UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
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Subject: GPR Assistance ARS, Morris, MN.

Date: March 26, 1991

To: George R. Benoit
Supv. Soil Scientist, ARS
North Central Research Lab.
Morris, Minnesota

Background:

At the request of August Dornbush, Jr., Director, Midwest NTC, Jim Turenne, Soil Scientist (GPR Operator, SCS Massachusetts) provided ground-penetrating radar (GPR) assistance in place of Jim Doolittle, Soil Specialist, Chester PA., to the Agricultural Research service (ARS) North Central Soil Conservation Research Laboratory in Morris MN. The GPR assistance took place the week of February 19 to 22, 1991.

Purpose:

The ARS is conducting research on the overall movement of nitrate and pesticides through soils as a result of variations in landscape position and the presence of frozen ground. The GPR was used to determine if the frost line could be recorded with the radar and also to locate areas of coarse material (sand and gravel) which is found at lower soil depths in the area.

Geophysical Equipment:

The GPR unit used is the SIR (Subsurface Interface Radar) System-3. The System-3 consists of a model 8300 profiling recorder, a model 3110 antenna (120 MHz), and a power distribution unit.

The GPR is a broad bandwidth, pulse modulated radar system that has been specifically designed to penetrate earthen materials. Relatively high frequency, short duration pulses of energy are transmitted into the ground from a coupled antenna. When a pulse strikes an interface (boundary) separating layers of differing electromagnetic properties, a portion of the pulse's energy is reflected back to the receiving antenna. The reflected pulse is received, amplified, sampled and converted into a similarly shaped waveform in the audio frequency range. The processed reflected signal is displayed on graphic paper for further analysis.
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Procedure:

Upon arrival at the ARS laboratory (Thursday, February 21), the Swan Lake project was discussed with research personnel. It was decided that a large grid would be established across an 8Ø acre research field, and a tight grid would be established across portions of the research field where the majority of research activities was being conducted. Several trial runs were made with the radar to calibrate the unit and establish a depth scale. The antenna was towed across steel tensiometers which were buried at a depth of approximately 5 feet. These features were not detected on the radar profile. Based on the trial runs, it was estimated that radar signal was being completely attenuated within 3 feet of the soil surface.

Before continuing with the transects it was decided that Jim Doolittle should review the radar profiles for input on the survey. A sample profile was faxed to Jim's office and the profile was discussed over the phone. Mr. Doolittle stated the penetration was poorer than was expected based on the literature pertaining to radar surveys conducted in areas of frozen soils. Profiling depths were estimated to be less than three feet. Mr. Doolittle suggested several adjustments to the GPR unit, and to cross a buried utility pipe to obtain an accurate depth scale. We returned to the site and towed the radar antenna across a drain pipe which was approximately two feet below the surface. The radar was able to detect the pipe. The depth scale confirmed the depth of penetration to be about 2.5 feet. Further adjustments on the radar unit did not yield any deeper penetration.

Within the 8Ø acre research field six transects (AØ-A12, BØ-B12, CØ-C12, DØ-D12, EØ-E12, FØ-F12) were run in an east to west direction. Along each transect observation marks were placed at 1ØØ foot intervals. Transects were spaced 5ØØ feet apart from a north to south progression. In addition, a seventh transect (GØ-G3) was run in a south to north direction. This transect was established close to wells 12, 7, 4 and 2.

On Friday, February 22, two depressions in the west central part of the research site were gridded. Transects TB1-TB12 and TD14-TD22 included several sample sites. SCS soil sample logs from the sites were used to correlate soil types with radar imagery. While the remaining grid was being established, the radar was used to profile the bottom of Swan Lake. Three transects (LA2-LA9, LB1-LB11, LCØ-LC14) were made in an south to north direction, observation marks were located at 1ØØ foot intervals. Transect LDØ-LD15 was run perpendicular (west to east) across the lake and transect LEØ-LE11 was a long transect run north to south with observation marks at 1/1Ø mile intervals. The remaining (T - transect line) was then completed and the activities concluded around 2PM.

Discussion:

Soil Types Mapped on Swan Lake West 8Ø (Sec:34, T:126N, R:41W):

The Soil Survey of Stevens County, Minnesota (June 1971) has the following soil series mapped within the site (map publication scale 1:1584Ø): **Barns** (fine-loamy, mixed Udic Haploborolls), **Hamerly** (fine-loamy, frigid Aeric Calciaquolls), **Parnell** (fine, montmorillonitic, frigid Typic Argiaquolls), **Oldham** (fine, montmorillonitic (calcareous), frigid, Cumulic Haplaquolls)), **Svea** (fine-loamy, mixed, pachic, Udic, Haploborolls). Limy spot symbols and small depression spot symbols are also delineated on the soil map (atlas sheet 24).

These soils have moderately fine to fine textured control sections, relatively high base saturation and noticeable concentrations of soluble salts (calcium carbonate and gypsum). These factors increase the soils electrical conductivity and restrict the profiling depth of the GPR. Attenuation of the radars signal is generally caused by increased electrical conductivity of the soil. The principal factors influencing the conductivity of soils are (1) moisture content, (2) presence of soluble salts and (3) amount and type of clay content. Based on studies conducted in North Dakota (October 1986) profiling depths of less than 2 feet were anticipated in these soils. However research conducted by the U.S. Army Corps of Engineers in Alaska, indicated that under frozen conditions, profiling depths could be increased by a factor of 2 (compared to similar textured unfrozen soil). This study revealed that the profiling depth of the GPR is not significantly increased by frozen condition in moderately fine and fine textured soils formed in calcareous tills. The potential for using GPR techniques in these soils is poor and it does not improve under frozen conditions.

GPR Profiles:

Soil Transects:

Figure one is a representative GPR profile from transect TB-9 to TB-12 (run in a SW-NE direction). Interpretations of the graphic profile are limited by lack of adequate ground-truth data. Without ground-truth reference data, it is impossible to accurately identify the imagery. Depth of penetration is less than 3 feet throughout this transect, the weakly expressed interface between 2 and 2.6 feet is interpreted to be the mollic/calcic interface (A-horizon and Bk-horizon). An SCS soil description (description location T-11) taken near station TB-11 shows the clay loam textured A3-horizon and the fine sandy loam textured Bk horizon to be at 21 inches, complete signal attenuation occurs below this depth.

Lake Transects:

Depth of penetration was also poor on the Swan Lake transects. Although ground-truth data was not available, the depth of penetration was estimated using "tabled" values for the assumed average relative dielectric constants of the medium. Total depth of penetration was less than 4 feet. In the field, it was interpreted that the radar was recording the subsurface topography of the lake (this was the operators first experience using the GPR on water), however office investigation revealed that the interpreted lake bottom was noise caused by the unit.

Conclusion:

Due to the shallow depth restriction of the radar, the frost line could not be delineated using GPR techniques at this site. A lower frequency antenna may provide deeper profiling depths, however resolution would not be as clear and it is doubtful the frost line could be recorded. The GPR investigation at this site did document some very useful information concerning the GPR's use on frozen soils and the data collected will be helpful for future studies of this nature.

I greatly appreciate the opportunity to work with you and to explore the use of GPR techniques in Minnesota. I would like to thank you and your staff for the help and hospitality I received in Morris.
Please feel free to contact me if you have any questions about the GPR.

James Turenne

James Turenne
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enclosures: GPR Profiles, Transect Location Map

cc:
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Figure One: GPR Profile, Swan Lake 8Ø, Transect TB9–TB12 (1ØØns)