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Geologic assessment predicts contaminant movement

Factors to study that reveal transport in the subsurface

By Anthony Maggio

The objective of a geologic assessment is straightforward: to characterize the fate and transport of contaminants in the subsurface. This includes the ability of sediments to absorb or transmit fluids and the rate of movement of contaminants through those sediments. Ultimately, the assessment should be able to provide enough information to develop a remedial action plan.

The most important value to estimate is hydraulic conductivity. This value alone allows one to estimate how many pumping wells may be needed, the yield of each well and the radius of influence of each well in the surrounding aquifer at a given yield.

Some basic parameters are necessary to derive this information: grain size and uniformity coefficient of the sediments, porosity measurements and moisture and carbon content for certain modeling variables. Accurate measurements can translate into huge savings in remediation design, operation and maintenance costs.

The hydraulic conductivity scale measures the ability of the geologic medium to transmit fluids and is fluid dependent. It is also an exponential scale as seen in figure one, page 7. Each unit on the scale has an order of magnitude difference from the unit above or below it. Therefore, knowing as accurately as possible the values of hydraulic conductivity over a site is essential for proper engineering design of a remediation system.

Data that is collected and used in geologic assessments has to fill two requirements. First, it must conform to current standards in the geologic and engineering industry. For example, a given sediment sample is not a “fine-grained sand” because a field geologist “says so.” It is a fine-grained sand because its effective size falls within a classified grain-size range as determined from a sieve analysis performed to ASTM standards. And second, the data must be pertinent to the objective at hand. For example, using the porosity of a sediment sample to estimate hydraulic conductivity is erroneous. A rock such as pumice is very porous, yet its permeability is low because the pore spaces are not interconnected.

There are a minimum of five types of data essential to collect and analyze in a geologic assessment.

Grain size analysis

The most widely used method to find grain size is by sieve analysis. This involves passing the sediment sample through a stacked set of eight-inch brass sieves which are shaken down in a vibratory machine. Each sieve filters out a certain percentage of the entire sample. The finest material collects in the bottom pan. Plotting the percentages of the whole sample provides the grain size distribution curve which shows at a glance how much of the sample material is smaller or larger than a given particle size.

A specific point on a grain size distribution curve is used as a general index of fineness. This point is called the effective size. The effective size is defined as the particle size where 10 percent of the sample is finer and 90 percent is coarser. Once the size is determined, the value is compared to the Wentworth scale, developed in 1922. (In California, the Department of Health Services has specified the 50 percent size as the effective size and uses the United Soil Classification System instead of the Wentworth scale.)

The slope of the grain size distribution curve yields useful information. One useful term is the uniformity coefficient. It is defined as the 40 percent retained particle size divided by the 90 percent retained size. The lower its value, the more uniform is the grading of the sample between these limits. It is meaningful only when its value is less than five.

Though there is no precise way to calculate hydraulic conductivity directly from the grain size distribution curve, it is possible to estimate the relative yields of different sediments by careful consideration of the effective grain size and the uniformity coefficient.

After a borehole is drilled, it is often converted into a groundwater monitoring well, a pumping well or a soil vapor collection point. Data derived from the sieve analysis is essential to design screen slot size and sand pack specifications. Proper well design and well materials, especially for a well intended to pump water, saves the well owner money in lower pumping and maintenance costs over the lifetime of the well.

As a rule of thumb, take three or four samples per borehole and generate distribution curves. However, it is advisable to have a sieve analysis performed on at least one sample in the vadose zone and one in the saturated zone. It may also be advisable to take a sample and run a sieve analysis any time the lithology shows a significant change during drilling. The average cost to run a sieve analysis at most labs is $50 to $70—inexpensive considering the information they provide.

Borehole geophysical logs

This uses geophysical instruments in the borehole to investigate subsurface
**Figure one: Hydraulic conductivity and permeability**

lithology. A good log gives a detailed picture of the character and thickness of the various strata in a borehole by locating the top and bottom of each distinct unit and differentiates clean sand from silty or clayey units. Unlike the grain size distribution curve, which is point specific in a borehole, geophysical logs are usually continuous readings which are most useful in the preparation of accurate geologic cross sections. They also provide permanent records of the borehole and greatly reduce the speculation that can occur regarding the subsurface geology should disputes arise.

Resistivity logs, usually called electric logs, or simply E logs, combined with the spontaneous potential curve (SP curve) are common in the water well industry. An E log is generated by suspending one or more electrodes on a

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Write in 296

May 1993 Soils 7
‘Oil’ you need to know about crude

Implications of TPH data for common petroleum products

By Brian Sullivan and Sidney Johnson

The ability to interpret TPH data is only as good as your knowledge of the hydrocarbon contaminant under consideration. Total petroleum hydrocarbon (TPH) analysis is a primary regulatory tool to establish soil remediation goals for petroleum contamination. To better understand the nature of petroleum products, and the significance of TPH data, it is useful to consider the basics of the oil refining process.

The production of petroleum products takes advantage of the broad range of boiling points for various hydrocarbon constituents. During the distillation process, crude oil is heated to the boiling point and directed to a distillation tower, where the various petroleum fractions condense at different levels as their vapors ascend through the tower. Figure one, above,

Brian Sullivan is an environmental scientist and Sidney Johnson is a senior hydrogeologist for K.W. Brown Environmental Services, College Station, Texas.

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In chemical terms, crude oils from which petroleum products are produced are incredibly complex, composed of thousands of constituents. However, the hydrocarbon constituents can be grouped into five basic categories: paraffins, isoparaffins, aromatics, naphthenes and asphalts.
Figure two: Chemical structures and boiling points of typical hydrocarbon constituents.

**Paraffins and Isoparaffins**

All types of paraffin molecules are sometimes referred to as “saturated” hydrocarbons, since all available carbon bonds are occupied by the maximum number of hydrogen atoms. Normal paraffins (n-paraffins) exist as straight carbon chains, such as hexane (figure two, above) or possess a branched structure due to the presence of one or more side chains, like 2,2,4-trimethylpentane (iso-octane). These branched paraffins are also referred to as isoparaffins.

In crude oil, about 60 different straight chain paraffin molecules may be found (i.e. C1 to C60), but the six paraffins ranging from pentane (C5) to decane (C10) predominate. On average, crude oil contains about 25 percent n-paraffins and isoparaffins. Lighter paraffins exist as volatile liquids, while the largest paraffin molecules may occur as solid waxy materials. As a molecular class, paraffins must not be confused with commercial paraffin, which is a specific product consisting of n-paraffins ranging from C20 to C30 with lesser quantities of isoparaffins, naphthenes and trace aromatics.

As a group, paraffins tend to be relatively inert and non-toxic to

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Continues on page 10
The hydrocarbon constituents present in a petroleum product may vary significantly, depending on the crude oil source and processing methods. As a result, most products are defined more in terms of physical characteristics, such as ignitability, viscosity, etc. However, when taken as a whole, each class of products exhibits general chemical properties which can help predict their impact and fate in the environment.

**Gasoline**

Gasoline is composed of hydrocarbons primarily in the C5 to C10 range. Its boiling temperature ranges from about 215 to 210°C. The gasoline fraction is dominated by paraffins, isoparaffins, cycloparaffins and, to a lesser extent, low molecular weight aromatics. Depending on the source, a barrel of crude yields about 10 to 40 percent gasoline from straight distillation. Secondary processes, such as cracking, polymerization and reforming can increase the gasoline yield from a barrel of crude to as high as 70 percent.

**Naphtha**

Naptha is a very broad category for distillate fractions ranging from about C6 to C12, and that fall within a distillation temperature range of approximately 65 to 210°C. The term “naphtha” is primarily a functional classification rather than a designation for a specific set of hydrocarbon compounds. Chemically, naphthas are highly variable, ranging from pure formulations of short, straight-chain paraffins or single ring aromatics, such as toluene and xylene—or, more typically, as complex mixtures of paraffins and aromatic hydrocarbons. Major industrial uses of naphthas are as solvents, degreasers and thinners for various gums, resins, varnishes and paints.

Historically, early naphtha formulations (which were highly variable in composition) were called “mineral spirits,” a generic term still in use. Modern mineral spirits, such as Stoddard solvent, may be produced solely by straight run distillation processes. However, the production of most industrial naphthas is more likely to involve multi-step processes.

**Kerosene and jet fuels**

Kerosene is primarily composed of hydrocarbons in the C11 to C13 range that fall within a distillation boiling range of about 150 to 250°C. Kerosene contains a higher proportion of multi-ring compounds (both paraffins and aromatics) than gasoline. Kerosene range distillates are major components of jet fuels. In general, jet fuels can be classified into two main types:

- **Wide cut**: exhibits a relatively wide boiling range, consisting of both gasoline and kerosene fractions;
- **Kerosene**: composed primarily is distillates within the kerosene boiling point range.

In the U.S., the accepted civil specifications for jet fuels are defined by the American Society for Testing and Materials (ASTM). The specified kerosene aviation fuel is classified as jet fuel A, with jet fuel A-1 being a minor variation. The specified wide cut fuel is designated as jet fuel B.

**Diesel and fuel oils**

The light gas oils include diesel fuel and No. 1 and No. 2 fuel oils.

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**‘Oil’ you need to know, from page 9**

biological systems at low concentrations. Hexane, a low weight, naphthenic compound, is routinely used during the decontamination rinsing of environmental sampling and analysis equipment. Pristane, an isoparaffin considered to be a predominant constituent of petroleum, is also a common isoprenoid, synthesized by many types of living organisms. A layer of waxy paraffins is often applied to the outside skin of consumable vegetables and fruits—as anyone knows who has ever purchased a cucumber in the grocery store.

**Naphthenes**

Paraffins that have carbon chains that are closed to form a ring structure are known as naphthenes. They are also sometimes referred to as cycloparaffins. In crude oil, these compounds contain either five or six carbons per ring, and are likely to possess additional side chains. See figure two, page 9. The average crude oil contains about 50 percent naphthenes, with the quantity increasing in the heavier distillation fractions.

**Aromatics**

Depending on the crude oil source, aromatic hydrocarbons may amount to as much as 15 percent of the total crude volume. Aromatic compounds are primarily built around the structure of the benzene ring, and are unsaturated.

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Continues on page 12→
The molecular size for these products typically ranges from about C14 to C18. These products tend to be quite diverse in their physical and chemical makeup, which is reflected in the relatively wide distillation boiling temperature range of approximately 160 to 400°C. These products range from light amber to dark in color. As is true for the other products above, the light gas oils have fairly low viscosity and flow somewhat like water. No. 1 oil typically is a straight run distillate product, which, although slightly heavier than kerosene, is sometimes classified as a kerosene product.

No. 2 fuel oil can be either a straight run distillate coming off the refinery tower after No. 1 oil, or else be produced by catalytic cracking and blending. Straight run No. 2 is well suited for home heating units, while cracked No. 2 is more often found in industrial applications—such as smelting furnaces, ceramic kilns or small boiler furnaces. Both No. 1 and No. 2 fuel oil fractions may be included as blending components for jet fuel or diesel fuel formulations.

Due to the wide variety of diesel engines with markedly different fuel performance requirements, ASTM Classification D 975 provides specifications for three primary grades of diesel fuel: No. 1-D, No. 2-D and No. 4-D.

Included in the general category of diesel and light fuel oils is a product known as light cycle oil. Light cycle oil is not a straight run distillate, but is produced by the catalytic cracking of No. 6 fuel oil (described below). Depending on the characteristics of the feedstock, light cycle oil may be used in pure form as a diesel fuel or No. 2 fuel oil, or may be used as a blending ingredient for either of those products.

Heavy fuel oils

The heavy fraction gas oils (sometimes called "residual" fuel oils) include Nos. 4, 5 and 6 fuel oils. The approximate molecular size range for these products is C9 to C25, and the boiling range is approximately 315 to 540°C. These products are dark in color, and are markedly more viscous than water. No. 6 fuel oil (also called Bunker C) is a residual product of the refining process. It is a gummy black product used in heavy industrial applications where intense heat is available to fluidize the oil for pumping and combustion. It may also be used as a blending compound in asphalt formulations.

No. 5 fuel oil is nearly always produced by blending No. 6 fuel oil with lighter distillate fractions. Depending on the crude oil source, No. 4 fuel oil may be generated as a straight run distillate. However, since heavy straight run distillates used to produce No. 4 are more valuable as charging stocks for cracking units, No. 4 fuel oils are more typically produced by blending No. 6 with various light distillates. No. 6 fuel oil is denser than water, which means that when it comes in contact with a body of water, most of it will sink rather than float on the surface.

Lubricating oils

Lubricating oils fall within an approximate molecular size range of C20 to C45, with a distillation boiling range of about 425 to 540°C. Lubricating oils are enriched for the most complex molecular fractions found in crude oil, such as cycloparaffins having as many as 10 or more rings, multi-ring aromatics, etc. Many lube oils possess large amounts of asphaltic compounds—molecules containing nitrogen, sulfur and oxygen.
‘Oil’ you need to know, from page 10

hydrocarbons, since they do not contain the maximum possible number of hydrogen bonds as in figure two. Light aromatics, such as toluene and xylene possess additional carbon side chains on the basic benzene ring. Benzene rings may fuse to form polycyclic aromatic structures such as phenanthrene, as seen in figure two.

Single ring aromatics possess low boiling temperatures and are predominant aromatic constituents in light petroleum distillation fractions, such as gasoline and some naphtha products. Heavier fractions progressively contain greater amounts of the polycyclic aromatics, which have higher boiling temperatures.

Compounds in which aromatic and napthenic rings have condensed to form a hybrid, exhibiting both types of cyclic structures in the same molecule, are called napthoaromatics.

Many low weight aromatic compounds are represented in analytical target compound lists as volatile or semivolatile constituents. Due to the nature of their chemical structure, some aromatic compounds, or their metabolic breakdown products, may be highly reactive in biological systems, resulting in carcinogenic or mutagenic effects.

Asphalts

Crude oil typically contains sulfur, nitrogen and oxygen. These elements are primarily present in asphaltic compounds. Several petroleum asphalts are shown in figure two. The asphaltic compounds contribute most of the color and odors to crude oil and its heavier products. The asphaltic content of a crude oil may vary widely, but is typically about five to 10 percent of the total crude volume. As might be expected, the amount of asphaltic compounds present in a petroleum distillation fraction steadily increases with the heaviness of the fractions, which explains why heavier petroleum distillation fractions are also increasingly darker in appearance. For instance, a heavy lubricating oil may possess seven times as many asphalts as a kerosene product.

The odor of certain asphaltic compounds, such as some mercaptans and amines, is readily detectable by the human sense of smell, even at extremely low concentrations. As a result, the scent of trace asphalts in the absence of significant quantities of other hydrocarbons, can falsely suggest high levels of contamination.

Figure three, above, provides general ranges for molecular sizes and distillation temperatures of the main hydrocarbon classes found in an example crude oil and some of its refined petroleum products. (Since these ranges are based on a specific source, they are not necessarily identical to the distillation ranges in figure one.) Figures one and three help to illustrate that a product’s distillation range is generally related to its molecular size. Further, as hydrocarbons are considered across a spectrum of increasing molecular mass, in general, viscosity increases,
volatility and water solubility decrease and general bioavailability decreases. As a direct consequence of these characteristics, heavier hydrocarbon fractions persist in the environment longer than lighter fractions.

Significance of TPH data
EPA method 418.1 (gas chromatography-infrared spectroscopy, typically modified by addition of EPA extraction method 3550 for soils) provides gross quantification of total petroleum hydrocarbons in environmental samples. But, a TPH quantitation, as it is routinely reported, provides virtually no information regarding either the quantities or types of individual hydrocarbon constituents that are present in a sample.

Depending on the nature of the contaminants, vegetation, soil invertebrate organisms and microbes may thrive in soils with TPH concentrations as high as 10,000 ppm. However, such observations would not be expected if the hydrocarbon constituents were all the result of a recent gasoline spill. While hydrocarbons vary widely in terms of their environmental fate and toxicity, these differences are not always discernible in TPH data.

In the absence of other guidelines, government regulators may be tempted to apply TPH remediation standards designed for specific programs to inappropriate situations. For example, a state which mandates TPH cleanup of 100 ppm for subsurface releases of gasoline or diesel from underground storage tanks may be adopt that level at an industrial site where several barrels of unused lubricating oil have spilled on surface soils that are far removed from surface water or groundwater. The costs to remediate the industrial site to 100 ppm in this example would not be remotely justifiable in terms of the risk reduction achieved.

The use of TPH-based cleanup criteria, inappropriately adopted for purposes for which they were not originally intended, seems to be growing more common. As a former EPA regional administrator observes, state laws dealing with leaking underground storage tanks have put a "strange spin" on the management of oil spills in the U.S., resulting in needless, wasteful or damaging remedial activity.

Appropriate, soil based cleanup standards for hydrocarbon spills involving heavy fraction petroleum products, such as lubricating oils or heavy fuel oils could be patterned on standards established for the remediation of crude oil spills. While it is useful to consider an overview of the characteristics of the various petroleum hydrocarbons, each site must certainly be considered and analyzed individually. Nevertheless, a practical understanding of the nature and variability of petroleum hydrocarbons provides a basic foundation for efficient assessment, interpretation of TPH data and potential responses at any site.

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Write in 218

May 1993 Soils 13
Communication is key to Iowa fund success

Community approach to cleanups brings down costs

By Robb Hubbard

One of the biggest success stories in the industry is the efficient and solvent functioning of the Iowa UST Tank Fund. While some state funds are teetering toward depletion, and others are drowning in a backwash of administrative paper shuffling, the Iowa fund is fat and rich and is cheerfully ticking off remediated sites in snappy order.

Communication and information are the key issues that contribute to Iowa’s success story. Consider:

- The Iowa fund board pays for 100 percent of the cost of the site cleanup report, up to $20,000.
- In the first 24 months, the program prepared, produced and issued over 20 informational mailings to owners, operators, installers and remedial contractors working with USTs.
- Nearly 2,800 insurance policies have been issued.
- The release rate is approximately 60 percent of active tanks, compared to the predicted 10 percent.
- The board has funded innovative technologies, including bioremediation, incineration, community remediation, soil venting combined with bioremediation and venting combined with pump and treat.
- The board funded a geographic information system which mapped the communities involved with the community remediation program to identify all UST sites.
- The board funded four staff assistance positions to assist the regulating agency with backlogged caseloads.
- Two series of tax exempt bonds have been issued by the Iowa Finance Authority, totaling over $71.8 million for the program, “AA” rated, with an interest cost of about six percent.

A big factor in the success of the Iowa program is the community remediation approach. Community remediation programs address contamination from a regional standpoint by combining a number of sites into one project. This approach reduces costs by eliminating duplication of reports, mobilization and startup costs. Through this program, one contractor assesses every eligible site in a designated region or city, and completes a site cleanup report. The report defines the horizontal and vertical extent of contamination from each site. Orphaned tanks and other potential sources are identified throughout the city. Each site is then classified as high, low or no risk.

Over 150 vendors have reviewed the various projects, and up to 20 qualified proposals have been received on each project up for review.

By late fall 1993, over 50 communities and nearly 50 percent of all eligible UST sites will have their site cleanup reports initiated. The size of the projects will range from nine to 250 sites per city. The larger projects have correspondingly larger cost savings. Lab costs have been reduced from $120 per sample to around $80 per sample. Borings have been reduced by $7 per foot, and total cost per site has been reduced to under $7,000 per site. This is one half of Iowa’s already low average per site cost of $14,000 which was established by the pre-approved budget program.

To make the most efficient use of the dollars spent on remediation, the program is designed to address the sites which pose the greatest threat to the environment. Program funds are available to reduce high risk sites down to low risk—but not to a “no further action required” classification. Funding is available for long term monitoring of low risk sites. This system of funding prioritizes the sites which present the highest level of risk, and should be capable of addressing all the estimated 1,800 high risk sites currently identified.

Finally, to further increase the environmental effectiveness of the community remediation programs, sites which are not participating in the overall Iowa UST program may wish to “buy in” to the program through a pre-arranged agreement between the responsible owner/operator and the board. Non-eligible parties can agree to pay the contract cost for borings, wells, samples and reports related to assessment activities associated with USTs on their property—if it is within a community boundary. Although the non-eligible party has to pay his or her own costs, the program costs are far below market costs for single site assessments. This provides an incentive for non-eligible parties to conduct the appropriate assessment services for Williams & Co. Consulting, Des Moines, Iowa; and is administrator for the Iowa Underground Storage Tank Program.

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immediately, instead of waiting for an enforcement action by the Iowa Department of Natural Resources to require them to begin the assessment.

When the Iowa state legislature enacted the Iowa Comprehensive Petroleum Underground Storage Tank Fund Act in 1989, they created a separate fund in the state treasury for the fund’s board to establish a guaranteed loan and insurance program for USTs. At the same time, the legislature authorized the board to contract with a private company to administer the program.

The board was required to promulgate rules to administer and implement the requirements of the federal UST law, and issue bonds to pull money from the state’s Use Tax and tank management fees to fund the program. The program is currently funded through a one cent per gallon fee on all regulated fuels placed into regulated tanks. To ensure adequate funding for the program, the board developed cost containment programs to minimize expenses while meeting the federal mandates.

Currently, the board offers three major financial assistance programs to tank owners and operators facing federal compliance requirements. The remedial fund provides benefits up to $1 million for expenses related to remediation of petroleum releases. The loan fund guarantees up to 90 percent of a loan required to install new tanks or pay an owner’s share of remedial expenses. The insurance fund provides subsidized insurance programs for future petroleum releases allowing owner/operators to comply with the federal requirement of financial responsibility.

The fund administrator has the authority to prioritize claim payments if claims exceed the funds available. The legislature also gave the administrator authority to invalidate contracts for services eligible for program funding if the contracts were not pre-approved by the administrator. To receive approval, the costs must be usual and customary and the services must be necessary for the owner/operator to comply with program or regulatory standards. In addition, the administrator may require specific terms and conditions in contracts eligible for program funding.

The administrator also has the authority to enter into exclusive contracts to provide goods and services for the program or for individual owner/operators at reasonable cost—subject to board approval.

Through these provisions, the board and the administrator were able to implement a cost containment program designed to reduce expenses and provide contract oversight and assistance to owner/operators who were unfamiliar with the remediation industry.

Although some remedial actions may take years to complete, approximately 700 claims have already been closed. A total of 4,016 releases have been reported. Based on the cost

Continues on page 16→

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Tips for managing a cleanup

There are a number of steps the Iowa UST Fund administrators recommend to any person paying for environmental cleanup:

- Establish claim review and payment procedures and stick to them.
- Define your market. Establish what you will pay as reasonable, but base it on site-specific considerations, not a price schedule. Whether you have one or 100 locations, establish scope of work and parameters. Tell the consultant what to do, including footage to drill, number of borings, wells, test count, etc., based on which regulatory agency is reviewing the work requirements.
- Establish unit prices for the individual job, not a contract which has time and material costs for the person doing the job.
- Have historical use and title research conducted. Significant amounts of money can be recovered from prior owner/operators or other responsible parties.
- Don't be afraid to establish and use your own contract form. Make the professional performing the work stick to your stancards.
- Go to more than one firm. Where you can avoid professional bid lists, do so to avoid so called pre-approved lists.
- Require budgets before work is done. Have steps to measure progress and require monthly activity reports from the consultant.
- Be a part of the process. Insist on being informed. Ask questions and demand answers.

containment strategies used by the board, it is estimated that the average cleanup cost to the program will be approximately $90,000 per site. Although the program is currently funded with over $54 million in reserves, long term costs may require additional funding to complete all remedial activities. The board has approved and paid out total remedial benefits of $40 million.

The program addresses long term liability by funding technologies which address ultimate disposal and destruction of contaminants. Currently, soil incineration cost is $34 per ton, plus hauling charges. Bioremediation projects, both in site and near site, have been successfully completed with costs varying, depending on the nature of the media. However, in all cases, costs of bioremediation remained competitive with the incineration process. The feasibility of future projects to include ultraviolet treatment of contaminants is under consideration.

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TARMAC EQUIPMENT CO., INC. Soils Division 800-833-4383
219 N. 7 Highway • Blue Springs, MO 64014
Automation streamlines vapor extraction pilot tests

Computer aids critical design step

By Jeffrey Sims

Correct design of a soil vapor extraction system makes or breaks the effectiveness of any cleanup site—not to mention the negative impact of inefficient design on the site owner’s pocketbook. Recent developments in automated pilot testing systems streamline and enable accurate, cost-saving vapor extraction system designs.

Soil vapor extraction (SVE) is being used more on sites with widely varying conditions, including broader ranges of volatile contaminants and geologic settings. It is also being more widely used in combination with other remediation options, such as bioremediation and air sparging. But, the successful application of SVE technology requires careful system design and selection of equipment to maximize the effectiveness of the cleanup. Ultimate control of overall operating costs over the system’s life is determined in the design phase.

The goals of an SVE pilot test are to obtain the necessary data to support the design of the system, and to collect that data in the most thorough, rapid and cost-effective manner possible.

An automated SVE pilot test system features computerized data logging and processing capabilities, augmented by a rapid method of installing vapor monitoring test probes. Test results are immediately available on site. Indeed, the potential for remediating a site with SVE can be assessed with an automated system in a single site visit.

Once the areal extent and depth of contamination have been established through analysis of data from monitoring wells, soil borings or soil vapor surveys, the feasibility of SVE can be evaluated. While the equipment needed to perform SVE is relatively straightforward, a number of design factors must be considered prior to installation of the equipment. Foremost among these factors is to find achievable contaminant removal rates.

These rates are determined by measuring the achievable air flow rates and vacuum levels. The final design must include a vacuum system capable of drawing subsurface vapors at an air flow rate and associated vacuum level that withdraws the contaminated vapors as rapidly as possible, while balancing the costs of the extraction system.
The design and spacing of the extraction wells is just as important as the selection of a vacuum pump. The required air flow rate and vacuum level of the extraction system influence the depth of the well, height of the well screen, screen slot size and diameter of the well. The depth of the well is dictated by the zone of contamination and the depth to groundwater.

The extraction well screen height should be no longer than the thickness of the zone of contamination, and is located above the groundwater table. The screen slot size is selected to maximize the open area of the screen, as determined by considering the desired air flow rate and the observed grain sizes of the soils in the zone of contamination. Well spacing, well locations and number of wells are defined by the radius of vacuum influence of the well and the areal extent of contamination.

The duration of SVE operations on a site is estimated from the contaminant removal rates of the test wells. Models used to estimate the extraction period combine the achievable contaminant removal rates and extraction air flow rates with the chemical characteristics of the contaminants to predict the expected duration of vapor extraction.

Treatment of the airstream containing the volatilized contaminants is necessary prior to its release to the atmosphere. A number of treatment alternatives are commonly used, including granular activated carbon, thermal oxidation and catalytic oxidation. The estimated duration of the extraction, local

*Continues on page 20*
Independent monitoring devices with full user sampling rate selection. Four of the channels monitor pressure decline at vapor monitoring probes or monitoring wells. Air flow rates at the inlet, exhaust and air: dilution ports of the vacuum system are measured and recorded. Other channels monitor and record vacuum pump outlet pressure and extraction well vacuum levels, soil and ambient temperatures, volatile organic compound levels in the extraction well and the inlet and outlet of the treatment system. A diagram of the automated system is shown in figure one, page 19.

Extraction well and vapor monitoring probe locations are selected by identifying the depth of the contamination, the areal extent of the contaminated soil and cultural considerations, such as buildings, foundations, utilities or other potential interferences. Existing monitoring wells are commonly used for pilot tests if they are screened and located appropriately. If a suitable monitoring well is not available, one must be installed.

Vapor monitoring probes are normally installed along several radial traverses from the extraction well at measured distances appropriate for known soil conditions and the extent of the contamination. Vapor monitoring probes can be quickly and inexpensively installed with direct push technology. A one inch diameter hole is hydraulically driven to a selected depth, followed by installation of the vapor probe.

The vacuum pump system is securely attached to the extraction wellhead. Plastic tubing connects the vapor monitoring probes to high sensitivity pressure transducers and air flow meters mounted in the instrument console. Organic vapor analyzers equipped with flame ionization or photoionization detectors measure volatile organic compound levels. The output of the organic vapor analyzer is monitored by the data logger. Temperature probes and pressure fittings at the extraction wellhead are connected to sensors on the instrument console. A typical automated pilot test installation is shown in figure two, above.

Once the vacuum pump starts and draws vapors from the well, all monitoring probe levels can be observed by the operator during the test and corrective actions can be taken, if necessary. Short term tests are conducted with a constant extraction air flow rate until steady state conditions are observed in the pressure decline data. Contaminant yield rates are monitored during extraction on long term tests.

At the conclusion of each individual pilot test, the data processing system is activated. Data are converted from the data logger to a spreadsheet format. The data processing system calculates the permeability at each monitoring probe,
Figure three

creates graphs of pressure decline vs. time, and tabulates the maximum pressure decline at each vapor monitoring probe. The maximum pressure decline vs. distance from the extraction well is graphed. The volatile organic compound results from each sampling port are also tabulated. After all calculations and tabulations are complete, graphs and tables of the results print. Figure three, above, shows a typical pressure decline vs. time graph. The individual curves represent the pressure decline observed at each vapor monitoring probe at measured distances from the extraction well in response to the vacuum applied at the extraction well. The maximum pressure decline vs. distance is used to estimate the radius of vacuum influence of the test area. A

radius of influence graph is shown in figure four, above.

Fast access to test results enables personnel to make immediate decisions whether modifications need to be made for subsequent tests while all the equipment is still set up on site. These modifications may include installation of additional vapor monitoring probes, alterations to the air flow rate of the vacuum system, or rescaling of the measurement devices.

Accurate pilot test information is vital to design an effective SVE system. The automated system is a significant step to enhance design capabilities while keeping costs in line."

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Write in 213

Soils May 1993 21
Eye on the EPA

Developments of interest to the industry

The EPA reached a $30 million bankruptcy settlement with the Circle K Corp., an Arizona-based convenience store chain, to resolve Circle K’s liabilities for potential contamination from underground storage tank systems at over 1,000 sites operated by the company prior to bankruptcy. The settlement sets a precedent for dealing with companies in bankruptcy with respect to their responsibilities to clean up their contaminated sites.

The National Association of Attorneys General coordinated litigation on behalf of the 30 states affected by Circle K sites.

The settlement requires the reorganized Circle K Corp. to pay a total of $30 million into various state trust funds in proportion to the number of sites located in each state. The funds, to be paid over a six year period, will compensate states and landowners for costs incurred to clean up contamination that resulted from leaking tanks at Circle K sites.

“This settlement deals with difficult issues and resolves them in a fair manner. It provides substantial funds to pay for the cleanup, stagers the payments and helps an Arizona company emerge from bankruptcy,” says Grant Woods, Arizona attorney general. “Furthermore, it keeps ‘mom and pop’ landowners from having to shoulder the entire burden of expensive cleanup costs,” he adds.

Myles Flint, acting assistant attorney general for the Department of Justice environmental division, says the settlement demonstrates the EPA’s “commitment to vigorous enforcement of environmental laws, even with respect to companies reorganizing in bankruptcy.”

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PEI releasing vapor guide

The Petroleum Equipment Institute has released, “Recommended Practices for Installation and Testing of Vapor Recovery Systems at Vehicle Fueling Sites.” The 24-page manual explains preferred practices for installation and testing of Stage I and Stage II vapor recovery systems.

Vapor recovery is a general term to describe methods to prevent the emission of volatile organic compounds into the atmosphere. Stage I vapor recovery controls emissions during deliveries from truck transports into facility storage tanks. Stage II vapor recovery refers to the capturing of vapors at the vehicle fill pipe and returning them to the facility storage tanks. The Clean Air Act Amendments of 1990 prescribe Stage II vapor recovery in the worst polluted areas of the country (called ozone nonattainment areas).

The procedures outlined in the manual are largely a synthesis of regulations and recommendations published by federal and state environmental agencies, along with comment from the petroleum marketing industry.

The manual includes information of different types of vapor recovery systems, installation methods, testing during construction, vapor recovery piping, pressure decay, dynamic back-pressure testing and blockage testing.

The manual is specifically for vehicle fueling facilities. It does not cover practices associated with bulk loading at terminals, bulk plants or on-board transports. Cost of the manual is $15, postage and handling included. Discounts are available for larger quantities. Payment must accompany order.

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Write in 371
Cone penetrometry testing is rapidly emerging as an alternative for drilling for the environmental characterization of subsurface contamination. In cone penetrometer testing (CPT), probes collect pore water pressure data that can accurately define the water table elevation and collect soil vapor samples at discrete depths for volatile organic contaminant screening.

Conventional drilling generates waste soil cuttings, exposes personnel to potentially toxic vapors, and disrupts the surface environment. CPT is replacing drilling because it can delineate subsurface soils without generating waste soil or disturbing the surface. And, typical CPT productivity is around 500 feet per day, versus 200 feet per day using conventional drilling.

When outfitted with an appropriate instrument package, CPT can continually delineate soil gases as the probe advances, detect groundwater, measure hydrostatic pressure in the aquifer, sample soil and groundwater and perform analyses in a mobile lab.

**Lithologic logging**

Cone penetrometer testing consists of a hydraulic ram that pushes a steel rod downward into the soil. Soil is pushed aside so no soil cuttings are produced at the surface. The tip of the rod contains a cone with a cone tip apical angle of 60° and a cross sectional area of 10 square centimeters. The cone is advanced into the soil at a constant rate of two centimeters per second. The cone tip and sleeve above the tip are connected to strain-gauged load cells mounted in the probe body, which measure tip stress (qc) and frictional stress (fs), respectively. See Figure one, left.

These stress values are monitored electronically and logged into an on-board computer at regular intervals, typically two to five centimeters. The stress values are automatically plotted on an empirical soil classification chart in the computer software, and each stress measurement is translated into a soil type. This produces a lithologic log with a resolution of two to five.

*Steven Edelman is senior geologist and Andrew Holguin is president of Holgain, Fahan & Associates, Inc., Ventura, Calif.*
centimeters. The CPT system produces a borehole log without requiring sampling or visual inspection.

The cone, called a piezocone, is commonly outfitted with a porous element and pressure transducer to measure dynamic pore pressure—pressure during cone advancement. Dynamic pore pressure measurements are logged along with tip stress and sleeve frictional stress, and can be used for refined soil classifications and better lithologic resolution in layered soils. Dissipation tests, which measure the decay of pore pressure when cone advancement stops, can be used to estimate local values of hydraulic conductivity. After complete dissipation, the piezocone measures static groundwater pressure, which can provide a measurement of groundwater depth.

**Hydrogeologic characterization**

Standard piezocone transducers typically have ranges of 250 to 500 psi, which is necessary to measure the dynamic pore pressures generated while the probe advances. Uncertainty in transducer measurements is a function of their pressure range—generally up to one percent of full scale. Standard CPT probes, therefore, have a 2.5 to five psi error associated with any measurement, or six to 12 feet of water column. When this standard transducer is used to determine hydrostatic pressure—water table elevation—by stopping the probe and allowing the dynamic pore pressure to dissipate to hydrostatic conditions, the uncertainty in the water table depth measurement amounts to six to 12 feet. This is greater than the total relief of the water table at many sites, and therefore is useless to determine groundwater gradient.

One of the newer instrument packages available for CPT is a low pressure (10 psi) transducer, designed and field tested by Holguin, Fahan & Associates, Inc., Ventura, Calif., which is integrated into the standard piezocone. This low pressure transducer allows collection of hydraulic head measurements with accuracy of 0.1 psi, or 0.2 foot of water table elevation. This measurement, along with surveyed ground surface elevations at three or more locations over a site, can provide information on direction of groundwater flow and gradient—without installing monitoring wells. Measurements at several depths can identify vertical gradients as well as perched and confined aquifers.

**Soil vapor sampling**

As another refinement, Holguin, Fahan & Associates designed a soil vapor sampling probe into its CPT probes to allow for discrete, vertical sampling of volatile organic vapors as the probe advances into the subsurface. This capability replaces headspace monitoring of cuttings and soil samples while drilling, and can determine optimal soil sampling locations for lab analyses. The proprietary, two-line vapor sampling design permits continuous purging of the vapor collection lines between samples. Soil vapor samples are collected at selected intervals during advancement of the CPT probe, depending on the investigator’s needs. The resulting vapor sample is either analyzed with an integrated flame ionization detector for

*Continues on page 26*
total petroleum hydrocarbons, or a bag sample can be collected and analyzed with on-board gas chromatograph methods for quantitative, certified analysis of volatile compounds.

**Soil and groundwater sampling**

Soil samples are retrieved with a probe that has a retractable tip and standard stainless steel or brass sampling rings. Sampling depths are determined by evaluating subsurface site conditions such as depth of water table, geologic layering and elevated volatile vapor concentrations. Soil sampling is accomplished without site disturbance, cuttings or waste soil disposal concerns.

Groundwater samples are collected with a Hydropunch or BAT type samplers. These probes collect groundwater samples at various depths within an aquifer, allowing for vertical profiling as well as lateral delineation of contaminant plume boundaries. As with Hydropunch or BAT samples collected with a conventional drill rig, the results cannot be used to define plume boundaries to most regulatory standards. However, this information, together with groundwater flow direction and other hydrogeological information gathered with the CPT rig, can be used to determine optimal monitoring well locations. (Figure two, right).

The total number of monitoring wells needed to assess the site can thus be minimized as compared to the “stepping out” approach normally used. Minimizing the number of wells needed to define a groundwater plume is an important advantage of CPT and results in substantial savings in well installation costs and long term groundwater monitoring expenses.

A resistivity module can be added to the CPT probe to measure the bulk electrical resistivity of the soil. This is especially useful to identify contaminated groundwater and helps to determine its migration and flow rate through the soil. It can also identify brine contamination.

**Health and safety advantages**

Because the CPT system produces no soil cuttings, health risks to on site personnel are minimized as compared to conventional drilling. The potential for worker exposure to toxic vapors and liquids is reduced to nearly zero, avoiding decreased efficiency when workers must wear personal protective equipment. Health risk or reduced productivity associated with heat stress is eliminated because CPT operations require relatively light work done in an air conditioned van.

The CPT rig is safer than a drill rig because the CPT system does not have the heavy augers, tall masts, lengths of A-rod or heavy samplers suspended on cables that a drill rig requires. And, CPT workers are generally not exposed to traffic or overhead high voltage lines and other dangers that may threaten drillers.

**Phase II “Due diligence” sampling**

The CPT technique is uniquely suited to perform Phase II sampling investigations. Phase I property transaction assessments often identify potential areas of subsurface contamination that require Phase II sampling in order to verify the presence of contaminants. Conventional drilling for Phase II sampling results in site disturbance that may disrupt business operations, on site waste soil and water storage, and the possibility of installing monitoring wells at a site that may have no contamination.

The party performing a Phase II investigation is often not the property owner, but a prospective buyer, for example. So the need to complete the investigation with minimal site disturbance is often critical. A CPT rig can enter a property and collect vapor, soil and groundwater samples noninvasively from the van.

Figure three, page 27, shows cost breakdowns for a typical day of work for a hollow stem drill rig and a CPT van outfit. The costs are based on each system completing 200 feet of investigation with lithologic characterization, vapor sampling and soil sampling. Although individual jobs vary, this example illustrates that CPT is less
expensive on a per foot basis than drilling—chiefly due to waste disposal cost savings.

Additional cost savings can be realized with the CPT if fewer soil samples are collected. Straight CPT—lithologic characterization only—can produce in excess of 800 feet per day. And, fewer field personnel are generally needed because borehole logging is not required, waste soil drums do not need to be moved and stored, and site cleanup is minimal.

**Limitations and advantages of CPT**

Certainly, CPT cannot penetrate bedrock, where air rotary and mud rotary drilling methods are generally the only applicable techniques. CPT may be refused at shallower depths than hollow stem augers in gravelly or heavily overconsolidated soils. The depth range of CPT is generally 100 to 150 feet in normally consolidated alluvial soils. Soundings up to 300 feet have been conducted. Soil sampling with cone penetrometers may be slower than hollow stem augers equipped with cable samplers, but this is generally not a problem in areas of volatile organic contamination because the newer CPT rigs are capable of continuous soil vapor screening.

In most environmental applications, these limitations are outweighed by CPT’s ability to conduct lithologic logging, sample soil vapors at depth, determine groundwater flow direction, and sample soil and groundwater for analysis in the van’s on-board lab.

The result is a detailed site characterization, or site assessment, that can be faster, cheaper and safer than an equivalent investigation conducted with conventional drilling techniques.

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May 1993 Soils 27
Assessment equipment assessment

Confusing? Not really...here's a comparison of electromagnetic surveys and ground penetrating radar for site assessment

By Frank D’Addario

Two of the most effective and popular geophysical methods for site assessment are EMS (electromagnetic surveys) and GPR (ground penetrating radar). They are quick screening technologies that produce rapid characterization of a contaminated site. They can readily identify geophysical conditions, buried wastes and utilities, extent of contamination and potential migration routes.

EMS and GPR should be used prior to more expensive, traditional site assessment techniques, such as drilling, since they can dictate the best location for borehole and monitoring wells, installation, as well as help in the remedial investigation to determine site remediation options.

EMS measures the electrical conductivity of subsurface soil, rock, groundwater and contamination. GPR emits radio wave frequencies which respond to changes in the electrical properties of subsurface components. Both can produce a continuous profile, a color contour map or a three dimensional map of shallow subsurface conditions.

While both EMS and GPR are used to identify hot spots of a site, each has specific applications for which it is best chosen. Figure two, page 30, offers a summary of best application features of each technique.

EMS and GPR are often used together or with other geophysical techniques, such as electrical earth resistivity, seismic technology, metal detectors or magnetometers, to fully characterize a site.

Various EMS equipment can be used, depending on site conditions and type of survey needed. Figure two, below, is a comparative description of the performance characteristics of the most commonly used equipment.

Both methods are a primary means to map lateral and vertical changes in geohydrologic features. Electrical earth resistivity and seismic techniques are also appropriate choices to accomplish this.

EMS is a primary choice to map conductive leachates and their location, as well as location, depth, distribution and horizontal extent of the contaminant plume while GPR is a secondary method to consider for this purpose depending on the site.

Both methods are also a primary choice to locate boundary definition of buried trenches, but secondary means to locate buried metallic objects. A magnetometer is the best technique to locate underground tanks, drums and utilities.

Write in 701 for more information

<table>
<thead>
<tr>
<th>Comparison Criteria</th>
<th>EMS Equipment</th>
<th>Penetrating Radar</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>EM31</td>
<td>EM34-3</td>
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<tr>
<td>Surveying Depth</td>
<td>3 to 6 m</td>
<td>7.5 to 60 m</td>
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<tr>
<td>Speed of Measurement</td>
<td>5 seconds</td>
<td>20 seconds</td>
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<td></td>
<td>(up to 8 km/hr)</td>
<td>(or up to 8 km/hr)</td>
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<tr>
<td>Number of Operators</td>
<td>one</td>
<td>two</td>
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<tr>
<td>Continuous Profiling</td>
<td>yes</td>
<td>no</td>
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<tr>
<td>Measured Quantity</td>
<td>Apparent Conductivity (mmho/m)</td>
<td>Apparent Conductivity (mmho/m)</td>
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<tr>
<td>Probes Inserted in Ground</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Used Over Frozen Ground, Snow/Asphalt</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>Susceptible to Interference</td>
<td>yes</td>
<td>yes</td>
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28 May 1993 Soils
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Write in 358
### Applications of EMS and GPR

<table>
<thead>
<tr>
<th>Application</th>
<th>EMS</th>
<th>GPR</th>
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<tr>
<td><strong>Spatial detection ability:</strong></td>
<td>• Excellent lateral resolution</td>
<td>• Excellent lateral resolution</td>
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<tr>
<td>Detecting lateral variations</td>
<td>• Continuous profiling available on commonly used equipment (EM 31) potentially allows for total site profiling</td>
<td>• Can profile to about 10 meters, but is highly dependent on specific conditions</td>
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<tr>
<td>(Profiling)</td>
<td>• Good vertical resolution of geological conditions and contaminant plumes</td>
<td>• Continuous surveying potentially allows for total site coverage</td>
</tr>
<tr>
<td>Detecting vertical variations</td>
<td>• Resolution decreases with increased depth penetration</td>
<td>• Very good resolution of geological conditions</td>
</tr>
<tr>
<td>(Sounding)</td>
<td>• Vertical information is provided in a relative sense (thick vs. thin, shallow vs. deep)</td>
<td>• Adequate resolution of extent of shallow contaminant plume area</td>
</tr>
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<td>• Can sound to a depth of six meters with continuous surveying (EM 31) or to a depth of up to 60 meters with stationary sounding (EM 34-3)</td>
<td>• Poor resolution of contaminant plume depths</td>
</tr>
<tr>
<td></td>
<td>• Some EMS instruments can reportedly sound to depths of 330 meters or more</td>
<td>• Continuous surveying potentially allows for total site coverage</td>
</tr>
<tr>
<td></td>
<td>• Continuous surveying potentially allows for total site coverage</td>
<td>• Can only sound to about 10 meters, but is highly dependent on specific site conditions</td>
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<td></td>
<td>GOOD</td>
<td>• Better sounding results obtained on dry, sandy or rocky sites—Poorer results on moist, clayey or conductive soils</td>
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<td></td>
<td>EXCELLENT</td>
<td>LIMITED APPLICATION (site specific)</td>
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<td>GOOD (provides relative depth)</td>
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<td>MODERATE (site specific)</td>
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<td></td>
<td>GOOD</td>
<td>MODERATE (site specific)</td>
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<td></td>
<td>GOOD (if plume has electrically conductive component)</td>
<td>POOR</td>
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<td></td>
<td>EXCELLENT</td>
<td>GOOD (high resolution, limited to shallow investigations in non-conductive surface soils—can map tcp of shallow plumes—quick mapping as continuous survey—use GPR if EMS gets interference)</td>
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<td>Determining natural geologic and hydrologic conditions:</td>
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<td>GOOD (high resolution, limited to shallow investigations in non-conductive surface soils—can map tcp of shallow plumes—quick mapping as continuous survey—use GPR if EMS gets interference)</td>
</tr>
<tr>
<td></td>
<td>MODERATE (site specific)</td>
<td></td>
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</tbody>
</table>

Figure one: from page 28

30 May 1993 Soils
The Association for the Environmental Health of Soils presents...

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Write in 380
Often, the final step in a cleanup event involves restoring the site with an eye toward the next intended use of the land. A pile of remediated soil is not always enough to close the file. Arranging remediated soils for erosion and water management control is the next step toward making a site useful—which is often the whole point of the cleanup.

Many computer software programs are available to aid in terrain design for remediated sites. Engineers in Licking County, Ohio are using Quicksurf software from Schreiber Instruments, Inc., Denver, Colo., integrated with AutoCAD to develop grassed waterways, open ditches and water control structures to restore remediated sites.

After collecting basic site data and topographic survey points to create a database, the Quicksurf program grids and contours the data to allow input of the site survey points. The program also develops profiles, and cross-sections of ditches and waterways to show the landscape, drainage and other characteristics.

Soil erosion control and water quality improvement is the primary mandate of the Licking County Soil and Water Conservation District, according to Daniel Blatter, district engineer for Licking County. The county is located east of Columbus in a glacier-formed portion of Ohio, featuring relatively flat or gently rolling terrain in the west, with more hilly terrain in the eastern part of the county. Agricultural operations in the county encompass a diverse mix of cattle, hog, dairy and poultry enterprises, feedgrain operation, including corn, wheat and soybeans. Farm and ranches that regularly deal with more than 1,000 animals fall under the jurisdiction of the EPA.

“It would be virtually impossible to develop usable drawings without a high performance terrain modeling program,” Blatter says. “The combination of Quicksurf and AutoCAD allows you to perform more ‘what if...’ scenarios and study alternatives and options.”

Blatter and his fellow engineers are running AutoCAD on a 20 Mhz 386 computer with eight megabytes of RAM. The system honors specific break lines which allow the user to produce a mesh with second derivatives mixed with zero derivative surface breaks.

“Computer technology means that our facilities and structures are more likely to function the way they were designed to function,” Blatter says. “We believe our plans are complete to the point that the contractor can do the best job possible building the structure.”

Some of the Quicksurf features include conversion of surface mapping data into contours, grid and triangulated irregular networks. The user can color surfaces by slope, elevation, visibility, light or the Z values of another surface. The system stores multiple surfaces in memory—not in the drawing—to enable the user to perform surface-to-surface functions instantly. The program also includes a Kriging algorithm. In addition, contours can be drawn with multiple internal and external boundaries. The user may also draw contours as closed polygons for color filling or hatching purposes, or generated in color schemes by interval, split, or by cycling through colors.
Stokes blower pushes and pulls

Stokes Vacuum, Inc., Philadelphia, Pa., says their positive displacement blower can inject air into wells as well as create the vacuum to pull air out of extraction wells. Because they are positive displacement blowers, their capacity varies little with differences in vacuum or pressure, says the company. And, since they can be V-belt driven, the capacity can be changed by using different sheave combinations. The blowers are available in capacities from 10 to 26,000 cfm vacuum and to 27 inches Hg. and pressures to 15 psig.

Write in 705 for more information

Tank profiler predicts future

International Lubrication and Fuel Consultants, Inc., Rio Rancho, N.M., says their non-invasive Tank Environmental Profiling® service can determine the status of underground tanks without excavation or internal inspections. The service assesses the corrosive state of the tank and detects contamination in surrounding soils. The results enable tank owners and managers to make tankage decisions at about 1/3 the cost of conventional inspection methods, says the company.

Write in 706 for more information

Sorbent blanket offers surface cleanup of oils, chemicals

Conwed Environmental Products, Riverside, N.J., says their sorbent blankets unroll easily to provide rapid cleanup of large volume oil and chemical spills. In a recent test, the blanket picked up 22 times its weight in No. 2 diesel fuel in 18 seconds. Though designed for bulk use, the blanket can be cut for smaller sizes and specific shapes. The blankets measure 36 inches wide in 150 foot lengths and can absorb up to 900 pounds (112 gallons) of oil. Biodegradable polypropylene netting provides durability and strength for easy handling, says the company.

Write in 707 for more information
Aboveground tank fits small areas
Aero-Power Unitized Fueler, Inc., Smithtown, N.Y., says their two new tank models take up only 18 or 21 square feet of space. Both have secondary containment and overflow protection. They store heating oil, lube oil, motor fuel, waste oil or waste solvents and are equipped with a hatch to allow filling from portable containers.
Write in 708 for more information

Computerized trailer extracts hydrocarbons from soils, water
Continental Recovery Systems, Wellesley, Mass., introduces the latest version of the Automatic SoilVent Trailer™, a self-contained, microprocessor-controlled system that uses high vacuum extraction and carbon adsorption to remove hydrocarbons, solvents and petroleum products from low-permeability soils and groundwater.
The system produces clean soil and water, and recovers recyclable organics without releasing volatile organic compounds into the environment. The trailer also regenerates carbon on site, the company says. Remote monitoring allows for 24 hour operation. The oxygen added to the soil enhances bioremediation. And, the system eliminates the need to dispose of contaminated media.
Write in 709 for more information

Tanknology keeps eye on tanks
Tanknology Environmental, Inc., Houston, Texas, has a new Continuous Monitoring System for aboveground tanks based on fiber optic sensing. They also have Sirplus™, a new monitoring system for underground tanks that combines statistical inventory reconciliation with automatic tank level monitoring.
Write in 710 for more information

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<tr>
<td>PCBs</td>
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<tr>
<td>Total Petroleum Hydrocarbons</td>
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<td>PCP</td>
<td>5 ppb-50 ppm</td>
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<tr>
<td>PAHs†</td>
<td>1-100 ppm</td>
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</tbody>
</table>

† Not an SW 846 Series 4000 method.

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Work Group Committee for Inclusion into SW-846.

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34 May 1993 Soils
Line leak probe passes toughest tests

Tidel Engineering, Inc., Carrollton, Texas, says their newest product line leak detection probe has undergone the extremes of testing—both the three GPH hourly test and the 0.1 GPH annual tightness testing specs of the EPA. The EMS-3500 can perform a variety of monitoring applications: automatic tank gauging, monitoring wells, interstitial monitoring of double wall tanks, reservoirs, and sumps. Write in 711 for more information.

Art’s scores vapor points

Art’s Manufacturing & Supply, American Falls, Idaho, announces their gas vapor probe system has received a patent on vapor points. The newly patented Retract-a-Tip and dedicated points in the vapor probe system can take gas vapor samples around underground tanks, landfills or in areas of shallow groundwater. It can be manually driven or power driven, and is extendible to get to the depth you need, says the company. Write in 712 for more information.

New portable magnetometer finds buried ferrous objects

EG&G Geometrics, Inc., Sunnyvale, Calif., introduces a new portable cesium magnetometer, a modified version of ferrous object and ordnance locators built for the U.S. Navy. The G-822L is a sensitive, continuous-reading, total field magnetometer, designed for magnetic searches for buried drums and tanks, well heads and pipelines. The continuous-reading feature allows a walking individual to survey five times faster than with interval-reading models. Magnetic readings are provided 10 times per second for automatic data storage through an RS-232 port interfaced to an external computer. Software is also available. Write in 713 for more information.

Ben Meadows Co. brings new product line from Europe

Ben Meadows Co., Atlanta, Ga. announces the full line of Eijkelkamp augers and soil samplers is now available. The line includes a complete selection of one and two piece augers made of forged steel. The sampling kits include all necessary components for field work. Write in 714 for more information.
Quick Takes

• J.J. Keller & Associates, Inc., Neenah, Wisc., introduces a basic guide to environmental compliance to issues and regulations in EPA, OSHA and DOT. The 500-page, 3-ring bound manual covers Underground Storage Tanks, Worker Right To Know, HAZWOPER, Plant Safety, Storm Water, Hazardous Waste, Clear Air and other issues. It includes a directory of state agencies and phone numbers. For more information, call 1-800-327-6868.

• The North American Thermal Soil Recycling Association, Lorton, Va., announces the appointment of Donald Adams as executive director. NATSRA’s headquarters have moved to the Washington D.C. area. For membership information, their new address is Box 1468, Lorton, Va. 22199. Phone 703-643-9619.

• Wynn Associates, Chatsworth, Calif., forms a full service consulting group specializing in thermal desorption. The group provides consulting services to contractors, manufacturers and generators. They have identified an extensive list of sites that need thermal desorption treatment. For more information, call 818-709-9966.


• Millgard Environmental Corp., Livonia, Mich., receives the 1993 NOVA award for their MecTool® system. NOVA awards recognize innovations that improve the quality, safety and cost-efficiency of construction.

• Geraghty & Miller, Plainview, N.Y., announces that its joint venture, Alternative Remedial Technologies, Inc., (ART) of Tampa, Fla., has been selected to perform the first full scale soil washing project in the U.S. ART is a joint venture between Geraghty & Miller and Heidenij, of Arnhem, The Netherlands. The $10 million project is site in Winslow Township, N.J.

conductor cable and lowering it into a borehole filled with drilling fluid. An electric current is forced to flow from these electrodes to other electrodes that may be in the borehole or placed in the ground near the well top. The logging instrument then measures the current loss between the two electrodes. Changes in electrical resistance of the entire circuit are recorded against depth to produce an E log graph or curve as in figure four, page 39.

An E log should be run on all pumping wells to ensure proper well design and to act as a permanent record of the well. Many states require an E log to be run on all pumping wells, and some states require them on all wells. E logs can only be done in boreholes that do not have casing and are filled with drilling fluid or water.

Gamma logs are measurements of naturally occurring radiation emitting from the materials encountered in the borehole. Unlike the E log procedure, a gamma log can be run in cased, dry holes. Gamma radiation is emitted from certain elements in rocks and minerals that are unstable and decay spontaneously into other, more stable elements. Clays and shales contain high concentrations of radioactive isotopes, usually potassium. Sands and gravels, however, contain silica, a stable mineral, and emit low levels of radiation. Likewise, limestone and dolomite also emit little radiation.

A gamma probe consists of a scintillation-type receiver and counting circuit. Radiation intensity is measured by the number of pulses detected by the instruments per unit of time (usually expressed as counts per minute). No surface lines or stakes are required. All the equipment is contained in the logger and probe.

One factor in gamma logging occurs when sands include a high proportion of feldspar grains. Unlike quartz, feldspars contain potassium and radioactive potassium-40. A feldspar rich sand emits gamma rays at an intensity similar to that of clay. This should be considered when logging in glacial till deposits or near igneous source rocks.

Knowledge of local geology is important to interpret logs in such areas. Costs for E logging a borehole can range from $1,500 to $2,000 per job. Gamma logging costs range from $1,000 to $1,500 per job. Portable E logging and gamma logging equipment range in cost from $5,000 to $10,000.

Aquifer tests
While costly, an aquifer test is the best way to understand how the aquifer will respond under pumping conditions. The costly part is disposing of contaminated water pumped at a contaminated site where the produced water must be stored, tested and permitted prior to disposal.

There are less expensive ways to estimate aquifer characteristics once a monitoring well has been completed. One common method is to perform a slug test. This test employs the instantaneous displacement of the static

Continues on page 38→
Figure two: Grain size distribution curves

Geologic assessment, from page 37

water level within a well by either injecting or withdrawing a known volume (slug) of water and measuring the response with a pressure transducer and data logger. The data is then plotted on a curve which is matched to a type curve to estimate hydraulic conductivity value. Judgement does enter in when conducting the test because whether the slug is injected or withdrawn depends on the way the well has been constructed within the aquifer. In addition, corrections may be needed for sand filter effects in some wells. This test is most applicable to zones of low conductivity. Zones of high permeability should be tested by pumping or recovery test.

Other cost-effective lab tests

There are many inexpensive lab tests that can aid the field geologist to estimate how much soil it will take to immobilize a contaminant spill of a given volume, how far a contaminant will travel and how much contaminant can be recovered from the subsurface.

Permeability tests can be run on core samples with a simple flow tube type permeameter. Permeability and hydraulic conductivity can be estimated using different fluid types or by using nitrogen gas to estimate air permeability, which is useful in soil ventilation design.

Both the contaminant movement rate and the absorption capacity of porous media are influenced by the volume and characteristics of the contaminant lost to the subsurface, the total porosity of the sediment and the residual water saturation (moisture content) retained in the pore space.

The oil industry has thoroughly studied the simultaneous flow of mixtures of liquids and/or gases to ensure maximum recovery from producing oilfields. These flow studies have demonstrated relationships between the saturation of the pore space and the relative permeability to specific fluids. Simply, they imply that as one phase (water) increasingly fills pores, the flow of the other phases (gasoline and air) is restricted.
accordingly. Generally, a contaminant such as gasoline travels quicker and is retained in greater volumes if the porous medium it is travelling through is dry. As water saturations increase, the available space to be occupied by gasoline decreases and the capacity of the soil to absorb gasoline decreases, since most of the grains are coated with films of water which gasoline cannot replace. For these reasons, a body of gasoline which has infiltrated into a semi-saturated soil is expected to migrate further than one that entered a dry medium, yet at a reduced migration velocity.

The volume of porous medium required to immobilize a volume of gasoline can be estimated from the following relationship:

\[ V_{medium} = \frac{V_{oil}}{n \cdot S_o} \]

where, \( V_{oil} \) = volume of gas lost
\( n \) = porosity
\( S_o \) = residual gas saturation

Porosity and residual gas saturation can both be easily obtained by analysis of core samples at a qualified lab.

Mineral analysis of groundwater

If a remediation system is going to involve pumping and treating of contaminated groundwater, it is always advisable to run a mineral analysis on a few water samples from around the site. A standard mineral analysis will show whether or not to expect fouling problems in air-stripping towers due to calcium or magnesium carbonate deposition, iron fouling or buildup in the pumping well—or a host of other mineral related problems that may require treatment or consideration in the engineering design.

If bioremediation is a considered alternative, nitrogen and phosphorus concentrations will need to be known as well as a plate count of bacterial species present in the groundwater. Typical cost for a total minerals analysis is around $450 per sample.

While it is true that geology is an interpretive science, there is no room for speculation at contaminated sites. Good geologic assessment is based on industry accepted data. The old adage, “do it right the first time,” certainly applies to geologic assessments.

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<tr>
<td>Casing</td>
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<tr>
<td>Dry sand</td>
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<tr>
<td>Sand with fresh water</td>
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<tr>
<td>Clay</td>
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<tr>
<td>Clayey sand with fresh water</td>
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<tr>
<td>Sand with brackish water</td>
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<tr>
<td>Clayey sand with salt water</td>
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<tr>
<td>Sand with salt water</td>
<td></td>
</tr>
</tbody>
</table>

Figure four: Electric log curve

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40 May 1993 Soils
Rollins Environmental Services, Wilmington, Del., says their Rotary Reactor functions like a fluidized bed combustor with a bed of sand which serves as a heat sink to improve mass transfer between incoming contaminated soils and the oxygen in the combustion gases. This combination leads to high destruction efficiencies at lower operating temperatures. The kiln rotates at two to five revolutions per minute, and is equipped with internal flights to enhance mixing. Soils are fed through the front wall directly into the sand bed, where accelerated heat transfer raises the soil temperature to combustion level almost immediately. The external helixes are conduits for recirculating the sand from the discharge end of the chamber back to the inlet end. They operate on the principle of an Archimedes screw. The incinerator operates at 1,200 to 1,600°F depending on contaminant characteristics. Heat released during combustion is transferred back to the sand for reuse. Sludge wastes are fed via a series of positive displacement piston pumps and pipelines to a non-atomizing lance which penetrates the front wall. Solids are shredded and discharged into feed screw conveyors which meter and move the materials to the final feed screw conveyor which discharges into the chamber. Liquid materials are pumped directly into the chamber. An afterburner chamber subjects flue gases to a minimum two seconds residence time at a temperature of at least 2,000°F, then flow to a saturator where water reduces bulk temperature to around 190°F. Then they enter a venturi scrubber where acid gases and particulate matter are removed. Flue gases leaving the scrubber are discharged to the atmosphere. The permitted capacity of the unit is six tons per hour, although the unit is capable of higher throughput rates, says the company.

Write in 703 for more information.
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May 1993 Soils 43
Cedarapids, Inc., of Cedarapids, Iowa decided to do something about the most underrated phase of thermal remediation—upstream, initial material handling problems. In most cases, petroleum contaminated soils are wet, sticky and loaded with debris—chunks of metal, rock, concrete, asphalt, wood, etc. The company says their Soil Pre-Conditioning unit (SPC) can handle virtually any solid feed material problems in a three stage, closed loop process. This pre conditioning step enables thermal treatment to proceed, eliminates multiple handling steps, extra equipment and personnel that often add time and expense to treatment operations, says Cedarapids. In stage one of the process, soil is scalped through a hydraulic tipping grizzly section. Soil passing the grizzly enters the feed hopper, which has steep sides to promote flow of highly plastic soils. The material is drawn out of the hopper and sliced on a variable speed, bar chain drag slat feeder. Material passes through an electronic metal detector. As metals are detected, operations stop automatically so tramp metals can be removed. Stage two consists of an inclined single deck screen to separate oversized from sized particles. Material passing this screen goes into a surge hopper and is fed by a bar chain feeder to the thermal processor. Oversize material drops to a reversible cross conveyor which gives the operator the choice of rejecting oversize particles or sending them on to stage three. Stage three is an impact mill equipped with air blasters that can shred clay or crush solids such as rock. Discharged material from the crusher falls on the original gathering conveyor to be returned to the sizing screen for final separation. The unit is mobile and provides a steady flow of preconditioned soil to any thermal processing unit. Write in 704 for more information.
I hope you’ve noticed I am running more articles about the state assurance funds. Everybody seems to be intensely interested in money matters in this business—as in every other business. In this issue, for example, the money article (page 14) reveals the inside secrets of the Iowa fund, widely regarded as one of the most successful in the nation.

Little wonder the financial aspects of the soil remediation industry get the glare of everyone’s scrutiny—the latest estimates indicate costs to remediate soils contaminated with petroleum products from leaking tanks could soar to $41 billion (with a “b”) before all the dirt is clean.

While there is a great deal of focus on the direct costs of cleanups, there are indirect costs that do not always get as much consideration. According to Jenifer Heath, risk assessment practice associate for Woodward-Clyde Consultants in Denver, Colo., the negative financial stain of a contaminated site can spread to the neighbors, the local government and lending community as well.

Neighbors to a contaminated site may see their property values wobble due to concerns about the contamination. As property values drop, so do property tax revenues, always a matter of concern to local governments. “Lenders may also suffer, both because foreclosure values decrease with property value, and because as real estate transfers in the area slow, so does mortgage interest income potential,” explains Heath.

“Particularly in urban areas, UST-related contamination can initiate a cycle that results in abandoned properties, decreased property values, depleted trust funds and decreased tax revenues,” Heath says.

Too often, perceived health risks of petroleum contaminated soils are not realistic—people panic, assume the worst, and unnecessarily feed this downward financial spiral.

It is up to site owners and their consultants take steps to mitigate these destructive community perceptions—for everyone’s benefit. Heath suggests:

- Investigations of UST-related contamination should be focused and cost effective.
- Parties should insist that cleanup decisions be based on real risk reduction rather than routine application of generic standards.
- Parties should take proactive steps to help local media understand UST-related risks, so that low risk sites are not unjustly saddled with scary images and negative reputations.

- Parties must work together to identify and promptly address cleanup goals that reflect likely future land and groundwater use at the site and on adjacent properties.
- Parties can encourage recognition of the productive role of passive bioremediation for UST-related contamination.

I think those in the industry who are responsible for petroleum storage and the environmental consultants who deal with the problem every day can easily lose sight of the fact that, to vast majorities of the population, the problems caused by leaking underground tanks are largely unknown or poorly understood. Public perception of “environmental problems” generally includes an element of fear—as well it should. Fear that is based on fact motivates the changes we need to solve the problems. However, fear that is based on lack of information or misunderstanding can be destructive.

All of us need to be attentive to our responsibility to continue to educate neighbors, lenders, real estate agents, lawyers and the media about the particular causes and cures for petroleum contaminated soils. This responsibility gets the best results when it is planned in advance. That may mean something as simple as preparation of an information sheet to be mailed to the affected community. It may mean scheduling of a meeting or two to inform and hear from interested parties. It might include some time spent with reporters to explain the situation and the action plan. All this is better than waiting for concerned neighbors to show up on your doorstep demanding answers—and is certainly better than images of yourself stammering defensively into a microphone on the six o’clock news.”

“All this is certainly better than images of yourself stammering defensively into a microphone on the six o’clock news.”

By Susan Parker

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