Jim P
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Soil Conservation Service

Northeast NTC
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Chester, PA 19013

Subject: SOI - Ground-penetrating Radar (GPR) Field Study in North Dakota; October 1-7, 1986

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To:
August J. Dornbusch
State Conservationist
Soil Conservation Service
Bismarck, North Dakota

PURPOSE

To explore the potential of using ground-penetrating radar to characterize soils in North Dakota and to acquaint field and staff specialists with GPR techniques.

PARTICIPANTS

Jim Berg, Geologist, PSC, Bismarck, ND
John Bluemle, Geologist, ND Geol. Survey, Grand Forks, ND
Scott Carter, Soil Scientist, NDSU-LRRC, Mandan, ND
Carl Carlson, Geologist, SCS, Bismarck, ND
Jim Doolittle, Soil Specialist (GPR), SCS, NENTC, Chester, PA
Terry Gisvold, District Conservationist, SCS, Carson, ND
Kenneth Harris, Geologist, ND Geol. Survey, Grand Forks, ND
Michael Haupt, Soil Tech., NDSU-LRRC, Mandan, ND
Cornelius Heidt, Soil Correlator, SCS, Bismarck, ND
David Hopkin, Instructor, NDSU, Fargo, ND
Jim Knuteson, Asst. Professor, NDSU-LRRC, Mandan, ND
Rod Kyar, Soil Scientist, PSC, Bismarck, ND
Dave Nilson, Recl. Spec., Basin Elec., Bismarck, ND
Ken Potter, Asst. Soil Spec., NDSU-LRRC, Mandan, ND
Paul Satchell, Mining Eng., BC&W, Washburn, ND
John Shultz, Recl. Manager, Basin Elec., Stanton, ND
Mike Spry, Soil Scientist, PSC, Bismarck, ND
George Stull, Conservation Tech, SCS, Carson, ND
Jim Thiele, Asst. State Soil Scientist, SCS, Bismarck, ND
Ken Thompson, Area Soil Scientist, SCS, Dickinson,

Equipment

The radar unit is the SIR System-8. Components of the SIR System-8 include the Model 4800 control unit, the ADTEK DT-6000 tape recorder, and the ADTEK Model 8004H graphic recorder. The 300, 120, and 80 MH_z

antennas were used with the SIR System-8 in an attempt to optimize depth of penetration with signal resolution. The high electrical conductivities of the selected soils severely limited the depth of penetration of all antennas and made the 300 MH_z antenna virtually ineffective. A pre-programmed microprocessor was used to enhance desired subsurface signals and to remove background noise. Generally, the microprocessor produced marginal signal enhancement of subsurface images.

The Models 705, 705DA, and 705DA2 transceivers; and the 775 High Power transmitter were used interchangeably with the 120 and 80 MH_z antennas in an attempt to maximize the probing depth of the GPR. The 120 MH_z antenna with the 705DA transceiver produced the best balance of depth of penetration and signal resolution.

The ADTEK DT-6000 tape recorder was inoperative during the field study. However, the lack of the tape recorder did not restrict the field study.

DISCUSSION

Compared with other areas in the United States, the potential for using the present GPR system in North Dakota is low. In most soils of North Dakota, high rates of signal attenuation severely limit the effective probing depth of the GPR.

Soils having high electrical conductivities rapidly absorb the radar's energy and limit the probing depths. The electrical conductivity of soils increase with moisture, concentration of dissolved salts in the soil solution, and the amount and type of clays.

Electrical conductivity is an electrolytic process. Wet soils are more conductive to electromagnetic energy than dry soils. The conductivity of soils is proportional to the total number of ions in solution. Expanding 2:1 lattice clays, having higher exchange capacities than 1:1 lattice clays, exhibit higher electrical conductivities, and are more restrictive to the radar.

The soils of North Dakota are very conductive to electromagnetic energy. High concentrations of carbonates and other soluble salts, and the predominance of medium and moderately-fine textured soils with large proportions of smectitic clays produce a rapid wastage of the radars energy and limits the probing depth of the GPR.

Soils examined with the GPR in North Dakota include: Banks (sandy, mixed, frigid Typic Ustifluvents), Flasher (mixed, frigid, shallow Typic Ustipsamments), Seroco (mixed, frigid Typic Ustipsamments), Vebar (coarse-loamy, mixed Typic Haploborolls), and Williams (fine-loamy, mixed Typic Argiborolls). Generally, in areas of coarse textured soils (Banks, Flasher, Seroco) the radar provided detailed and interpretable imagery to depths of 50 to 60 inches. In finer textured soils such as Williams, probing depths were less than 20 inches or to the top of the argillic horizon.

In areas of Flasher and Vebar soils, the GPR was used to chart the depth to bedrock. The GPR was effective in areas where the depth to bedrock is within 60 inches of the surface, the soils well drained to excessively drained and coarse or moderately coarse textured, and the underlying bedrock fairly hard and noticeable with hand augers.

In areas of wind blown or water laid deposits (Banks and Seroco soils), the GPR charted the depth to and lateral extent of buried surface layers and strata of differing textures. The maximum depth of penetration, though dependent upon clay and salt content, ranged from 40 to 60 inches in the selected soils.

The GPR was tried unsuccessfully on a RAMP site near Wilton, North Dakota. All components of the present system, including the high powered transmitter and WARR (wide angle reflecting and receiving) methods were used in this study. However, the maximum soil depth at which an underlying cavity could be detected in the moderately-fine textured Williams soil was only 16 inches.

One of the principal areas of interest for the use of GPR techniques in North Dakota is on reclaimed coalfield areas. Prior to this field study, it was hoped that the GPR could be used as a monitoring tool for the determination of first and second lift thicknesses. In most areas, the contacts separating the different lift materials are conspicuous. These contacts are abrupt and generally separate materials which are highly contrasting in terms of bulk densities, organic matter content, particle size, moisture content, and mineralogy.

GPR results from the reclaimed coalfield sites were disappointing. In most areas, the GPR failed to discern the contact separating the different lift materials. This failure is principally attributed to the high rates of signal attenuation in the earthen materials. Other causal factors include: 1) moist field conditions (moisture weakens the electromagnetic gradients and reduces the reflection coefficient across an interface), 2) similarities in the electrical properties of lift materials across an interface, and 3) design limitations of the present radar system.

At the Glenharold reclaimed coalfield site near Stanton, North Dakota, an area was selected in which the first lift material is coarse textured and the second lift material is moderately-fine textured. The differences in texture and bulk density were apparent and the reflection coefficient across this interface was greater than in other study areas. Also, the rate of signal attenuation was lower at this site due to the lower clay content of the first lift material. While this site is perhaps not representative of large areas of reclaimed minesoils, the radar was able to chart the contact between the first and second lift materials and provided detailed imagery of the upper 40 inches of the profile. This site represented the lone success of the radar when used as a monitoring tool.

RESULTS

Results of this field study are discouraging in terms of an immediate use for the present radar system. SCS's state-of-the-arts impulse radar system does not work well nor can it be used effectively as a quality control or monitoring tool in most areas of North Dakota. High electrical conductivities limit the radar's probing depth and the clarity of the graphic images, and make this geophysical tool unsuitable for most soil investigations in areas of loamy and clayey soils.

Annotated copies of the graphic profiles have been returend to Sy Ekart, State Soil Scientist, under a separate cover letter.

I wish to thank you for this opportunity to return to North Dakota and to explore the potentials of GPR technology. while disappointing, the results of this field study are vital for the assessment of GPR techniques within SCS. I wish to extend a special thanks to members of your staff for a most enjoyable and profitable field experience.

With kind regards.

JAMES A. DOOLITTLE
Soil Specialist (GPR)

cc:
A. Holland, Director, NENTC, Chester, PA
T. Shiflet, Director, MWNTC, Lincoln, NE
R. Arnold, Head of Soil Survey Staff, NHQ, Washington, DC