST Fund reimbursement files in the IEPA.

The OSFM serves in a safety oversight role. The OSFM issues permits for and oversees tank removal operations, makes preliminary evaluations of the severity of releases observed during tank removals, and must also be notified in the event of spills and overfills.

The IEPA is the primary agency overseeing remediation efforts once a release has been identified. The IEPA establishes standards and procedures for environmental cleanup; issues permits for disposal of contaminated soils and ground water, design and operation of soil and ground water treatment systems, and discharges of contaminated water and air emissions to surface water, ground water, or the atmosphere; disburses reimbursements for remediation costs from the Illinois LUST Fund; and determines when remediation efforts are complete and when the site can be considered clean.

The IEPA is divided into various organizational units dealing with different aspects of environmental protection. The primary unit that owners/operators of LUSTs must interface with is the LUST Section in the Bureau of Land. The LUST Section manages the response to the release and regulates the technical remediation efforts at the release site. However, permitting the various aspects of the remediation of a site can involve virtually the entire agency depending on the remediation technology(ies) selected. The Permit Sections of the Bureau of the Land, the Bureau of Water, and the Bureau of Air may all need to be contacted.

In addition, IEPA interdisciplinary committees become involved when unusual site-specific issues must be resolved. These committees are composed of agency staff from various divisions and programs selected for their technical expertise. Alternative remediation approaches must be reviewed on a case-by-case basis by the Alternative Technology Assessment Group (ATAG).

Requests for site-specific cleanup objectives for LUST sites are evaluated by the Office of Chemical Safety (OCS) and a committee for Cleanup Objectives Review and Evaluations (CORE). In essence, the OSC serves as a technical advisory team providing scientific recommendations for CORE. CORE formally adopts the alternative and/or site-specific cleanup goals based on these technical recommendations and regulatory, legal, or agency policy considerations. If IEPA has adopted a generic cleanup objective for a particular contaminant, requests for site-specific alternative cleanup objective are evaluated directly by CORE. However, if there is no generic cleanup objective, the request will first be evaluated by the OCS, which will develop the scientific rationale for the proposed objectives.

IEPA regulations govern remediation of LUST sites; cleanup objectives; surface water, ground water, and air quality; and permitting of remediation systems and discharges to the environment. Over time these regulations are subject to change. For LUST sites, the IEPA has initiated efforts to coordinate the various air, water, and land permitting procedures. Environmental professionals who stay in close touch with the regulatory officials should be used to assist in ensuring that regulatory and permitting requirements are met.

7.1 Release Detection and Reporting

Leaking USTs are generally discovered during routine tank activities, such as tightness testing, tank removal, upgrading for corrosion protection or leak detection, facility remodelling, or property transfer. A LUST may also be discovered by the presence of contaminants in the vicinity of the site. For example, gasoline vapors may be discovered in nearby basements or sewers. LUSTs can also be discovered by leak detection systems, inventory discrepancies, or because of unusual operating conditions in the UST system.

7.1.1 Existing Standards

A detected or suspected release from an UST must be reported within 24 hours to the Illinois Emergency Management Agency (IEMA). The IEMA issues an Incident Number for the release and notifies the IEPA. The IEMA Incident Number becomes the case number and must be retained for use in subsequent correspondence with the state regarding the release or any corrective actions taken at the site. Spills and overfills of petroleum or hazardous substances also must be reported to the Office of the State Fire Marshall (OSFM).

Suspected releases must be investigated immediately. Upon confirming that a release has occurred, the Illinois Environmental Protection Agency (IEPA) must also be notified. The IEPA has issued standard forms for the reporting of site investigation and corrective action activities (see Section 7.3). No corrective action or reporting to the IEPA is required if the site does not have a release and there is no evidence of contamination.

Besides these notification requirements, the owner/operator must take immediate action to prevent any further release or spread of contaminants in the environment, and to minimize any potential fire or explosion hazard.

7.1.2 Proposed Standards Under House Bill 300

For detected or suspected leaks from USTs reported to the IEMA after September 12, 1993, the standards outlined in House Bill 300 may apply. IEMA, IEPA, and the OSFM must be notified as mentioned above. However, a site classification must also take place as described below.

Site Classification

Before any site evaluation activities take place, the owner/operator must submit a Site Classification Plan to the IEPA, including soil and water investigation plans and plans for other site evaluation activities. A Site Classification Budget Plan must also be submitted at that time.

Sites will be classified under three general categories, "no further action" sites, "low priority" sites, and "high priority" sites. Qualifications necessary for these classifications are outlined in the "Proposed Regulations under Title XVI - Petroleum Underground Storage Tanks" by the IEPA and are briefly summarized below.

- "No Further Action" sites: These sites include ones with contamination that does not extend past the owner's property line and does not affect the ground water. This is different from the existing standards because it allows contamination to remain "in one's own backyard." For this reason, owners of LUSTs who notified the IEMA before September 12, 1993 may elect to proceed in accordance with this proposed bill (if it is passed).

- "Low Priority" sites: These are the sites with contamination that affects the ground water but does not travel outside the owner's property line. At these sites, usable amounts of ground water are transmitted and no exposure pathways are identified.

- "High Priority" sites: These are the sites with contamination that affects not only the ground water but also potable water supply wells and/or surface waters. At these sites, potential exposure pathways are encountered, which must be mitigated.

7.2 OSFM Permitting and Oversight of UST Removals

Removal of an UST, whether because a leak is suspected or for routine purposes such as upgrading, rebuilding, or divesting the site, requires that a permit be acquired from the Office of the State Fire Marshall (OSFM), Division of Petroleum and Chemical Safety. Applications for the permit are obtained from the Division of Petroleum and Chemical Safety at 1035 Stevenson Drive, Springfield, Illinois, 62703-4259, (217) 785-5878. A $100 permit fee must accompany the completed application. The permit application or other written notice of the removal must be given to the OSFM at least 30 days before work begins. Late applications are charged an additional $500 late fee. A representative of the OSFM must be present at the removal activity to oversee the work. The OSFM representative will assist in determining that a release or suspected release has occurred, based on observations and monitoring during the removal.

Before the removal action is complete, the owner/operator must have a site assessment conducted to confirm the presence or absence of a release from the tank and piping. The assessment is accomplished through the taking of soil and/or water samples from the site. The methods used to measure for the presence of a release are not specified. They can be determined using the best professional judgement of environmental consultants. There are no Federal or State guidelines concerning the site assessment. The report of the OSFM is not considered to be a site assessment by that office. In selecting sample types, locations, and methods of analysis, the type of tank, the configuration of the tank system, the method of removal, the substance(s) stored in the tank, the type of backfill, the depth to ground water, and any other factors appropriate to identifying the presence of a release should be taken into account.

7.3 IEPA LUST Section Reporting and Approval of LUST Corrective Actions

The Illinois EPA, Division of Land Pollution Control, Leaking Underground Storage Tank (LUST) Section, regulates corrective actions at LUST sites, as well as reimbursements from the Illinois UST Fund. A guidance manual and standardized corrective action reporting forms are available from the LUST Section, 2200 Churchill Road, P.O. Box 19276, Springfield, Illinois, 62794-9276.

Within 20 days of release confirmation a **20 Day Certification** form must be completed and submitted. This form identifies the site of the release and certifies that appropriate response actions have been and/or are being undertaken.

Within 45 days of release confirmation, a **45 Day Report** form is to be submitted. The 45 Day Report provides information on the site, the nature of the release, and the responses taken and planned. A completed **Corrective Action Form** that includes a Groundwater Investigation Plan is to be submitted within 30 days of the 45 Day Report if certain conditions occur:

- when corrective action is going to take longer than 45 days;
- when free product is encountered; and/or
- when ground water is encountered during removal of a tank or excavation of contaminated soils.

Professional environmental consulting firms typically provide the required site investigations, corrective actions, and report submittal.

The Illinois EPA also administers the Illinois LUST Fund. Owners/operators of LUSTs can seek reimbursement of their cleanup costs from the UST Fund if they meet the reimbursement eligibility requirements. Basically, the owner/operator is eligible to receive reimbursement if the tank was properly registered with the OSFM, if all required fees have been paid, and if the cleanup costs were incurred as a result of a release of petroleum from an underground storage tank.

There are restrictions on the kinds of costs that are eligible for reimbursement. The following are significant cost categories that are not eligible for reimbursement:

- costs of removal, treatment, or disposal of clean soils or ground water;
- costs incurred before notifying the IEMA of the release;

- costs incurred prior to or inconsistent with an approved, IEPA-required work plan; and

- costs of an alternative remediation technology that exceed the costs of conventional technology (i.e., excavation and landfill disposal) by 20% or more.

Reimbursements from the UST Fund are also subject to deductibles ranging from $10,000 to $100,000, depending on the dates when the tanks at the site were registered and the date when the release was discovered. More information regarding owner/operator eligibility, specific eligible and ineligible costs, deductibles, as well as the Application for Reimbursement from the UST Fund for Corrective Action Costs can be obtained from the IEPA Remedial Projects Accounting and Procurement Unit, 2200 Churchill Road, P.O. Box 19276, Springfield, Illinois 62794-9726.

It is important to note that, if reimbursement is to be sought, it is essential that the release be reported promptly, and that IEPA approval be obtained prior to incurring cleanup costs if an alternative remediation approach is to be used. Prior IEPA approval is also needed if the costs of cleanup, whether using conventional technology or alternative technology, are expected to exceed $150,000.

Finally, IEPA approval is required if free product is encountered, ground water is encountered during a tank removal or soil removal, or remediation is expected to take more than 45 days (see above). In this case, a Corrective Action Form including a ground-water investigation plan is required. Conducting the investigations and corrective actions proposed in the plan without IEPA approval may disqualify the costs from reimbursement.

7.4 Generic Cleanup Objectives and Confirmatory Sampling

When a LUST release has been confirmed, soils contaminated with petroleum hydrocarbon constituents must be remediated to meet the IEPA generic soil cleanup objectives listed in Table 10.

These cleanup objectives are subject to change by the IEPA. Field screening of soil excavations is commonly accomplished with portable organic vapor monitoring instruments. Soil sampling is used to define the extent of contamination and to demonstrate that the cleanup objectives have been met. The sampling takes place from the walls and floor of excavations, and/or from borings drilled to define the areas of contamination. The sampling requirements for tanks containing various kinds of petroleum hydrocarbons are listed in Table 11.

Table 10: IEPA Generic Cleanup Objectives and Acceptable Analytical Detection Limits

Parameter	Soil Cleanup Objectives *(mg/kg)*	Ground Water Cleanup Objectives *(mg/l)*	ADLs *(1)* Soil *(mg/kg)*	ADLs *(1)* Ground Water *(mg/l)*
Benzene	0.005	0.005	0.002	0.002
Ethylbenzene	--	--	0.002	0.002
Toluene	--	--	0.002	0.002
Xylenes (Total)	--	--	0.005	0.005
Total BETX *(2)*	11.705	11.705	--	--
Lead *(3)*	--	--	0.005	0.005
Naphthalene	0.025	0.025	0.660	0.010
Acenaphthalene	8.4	0.42	1.200	0.018
Anthracene	42.0	2.1	0.660	0.0066
Fluoranthene	5.6	0.28	0.660	0.0021
Fluorene	5.6	0.28	0.140	0.0021
Pyrene	4.2	0.21	0.180	0.0027
TOTAL CARCINOGENIC PNAs	0.004	0.0002	--	--
Benzo(a)anthracene	--	--	0.0087	0.00013
Benzo(a)pyrene	--	--	0.015	0.00023
Benzo(b)fluoranthene	--	--	0.011	0.00018
Benzo(k)fluoranthene	--	--	0.011	0.00017
Chrysene	--	--	0.100	0.0015
Dibenzo(a,h)anthracene	--	--	0.020	0.0003
Indeno(1,2,3-c,d)perylene	--	--	0.029	0.00043
TOTAL NON-CARCINOGENIC PNAs	4.2	0.21	--	--
Acenaphthylene	--	--	0.660	0.010
Benzo(g,h,i)perylene	--	--	0.051	0.00076
Phenanthrene	--	--	0.660	0.0064

Notes: *(1)* *ADLs are Acceptable Detection Limits. Any of U.S. EPA SW-846 Analytical Laboratory Procedure methods 5030,8020,8240, and 8310 may be used to determine contaminant levels as long as the selected method meets the ADL listed in the table. The ADLs are the lowest Practical Quantitation Limits using SW-846 methods. If a cleanup objective is below the corresponding ADL, a "non-detect" analytical result while achieving the ADL is taken as de facto compliance with the cleanup objective.*

(2) *Total BETX is the sum of the benzene, ethylbenzene, toluene and xylene concentrations.*

(3) *Analyses for lead apply at cleanups involving leaded products. The ADL concentration is for lead in the TCLP extract from soil. The cleanup objectives for lead are set case-by-case.*

Source: IEPA, 1991, Table 2.

Table 11: IEPA Sampling Requirements for Soils and Ground Water at Different Types of USTs

Type of Underground Tank	Soil Sampling	Ground Water Sampling
MOTOR GASOLINES (B.P. 150°F. - 300°F.) leaded *(1)*, unleaded, premium, gasohol	Benzene BETX *(2)*	Benzene BETX *(2)*
MIDDLE DISTILLATE FUELS (B.P. 350°F. - 700°F.) aviation turbine fuels (A,A1,B) *(1)* jet fuels (JP4, JP5) diesel fuels (grade 1d, 2d) gas turbine fuel oils (Nos. 0, 1, 2) heating fuel oils (Nos. 1, 2) illuminating oils (mineral seal oil, long time burning oil, 300 oil, mineral colza oil) kerosene	Benzene BETX *(2)* Naphthalene Acenaphthene Anthracene Fluoranthene Fluorene Pyrene Total Carcinogenic PNAs Total Non-Carcinogenic PNAs	Benzene BETX *(2)* Naphthalene Acenaphthene Anthracene Fluoranthene Fluorene Pyrene Total Carcinogenic PNAs Total Non-Carcinogenic PNAs
HEAVY ENDS (B.P. > 500°F.) lubricants (automotive and industrial) liquid asphalt and dust laying oils transformer oils *(3)* and cable oils crude oil and crude oil fractions petroleum feedstocks and petroleum fractions heavy oils hydraulic fluids	Benzene BETX *(2)* Naphthalene Acenaphthene Anthracene Fluoranthene Fluorene Pyrene Total Carcinogenic PNAs Total Non-Carcinogenic PNAs	Benzene BETX *(2)* Naphthalene Acenaphthene Anthracene Fluoranthene Fluorene Pyrene Total Carcinogenic PNAs Total Non-Carcinogenic PNAs
WASTE OILS	Total Priority Pollutants *(4)*	Total Priority Pollutants *(4)*
HAZARDOUS SUBSTANCES petroleum spirits (Type 2, 3, 4 commercial hexane) mineral spirits or Stoddard solvent (type 1, petrol spirit) high-flash aromatic napthas (Types I and II) VM&P naphthas - moderately volatile hydrocarbon solvents (Types I, II, and III) petroleum extender oils (Types 101, 102, 103, 104)	Total Priority Pollutants *(4)*	Total Priority Pollutants *(4)*
SPECIFIC CHEMICAL TANK	Specific Chemical	Specific Chemical

Notes: *(1)* *Leaded gasoline and leaded aviation fuels may require sampling for lead (TCLP in soils).*
(2) *BETX is the sum of benzene, ethylbenzene, toluene, and xylene concentrations.*
(3) *Transformer oils require sampling for PCBs.*
(4) *Priority Pollutant analyses should include metal (TCLP in soils), volatile, acid extractable, base/neutral extractable, and pesticide/pcb fractions.*

Source: IEPA, 1991, Table 1.

7.5 Excavation, Transport, and Landfilling

Materials contaminated with petroleum hydrocarbons from leaking USTs are classified as Special Wastes. These materials can include out-of-service, excavated tanks and piping; contaminated soils; residuals from on-site soil and/or water treatment systems (e.g., spent carbon, recovered liquid petroleum hydrocarbons, biotreatment sludges); and ground water or runoff collected during a tank or soil removal. To properly remove, transport, and dispose of Special Wastes from a LUST site, IEPA Special Waste requirements must be satisfied and permits must be in place. The generator of the waste (i.e., the site owner/operator) must apply to the IEPA Bureau of Land, Permit Section, for a Generator Identification (ID) Number which will allow the IEPA to track the contaminated soil. The IEPA Permit Section can also provide lists of properly licensed treatment and disposal facilities.

If contaminated ground water is encountered or other waste water is generated at the site, the same Generator ID number issued for the soil removal action is applicable for the off-site, commercial disposal of the liquid waste.

Prior to disposal, the excavated soil must be chemically characterized. Each landfill should be contacted for the specific set of chemical analyses that must be completed before it will accept the contaminated soil. Tests for flash point are always necessary; soils with flash points less than 140°F. are ignitable and must be handled as hazardous wastes. The pH of the soil must be determined. In addition, tests for TCLP lead, the Total Petroleum Hydrocarbons content, BTEX, and possibly a screening for PCB's may be required. PCB analysis is always required if transformer oils were contained in the tank. Tests for priority pollutant organics and metals other than lead (TCLP analysis in soils) may also be required, depending on the type of site from which the soils have been removed, and the disposal facility where they are being sent. Finally, the paint filter liquids test must be conducted to demonstrate that the waste material is not a liquid waste. An approval number will be issued by the landfill for disposal once the tests have been completed by an accredited laboratory and the soils are approved for disposal. Facility-specific analytical tests must also be run on waste waters before a waste water treatment facility will accept the waste.

All shipments of soil (or ground water) to a treatment or disposal facility must be manifested. Manifests can be obtained by contacting the IEPA Bureau of Land, Planning and Reporting Section. Wastes must be transported by a licensed special waste hauler and disposed of at a permitted waste disposal facility. The Illinois Transporter ID number and Illinois Facility ID number must be obtained from the transporter and landfill, respectively. These must be included on the waste manifest when the soil is shipped. The owner/operator is legally responsible for ensuring that all permits have been obtained and requirements met.

7.6 On-site Soil Treatment

The permitting requirements associated with the on-site treatment of soils contaminated with petroleum hydrocarbons from UST releases vary depending on whether the treatment is being conducted in a new, site-dedicated facility or in a pre-existing, mobile, commercial treatment system. Commercial treatment systems such as mobile soil thermal treatment units or biological treatment systems should be permitted by the vendors prior to mobilization to the site. Dedicated, on-site treatment facilities such as soil piles or landfarms must be permitted as Special Waste Treatment, Storage, or Disposal Facilities (TSDF) by the IEPA Bureau of Land.

The permit application for a special waste treatment, storage, or disposal facility actually consists of several application forms listed in Table 12.

The forms are designed primarily for facilities that will be receiving wastes commercially from other sites for storage, treatment, or disposal. For on-site LUST treatment facilities, completing the forms is relatively simple. Design documents from environmental specialists and engineers must be provided describing the site and the proposed treatment process. This is information that is also required for completing LUST Corrective Action Forms (see Section 7.3) and developing Corrective Action Plans.

Chemistry data characterizing the soil to be treated is submitted on the "green sheet", the application for a Special Waste Stream Permit. However, soils contaminated with petroleum hydrocarbons from LUST sites are temporarily exempt from full TCLP analysis and the applicant need only provide analyses for flashpoint, paint filter test, and TCLP lead.

7.7 Water Treatment and/or Disposal

Water requiring treatment and/or disposal can be generated on a LUST site from a variety of sources, including:

- precipitation and runoff collected in a tank removal excavation;
- runoff from stockpiles of contaminated soil excavated during a tank removal or corrective action;
- runoff or surface waters impounded or collected during response to a petroleum hydrocarbon spill;
- ground water infiltrating into a tank removal or soil corrective action excavation;
- ground water intentionally recovered from an aquifer as part of the corrective action at a site, whether in conjunction with aquifer testing, sampling, controlling flow in the aquifer, dewatering, or recovery and treatment of contaminated ground water; and
- condensate, trapped or separated byproduct, and/or other water produced from the soil, ground water, or process during the treatment of contaminated soil using alternative treatment technologies such as bioremediation, soil vapor extraction, thermal desorption, or soil washing.

Table 12: Application Forms for On-Site Special Waste Treatment, Storage, and Disposal Facilities

Title	Form Number	Description
General Application for Permit	LPC-PA1	A general, 2-page form used to identify the project and insure proper administrative processing of the application by the IEPA. It is submitted essentially as cover sheets for other forms to readily identify the type of permit application, the type of facility, and the type of waste.
Application for a Solid Waste Management Permit to Develop Treatment and/or Storage Facilities	LPC-PA3	The main application to develop a new treatment and/or storage facility. The form consists of only two pages. However, the application form must be supplemented with plans, specifications, and reports completely describing the site and the development and operation of the proposed treatment and/or disposal facility. Special instructions are provided for describing additional information and requirements that need to be met when applying for land application ("landfarming") permits.
Application for Operating Permit	LPC-PA4	This 2-page form is used to apply for permission to operate a facility permitted under the LPC-PA3 application described above. Sufficient supporting documentation must be submitted with the application to demonstrate that the facility was constructed in accordance with the terms of the development permit. A pre-operational site inspection will be conducted by the IEPA before an operating permit is issued.
Certification of Siting Approval	LPC-PA8	This form is used to provide the certification of the local county or municipality that the site location suitability has been approved. It also serves as the vehicle for establishing any development or operating conditions imposed by the local government.
Notice of Application for Permit to Manage Waste	LPC-PA16	This is a standard form for mailing to local officials, notifying them that the permit application has been submitted, and of their right to comment on your plans, if they desire. Copies of the form and a list of the people to whom it was sent must be submitted each time a development, operating, or waste stream (see below) application is submitted to the IEPA.
Special Waste Stream Permit Application	"Green Sheet"	The special waste stream application is used to obtain authorization to treat or store a specific waste, rather than authorization to operate a specific facility. The "green sheet" includes spaces for providing information on the identification of the facility, and the treatment or storage method to be used. But most of the space on the form is to provide information on the chemical characteristics of the waste. The form is designed to facilitate computer entry by IEPA staff. The chemistry data provided must be accompanied by copies of original signed laboratory reports of the lab analysis of the waste.

There are basically four ways to dispose of these waters. The wastewater can be collected and sent off-site for disposal at a commercial wastewater treatment facility. The wastewater can be discharged to a sanitary sewer for treatment at a publicly-owned treatment works (POTW - i.e., the municipal sewage plant). In this case, pre-treatment might be required before the POTW will agree to accept the wastewater. The wastewater can be treated on-site until discharge criteria are met, then discharged to nearby surface waters under a National Pollutant Discharge Elimination System (NPDES) permit. Discharge to a storm sewer also requires a NPDES permit. The water can be treated on-site and reinjected into the aquifer or allowed to infiltrate into the ground.

Generally, these approaches require that a permit or approval be obtained from the IEPA Bureau of Water. If wastewaters need to be treated (or pre-treated prior to disposal) on-site, a permit to construct and operate a wastewater treatment works is required. If the treated wastewater is to be discharged to surface water or a storm sewer, a NPDES permit is also required. The only case where a Bureau of Water permit is not required is when the wastewaters are shipped to a commercial treatment facility without pretreatment in that case a special waste permit is required. The various approaches to handling wastewater are depicted in Figure 22 and discussed below.

7.7.1 Transport to Commercial Industrial Wastewater Treatment Facility

Water produced from a LUST corrective action is considered special waste. The water can be collected, stored temporarily on-site, and then transported to a commercial wastewater treatment facility for disposal. Commercial facilities are also able to reclaim or dispose of liquid petroleum hydrocarbons (LPH) recovered from soil treatment, ground water treatment, or free product recovery operations at LUST sites.

As with the disposal of soil, the wastewater must be characterized, hauled to the treatment facility by a licensed special waste transporter, and disposed at a treatment facility licensed to treat special wastes. The owner/operator of the LUST site must obtain an IEPA special waste Generator ID Number (the same number can be used for soil disposal). The wastewater must be shipped to the treatment facility using the Illinois special waste manifest. IEPA Bureau of Land special waste regulations must be obeyed.

Disposal of LUST wastewaters at a commercial facility is usually simple. However, there may be times when the wastewater contains a substance of a particular nature or at a concentration such that pretreatment of the water is required before the treatment facility will accept it. If it is necessary to treat or pretreat wastewater on-site, permits to construct and operate a treatment works must be obtained from the IEPA Bureau of Water. Wastewater treatment/pretreatment permits are discussed further in section 7.7.3 below.

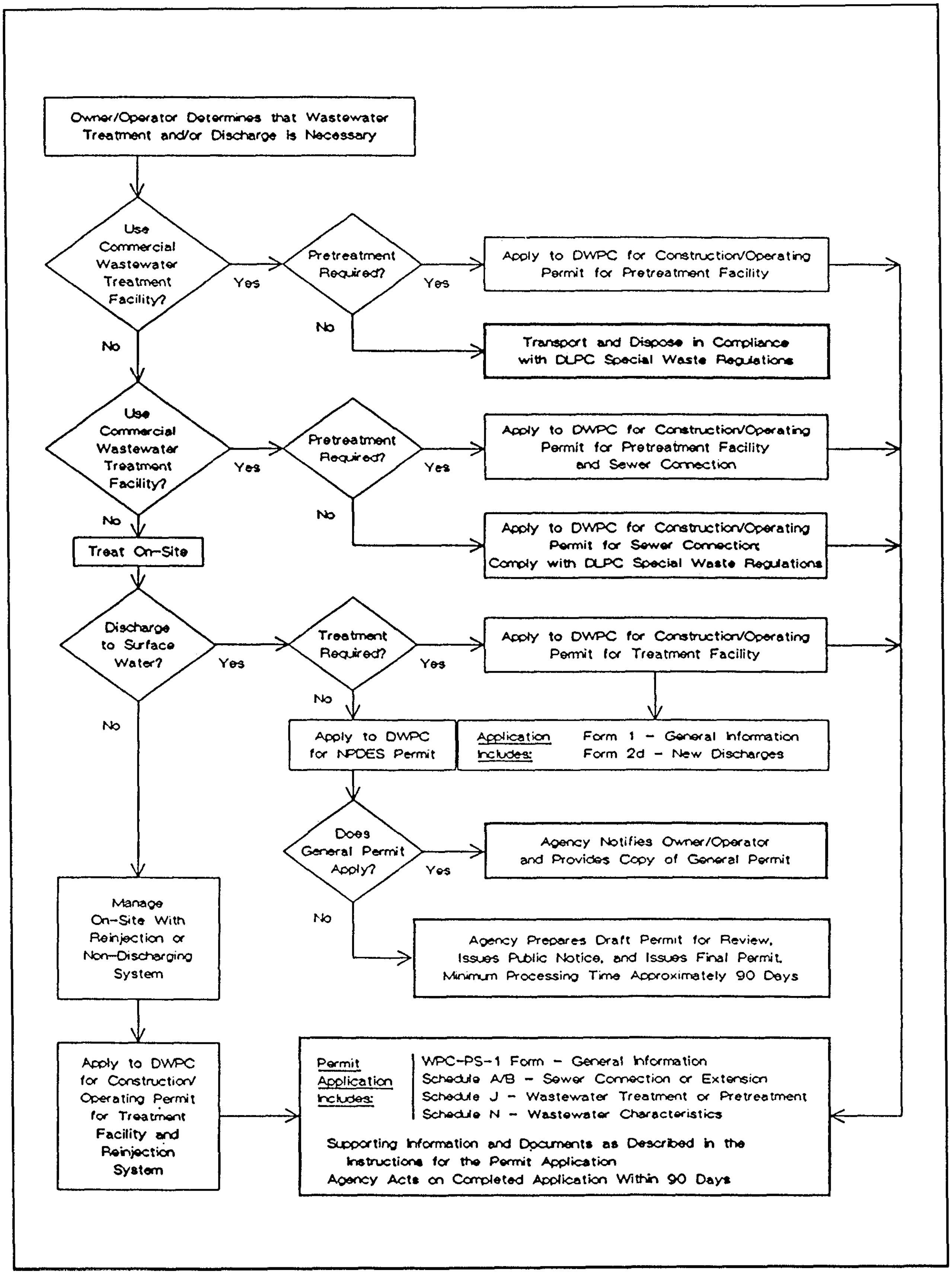

Figure 22: The IEPA Bureau of Water Permitting Process for Wastewater from LUST Sites

7.7.2 Discharge to POTW

In order to discharge wastewaters to a publicly-owned treatment works (POTW), it is necessary to obtain approvals from all intermediate sewer systems and the treatment plant that will receive the wastewater. These approvals take the form of certifications that the sewer systems and treatment works have adequate carrying and treatment capacity to handle the projected flows from the site, and that the treatment plant can effectively treat the wastewater. The certifications are made by the treatment plant owner (generally a unit of local government) on the IEPA general application form WPC-PS-1. The application with completed certifications must be submitted to and approved by the IEPA before the discharge can begin. Additional information on the permitting process is provided in Section 7.7.3 below.

The POTW may decline to accept the wastewater from the LUST site, for any of several reasons. For example, the POTW may already be operating at or above capacity and be unable to accept any additional flow. The POTW may feel that the contaminants in the wastewater would not be effectively treated at the plant, or would interfere with the effective treatment of the wastewaters normally treated at the facility. If the POTW declines to accept the wastewater, an alternative disposal method must be found.

In some cases, the POTW may accept the wastewater only if it is pretreated prior to discharge into the sanitary sewer system. The POTW will provide pretreatment criteria (i.e., limits to which the wastewater must be treated before discharge into the sewer system) when the request is made for the certification discussed above. In this case, permits must be obtained to construct and, subsequently, to operate the pretreatment system (see Section 7.7.3).

A permit is also required to construct and operate the tie-in connection to the public sanitary sewer serving the site. Sewer connection and pretreatment facility permits are applied for in one step by attaching supplementary Schedules (Schedule A/B for a Private Sewer Connection/Extension, and Schedule J for Industrial Treatment/Pretreatment) to the DWPC general application form WPC-PS-1 (see Section 7.7.3). Construction permits must be obtained for pretreatment systems and sewer connections before construction of these facilities begins.

7.7.3 On-Site Treatment or Pre-treatment

If wastewaters are to be treated on-site prior to disposal, or pretreated prior to further treatment at a POTW or commercial treatment facility, permits are required to first construct the wastewater treatment unit and then to operate it. Wastewater treatment systems at LUST sites are considered Industrial Treatment Systems by the IEPA. Applications for construction and operating permits can be made separately or combined in a joint construction/operating permit application.

The general application form WPC-PS-1 is used to apply for all construction and operating permits for wastewater treatment system components, including the treatment system itself, sewer tie-in connections, lift stations, spray irrigation systems, and treatment sludge disposal. The application is completed by attaching various supporting schedules to the general application, as appropriate. The supporting schedules are listed in Table 13. The only schedules required for most LUST sites are Schedule J for Industrial Treatment/ Pretreatment, and Schedule N for reporting the Wastewater Characteristics.

Table 13: Supporting Schedules for DWPC Application for Permit or Construction Approval for Wastewater Treatment Projects

Type of Project	Schedule	Type of Project	Schedule
Private Sewer Connection/Extension	A/B	Spray Irrigation	H
Sewer Extension Construct Only	C	Septic Tanks	I
Sewage Treatment Works	D	Industrial Treatment or Pretreatment	J
Excess Flow Treatment	E	Waste Characteristics	N
Lift Station/Force Main	F	Erosion Control	P
Sludge Disposal	G	Trust Disclosure	T

Schedule J provides for submission of information on the design and operation of industrial wastewater treatment or pretreatment works. In addition to the form itself, supporting documents on the design of the facilities are required. These include location maps, maps showing the locations of any discharge points, process flow diagrams, and any other plans and specifications. The instructions for completing Schedule J refer to the instructions for completing Schedule D (Sewage Treatment Works), so both schedules should be obtained from the IEPA even though the facility is not a sewage treatment plant and Schedule D will not need to be submitted.

Schedule N provides for submission of data on the quantity (flow rates) and composition of the wastewater to be treated. The actual form for Schedule N is oriented toward facilities treating domestic sewage, and provides spaces for reporting the concentrations of drinking water parameters (e.g., arsenic, chromium, lead, nitrate, oil and grease, selenium, phenols, and total dissolved solids) in the wastewater. However, additional or different data are required for wastewaters from industrial sites.

Vendors of commercial soil remediation systems such as transportable thermal treatment units or slurry-phase biological treatment units should obtain permits for their water treatment. However, they should be provided with samples of the soil to be treated, if requested, to ensure that they can effectively treat the soil, to establish operating conditions for the treatment, and to ensure that permit limits or requirements on their water treatment system can be met. The disposal of water from treatment systems may also be handled by the vendor, if convenient. However, owners/operators of LUST sites are responsible for ensuring that all permitting and regulatory requirements are met.

7.7.4 Discharge Under a NPDES Permit

The National Pollutant Discharge Elimination System (NPDES) was created under the Clean Water Act to regulate discharges of pollutants to the waters of the United States. The Illinois EPA has been authorized to administer the NPDES permitting program by the U.S. EPA. Permit applications can be obtained from the IEPA Bureau of Water, P.O. Box 19276, Springfield, Illinois, 62794.

In the summer of 1992 the IEPA issued a general NPDES permit (IEPA General Permit Number ILG910000) covering the following common discharges from LUST sites: (1) discharges of contaminated or uncontaminated ground water from remediation systems; (2) surface water accumulating in excavations; (3) surface water and ground water contaminated by spills; and (4) ground water resulting from pump tests and aquifer monitoring. Table 14 lists the effluent quality limitations and monitoring requirements under the general permit.

To discharge under this permit, the discharger must submit plans and specifications for the treatment system, and data on the pretreatment and expected post treatment concentrations of contaminants. The application is made on the Federal EPA Consolidated Permits application, Forms 1 and 2D. If the IEPA determines that the general permit is applicable to the discharge, a simple letter of authorization is sent to the discharger, along with a copy of the permit. However, if the general permit is not applicable to the discharge, a draft permit must be prepared, a public hearing on the draft permit must be held, and a final permit must be prepared and issued. This process takes a minimum of 90 days from receipt of the completed application.

7.7.5 Underground Injection

Table 14: Effluent Limitations and Monitoring Requirements Under Illinois General NPDES Permit for Discharges from Petroleum Hydrocarbon Corrective Actions

	Concentration Limits (mg/l)			
Parameter	30 Day Average	Daily Maximum	Sample Frequency	Sample Type
Flow			1/month*	Measure when monitoring
Oil and Grease	15	30	1/month*	Grab
Benzene	--	0.05	1/month*	Grab
Ethylbenzene	0.017	0.216	1/month*	Grab
Toluene	0.14	1.75	1/month*	Grab
Xylenes (total)	0.117	1.5	1/month*	Grab
Total BETX	--	0.75	1/month*	Calculation
Priority Pollutant PNAs**		0.1	1/month*	Grab

Notes: * *During the first month of operation of a new discharge, the sample frequency shall be once per week. During the next two months, the frequency shall be twice per month, and thereafter the frequency shall be once per month. Discharges of less than one week duration shall be monitored at least once per discharge event.*

** *Not required for discharges involving only gasoline.*

Treated ground water may be reinjected into the ground. If the wastewater is to be managed on-site and reinjected or disposed in some other non-discharging system (e.g., used in an industrial process), it is only necessary to include the plans and specifications for the treatment and reinjection system in the application package for the construction and operating permit for the treatment facility, as described in Section 7.7.3. The treatment must be effective in reducing the concentrations of contaminants below the ground water cleanup objectives; usually, this requires gravity separation followed by treatment for dissolved contaminants.

7.8 Air Emissions

For any corrective action that uses pollution control equipment (such as thermal or catalytic oxydation units, GAC beds, etc.) or that may be a source of process emissions of contaminants (such as air strippers, thermal desorption units, soil vapor extraction systems, etc.) a permit must be obtained from the IEPA Bureau of Air, even if the anticipated emission levels are well below regulatory limits. In addition, emissions associated with landfarming or bioremediation are evaluated by the Bureau of Air on a case-by-case basis.

As with other IEPA permit applications, the basic permit application is supplemented by additional forms that are determined by the specific project on a case-by-case basis.

The APC-206 form is an informal, general information form used to initiate discussion with the DAPC. By completing the APC-206, the owner/operator is able to get advice from the DAPC regarding the specific forms and supplemental information that must be submitted for a particular project. In addition to the application forms, supplemental information that may be required includes the following:

- a plot plan/map of the site vicinity showing distances to adjacent residences, hospitals, schools, other emission sources (if known), etc.;
- a detailed process description;
- a process flow diagram identifying all emission sources and pollution control equipment; and
- a fugitive dust control plan for soil treatment projects such as thermal desorption.

Depending on the project, other information may be required, including:

- the expected amounts of contaminated soil and water to be treated;
- the expected before and after-treatment concentrations of contaminants in the soil and/or water, including the total VOC concentration and the individual concentrations of benzene, ethylbenzene, toluene, xylenes, and other contaminants of concern;
- the flash point of the contaminated soil; and,

- operating parameters for the emission source(s), including water flow rates, soil feed rates, air volummetric flow rates, operating temperatures, operating hours, and the duration of the project.

Emissions from soil or ground-water treatment systems are subject to a maximum one hour VOC emission limit of one pound per hour throughout most of the state. The non-attainment areas in and around Chicago and St. Louis have more stringent controls. In these areas no new "major sources" are allowed. A major source is defined as an emission source emitting more than 25 tons of VOCE per year. On a steady, continuous, 24 hour-per-day basis, this is equivalent to 5.7 pounds per hour. A soil or ground-water treatment system with the potential to emit more than the allowable limit would be required to incorporate air emission control equipment sufficient to ensure that the limit is not exceeded.

SECTION 8
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APPENDIX A

Costs of LUSTs Cleanup in Illinois

IEPA released the statistics for dollars paid out of the LUST fund through October 22, 1993.

1)	Number of Bills Paid:	1249
2)	Total Amount Paid Out:	$74,780,113.77
3)	Average Payout Per Bill:	$59,871.99
4)	Number of Sites Paid On:	833
5)	Average Total Payment Per Site:	$89,772.05
6)	Total Reduction Through Bill Reviews:	$8,225,812.51
7)	Percentage of Costs Reduced Through Reviews:	11%
8)	Total Reduction Through Deductibles:	$10,005,000.00
9)	In-house bills	760
10)	Approximate Total of These 760 Bills:	$45,502,712.00

As of February 1994, out of more than 11,000 LUST sites in Illinois, 74 sites have been approved for alternative technologies by IEPA. Sixteen of these sites have reached cleanup objectives. As for the other 58 sites, IEPA attributes lack of operating time, site complexity, and clayey soils as the reason why cleanup objectives have not yet been met. According to IEPA, soil vapor extraction and bioremediation have been the most popular alternative technologies for remediating contaminated ground water. Eleven sites have proposed soil vapor extraction; to date, none have reached closure. Fourteen sites have proposed bioremediation, and so far, one site has achieved closure.

As for alternative technologies for soil, the following lists the type of technique as well as the number of sites which have been approved by IEPA and received closure.

Table A1:

TECHNIQUE	APPROVED	CLOSED
SVE	13	3
Bioremediation	14	2
Thermal Desorption	8	4
Land Treatment/Bio-Cell	7	4
Land Farming	6	2

This Appendix on Field Applications of Design methods was developed from files of actual LUST sites in Illinois which are currently proposing or using alternative techniques for remediating ground water. Information was obtained through the Freedom of Information Act and is current through August 31, 1993.

Table A2: COSTS FOR ALTERNATIVE TECHNOLOGY SITES THAT HAVE RECEIVED CLOSURE FROM IEPA

System Type	Cost			Volume of Soil (yds^3)	Source
	Estimated Conventional	Alternative Technology	Alternative Technology (per yd$^{3)}$		
Land Treatment/ Bio-Cell	$408,000	$498,000	$130	3,750	Gasoline
Low Thermal Desorption	$139,000	$153,000	$75	2,000	Diesel
Land Treatment/ Bio-Cell	$2,308	$1,830[1]	$50	37	Gasoline
Low Thermal Desorption	$49,060	$50,930	$140	370	Gasoline
Land Farming	$247,194	$198,663	$80	3,150	Gasoline
Soil Vapor Extraction	$85,940	$85,120	$130	670	Gasoline
Bio-Remediation	$100,000	$35,100	$40	905[2]	Gasoline
Low Thermal Desorption	$601,846	$735,404	$155	4,800	Gasoline

[1] Does not include tilling cost

[2] Ground water remediation

Source: IEPA, 2-16-94

Table A3: COSTS OF ALTERNATIVE TECHNOLOGIES FOR GROUND WATER REMEDIATION

TYPE	SIZE (YD^3)	ALTERNATIVE COST	CONVENTIONAL COST	AVERAGE COST/YD^3
In-situ Bioremediation				
	905	$35,000	$100,000	
	33,000	$540,000	$2.5 million	
AVERAGE:	5,000	$124,000	$491,000	$25
Soil Vapor Extraction				
-air sparging	540	$35,000	$45,000	
-SVE alone	1,100	$116,000	$ *not feasible due to nearby buildings*	
-heated SVE	28,000	$600,000	$2.2 million	
AVERAGE:	8,100	$206,000	$750,000	$25
SVE + Pump and Treat	3,500	$153,000	$ N/A	
	7,000	$537,000	$766,000	N/A
Composting + Pump and Treat	4,500	$300,000	$417,000	N/A
Pump and Treat (*no closed sites*)	N/A	N/A	N/A	N/A

Source: IEPA, 2-16-94

Table A4: ALTERNATIVE TECHNOLOGY SITES IN ILLINOIS FOR SOIL AND GROUND WATER TREATMENT

SITE NAME	CITY	INCIDENT #	IEPA #	TECHNOLOGY
Coverall Laundry	Chicago	903046	0316005876	**Soil Flushing**
Xerox	Des Plaines	913168	0310635280	**Air Sparging**
Illinois Central College	East Peoria	910060	1790800083	**Bioremediation**
Ralph and Sue Ollman	Elgin	922518	0894385211	**Bioremediation**
Butler Manufacturing	Galesburg	921363	0950200009	**Bioremediation**
Granite City Firehouse	Granite City	911147	1190405068	**Bioremediation**
Granite City Street Dept.	Granite City	911148	1190405067	**Bioremediation**
Quick Trip	Granite City	891395	1190405056	**Air Sparging/ Vapor Extraction**
Village of LaGrange	LaGrange	881665	0311535030	**Soil Vapor Extraction with air sparging**
CITGO	Libertyville	930358	0970905119	**Bioremediation**
Frams Materials Company	McHenry	920902	1110605090	**Air Sparging**
Fruit Belt Service	Metropolis	913216	1270155011	**Air Sparging**
Turtle Wax Car Wash	Mundelein	900031	0971155061	**Bioremediation**
Peoria Disposal Company	Peoria	913644	1430653007	**Biotreatment Study**
Stonington Grain Co-op	Stonington	921695	02105550044	**Bioremediation**
Palwaukee Aviation	Sugar Grove	901959	0890850002	**Soil Vapor Extraction/ Air Sparging**
Martin Oil	Wheeling	913579	0314975129	**Bioremediation**

Source: IEPA, 8-31-93

APPENDIX B

Site Descriptions with Remediation Technology, Time, and Costs

SITE:	Stonington Grain Co-op Stonington, IL Incident #921695
CONTAMINATION:	Benzene
SOIL TYPE:	Sand and gravel backfill
WHY ALTERNATIVE TECHNOLOGY?:	Excavation would threaten structural integrity of nearby structures.
REMEDIATION:	***BIOREMEDIATION*** *Bio-Rem, Inc.* of Butler, Indiana will provide their Product "H-10." *Bioenvironmental Services* of Taylorville, Illinois will place product and monitor results.

Bioremediation was proposed to remediate ground water by using Bio-Rem's Product "H-10," a proprietary blend of microaerophilic bacteria and micronutrients. Approximately 92 lbs of H-10 were to be injected through two 4" plastic field tiles in the backfill, one stainless steel monitoring well, and two slotted 12" corrugated metal pipe wells.

COST:

CONVENTIONAL (PUMP AND TREAT)
(Costs provided by *Laker Petroleum* of Taylorville, IL)

Engineering	$10,000
Capital, activated carbon treatment unit	60,000
Power source	3,000
Piping and wells	5,000
Filter media	2,000
Operation and Maintenance ($3000/week, estimate 1 year)	159,000
Filter media, purchase and disposal ($4,000/mo, estimate 12 months)	48,000
Closure samples	1,200
ESTIMATED TOTAL	**$288,200**

ALTERNATIVE (BIOREMEDIATION)

Engineering, reports and on-site supervision	$4,000
Product "H10" biomass	3,100
Labor and Installation	15,000
Monitoring and Maintenance	9,000
Closure samples	1,200
Capital	2,800
ESTIMATED TOTAL	**$35,100**

TIME REQUIREMENTS:

Bioremediation was approved by IEPA on 1-12-93. Injection time was estimated at 4 to 5 days. Remediation time was expected to take 3 to 5 months. Baseline PID readings were taken prior to injection at each injection point. Placement of the biomass product took place on 2-10,11,12-93, and weekly PID monitoring was performed. Cleanup objectives were met by 3-10-93.

SITE:

Street Department
2301 Adams Street
Granite City
Incident #911148

CONTAMINATION: BETX and PNA's

SOIL TYPE: Silty clay turning to sand clay

WHY ALTERNATIVE TECHNOLOGY?: Excavation would interrupt daily on-site operations.
Cost comparisons revealed that in-situ bioremediation would result in significant savings over excavation or pump and treat applications.

REMEDIATION: ***BIOREMEDIATION***

Schreiber, Grana & Yonley, Inc. is the environmental consultant.
Alpha Environmental, Inc. of Austin, Texas supplies the microbial system.

Bioremediation was proposed to remediate 3,320 cubic yards of soil and groundwater. The biomass would be introduced via an infiltration gallery consisting of three lateral 2" PVC screens in tank excavation and a 2" observation sump. The biomass would be mixed with nutrients and a biocatalyst, and 2,325 gallons of the slurry will be pumped into the riser pipe of the infiltration gallery. This procedure would require 40 gpm mixing pumps, 15 gpm submersible pump, and two 1,100 gal mixing tanks. Additional groundwater remediation would be enhanced by injecting 1,300 gallons of the biomass into four monitoring wells with thirty feet of head to insure application of biomass to the ground water.

COST:

CONVENTIONAL (EXCAVATION AND DISPOSAL)

Labor Costs	
Subcontractor ($30/cubic yard for 5,500 cubic yards)	$165,000
Professional Costs	
Excavation Supervision	3,200
Backfill Supervision	2,000
Verification Sample Collection	1,100
Laboratory Fees	3,000
Permitting Preparation	1,000
Landfill Costs	
Transportation ($12/cubic yard for 5,500 cubic yards)	66,000
Disposal (417/cubic yard for 5,500 cubic yards)	93,500
Reporting Requirements	
Closure Report	2,100
ESTIMATED TOTAL	**$336,900**

ALTERNATIVE (BIOREMEDIATION)

Material Costs

Microbial Blending/Infiltration System	1,500
Microbial Treatment System	70,700
<u>Labor Costs</u>	
Contractor (installation of infiltration system, piping and gravel)	4,500
<u>Professional Costs</u>	
Microbial System Development (observation/supervision of system installation)	4,100
Remediation Start-up (observation/supervision of microbial injection)	6,200
Baseline Sample Analysis (collection of baseline samples of contaminated media)	400
Lab Fees for Baseline Analysis	3,000
<u>Performance Monitoring</u>	
Ground Water Sampling	2,400
Lab	4,500
<u>Clean-up Verification</u>	
Sample Collection	2,200
Lab	10,500
Reporting Requirements	2,100
ESTIMATED TOTAL	**112,100**

TIME REQUIREMENTS: Bioremediation began in January 1993. Biomass injection was scheduled to take 4 days. The estimated completion time was 6 months. Soil and ground water samples were to be taken prior to injection of the biomass followed by monthly ground water sampling until cleanup objections were met. Soil samples were to be taken 6 months after the initial biomass injection. Monthly thereafter, maintenance biomass injections were performed.

SITE: Fruit Belt Service Company
120 Ferry Street
Metropolis, IL
Incident #913216

CONTAMINATION: BTEX, TPH (Total Petroleum Hydrocarbons)

SOIL TYPE: Brown, sandy clay to 10' to 14' depth; Medium to coarse sand to 25' depth; gravel backfill.

WHY ALTERNATIVE TECHNOLOGY?: (not stated)

REMEDIATION: *AIR SPARGING*

Massac Environmental Technologies, Inc. has proposed air sparging to remediate approximately 2850 cubic yards of soil and 574,500 gallons of ground water.

A ground water distribution network would spray contaminated ground water over the former UST pit. The pit would be filled with 2" gravel to act as packing material for a large natural aeration tower. Beneath the gravel would be a 30' long pipe network manifolded to a 2.5 Horsepower regenerative blower for ground water aeration (sparging). The pipe network would be 2" diameter Schedule 40 PVC with a slotted lower horizontal section for air distribution. The vent pipe would be 1.5 to 2 feet below the water table. Pressure gauges would be installed at the top of each vertical shaft to monitor pressure distribution in the system.

While the sparging system injects air at the bottom of the pit, an air operated diaphragm pump would draw ground water from two points and spray it over the gravel pit. Ground water would be drawn from the down-gradient side of the site and sprayed over the up-gradient side to reinforce natural flow and increase circulation.

Contaminated soil above the water table would be remediated through soil flushing with the annual fluctuation in the water level.

COST:

ALTERNATIVE (AIR SPARGING)

Backfill	$7,000
Recovery Well #1	150
Pumping System	1,000
Sparging Network	2,000
Recovery Well #2	1,400
Sampling	8,840
Security	1,800
Design/Procurement	1,200
Installation	3,360
Operation	4,680
Maintenance	1,080
Closure	720
ESTIMATED TOTAL	**$33,230**

TIME REQUIREMENTS: Initially, weekly samples would be taken from the wells and pit until a pattern of remediation progress was established. From that point on, monthly lab reports will indicate when cleanup objectives have been met. The estimated time to completion was 1 year; the SVE/Air Sparge System was implemented in April 1994.

SITE:

Butler Manufacturing Co.
Galesburg, IL
Incident #921363

CONTAMINATION: BTEX, PNA's

SOIL TYPE: 3' to 5' of sand and gravel fill; 10' to 15' of Peoria Loess

WHY ALTERNATIVE TECHNOLOGY?: Because of the large area involving buildings, roads, railways, and operations coupled with the high cost of excavation and disposal, bioremediation was considered the most viable technology.

REMEDIATION: ***BIOREMEDIATION*** combined with Pump and Treat for soils and ground water.

ESE Biosciences, Inc. has proposed bioremediation to remediate an estimated 33,100 cubic yards of soil and ground water.

Contaminated ground water would be pumped to the PetroClean® Bioremediation System via recovery wells and trenches. The treated effluent would be supplemented with nutrients, oxygen, and acclimated bacteria that would metabolize and degrade the petroleum contaminants. This system would be gravity drained and allowed to reinfiltrate into the soil through a series of infiltration galleries.

Five shallow recovery wells and two recovery trenches would be installed to intercept contaminated ground water for bioremediation. The two recovery trenches would be 13' deep, lined with gravel, and backfilled with excavated material. The sump for the trench would be located 2-3' below the depth of the trench. 2500 to 6000 gallons/day of ground water would be pumped from the recovery wells and trenches through an oil/water separator to a 4000 gallon bioreactor tank. Nutrients and oxygen would be added in the bioreactor to stimulate the microbes. The biomass would then drain through the reinfiltration galleries into the soil.

COST:

CONVENTIONAL (EXCAVATION AND DISPOSAL)

Disposal ($35/cubic yard for 33,100 cubic yards)	$1,158,500
Transportation (2,210 trips)	430,950
Landfill Permitting (Analytical expenses)	1,000
Excavation ($7.50/cubic yard for 33,100 cubic yards)	248,250
Backfill Material ($8.50/cubic yard for 33,100 cubic yards)	281,350
Plastic Liners for Trucks ($15/trip for 2,210 trips)	33,150
Special Waste Manifests ($1/manifest for 2,210 loads)	2,210
Lab (BTEX and PNA's at $350/sample for 100 samples)	35,000
Pavement Replacement	27,000
Site Restoration/Replacement	32,090
On-site/Consulting (at $1,210/day)	60,500
Per Diem (at $50/day)	2,500
Ground Water Treatment System (Design, installation, operation, and maintenance)	170,000
ESTIMATED TOTAL	**$2,482,500**

ALTERNATIVE (BIOREMEDIATION)

PetroClean® Bioremediation System includes:

- 2 Ground water interceptor trenches with
  - Geotextile wrapped aggregate envelope with perforated pipe
  - Clean-put at each end point
  - One collection sump with pneumatic pump
- Paved area for construction of Infiltration System
- 4 Separate treated effluent Infiltration Systems with
  - Aggregate
  - Piping
  - Backfill
  - Ancillary features
- 5 Shallow recovery wells each with well vault and pneumatic pump
- Air supply and water discharge piping system
- Bioreactor
- Oil/Water Separator

Other Consulting Expenses include:

- Reporting
- Sampling
- Operation and Maintenance
- Supervision/Oversight

ESTIMATED TOTAL $390,000 to $540,000

TIME REQUIREMENTS: The time for the microbe mix to cover the distance between the trenches was estimated at 4 to 9 days. From that time on, the PetroClean Bioremediation System would operate 24 hr/day, 365 day/year. Operation would be monitored weekly by the consultant. Ground water would be sampled weekly for the first month, then two samples per month for the next four months, and then monthly until clean-up objectives were met. The estimated completion time was 3 to 4 years.

SITE: Peoria Disposal Company Transportation Center
1113 North Swords Avenue
Peoria, Illinois

CONTAMINATION: BTEX, PNA's

SOIL TYPE: Silty clay at 0 to 14' with overlying sand

WHY ALTERNATIVE TECHNOLOGY?: (not stated)

REMEDIATION: ***BIOREMEDIATION***

PDC Technical Services has proposed in-situ bioremediation to remediate contaminated soil and ground water.

Percolation field piping and recovery wells would be installed. Recovered ground water would be pumped from the recovery wells through an oil/water separator, a granular activated charcoal tank, and a nutrient mixing tank. The biomass would then be introduced into the percolation field piping.

COST:

ALTERNATIVE (BIOREMEDIATION)

Bench-Scale Study	$22,400
Full-Scale	to be determined by bench-scale results

TIME REQUIREMENTS: 6 months were allotted for the bench-scale study. Time to complete the full-scale operation would be determined by results of the bench-scale study.

SITE:
Palwaukee Aviation/Priester Aviation
Aurora Airport
Aurora Illinois
LUST Incident #901959

CONTAMINATION: BTEX

SOIL TYPE: Clay to silty clay in upper layer; Well sorted, very fine yellow to brown sand in lower layer

WHY ALTERNATIVE TECHNOLOGY?:

REMEDIATION: *SOIL VAPOR EXTRACTION with AIR SPARGING*

Mittelhauser Corporation of Naperville, IL has proposed a soil vapor extraction (SVE) system designed by *XIT Technologies* of Long Beach, CA.

SVE combined with pump and treat were proposed to remediate 1,888 to 3,777 cubic yards of contaminated soil and ground water. A vapor extraction test was used to determine volumetric flow rate, realistic contaminant-removal rate and concentration, volumetric vapor flow rate, and area of influence of vapor extraction well. Once an air permit had been obtained and a full-scale SVE system had been installed, a ground water pump and treat system was used to provide additional remediation. The ground water treatment system consisted of a product separator tank, air stripping using a double diffuser, and discharge into a nearby storm sewer.

Air sparging was later proposed to supplement the SVE and pump and treat systems. Three air sparge wells would be installed along with two additional vapor extraction wells to remove the vapor-laden air generated by the air sparging system.

COST:

CONVENTIONAL (EXCAVATION AND DISPOSAL)

Excavation and Soil Disposal	$132,160 to 264,390
Tank Replacement (2 tanks)	40,000
ESTIMATED TOTAL	**$172,160 to $304,390**

ALTERNATIVE (SOIL VAPOR EXTRACTION)

Vapor Extraction	
Equipment Rental ($2,000/mo for 6 months)	$12,000
Electrical Charges ($0.08/kw-hr for 15 Hp motor)	4,000
Monitoring and Maintenance (monthly)	4,000
Confirmatory Soil Sampling	4,000
Ground Water Remediation	
Installation of Pumping Well and Piping	4,000
Ground Water Treatment (1 year)	12,000
Electrical Charges ($0.08/kw-hr for 2 Hp motor)	1,000
Double Diffuser Air Stripper	N/A
Monitoring and Maintenance	2,000
Confirmatory Sampling (6 samples)	2,000
(Air Sparging to be added at a later date)	
Reporting and Permitting	20,000

Contingency (10% of Subtotal)	6,500
ESTIMATED TOTAL	**$71,500**

TIME REQUIREMENTS: Completion time for SVE was originally estimated at eight months. After 1 year, approximately 560 gallons of aviation fuel had been removed from the unsaturated soils and free product layer on the water table by the SVE system. However, after treating approximately 340,000 gallons of water, cleanup objectives had still not been met for ground water using the pump and treat system. Air sparging pilot-scale tests were proposed to determine feasibility and design parameters.

SITE: Ollman
Elgin, Illinois
Incident #922518

CONTAMINATION: BTEX, PNA's, Heating Oil

SOIL TYPE: Sand and gravel; some silty clay

WHY ALTERNATIVE TECHNOLOGY?: In-situ bioremediation was selected to avoid disturbing on-site structures and operations as well as the high cost of excavation and disposal.

REMEDIATION: ***BIOREMEDIATION***

Environmental Control Technologies, Inc. has proposed bioremediation using their ALPHA Process.

The system would be installed over most of the site, measuring approximately 100 ft. x 100 ft. A network of horizontal 2" slotted PVC inoculation pipes would be installed 6 to 8 ft. deep. The horizontal trenches would be placed 12 ft. apart. Vertical PVC standpipes would be constructed above ground to allow substrate and biocatalyst into the open excavation prior to backfilling. Approximately 2 weeks later, another application of the microbes/nutrients would be introduced through the vertical pipes followed by another application 1 month later. A typical application rate would be 55 gallons of nutrient solution for every 12 cubic yards of soil to be treated. Each application would require an estimated 2500 gallons of solution.

COST:

CONVENTIONAL	N/A
ALTERNATIVE (BIOREMEDIATION)	
Excavation	
Placement	
Backfilling	
Initial application of biomass product	
Grading of site	
SUBTOTAL	$49,805
Additional application after first 6 months	$1,750/mo
Reporting	$4,500

TIME REQUIREMENTS: Soil boring samples would be taken quarterly beginning 6 months after the initial application of microbes and nutrients. Sampling would continue on a quarterly basis until concentrations were determined to be below cleanup objectives.

SITE: Granite City Firehouse
Granite City, Illinois

CONTAMINATION: BTEX, PNA's

SOIL TYPE:

WHY ALTERNATIVE TECHNOLOGY?: In-situ bioremediation was selected to reduce the disturbance to traffic flow in and out of the fire station and daily operations.

REMEDIATION: *BIOREMEDIATION*

The microbial system chosen by *Lafser & Schreiber, Inc.* for this application was manufactured by *Alpha Environmental, Inc.* of Austin, TX.

Bioremediation was proposed to remediate 5,800 cubic yards of soil and ground water in the vadose zone. The Infiltration Pit Design consisted of one pit measuring 40 ft. x 20 ft with 3 lines of infiltration screen and a second pit 20 ft. x 10 ft. with 2 lines of infiltration screen. The infiltration lines were constructed from 2 inch PVC Sch. 40, 20 slot continuous screen. A 2 inch riser pipe was connected to the lateral lines and fitted with a ball valve to distribute flow of bio-mass to both pits. After the lateral lines were installed, a geo-fabric membrane was used to line the walls and 3 ft. along the bottom of each pit. The lines were covered with 3 ft. of 3/4 inch backfill, 4 ft. of 2 inch minus backfill, and clean soil to grade.

The bio-mass slurry was mixed in 1100 gallon polyethylene tanks using a 40 gpm pump. The bacteria was mixed from a dry powder with city water and a biocatalyst agent. The bio-mass slurry was gravity fed at 15 gpm with approximately 45 feet of head pressure, injecting 2,500 gallons in the larger pit and 1,400 gallons in the smaller pit. In addition to the 2 pits, 2 vadose zone injection wells were used to inject 600 gallons of bio-mass slurry into the outer extents of the contamination plume. Four existing monitoring wells were also used in the bioremediation system to inject 1,300 gallons of biomass into the ground water.

COST:

CONVENTIONAL

(EXCAVATION AND DISPOSAL)

Labor Costs	
Subcontractor ($30/cubic yard for 5,800 cubic yards)	$174,000
Professional Costs	
Excavation Supervision	3,200
Backfill Supervision	2,000
Verification Sample Collection	400
Laboratory Fees	3,000
Permitting Preparation	1,000
Landfill Costs	
Transportation ($10/cubic yard for 5,800 cubic yards)	58,000
Disposal ($15/cubic yard for 5,800 cubic yards)	87,000
Reporting Requirements	
Closure Report	2,100
ESTIMATED TOTAL	**$330,700**

(PUMP AND TREAT -- Carbon Adsorption)

Capital Costs	
Pumping System Equipment	5,500

Building	5,000
Treatment System	10,300
Labor Costs	
Contractor Costs	18,000
Excavation of trench	
Installation of recovery sumps	
Piping trench	
Backfilling	
Disposal of soil	
Electrical service	
Professional Costs	
Interceptor Trench and Piping Trenches	5,000
Pumping System Installation	4,000
Pumps	
Control panels discharge meters	
Pump and control wiring	
Treatment System Installation	3,000
System Start-up	2,600
Calibration and observation of system	
Collection of ground water samples for chemical baseline	
Lab Cost for Baseline Analysis	2,200
Operation and Maintenance	
Reporting and routine maintenance	114,382
Laboratory costs	6,850
Professional costs	3,120
ESTIMATED TOTAL	**$179,952**

ALTERNATIVE (BIOREMEDIATION)

Capital Costs	
Microbial Blending/Infiltration System	$3,700
Microbial Treatment System	63,500
Labor Costs	
Contractor Costs	6,900
Installation of infiltration system, piping, and gravel	
Professional Costs	
Microbial System Development	3,100
Observation/supervision of system installation	
Remediation Start-up	6,200
Observation/supervision of microbial injection	
Baseline Sample Analysis	400
Collection of baseline samples	
Laboratory Fees for Baseline Analysis	3,000
Performance Monitoring	
Ground Water Sampling Costs	2,400
Laboratory Costs	4,500
Cleanup Verification	
Sample Collection	2,200
Laboratory Analysis	10,500
Reporting Requirements	2,100
ESTIMATED TOTAL	**$108,500**

TIME REQUIREMENTS: Catalyst and nutrients were injected monthly beginning in August of 1992. Biodegradation was monitored monthly. Significant degradation resulted in the first few months, but then levels began to rise possibly due to flushing in the vadose zone during water table fluctuations. A more aggressive treatment schedule was applied using 7 additional vadose zone injection points. Liquid-phase hydrocarbon recovery was implemented in MW-1 and MW-5; injection of nutrients and biomass has ceased as the source of the free product is unknown. Ground-water well monitoring and free product recovery continue.

SITE: Illinois Central College
East Peoria, IL
Incident #910060

CONTAMINATION: BETX

SOIL TYPE: Loess with underlying sand

WHY ALTERNATIVE TECHNOLOGY?: In-situ bioremediation was recommended based on the presence of existing structures on the site and the depth of existing hydrocarbon biomass.

REMEDIATION: *BIOREMEDIATION and PUMP AND TREAT*

Daily & Associates, Engineers, Inc. of Peoria, IL

Initially, 600 cubic yards of soil would be excavated and disposed. The underlying sand would be remediated through bioremediation. The ground water would be remediated using a pump and treat system.

Ground water would be pumped from 5 extraction wells spaced at 40 ft. intervals to a packaged treatment system equipped with an aeration tank (approximately 55 gal) vented to the atmosphere. The treated water would be discharged to an infiltration gallery just up-gradient of the contaminated area. A tank and metering pump would be used to add nutrients and hydrogen peroxide or other oxygen source to the treatment system discharge.

COST:

ALTERNATIVE (BIOREMEDIATION and PUMP AND TREAT)

Installation of 5 ground water extraction wells	$10,580
Installation of infiltration pipes	$2,132
Compressor building and compressor, air piping and installation of 5 well pumps	22,150
Well pump discharge piping to treatment system	1,760
Aeration building and installation of diffused aeration system (cold weather operation)	11,450
Chemical feed building and installation of 2 chemical feed systems (cold weather operation)	6,900
Discharge piping to the connection point for the infiltration gallery	1,040
Electrical service from main panel	7,020
Bituminous surface removal and replacement, seeding and fertilizing	2,900
Yard hydrant and 185 L.F. 2" PVC	1,760
ESTIMATED TOTAL	**$67,732**

TIME REQUIREMENTS: Soil boring samples would be taken once every 6 months after the first 12 months of operation.

SITE: Quick Trip
Granite City, IL
Incident #891395

CONTAMINATION: BETX

SOIL TYPE: Silty clay from 0 to 15 ft; sandy silt from 10 to 15 ft; sand from 15 ft down

WHY ALTERNATIVE TECHNOLOGY?: 19,000 cubic yards have already been removed. The remaining contamination exists beneath the roadway.

REMEDIATION: *AIR SPARGING/SOIL VAPOR EXTRACTION*

BDAT Environmental, Inc. of Chesterfield, MO has proposed in-situ Air Sparging in combination with Soil Vapor Extraction to remediate soil and ground water.

The Air Sparging/SVE system would consist of 7 sparge units and 7 vapor extraction units. The sparge units would be constructed of 2 inch sch. 40 PVC, slotted 2 ft. at the end, and installed approximately 3 ft. below the water table. Vapor extraction units would also be constructed of 2 inch sch. 40 PVC, slotted the entire length, and installed approximately 1 ft. above the water table. The sparge points would be manifolded to an air compressor, and the vapor extraction wells would be connected to a blower or vacuum pump. Emissions from the vapor extraction would be treated through a carbon filter.

COST:

CONVENTIONAL	N/A

ALTERNATIVE (SVE and AIR SPARGING)

<u>System Design</u>	
Engineering	$3,500
<u>System Construction</u>	
Materials	12,500
Excavation	10,000
Well Point Installation	3,600
Engineering	4,450
<u>Analytical</u>	
Vapor Analysis	4,900
Well Analysis	14,000
<u>Reporting</u>	
Progress Reports (5)	6,000
Final Report	2,650
Word Processing	1,050
<u>Operation and Maintenance</u>	
Equipment Maintenance	5,000
Engineering (4 hours/week)	18,000
<u>System Demobilization</u>	
Engineering	1,800
Equipment	750
ESTIMATED TOTAL	**$95,100**

TIME REQUIREMENTS: The estimated completion time was 15 months. Ground water samples would be taken prior to system startup and monthly thereafter until cleanup objectives were met. Soil samples would be taken 6 months after startup.

SITE: Frams Materials Company
McHenry, IL
Incident #920902

CONTAMINATION: BETX, PNA's

SOIL TYPE: Silty clay soil from 0 to 8 ft.; sand and gravel from 8 to 13 ft.; silty clay from 13 ft. down

WHY ALTERNATIVE TECHNOLOGY?: In-situ bioremediation was proposed as a more cost-effective alternative than traditional pump and treat methods.

REMEDIATION: *IN-SITU BIOREMEDIATION*

Prairie Environmental Specialties, Inc. of West Chicago, IL has proposed an in-situ bioremediation system designed by *B&S Research* of Babbitt, MN.

The in-situ bioremediation system would consist of an injection well and three infiltration trenches. Infiltration piping (4 inch diameter), a monitoring well, and an air injection hose would be used to feed the bacteria, nutrients, and oxygen into the soil and ground water. The bio-solution would be gravity fed into the infiltration piping and injection well and continuously bubbled with oxygen from the air injection hose. Reinoculation of the system would be done once approximately 2 weeks after the initial inoculation. A total of 9 gallons of bio-solution would be used during the two inoculations.

COST:

CONVENTIONAL (PUMP and TREAT)

1. **Installation of 2 additional recovery wells**

Hydrogeologic analysis to determine location; geologist on-site	$850
Mobilization of drill rig; well installation	1,600
Well materials (two 6 inch diameter PVC, 15 ft. deep)	1,500
Engineer/geologist to log well installation	850

2. **Installation and set up of system; permitting and system monitoring**

Mobilization of equipment and personnel	$1,500
Contractor for system set up	2,500
Two 4 inch diameter recovery pumps	1,200
One 2 inch diameter recovery pump	1,000
Three stage activated carbon canister filtration system	3,000
Spent carbon replacement (3)	1,500
Engineer/geologist for system set up, coordination, and project management (5 days)	4,250
Engineer/geologist for system monitoring and maintenance (2 days/mo for 6 months)	10,200
Permitting for water discharge/reinjection and air discharge	3,500

3. **Ground water sampling and analytical testing to confirm remediation**

Engineer/geologist for ground water sampling	$4,250
Analytical testing (5 groups of 4 samples)	4,000

4. **Reporting to client and IEPA**

Ground water monitoring reports (5)	$1,250

Site ground water closure report remedial system construction and installation bio-solution applications ground water monitoring/analytical testing	2,500
ESTIMATED TOTAL	**$45,450**

ALTERNATIVE (BIOREMEDIATION)

1. **Construction of infiltration trench and initial application of bio-solution**

Mobilization of construction equipment and personnel	$1,200
Construction equipment operator and laborers (3 days)	3,750
Infiltration piping for trench (250 ft)	375
Air compressor and supply hose to supply air to the system	2,200
B&S Research bio-product for initial treatment application	2,400
Engineer/geologist for project coordination to direct trench construction and to apply bio-solution	5,950

2. **Reinoculation of remediation system with bio-solution and system monitoring**

B&S Research bio-product for reinoculation	$3,000
Engineer/geologist to perform 3 reinoculations 3 site visits to monitor air injection and system performance	5,100

3. **Ground water sampling and analytical testing to confirm remediation**

Engineer/geologist for ground water sampling	$4,250
Analytical testing (5 groups of 4 samples)	4,000

4. **Reporting to client and IEPA**

Ground water monitoring reports (5)	$1,250
Site ground water closure report remedial system construction and installation bio-solution applications ground water monitoring/analytical testing	2,500
ESTIMATED TOTAL	**$35,975**

TIME REQUIREMENTS: Ground water would be sampled 4 weeks after the second bio-solution inoculation. Additional samples would be taken monthly for the next 3 months and then once again three months later. Time to reach cleanup objectives was estimated at 6 months.

SITE: CITGO
Libertyville, IL
Incident #930358

CONTAMINATION: BETX

SOIL TYPE: Silty clay with sand

WHY ALTERNATIVE TECHNOLOGY?: Due to the large volume of contaminated soil and ground water, in-situ bioremediation was proposed.

REMEDIATION: *IN-SITU BIOREMEDIATION* with PUMP and TREAT

Schrack Environmental Consulting, Inc. of Oak Brook, IL has proposed a bio-remediation system using *Bio-Rem, Inc.'s Product "H-10."*

Bioremediation is proposed to remediate an estimated 3,500 cubic yards of soil and ground water. The biomass would be introduced by use of injection piping in trenches measuring 3 ft. wide by 12 ft. deep across the site. Ground water would be extracted from the recovery trench, pumped to a 2,500 gallon equalization/sedimentation tank, and processed through a profile air stripper. The air stripper would not only provide additional oxygen for the bio-cultures but would also act as a biological trickling filter by developing a layer of bio-cultures to increase contaminant removal efficiency. The treated ground water would be pumped into a 500 gallon holding tank for monitoring and bio-augmentation if necessary and then recirculated into the bioremediation trenches at a rate of approximately 5 gallons per minute.

COST:

CONVENTIONAL (EXCAVATION and DISPOSAL, GROUND WATER TREATMENT)

UST Removal Permit	$100
Excavation, cleaning, and disposal of USTs (three 10,000 gal)	7,500
Excavation, transportation, disposal of soil ($47/cubic yard for 3,500 cubic yards)	164,500
Backfill ($12.50/ton for 5,250 tons)	65,625
Installation of ground water recovery sumps and pumping system	4,500
Construction of ground water treatment system	17,500
Ground water treatment system monitoring and sampling	12,500
Closure sampling (Install and sample 5 wells)	5,500
Analytical testing	5,220
System Decommissioning	1,500
Final Closure Report and PE Certification	4,750
ESTIMATE TOTAL	**$289,195**

ALTERNATIVE (IN-SITU BIOREMEDIATION)

UST Removal Permit	$100
Excavation, cleaning, and disposal of USTs (three 10,000 gal)	7,500
Excavation of ground water recovery trench and bio-application trenches	3,500
Backfill ($10/ton for 150 tons)	1,500
Installation of ground water recovery sumps and pumping system	6,500
Installation of Bio-application system	5,500
Construction of ground water treatment system	17,500
Bio-application including materials and labor for application	25,000

Engineering design and construction oversight	6,000
Bio-remediation monitoring and sampling	7,200
Closure sampling (Install and sample 4 wells)	6,850
Analytical testing	5,220
Site Decommissioning	1,500
Final Closure Report and PE Certification	4,750
ESTIMATED TOTAL	**$100,870**

TIME REQUIREMENTS: Ground water from the recovery trench would be sampled weekly. Soil would be sampled on a monthly basis until cleanup objectives were met. Ground water from monitoring wells would be taken for 1 quarter after remediation was complete. Time to completion was estimated at 6 months.

SITE: Turtle Wax Car Wash
Mundelein, IL
Incident #900031

CONTAMINATION: BETX

SOIL TYPE: Dense brown to grey clay; thin fine to medium grained sand lenses imbedded in clay matrix

WHY ALTERNATIVE TECHNOLOGY?: Bioremediation was selected for its cost effectiveness over excavation and disposal.

REMEDIATION: ***BIOREMEDIATION***

DePaul and Associates of Chicago, IL has proposed bioremediation to remediate approximately 2,000 cubic yards of soil and ground water.

The system was designed to extract ground water from an exfiltration trench and to treat it on site using activated carbon and nutrients to enhance biodegradation for reinjection into the subsurface soils. The exfiltration trench was used to recover ground water from the contaminated area. The trench measured 10 ft. deep (approximately 3 ft below the water table) x 180 ft. long x 3 ft wide and was backfilled with pea gravel and capped with asphalt. The trench was sloped with a 1% gradient to a collection sump where an electric submersible pump could deliver recovered ground water to the treatment system. Ground water was pumped to a 150 gallon equalization tank and through activated carbon canisters to remove hydrocarbon contamination. Treated ground water filled a gravity feed tank where it could be enriched with nutrients (nitrogen and phosphorous salts) and hydrogen peroxide. Treated and enriched ground water was reinjected into the subsurface soils through an infiltration gallery. The infiltration gallery consisted of 500 ft. of 1 inch slotted PVC piping connected to approximately 120 ft. of 2 inch unslotted PVC feeder pipe. The infiltration gallery piping was placed on 2 inches of pea gravel, backfilled with 6 inches of road rock, and capped with 6 inches of asphalt. The flow capacity of this system was 7200 gallons per day.

COST:

CONVENTIONAL (EXCAVATION and DISPOSAL)

Excavation and Disposal (for 2,000 cubic yards)	$245,000
Asphalt and concrete removal Soil excavation Soil disposal Excavation backfill Asphalt replacement Project oversight	
ESTIMATED TOTAL	**$245,000**

ALTERNATIVE (BIOREMEDIATION)

<u>Construction</u>	
Asphalt removal and replacement	$11,500
Trench excavation and disposal of backfill	20,000
Plumbing materials	3,500
Activated carbon adsorption units	2,000
Pumps	3,500
Nutrients	1,000

Tanks	1,500
Plumbing/Electrical contractor labor	11,500
Remediation design and oversight	15,000
Maintenance and Operation	
Maintenance and Carbon Replacement	$30,000
ESTIMATED TOTAL	**$99,500**

TIME REQUIREMENTS: Estimated time to achieve soil and ground water cleanup objectives is 2 years. After 1.5 years of system operation, BTEX levels dropped from 24000 ppb. to 100 ppb. Benzene levels also dropped from 1200 ppb. to 5.5 ppb.

SITE:

Coverall Laundry
Chicago, IL
Incident #903046

CONTAMINATION: BETX

SOIL TYPE: Sandy, Lake Michigan beach sand 13 ft. thick

WHY ALTERNATIVE TECHNOLOGY?: Excavation to remove contaminated soil was not possible without demolishing an existing building. Excavating the contaminated soil beyond the building and then requesting site specific levels was also not an option. The consultant had determined there was a possibility of further release migration due to recharging ground water.

REMEDIATION: *SOIL WASHING and GROUND WATER EXTRACTION*

Inland Consultants, Inc. of Skokie, IL has proposed a soil washing and extraction system to remove gasoline contamination from soil and ground water.

A pilot-scale system was used for initial evaluation and was later used as part of the full-scale operation. The system was operated on a 24 hr/day, 7 days/week basis. 30 inlet wells were placed in the contaminated area to a depth of 5 ft. and used to convey hot (140 degrees F) tap water to the subsurface. Contaminated ground water was extracted from 10 extraction wells fitted with 4 inch single phase, stainless steel, explosion proof, submersible pumps at a combined rate of 10 gal/minute. The extraction wells were placed to intercept the upper water table and extended approximately 3 ft. into the underlying clay unit for a total well depth of 17 ft. The extracted ground water was treated through granular activated carbon adsorption and discharged to the municipal sanitary sewer. The carbon filtration system was comprised of 2 vertical filter beds: 6 ft. x 4 ft. conical upright steel tanks each with 2,000 pounds of granular activated carbon. Ground water was gravity fed through the filtration system. Bed carbon contact time was approximately 15 minutes. A 35,000 gallon holding tank was used to store treated ground water until laboratory analysis confirmed levels were satisfactory for discharge to the sewer system. At full operation, the 35,000 gallon holding tank filled in approximately 2 days.

COST:

CONVENTIONAL (EXCAVATION and DISPOSAL)

Permits to Remove Tank	$135
OSHA Site Safety Plan	800
Remove Tank Liquids	425
Tank Removal and Disposal	3,200
Subsurface Soils Investigation and Sampling	14,500
Demolish Structure	
Demolition Cost	120,000
Remove Foundations	18,000
Brick Salvage	(4,000)
Building and Property Value	720,000
Less Land Value (15% of $720,000)	(108,000)
Soil Removal and Disposal ($58/cubic yard for 3,600 cubic yards)	208,800
Backfill	54,000
Closure Sampling (26 samples)	6,500
Ground Water Extraction and Disposal (for 45,000 gal)	27,400
Two Inch Monitoring Wells with Installation (5 wells)	2,750

Closure Water Samples (10 samples)	2,500
Sub Contracting and Overhead	18,000
Labor (Field Engineer, Technician, Principle, Clerical)	30,800
Closure Report	5,100

ESTIMATED TOTAL $1,120,910

ALTERNATIVE (SOIL WASHING and GROUND WATER EXTRACTION)

Permits to Remove Tank	$135
OSHA Site Safety Plan	800
Remove Tank Liquids	425
Tank Removal and Disposal	3,200
Subsurface Soils Investigation and Sampling	14,500
Two Inch Monitoring Wells with Installation (5 wells)	2,750
Four Inch Extraction Wells with Installation (11 wells)	8,800
Stainless Steel Extraction Pumps	4,400
Hot Water and Extraction Water Distribution Piping	9,000
Filter Bed Vessel (2 units)	8,000
Activated Carbon (4,000 lbs.)	4,000
Boiler Unit	4,000
Miscellaneous Expense	6,000
System Design (Engineer, Principle, Clerical)	21,880
Field Engineering (Engineer, Technician, Field Labor)	31,200
Sub Contracting and Overhead	8,000
Closure Soil Sampling (26 samples)	6,500
Closure Water Samples (10 samples)	2,500
Closure Report	5,100

ESTIMATED CONSTRUCTION COST $141,190

MONTHLY MAINTENANCE

Laboratory Sampling (35 rush BTEX samples)	8,750
Project Oversight (Engineer, Technician)	9,500
Pumping Cost (200 Kw at $.15 per Kw)	300
Carbon Regeneration (2,000 lbs)	2,000
Miscellaneous Expense	600

ESTIMATED MONTHLY COST $21,150
for an estimated 9 months = $190,350

ESTIMATED TOTAL $331,540

TIME REQUIREMENTS: Ground water sampling would be conducted monthly. Closure ground water sampling should be conducted when 2 consecutive sampling events for the monitoring wells and extraction well inflow were below cleanup objectives. Closure soil sampling would be conducted following the 2 consecutive "clean" ground water sampling events. Estimated time to reach cleanup objectives was 7 months.

SITE: Martin Oil
Wheeling, IL
Incident #913579

CONTAMINATION: BETX

SOIL TYPE: Silty clay with trace sand and gravel

WHY ALTERNATIVE TECHNOLOGY?: N/A

REMEDIATION: ***BIOREMEDIATION***

NIMCO Environmental Services of Valparaiso, IN with *Ram Engineering* of Montgomery, IL, *ESG, Inc.* of Merrillville, IN have proposed bioremediation to remediate an estimated 8,044 cubic yards of contaminated soil and ground water.

The bioremediation microbes, nutrients, and biocatalyst would be provided by *Alpha Environmental, Inc.* The biomass would be introduced using inoculation trenches and point injection. A series of 9 inoculation trenches measuring at least 2 ft. wide and 6 ft. deep would be constructed. A lower piping system would be placed in the bottom of the trench within a 1 ft. zone of 1-inch limestone material and covered by excavated soil. An upper piping system would be constructed at a depth of 2 ft. below grade in a 1 ft. zone of 1-inch limestone material covered by excavated soil and a layer of limestone screening (fines) to prevent surface runoff from entering the system. Riser pipes to the surface would be constructed throughout the upper and lower systems. Point injection would be used to remediate off-site property by means of inoculation wells.

Alpha's bioculture, biocatalyst, and nutrients would be mixed with municipal water in 1000 gallon batches and circulated for approximately 2 hours. Approximately a total of 40,000 gallons of the biomixture would be applied by gravity feed to the inoculation piping and well points. pH, dissolved oxygen, specific conductivity, and temperature would be monitored twice a month. The goal would be to have at least 2 ppm of oxygen and a temperature of at least 50 degrees F in the medium.

COST:

CONVENTIONAL (EXCAVATION and DISPOSAL)

Excavation and Disposal	$484,000

ALTERNATIVE (BIOREMEDIATION)

<u>System Design</u>	
Labor	$12,750
<u>System Installation</u>	
Equipment	25,450
Materials	15,221
Labor	17,152
<u>Treatment</u>	
Equipment	12,200
Materials (Microbes, Nutrients, and Biocatalyst provided by *Alpha Environmental, Inc.*)	212,764
Labor	27,930

Monitoring	
Labor	22,800
Site Closure	
Labor	19,375
ESTIMATED TOTAL	**$377,041**

TIME REQUIREMENTS: Ground water would be sampled prior to injection of the biomass and twice per month thereafter until cleanup objectives were met. The estimated completion time was 6 months.

SITE:

Village of LaGrange
LaGrange, IL
Incident #881665

CONTAMINATION: BETX

SOIL TYPE: Silty loam, clayey soils with thin layer of silt and numerous gravel and sand seams

WHY ALTERNATIVE TECHNOLOGY?: Costs for soil vapor extraction with air sparging combined with ground water pump and treat would be less than one third the cost of conventional excavation and disposal.

REMEDIATION: *SOIL VAPOR EXTRACTION with AIR SPARGING and PUMP AND TREAT*

Huff & Huff, Inc. of LaGrange, IL has proposed soil vapor extraction and air sparging to remediate approximately 5,000 cubic yards of soil and a pump and treat system with carbon to remediate ground water.

A 15 ft. x 15 ft. pit would be excavated near the center of the site. Horizontal bore holes would be installed in the side walls of the pit extending into the plume of the hydrocarbon containing soils at depths of 13 to 15 ft. Slotted PVC wells screens would be installed in these bore holes. Four air injection wells would be positioned around the center pit and a fifth injection well would be located in the middle of the center pit. The Soil Vac 4000 would require a 7.5 horsepower (HP), 230/460 voltage, 3 phase positive displacement vacuum pump for vapor extraction and a 10 HP vortex blower for sparging. Air flow rates would be approximately 200 cubic feet per minute (cfm) for air injection and approximately 300 cfm for withdrawal. Extracted vapors would be directly vented to the atmosphere. The average VOC emission rate was estimated at .03 lb/hr.

COST:

CONVENTIONAL (EXCAVATION and DISPOSAL)

Excavation	$300,000
Shoring	40,000
Ground Water Disposal	320,000
ESTIMATED TOTAL	**$660,000**

ALTERNATIVE (SVE with AIR SPARGING and PUMP AND TREAT)

<u>Construction Costs (for both systems)</u>	
Initial Soil Borings, Analytical and Design	$20,000
Soil Vac 4000 Unit	15,000
Vortex Blower for Sparging	4,000
Excavation and Shoring	10,000
Drilling and Installation of Horizontal Wells	17,000
Piping	10,000
Electrical	10,000
10 ft. x 12 ft. Shed	1,500
Sand Backfill	1,000
Air Injection Wells	4,000
Monitoring Wells (3 wells)	4,000
6 inch Recovery Well Installation	3,000
Ground Water Treatment System	8,000
3,500 gal Concrete Tank	3,000

Initial Dewatering Water Disposal	6,000
Engineering Oversight	8,000
Contingency	5,000
Operational Costs (Annual for both systems)	
Offsite Disposal of Ground Water (for winter months)	25,000
Electrical	4,000
Labor	7,000
Carbon Disposal/Replacement	6,500
Analytical	12,000
Maintenance	2,000
Closure Costs	
Post Closure Borings and Corrective Action Report	8,000
Grouting of Wells	2,000
ESTIMATED TOTAL	**$196,000**

TIME REQUIREMENTS: The system would be monitored 2 times/week with a photoionization detector (Hnu) for the first month and then once per week for the remainder of the remediation. Estimated time to reach cleanup objectives was 1 year for soils and 2 to 3 years for ground water.

SITE: Xerox
Des Plaines, IL
Incident #913168

CONTAMINATION: BETX

SOIL TYPE: Silty clay

WHY ALTERNATIVE TECHNOLOGY?:

REMEDIATION: ***SOIL VAPOR EXTRACTION with AIR SPARGING***

Woodward-Clyde Consultants have proposed the HIVAC Unit for SVE. A full-scale system would employ air injection wells to introduce compressed air into the contaminated soils. Vapors would be extracted from the subsurface using the HIVAC system and vented to the atmosphere. Ground water would be extracted to lower the existing water table, allowing vacuum extraction of volatile organic compounds from the dewatered capillary zone. Extracted ground water would be processed through an oil-water separator and activated carbon filters at a flow rate of 5 to 20 gpm. The treated effluent would be discharged to the sewer.

A twelve day pilot-scale test was performed to evaluate the feasibility of SVE technology at this site. During the pilot-scale test, the vapor extraction rate was calculated as 35 cfm. Ground water elevation rose approximately 1.8 ft. due to the vacuum effect. Based on laboratory analysis, SVE was estimated to have extracted 4 to 5 lbs of TPH per day, for a total of 48 to 60 pounds of fuel during the 12-day test.

COST:

CONVENTIONAL (EXCAVATION and DISPOSAL)

Soils Investigation to Define Excavation Zone		14,300
Subcontractor Labor/Equipment	$ 3,500	
Oversight, Measurement and Soil Sample Collection	1,800	
Lab Costs (32 Soil Borings)	9,000	
Excavate, Load, and Transport to Landfill for Disposal (800 cubic yards)		65,000
Oversight, Management	5,000	
Subcontractor and Landfill Costs	60,000	
Confirmatory Soil Sample Collection (32 samples)		9,000
Dewatering Costs		3,600
Vacuum Truck (8 days)	3,600	
Waste Water Disposal (12,000 gal)	4,800	
Analytical	500	
Backfill and Compact		8,000
Repave Surface with Asphalt		5,000
Ground Water Study		13,000
Well Installation	6,000	
Design, Oversight, Sampling	3,000	
Laboratory Costs (one round)	4,000	
	ESTIMATED TOTAL	**$123,200**

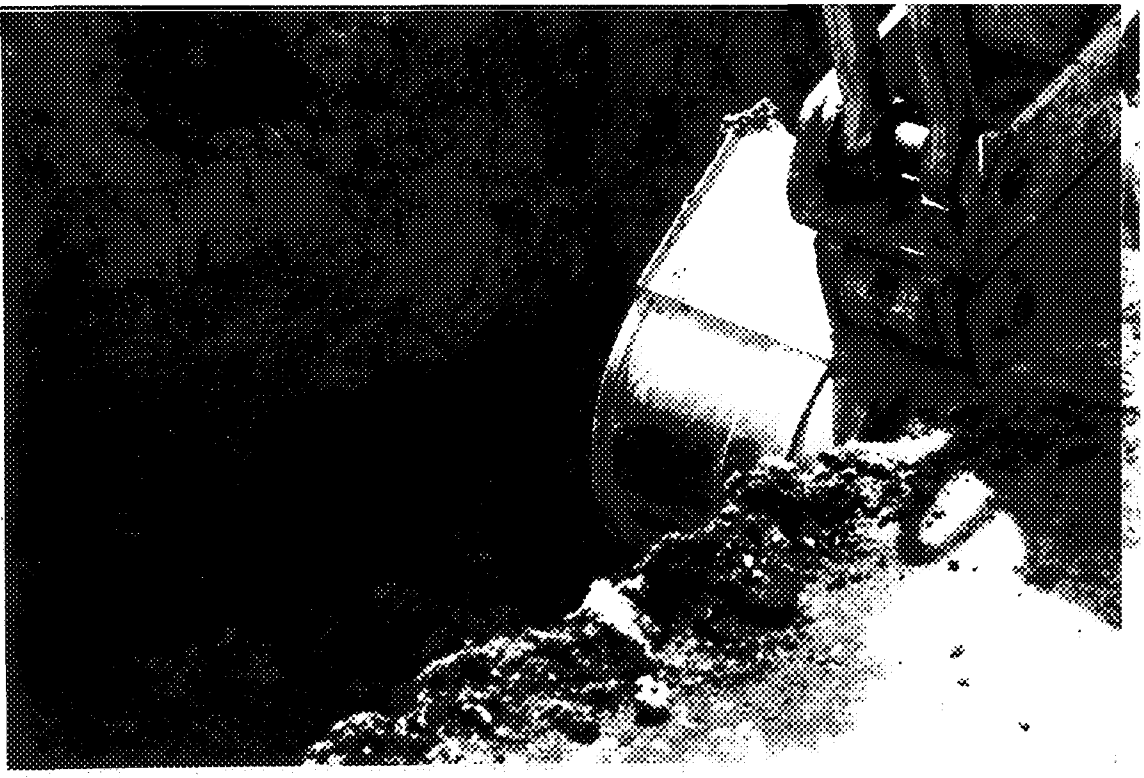
ALTERNATIVE (SVE with AIR SPARGING)

Permit Applications	$12,000

Recovery Well Installation (8)		9,000
Subcontractor/Equipment:	$ 3,000	
Well Materials:	3,000	
Design, Oversight, Sampling, and Field Measurements	3,000	
Injection Well Installation (8)		18,000
Subcontractor	2,700	
Well Materials	3,800	
Blower, Filter, and Tubing/Piping	9,000	
Design, Oversight, Sampling, and Field Measurements	2,500	
Mobilization/Demobilization of HIVAC Unit		9,500
Subcontractors	3,500	
Design, Management, and Oversight	6,000	
Operation/Maintenance (2.5 months)		34,000
3 Week Pilot Study	12,000	
Pilot Study Work Plan	6,000	
Pilot Study Report	5,000	
Pilot Study Lab Fees	7,000	
Sample Collection during Pilot Study	4,000	
Connective Piping/Valves, Trenching, Backfill, Design, Oversight, Management		11,000
Equipment/Miscellaneous		12,000
Two 300 lb Carbon Vessels	2,000	
Holding Tank (for standby use)	2,000	
Electrical Connections and Switches	3,500	
Duct Work for Air Emissions	3,000	
Berm Construction with Portable Sumps	1,500	
System Start-Up and Debugging		4,000
Operations and Maintenance after Pilot Study (app. 2 months)		10,000
Labor, Management	7,000	
Laboratory Cost	3,000	

ESTIMATED TOTAL $119,500
plus $6,000/month for each additional month over 3 months

TIME REQUIREMENTS: Estimated time to completion for the full-scale SVE system was 3 months.



picture
on both
covers

Cust I & III