STATE OF CALIFORNIA
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SAN FRANCISCO BAY REGION

STAFF SUMMARY REPORT (Roger Papler)
MEETING DATE: October 10, 2018

ITEM: **7C**

SUBJECT: **Advances in Investigation Technologies at Sites Contaminated with Volatile Organic Compounds –** Status Report

DISCUSSION: This status report (Appendix A) provides an overview of advances in technologies used to investigate sites contaminated with volatile organic compounds (VOCs). The report focuses on VOCs because they are the most common contaminant class at the sites we oversee. VOCs also tend to be very toxic and difficult to clean up. A followup status report will cover advances in technologies used to cleanup VOC sites.

When the Board's site cleanup programs were getting started in the early 1980s, investigation tools were fairly primitive. From the 1990s to the present, investigation technologies have gradually evolved as new technologies were invented and as we learned more about how contaminants travel. For example, subsurface contaminants take the path of least resistance through buried stream channels, coarse-grained layers, and backfill for underground utilities. Conventional investigation technologies may not identify significant areas of contamination due to non-uniform underground conditions.

Newer high-resolution investigation technologies increase the accuracy and resolution of investigations. This can lead to greater certainty that a site's pollution is characterized, which then often leads to faster and more efficient cleanup. A limitation of high-resolution methods is that they may increase the cost of the investigation in the short-term, and they do not always result in faster or more effective cleanup.

Under the Water Code, the choice of investigation methods is up to the discharger. We can encourage – but cannot require – high-resolution site characterization. We will continue to make dischargers aware of their investigation options and encourage them to use high-resolution methods where appropriate.

RECOMMEN-DATION: This is an information item only and no action is necessary.

APPENDIX A: Status Report

APPENDIX A

STATUS REPORT

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SAN FRANCISCO BAY REGION

Status Report

Advances in Investigation Technologies at Sites Contaminated with Volatile Organic Compounds

This status report provides an overview of advances in investigation technologies used at sites contaminated with volatile organic compounds (VOCs). The report focuses on VOCs because they are the most common contaminant class at the sites we oversee. VOCs also tend to be more toxic and more difficult to clean up. A followup status report will cover advances in cleanup technologies used at VOC sites.

Background

When widespread soil and groundwater contamination was initially detected in our Region in the early 1980s, the site cleanup programs borrowed tools to investigate contaminated sites from other sectors: soil borings from the geotechnical sector and groundwater monitoring wells from the water-supply sector. From the 1990s to the present, investigation technologies have gradually evolved both as new technologies were invented and as we learned more about how contaminants travel. For example, contaminants migrating in soil and groundwater take the path of least resistance through buried stream channels, coarse-grained layers, and backfill for underground utilities. Conventional investigation technologies may miss identifying significant areas of contamination due to non-uniform underground conditions.

A conventional investigation would typically begin by collecting soil samples near an expected pollution source. Soil sampling would progress outward from the source until the extent of soil contamination was defined. Groundwater monitoring wells would be installed downgradient from the source. Groundwater monitoring well installation would progress downgradient until the extent of groundwater contamination was defined. The site investigation would define the extent and magnitude of contamination. This information would be used to evaluate a site’s risk and to craft a cleanup strategy.

Most of the contaminated sites in our Region involve chlorinated solvents or fuels, both of which are VOCs. But we also have contaminated sites with metals, semi-volatiles (such as naphthalene), and pesticides. Different contaminant classes behave differently in the subsurface, and site investigation methods must be selected to match the contaminant class (e.g., metals generally do not migrate far in soil, so groundwater monitoring is often not needed).

Investigation Technologies

The following table lists some of the more common investigation technologies with the parameters they measure. The table is separated into conventional and high-resolution technologies. The differences between conventional and high resolution are described in subsequent sections.

Investigation Technologies for Characterizing Sites				
Technology	**Geology**	**Chemistry**		
		Soil Gas	**Groundwater**	**Soil**
Conventional				
Soil Gas Sampling		X	X	
Soil Sampling	X			X
Groundwater Sampling			X	
High Resolution				
Direct Push Logging	X	X	X	X
NAPL presence			X	X
Chemical screening		X	X	X

Note: NAPL = nonaqueous phase liquid (occurs when a VOC exists in soil or groundwater at a high enough concentration such that a portion of the VOC exists as pure, undissolved product)

Conventional Investigation Technologies

These technologies are referred to as conventional because they have been in use since the 1980s, they are the foundation of most site investigations, and they are still in use today:

Soil Gas Sampling
Soil gas is the gas present around soil particles above the shallow water table. When contaminated soil gas travels up into a building, it is known as vapor intrusion. A recent status report to the Board covered vapor intrusion. To sample soil gas, a hollow probe and tip connected to tubing is driven into the subsurface. A vacuum is applied to the tubing to withdraw soil gas. Soil gas surveys are performed to identify source areas, measure soil gas concentrations, track groundwater contamination, and delineate the lateral and vertical extent of VOCs.

Soil Sampling
A split tube is advanced into the soil to collect a soil sample. Upon retrieval, the soil samples are inspected and characterized in the field for geology parameters. The soil samples may be either screened with field instruments for qualitative contaminate levels or sent to a laboratory for chemical analysis. Soil sampling may be conducted by either collecting samples from predetermined depths or by using very frequent vertical screening of soil cores to select samples for analysis.

Groundwater Sampling
Truck-mounted drilling equipment, known as drill rigs, are used to drill into the ground and collect groundwater samples.

Hollow Stem Auger: This type of drill rig rotates a hollow screw, or auger, into the ground. The auger spirals cuttings up to the surface. Groundwater samples may be collected through the hollow space inside the auger, and a permanent groundwater monitoring well may be installed within the boring.

Mud Rotary or Air Rotary: This type of drill rig advances a rapidly rotating, hollow bit that grinds its way down into the subsurface. Drilling mud or air is forced down through the hollow drill stem and flushes the cuttings up to the surface outside the drilling stem. A permanent groundwater monitoring well is then installed within the boring. Sonic drilling is a variation on rotary drilling where a high frequency, vibrating, up and down force is added to the rotary head as it is pushed into the ground.

Challenges with Conventional Investigation Technologies

Conventional investigation technologies have the following challenges:

Inadequate Scale of Measurement - The underground flow paths for soil and groundwater pollution often change within small distances due to ancient, meandering buried stream channels that created the underground aquifers we encounter today. The scale of measurement, or distance between samples, for conventional soil and groundwater samples is often greater than what is needed to characterize these underground flow paths. For example, groundwater monitoring wells are sometimes spaced tens of meters apart. Underground flow paths can be variable and change on the scale of one meter. Further, chlorinated solvents are heavier than water and can sink to the bottom of an aquifer or attach to clay particles. These factors can lead to an inadequate scale of measurement for conventional investigation technologies. This leads to an incomplete characterization of the pollution, which in turn can lead to an ineffective cleanup.

High Cost for Adequate Data Density - Because of the potential variability in underground flow paths for pollution, a higher density of horizontal and vertical sample spacing may be needed. Using conventional investigation technologies, such high-density sample spacing would not be cost effective.

Lack of Real-time Data - Conventional investigation technologies yield samples that must be sent offsite to certified laboratories. Usually several weeks pass before the sample results are available. This causes a lack of immediate, or real-time, data. During an investigation, real-time data is helpful to immediately move subsequent sampling to the most advantageous locations.

Advances in Investigation Technologies

Over the last 20 years, there have been advances in investigation technologies that have enabled an increase in the accuracy and resolution of investigations. High-resolution site characterization is the term used to describe these types of investigations. High-resolution site characterization usually has the following attributes:

- Scale-appropriate measurement and sample density to define contaminant distributions and physical context
- Real-time measurement technologies such as direct-sensing tools
- Confirmation sampling with conventional investigation technologies
- Greater certainty that the pollution is fully characterized
- Often leads to faster and more effective cleanup

High-Resolution Investigation Technologies

The following technologies are examples of high-resolution investigation technologies:

Direct Push Logging
Direct push is a type of drill rig that uses the weight of the rig and a hydraulic system to push a sampling device or a direct-sensing detector into the ground. The sampling device can collect samples for soil gas, groundwater, or soil. The sensor can determine parameters such as soil type or contaminant level. A direct-push drill rig is considered a high-resolution investigation technology because it can provide continuous readings of geologic parameters or contamination levels as the sensor is pushed into the ground. It also has the benefit of rapidly collecting the data so that more sample locations may be investigated than conventional technologies in the same amount of time.

Nonaqueous Phase Liquid (NAPL) Presence
When a VOC is present in soil or groundwater as pure, undissolved product, it is referred to as NAPL. If NAPL is present at a site, it can significantly lengthen the time needed for cleanup. A technology referred to as *DyeLIF (dye-based laser-induced fluorescence)* has recently been developed to detect chlorinated VOCs that are present as NAPL. This tool delivers pulses of laser light into the ground via fiber optic cable. The tool measures the wavelength and intensity of the fluorescence produced by the light hitting the NAPL and dye. This tool can be used with a direct-push drill rig to get rapid, high-resolution characterization of NAPL.

Chemical Screening
Chemical screening technologies provide quicker, semi-quantitative or qualitative indicators of contaminant levels. A good example is the *membrane interface probe, or MIP*. A MIP is a steel probe about the size of a white-board marker. The probe is pushed into the ground by a direct-push drill rig. The tip of the probe is heated and causes any soil and groundwater pollution detected to volatilize. The volatiles are then drawn into the probe through a screen where they are pumped to the surface. The volatile chemicals are then immediately and continuously analyzed at the drilling location. The continuous analytical results are then plotted on logs to create a real-time picture of the magnitude of pollution versus depth.

A MIP may be used in combination with other types of direct-sensing detectors such as soil type (e.g., clay, silt, sand, gravel). The soil-type log is then placed next to the MIP-generated pollution log to get a real-time picture of how and where pollution is migrating in soil and groundwater.

The results from direct-sensing tools such as a MIP are semiquantitative in that they provide a relative magnitude of the level of the constituent. After a sufficient number of MIP logs at different site locations are generated, conventional investigation technologies are used for confirmation sampling of soil and groundwater concentrations at fewer, more focused locations.

<u>Advantages of MIP</u>
A MIP brings an increased resolution to the investigation because it provides a continuous vertical log of the pollution as it's detected instead of the typical resolution of conventional investigation technology of a sample every five feet. A MIP also enables shorter horizontal spacing between boring locations because a MIP is advanced faster in the subsurface, which allows for more drilling locations. The increased resolution in the investigation leads to greater

certainty that the pollution is characterized, which then leads to faster and more effective cleanup. This in turn can lead to lower total costs over the life of the cleanup.

The real-time data available from a MIP is helpful for immediately directing where to locate subsequent drilling and sampling. Several MIP logs can be placed side by side while drilling is ongoing to get an instantaneous picture of the pollution in the subsurface.

MIP investigations may be combined with the results of the early stages of an investigation to more accurately characterize the levels and extent of pollution detected and to identify locations for subsequent permanent monitoring wells. MIP investigations may also be beneficial at sites where mature investigations that have been completed but where the cleanup is not progressing as quickly as expected. At such sites, high-concentration areas and underground flow paths for soil and groundwater pollution may have been missed by prior lower-resolution conventional investigations.

Limitations of MIP

In the short-term, MIP investigations increase the cost of the investigation. The MIP equipment is more expensive to operate than conventional investigation technologies. MIP operators need to have additional training and experience. MIP results are in relative-magnitude concentrations so these results still need to be confirmed by a separate drill rig using conventional soil and groundwater sampling technologies to precisely quantify pollution levels.

The MIP is advanced into the subsurface using direct-push drill rigs. This approach is limited in the depth of the subsurface it can investigate due to difficulties in pushing a MIP into dense gravels and larger rocks.

Despite MIP investigation technology being well developed for the last 15 years, it has only been used at a small percentage of the sites we oversee because of the above-mentioned limitations.

Conclusion

There have been significant advances in investigation technologies since we started overseeing the cleanup of contaminated soil and groundwater in the 1980s. Newer methods allow us to form a more accurate picture of how contaminants are distributed and how they might be most efficiently cleaned up. High-resolution site characterization can result in shorter cleanup times and more cost-effective cleanup. Under the Water Code, the choice of investigation methods is up to the discharger. We can encourage – but cannot require – high-resolution site characterization. We will continue to make dischargers aware of their investigation options and encourage them to use the high-resolution methods where appropriate.

Resources

The following documents provide more detailed information about site investigation technologies:

- ITRC's 2015 Guidance Document titled *Integrated DNAPL Site Characterization and Tools Selection*
http://www.itrcweb.org/DNAPL-ISC_tools-selection/Content/Resources/DNAPLPDF.pdf

- CLU-IN website on High-Resolution Site Characterization
https://clu-in.org/characterization/technologies/hrsc/

- CLU-IN website on Membrane Interface Probe (MIP)
https://clu-in.org/characterization/technologies/mip.cfm

- PowerPoint slides from presentation on Utilizing the Membrane Interface Probe (MIP) from the 2012 conference of the State Coalition for Remediation of Drycleaners, 28 slides
https://drycleancoalition.org/docs/2012_meeting/Tues_4_Linn.pdf

- Geoprobe website on MIP including principles of operation, the MIP log, equipment
http://geoprobe.com/mip-membrane-interface-probe