

# **Environmental Management Science Program**

**Project ID Number 60199**

## **Seismic-Reflection and Ground Penetrating Radar for Environmental Site Characterization**

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### Research Objective

The project's goals are threefold:

1. To examine the complementary site-characterization capabilities of modern, three-component shallow-seismic techniques and ground-penetrating radar (GPR) methods at depths ranging from 2 to 8 m at an existing test site;
2. To demonstrate the usefulness of the two methods when used in concert to characterize, in three-dimensions, the cone of depression of a pumping well, which will serve as a proxy site for fluid-flow at an actual, polluted site; and
3. To use the site as an outdoor mesoscale laboratory to validate existing three-dimensional ground-penetrating radar and seismic-reflection computer models developed at the University of Kansas.

To do this, useful seismic and GPR data are being collected along the same line(s) and within the same depth range. The principal investigators selected a site in central Kansas as a primary location and, although the site itself is not environmentally sensitive, the location chosen offers particularly useful attributes for this research and will serve as a proxy site for areas that are contaminated. As part of an effort to evaluate the strengths of each method, we will repeat the seismic and GPR surveys on a seasonal basis to establish how the complementary information obtained varies over time. Because the water table fluctuates at this site on a seasonal basis, variations in the two types of data over time also can be observed. Such noninvasive in-situ methods of identifying and characterizing the hydrologic flow regimes at contaminated sites support the prospect of developing effective, cost-conscious cleanup strategies in the near future.

### Research Progress and Implications

As of the end of May 1998, the project is on schedule. The first field work was conducted using both of the geophysical survey methods in October of 1997, and the second field survey employed both methods in March of 1998. One of our stated tasks is to reoccupy the same survey line on a quarterly basis for two years to examine change in both the seismic reflection data and the ground-penetrating radar (GPR) data over time. Two factors drive these changes: First, the soil-moisture conditions vary on a seasonal basis at the site. Second, the water table rises and falls on the order of one meter in response to changes in the level of the Arkansas River and in response to the many irrigation wells found nearby. At our test site in the Arkansas River alluvial valley near Great Bend, Kansas, surface material consists of unconsolidated medium- to coarse-grained sand interspersed with clay stringers and lenses deposited by the Arkansas River. A hand-augered test hole 5 meters from the seismic line revealed sand to a depth of about 1.5 meters, where a hard pan was found—presumably a clay layer. At the time of our seismic and GPR surveys, the water table was at a depth of 2.1 meters, based on a measurement in a test well located 25 meters from the seismic line. A well drilled about 40 meters away from the seismic line encountered bedrock (a fine- to medium-grained Cretaceous-age sandstone) at a depth of 29 meters.

Our experiments with GPR included antennas with 110, 225, and 450 MHz center frequencies. Both common-offset and common-midpoint (CMP) surveys have been conducted. The CMP surveys greatly improved signal-to-noise ratio but did not greatly increase the depth from which we were

able to acquire interpretable data. Using GPR, we were able to see the water table clearly at a depth of about two meters and found indications of stratigraphic variation along the line.

In the past, shallow seismic-reflection methods have been used to image the subsurface from 2 to 30 meters. Because of near-source nonelastic deformation and insufficient receiver density, these technologies have not been adequate for imaging ultra-shallow subsurface geology. Modifying the field layout of the geophones and using an alternate seismic source have allowed us to image the subsurface from 0.6 to 2.1 meters using seismic reflections. In our experiments, three distinct reflections were observed within this range while using surface sources and receivers at our test site in the Arkansas River valley and were confirmed by 4th-order, finite-difference wave-equation modeling.

Our progress so far toward achieving workable ultra-shallow seismic reflection imaging is largely attributable to an improved ability to measure the near-source wavefield. To accomplish this, we collected data using a single 100-Hz geophone group interval of 5 cm. In contrast, typical "shallow" seismic surveys have receiver-group intervals of 1 m or more. Because we increased receiver coverage by a factor of 20 or more, our ability to delineate and improve the coherence of ultra-shallow reflections over other interfering phases was enhanced. Seismic-source energy was provided by a single shot from a .22-caliber rifle using subsonic solid-point short ammunition. We found that other larger, more powerful shallow seismic exploration sources tested at the site (commercial seisguns and sledgehammers) generated enough near-field nonlinear deformation to render near-source (i.e., ultra-shallow) reflection information undetectable.

Preprints of reports based on this work have been submitted to Science, Geophysics, and the expanded abstracts volume for the 1998 Society of Exploration Geophysicists (SEG) meeting in New Orleans in September as well as to the AAPG Explorer (see [Other Access To Information](#) section for a listing of titles and authors).

## Planned Activities

The third set of field surveys will be conducted in June 1998, and data will be processed and interpreted as originally proposed.

## Other Access To Information

Baker, Gregory S., Chris Schmeissner, Don W. Steeples, and Richard G. Plumb (1998) Seismic reflections from depths of less than two meters: submitted to Science, May 1998.

Steeple, D. W., G. S. Baker, C. Schmeissner, and B. K. Macy (1998), Geophones on a board: submitted to Geophysics, in review.

Steeple, D. W., and Gregory S. Baker (1998), Near-surface contributions to seismic static corrections: AAPG Explorer, in press.

Baker, G. S., R. G. Plumb, D. W. Steeples, M. Pavlovic, and C. Schmeissner (1998), Coincident GPR and ultrashallow seismic imaging in the Arkansas River Valley, Great Bend, Kansas: SEG Expanded Abstracts, SEG 1998 International Meeting, New Orleans, in press.

Baker, G. S., D. W. Steeples, C. Schmeissner, and B. K. Macy, (1998), In-situ, high-resolution P-wave velocity measurements within 1 m of the Earth's surface: SEG Exp. Abstr., in press.

Steeple, D. W., G. S. Baker, C. Schmeissner, and B. K. Macy (1998), Geophones on a board: SEG Exp. Abstr., in press.