

# UPDATE

STONE ENVIRONMENTAL NEWS ON RAPID ADAPTIVE SITE CHARACTERIZATION



FALL 1999

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## What is RASC?

Rapid Adaptive Site Characterization (RASC) is a more detailed and accurate way to characterize contaminant distributions than conventional methods, yet it typically costs half as much and takes far less time than a conventional investigation.

"Last time I checked, a conventional Superfund remedial investigation cost \$1.2–\$1.5 million. A comparable RASC investigation costs half that much, and other types of projects can be as little as a few thousand dollars," said Seth Pitkin, RASC group leader.

RASC yields a better understanding of the problem more quickly because it uses real-time spatial variability data—of contaminants, hydraulic conductivity, and soil strata—to continually adapt the sampling plan and iteratively hone in on what is happening underground. (For more information on

spatial variability, see below.)

Conventional approaches use fixed sampling points that can be too far apart to capture the significant changes in concentrations that can occur in just centimeters. "So they do a lot of interpolating, while we're taking actual measurements," Pitkin said. "With RASC, you spend your resources focusing on where the problem is, rather than where the problem isn't. And you do it in a scale-appropriate manner."

For example, the Air Force Base Closure Agency hired Pitkin and his team in 1996 to do a site characterization for potassium permanganate field trials at Pease Air Force Base. "Although everybody knew that DNAPL must be present, the conventional investigation was unable to find it, despite the fact that they did a perfectly good job—whereas we were able to determine the

location of DNAPL within several weeks of being in the field," Pitkin said. "Our sampling was more detailed—we collected samples on a closer vertical spacing because of the variability in concentration. And because of our unique sampling technique, we didn't lose the contaminant from the sample during handling. The conventional technique resulted in a lot of contaminant loss, so the DNAPL wasn't detected," Pitkin added.

RASC can also help save money during remediation. "If you don't fully understand the problem, the remedy you select may not be appropriate. It may not work very well and it may cost a lot more than it needs to," said Pitkin.

The SEI RASC team uses a customized approach for each project. However, there are three major technology innovations we frequently use:

- The direct push Waterloo Profiler, which allows rapid point sampling

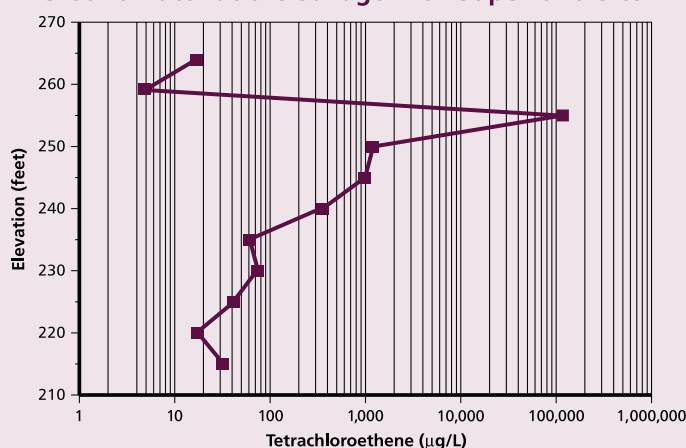
(see RASC, page 3)

## Spatial Variability: The Key to Site Characterization

Research done in the 1980s determined that hydrodynamic dispersion, or mixing, is very weak in groundwater. So when contaminant concentrations are high, they tend to stay high and they don't even out vertically or horizontally.

What does this mean for site characterization? The concentration gradients can be very steep and there can be changes of an order of magnitude or more in distances as small as 20 cm. "I've seen contaminants go from nondetect to over 100,000 parts per billion within 5 feet," said RASC Group Leader Seth Pitkin. "Because these drastic changes can take place over such small distances, conventional monitoring wells with 10-foot-long screens provide samples that yield average concentrations skewed

**Tetrachloroethene Concentration Profile in Groundwater at the Savage Well Superfund Site**



toward the higher hydraulic conductivity zones—they don't reflect what's really going on."

Because conventional monitoring wells are fairly expensive, and

(see Variability, page 3)

## Gas Drive Pump Overcomes Suction Limitation

The peristaltic pump used with the Waterloo Profiler has a suction limitation of 27 feet, which is deep enough for many hazardous waste sites. For those sites where the water table is deeper, Bob Ingleton, senior technician at the University of Waterloo, pioneered a gas drive pump that pushes water up from the bottom of the Profiler. At SEI, we designed our own pump, based on Ingleton's work, and are the first commercial concern to use a gas drive pump with the Waterloo Profiler to take samples where the water table is deeper than 27 feet.

The profiler has a small cylindrical reservoir with a check valve at the bottom of the rod. One tube connects to the top of the reservoir; another tube extends the full length of the reservoir and opens next to the check valve. The hydraulic head in the aquifer forces water through the check valve into the reservoir. We let the reservoir fill, then open a valve at the surface and push compressed nitrogen through the shorter tube. This forces the water to exit the reservoir through the longer tube, without bubbling. Since nitrogen is inert, it doesn't react with contaminants. SEI first used this pump in May of 1998. Since then, we've collected over 500 groundwater samples using this technique. ☞

## Direct Push Plumbs New Depths

### SEI Goes to 177 Feet

As part of a groundwater profiling demonstration at Otis Air National Guard Base on Cape Cod, Mass., the RASC team was able to advance the Waterloo Profiler to a new company record of 177 feet. The secret to the new record was the use of the SEI drive platform, which is a modified Mobile B-57 drill rig that has the capacity to perform both rotary and direct push techniques. This full-size drill rig can turn conventional hollow stem augers to depths of 100 feet. Typically, direct push rigs do not provide augering capability and, if they do, the rotary torque is only for light-duty applications.

The SEI rig also has an exceptionally powerful hydraulic hammer that rams 550 ft-lb of force per blow at a rate of 1,000 blows per minute. In contrast, standard GeoProbe® hammers provide only 175 ft-lb per blow. The SEI hammer, along with the down-pressure and retraction force of the B-57, allows for routine depth penetrations of 70–100 feet.

The Otis ANGB site has proven to be very difficult terrain for direct push rigs. The RASC team advanced hollow stem augers through the unsaturated soils to the water table at 60 feet below ground level. Then they placed the profiler inside the augers to begin direct push sampling. They collected 12 groundwater samples over the next 117 feet, along with a full index of hydraulic conductivity profile (KPRO). At 165', they encountered a dense silt unit that was tough enough to cause a nearby rotosonic rig to stop and change its approach. The RASC team kept drilling until 177', where they were finally stopped by the dense layer.

As the SEI team pulled the Profiler out, they were able to retraction-grout the hole with clay slurry, which protects the site from cross-contamination—another feature of the Waterloo Profiler. ☞

## Fast Field Lab Delivers Fixed-Lab Quality

Field laboratory results are no longer for screening use only. The SEI field lab replaces conventional sample preparation and concentration methods with Solid Phase Microextraction (SPME), followed by gas chromatography, for the analysis of a wide range of organic compounds. SPME delivers the same high quality as a fixed lab, but in minutes, instead of the days or weeks it takes to hear back from a conventional lab. Standard fixed-lab GC/MS analyses typically have 2-week turnaround times and cost \$130 per sample. Even with expedited turnaround times, which are considerably more expensive and require transportation to the lab, the results are furnished no sooner than the next day. The SPME field lab can analyze samples in 8–12 minutes for a fraction of the cost (as little as \$15 each). Using this new lab technique, our RASC team has reliable analytical data within minutes and can make immediate decisions about the course of an investigation.

The SPME field lab:

- works for water, soil, and air (or soil gas) samples
- dramatically shortens analysis times, from days to minutes
- matches fixed-lab accuracy for a fraction of the cost
- provides the resolution needed to quantitate a wide range of target compounds in a single run at ultratrace (low ppb) levels
- does not require toxic solvents
- does not need complicated instrumentation to concentrate volatile and semi-volatile compounds

### How SPME Works

The SPME sample preparation technique was developed 5 years ago by Dr. Janus Pawliszyn at the Chemistry Department of the University of Waterloo. It involves exposing a coated fused silica fiber,

either directly to the sample or to the headspace above the sample, for a known amount of time and allowing the analytes to adsorb onto the fiber. During this step, the sample can be stirred and/or heated to enhance the transfer of analytes to the adsorbent phase of the fiber. The fiber is then removed from the sample and placed into the heated injection port of a gas chromatograph (GC), where the analytes are thermally desorbed and transferred to the capillary column.

The SEI RASC team has been using SPME successfully for 4 years. A rigorous QA/QC program, which uses the guidelines set forth by the EPA SW846 800 methods, ensures the highest quality results.

The team recently completed a site investigation project in which 480 groundwater samples were analyzed using SPME, along with a Hewlett-Packard model 5890 GC equipped with dual injectors and flame ionization detectors. This dual configuration allowed for a complete analytical run time for two samples of approximately 12 minutes—including sample prepara-

tion, analysis, and reporting. The target analytes for this project included 18 volatile organic compounds ranging from light aliphatic compounds, such as vinyl chloride, to heavier aromatic compounds, such as 1,2,4-trichlorobenzene. On other RASC projects with shorter target analyte lists, the field lab has been able to report results within 8 minutes.

### Comparing SPME and Fixed-Lab Results

For QA/QC purposes, approximately 25% of the samples underwent confirmation analyses by conventional GC/MS fixed-lab techniques. One standard measure of the accuracy of a technique is the Relative Percent Difference (RPD) between its results and those of another standard technique. The EPA acceptance criterion for RPD is 30%. We achieved an average of 22%. A second measure is the correlation coefficient values for the two analyses. Our weighted average of 0.96 clearly demonstrates the reliability of this new field laboratory. ☞

### Confirmation Results for Samples Acquired from a Site Characterization Project in New Jersey

Compound Name	Relative Percent Difference (RPD)	Correlation Coefficient R <sup>2</sup>	# Sample Sets Compared
trans 1,2-dichloroethene	32	0.87	24
cis 1,2-dichloroethene	27	0.99	38
trichloroethene	19	0.99	19
tetrachloroethene	30	0.84	37
chlorobenzene	16	0.99	91
2-chlorotoluene	27	0.99	21
1,2-dichlorobenzene	16	0.94	79
1,2,4-trichlorobenzene	27	0.98	72
<b>Weighted Average</b>	<b>22</b>	<b>0.96</b>	<b>NA</b>

Note: The comparisons are based on samples having concentrations above the client-specified detection limit of 10 ppb. Method detection limits as low as 2 ppb were used throughout these analyses.

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# RASC Team Answers Questions Raised by Conventional Approach

*Determines Distribution of Contaminants at Ciba-Geigy Superfund Site, Toms River, New Jersey*

For nearly 15 years, Ciba Specialty Chemicals Corporation (formerly Ciba-Geigy) has conducted extensive conventional investigations of the geology, hydrology, and contaminant distributions at a Superfund Site in Toms River, New Jersey. Ciba currently operates a multi-million-dollar groundwater pumping and treatment system to effectively contain contaminants on-site. A sophisticated groundwater flow and transport model was developed by Ciba scientist Dr. Joseph Guarnaccia to serve as the basis for the evaluation of remedial options for contaminant source areas. The Ciba Corporate Remediation Services Team, led by Dr. Dave Williams, identified the need for additional data to resolve a key issue in their conceptual model for the site: whether contaminants in the aquifer below a clay aquitard were the result of contaminated groundwater spilling off the edges of the clay unit or whether contamination penetrated the clay as aqueous or non-aqueous phase material. The results of previous conventional investigations were inconclusive. Ciba engaged the SEI RASC team to undertake groundwater-quality profiling and on-site sample analysis to answer this question.

SEI completed the profiling in just 19 field weeks. The work comprised 54 profiles averaging 67 feet per profile, and on-site analysis of 549 groundwater samples using a solid phase microextraction technique. (For more information on SEI's field laboratory, see page 2.) We targeted 18 volatile organic compounds ranging from light aliphatic compounds, such as vinyl chloride, to heavier aromatic compounds, such as 1,2,4-trichlorobenzene. Compounds such as benzene and toluene, which are lighter than water, were included on the analyte list because they had been mixed with dense non-aqueous phase liquid (DNAPL) compounds and may have been carried below the water table. Field laboratory data were successfully validated against an on-site, client-run

analytical laboratory using standard protocols for VOCs.

We collected data on physico-chemical parameters (pH, ORP, specific conductance, dissolved oxygen, and temperature), the hydraulic head at each sample depth, and the real-time acquisition of an indicator of hydraulic conductivity (K) distributions. By tracking high and low K zones, we were able to identify the important aquitard unit(s) at each profile location and map the key geological features across the site. (For more information on K profiling, see page 4).

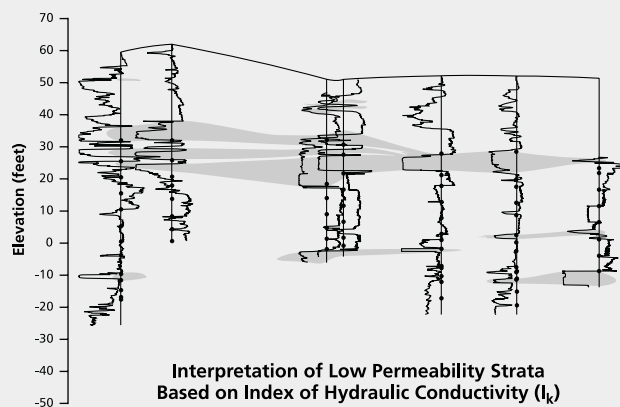
With this very detailed approach, we were able to observe DNAPL compound distributions that many would find counter-intuitive.

Usually DNAPL is assumed to pool above large, solid clay layers. But we often found higher concentrations immediately *under* the clay layer. We also were able to identify thin sand stringers within the clay unit. One such stringer proved to be a conduit for DNAPL compound migration along a very thin, well-defined path for several hundred feet in a direction perpendicular to the hydraulic gradient.

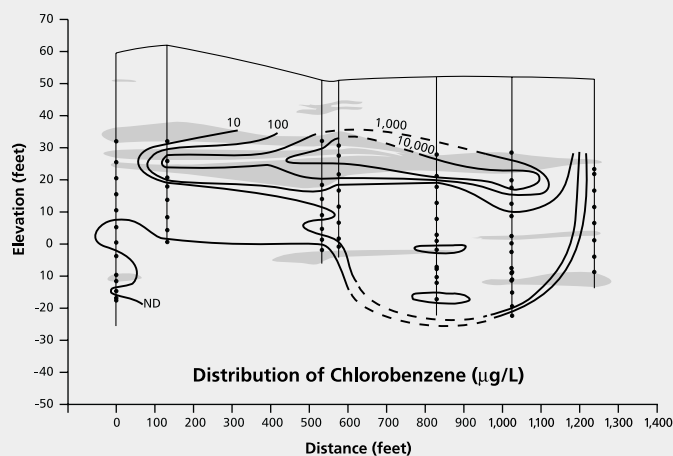
The information collected during the implementation of this project was useful to the client in validating the conceptual model for the site and in calibrating the contaminant transport model. The detailed information helped

(see Ciba, page 4)

## Using KPRO to Determine the Relationship Between Stratigraphy and Contaminant Distribution at the Ciba-Geigy Superfund Site



Interpretation of Low Permeability Strata Based on Index of Hydraulic Conductivity ( $I_k$ )



Distribution of Chlorobenzene ( $\mu\text{g/L}$ )

## RASC (continued from page 1)

at narrow depth intervals for more precise profiling than long-screen tools can achieve

■ KPRO, which provides a real-time index of hydraulic conductivity data that indicates the best depths for samples, rather than relying on pre-set intervals alone

■ The SPME field lab, which analyzes samples with fixed-lab quality in just minutes, enabling adjustments to the sampling plan in response to analytical results

Adaptive design is not a new concept—different scientists have applied it to various investigations over the years. The SPME lab and Waterloo Profiler were both developed at the University of Waterloo in Ontario, and SEI has added some improvements to them. But few firms have put it all together into one comprehensive service. “The U.S. Department of Energy does expedited site characterization,” said Pitkin. “There are one or two other firms doing it, but it’s still new, so not many people know about it yet.”

## Variability (continued from page 1)

they’re usually located based on educated guesses, they also tend to be spread quite far apart—hundreds of feet when the plume core may be only 30 or 40 feet wide.

The RASC team takes spatial variability into account when deciding where to collect samples and how many to collect. “It’s not unusual for our profile locations to be 15 to 30 feet apart. We have more sampling locations, but they still cost less than the conventional approach,” said Pitkin.

Typically, SEI starts sampling on the down-gradient face of the source area, and does a detailed transect of profile locations across it. This slice of where the contamination begins reveals two things: (1) how the contaminant source material is distributed within the source area and (2) where we should be looking for the plume further down-gradient.

By incorporating spatial variability into its RASC approach, SEI minimizes the money clients spend chasing the plume, and maximizes the information about where the actual source material is located.

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**Ciba** (continued from page 3)

with the development of a remedial strategy for perched groundwater management that was incorporated in the Draft Feasibility Study for the site, which was submitted to EPA in August. This strategy was developed after the information from the groundwater profiling project indicated the importance of the flow of contaminated perched water as a means of mass flux to the major shallow aquifer.

“During the course of the project, we were impressed by the spatially detailed information developed by the RASC team,” said Dan Pardieck, Ph.D., senior staff scientist, Ciba Specialty Chemicals. “The flexibility and responsiveness of the team in responding to results in almost ‘real time’ was important to us.

The field investigation was modified as our understanding of the site increased, which certainly was a cost-effective approach for us, relative to more traditional investigative approaches.”

For more information about the Waterloo Profiler, see the article “Field Demonstrations Using the Waterloo Ground Water Profiler,” Seth Pitkin et al., in the Spring 1999 issue of *Ground Water Monitoring & Remediation*, pp. 122–131.

## KPRO Adds Stratigraphy to Direct Push Profiling

Contaminants respond in different ways to different materials. For example, if the contaminant is gasoline, you know automatically that it is located in the upper portion of an aquifer. If it’s a DNAPL, you know its distribution is more complex. Since stratigraphy controls contaminant distribution, how can we find out more about the soil strata while we’re taking water samples?

While using water sampling tools, one typically wouldn’t have any idea what the soil types are. There are only two clues: how hard or easy it is for the tool to penetrate the layer, and how fast water comes through after you stop to take a sample. But neither of these tells you much.

What we’ve done at SEI is pioneer a way to see while we’re sampling how easily water can flow through the aquifer—or more accurately, whether the hydraulic conductivity is high or low. Using a direct push rig with a Waterloo Profiler, we’ve added an enhancement called KPRO (which comes from *K Profiling*) that measures the index of hydraulic conductivity in real time.

We push water down the tool with compressed nitrogen and measure the flow and pressure of the water at sampling depth, using a graphical software package that we developed to acquire, display, and save data instantly. It also

manages the data for later use in other software packages.

The field scientist monitors the index as the Waterloo Profiler is advanced and determines where samples need to be collected based on hydraulic conductivity (K) distributions. We have found that the interfaces between high and low K zones are often very important in determining how the contaminant mass is distributed. Where the K distributions are uniform, the sample spacing can be uniform (based on the degree of variability observed in previous

holes), but where significant low or high K zones are noted, additional samples are collected to assess the contaminant distributions and transport properties in more detail.

Then we take these data and import them directly into a software package called GMS (the US Department of Defense’s Groundwater Modeling System) to quickly create three-dimensional stratigraphic models. This helps us decide where to do any further sampling and determine the layers we need to concentrate on for the remedy. ☞

Comparison of Index of Conductivity Profile to Conventional Stratigraphy Soil Sample Log: Pease Air Force Base, Site 32

