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Seismic Surface-Wave Tomography of Waste Sites

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Research Objective

The objective of the Seismic Surface Wave Tomography of Waste Sites is to develop a robust technique for field acquisition and analysis of surface wave data for the interpretation of shallow structures, such as those associated with the burial of wastes. The analysis technique is to be developed and tested on an existing set of seismic data covering the K-901 burial site at the East Tennessee Technology Park. Also, a portable prototype for a field acquisition system will be designed and developed to obtain additional data for analysis and testing of the technique. The portable analysis system will display an image representing the shear-wave velocity structure. The image would be developed in the field from successive data samples.

Research Progress and Implications

As of May 1998, we established compatibility with computer programs at Georgia Tech and computed a preliminary singular value decomposition solution for the K-901 data. The analysis included modeling of surface wave dispersion and analysis of velocity structure. The analysis demonstrated that we needed additional field data to verify the conclusions and provide independent confirmation of velocity structure. The K-901 site data were obtained with 8 Hz geophones. The frequencies below 8 Hz are strongly attenuated in such recording instruments and are difficult to analyze. In particular, group velocities can have multiple answers for a given frequency. Consequently, without a record of the low-frequency energy, we found it difficult to identify the portion of the dispersion curve responsible for the seismogram. In particular, it was difficult to determine if the reverse dispersion observed in the frequencies above 8 Hz was caused by a low velocity layer or caused by observing only the frequencies above the group velocity minimum. In either model, synthetic seismograms can be made to match the observed data for the higher frequencies. The contract for the proposed work was completed in December. The field work was completed in March. The pending final report from William Doll at the Oak Ridge National Laboratory will provide background information on the test site and new uphole and seismic refraction data and interpretation for use in confirming the tomographic inversion.

The acquisition system and software were designed during the first year. The final system will consist of four programs: Data Acquisition, Trace Display/Correction, Velocity Analysis and Tomographic Inversion. During the second year the Data Acquisition and Trace Display/Correction programs were converted to run as compiled visual basic programs under windows NT. The original programs were in quick basic and ran under DOS 6.2. Windows NT allows simultaneous data acquisition not possible under DOS operating systems. The basis for the Velocity Analysis program is under development. The difficulty in determining group velocity is a major challenge in the inversion for near-surface velocity structure. Our original analysis used time-frequency analysis techniques to determine the arrival time of specific frequencies of energy in the surface wave. In particular, we used maximum entropy spectral estimators to optimize the resolution of frequency in small time increments. However, the uncertainty in the arrival time of a particular frequency was complicated by multiple modes and instrument response that introduced errors which were too large to allow a robust inversion. For the Tomographic Inversion program, we have experimented with the algebraic reconstruction technique (ART) with applications to synthetic data. The programs are currently running efficiently on a 486 vintage machine which has been successful in field acquisition trials. Program documentation is available for the first two from tim.long@eas.gatech.edu.

Using the acquisition system, we have obtained data from four sites with differing surface velocity characteristics. The first is the Cobb County test facility, a site for which we have knowledge of the location of various buried objects. The second and third are the sites of two earthquake monitors, stations GLS and HSP, where the near-surface velocity structure could assist other studies. The fourth is the ORNL K-205 site. At the ORNL K-205 site we recorded with 1.0 Hz geophones to obtain dispersion relations at frequencies below 8 Hz. We also obtained refraction data and data for tomographic inversions in two smaller sections of the K-205 test site.

Planned Activities

The third year, June 1, 1998-September 30, 1999, will be used to refine the techniques for surface wave inversion for the tomographic geometry. Principally we will implement the Velocity Analysis and Tomographic Inversion programs. During the coming summer quarter, we will be investigating interpretation techniques that will reduce scatter in group velocity estimates. In particular, we will be examining the use of the relation between perturbations in phase and group velocity to constrain group velocity measurements. The principal advantage is that the phases are highly and accurately correlated between adjacent traces. For the Tomographic Inversion program we will program the algebraic reconstruction technique to process data from the Velocity Analysis program.

We will continue to test the analysis on data obtained from the Cobb County test facility, seismic station HSP, seismic station GLS and the K-901 site. Other sites will be tested as appropriate and as made available when sufficient auxiliary data are available to make the study useful.

For 1999 we will consider transfer of the system to a faster portable computer. The existing system is sufficient for data acquisition and correction. However, it is a desktop version (hence inconvenient in the field) and not fast enough to use for simultaneous acquisition and inversion. We have delayed this because of obvious price and performance considerations.