Seismic Surface-Wave Tomography of Waste Sites

Project ID: 55218

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Research Objectives

The research objectives were to develop the computer programs and acquisition techniques for surface-wave group-velocity tomography and test these at three sites. Surface waves have many advantages for imaging the shear-wave structure in the near-surface, top 10 meters. The lack of robust analysis techniques has inhibited their application. The guiding objective of this project is to develop these techniques and make them available for application to environmental and waste site problems.

Research Progress and Implications

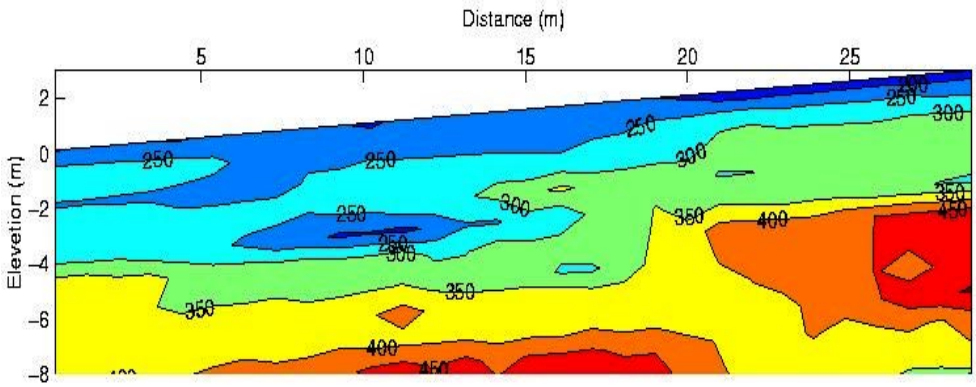
This report summarizes work after 3.5 years of a 3 year project with a one year unfunded extension. During the course of the work, we have developed computer programs to carry out the unique aspects of surface-wave group-velocity tomography. We believe that our computer programs and preliminary results demonstrate that useful data can be obtained using surface-wave group-velocity tomography.

In this project, we have applied the tomographic inversion of surface-wave velocities to areas with dimensions appropriate for near-surface structures that are often encountered in environmental problems. Surface-wave group-velocity tomography is made difficult by the complexities of the structure and by the indirect and computationally intensive techniques that are inherent in group-velocity interpretation. The advantages of tomography include, for example, the ability to image of shallow waste site structure from the site's periphery where access in not advised and the ability to reveal areas where trenches were used to dump wastes. The sensitivity of surface wave velocity to fluid saturation could allow surface-wave tomography to track fluid movement with time.

In order to compute the group velocities, we developed a damped and weighted least squares solution that is computationally a rigorous derivation and improvement to the simultaneous iterative reconstruction technique (SIRT). Four new data sets were obtained with a portable computer, and new acquisition programs written as part of this program. Additional programs were written to convert the acquired data to standard formats.

In the multiple filter technique, seismic data are filtered in the frequency domain. The group velocity for any given frequency is estimated from the arrival time of the peak instantaneous amplitude by our interactive visual program written using MATLAB. This program has been automated and tested with our current data. Arrival times that are found by the multiple filter technique must be corrected for group delays introduced by ground coupling of the instrument, instrument response, and source function. From the group arrival times, we obtained group velocity images at 1.0 Hz increments using the improved tomographic inversion method. Once the tomographic images are developed, dispersion curves for any position in the test area may be generated. These dispersion curves are then inverted for shear-wave structure. An example of a cross section of such interpretations is shown in the figure.

The results have two significant implications. First, the structures revealed in the figure have more detail than one could expect from traditional refraction methods, and at this shallow depth more detail than previously obtained using reflection methods. Second, we discovered conditions in the velocity structure that led to instabilities in the inversion for shear-wave structure. A related problem is that the inversion method assumes constant velocity layers, which are not good representations of the gradients observed in soils. Future studies should be directed to finding solutions that model the strong vertical gradients of real soil velocities.



Planned Activities

The work in the next 6 months will be directed toward completing the analysis of the Oak Ridge National Laboratory site data, which requires the development of a robust program to invert dispersion curves for shear-wave structure. These results will be made part of a paper describing the details of processing, analysis and structural interpretation of surface-wave group-velocity tomography. A paper on imaging near-surface buried structure with high-resolution surface-wave group-velocity tomography, which was submitted to the 2000 international conference on image processing, will be completed. With continued support during the next year, we will simultaneously 1) develop a robust inverse based of finite difference simulation of surface wave propagation in soils with velocity gradients and 2) obtain new data at 6 test sites to use in further testing and improving the analysis technique.

Publications

Long, L.T., and A. Kocaoglu (submitted September 1999) Surface-Wave Group-Velocity Tomography for Shallow Structures, Journal of Environmental and Engineering Geophysics,

Long, L.T.(1999). Seismic Surface Wave Tomography at Waste Sites, Research Note in: *Fast Times, The EEGS Newsletter*, February.

Long, L.T., and A. Kocaoglu, Processing Techniques for surface-wave group-velocity tomography, SEG Expanded Abstract, Annual Meeting, Calgary, Canada, August 2000.

Long, L. T., Kocaoglu, A. H., and Martin, J., Shallow S-wave structure can be interpreted from surface-wave group-velocity tomography, *in* Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Environmental and Engineering Geophysical Society, February, 2000 (SAGEEP00)

Long, L.T., A. Kocaoglu, W.E. Doll, X.Q. Chen, J. Martin. Surface-Wave Group-Velocity Tomography for shallow structures at a waste site, SEG Expanded Abstract, Annual Meeting, Houston, November 1-3, 1999.

Long, L.T., and Kocaoglu, A., (1999). Surface-Wave Group-Velocity Tomography for Shallow Structures, *in* Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Environmental and Engineering Geophysical Society, March, 1999 (SAGEEP99)