United States Department of Agriculture

Soil Conservation Service

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Subject: GPR Field Assistance in Michigan; August 20 to 26 1989

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To: Homer R. Hilner
State Conservationist
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File code: 430-13

Purpose:

To provide ground-penetrating field assistance to map soils at the Michigan State University Experiment Station, Benton Harbor, and to investigate areas of ortstein soils in Ottawa, Oceana, and Mason counties.

Participants:

Jim Doolittle, Soil Specialist (GPR), SCS, Chester, PA
Loren Brendt, Ass't. State Soil Scientist, SCS, East Lansing, MI
Delbert Mokma, Professor, Crop and Soil Science Dept., MSU, East Lansing, MI
Randall Schaetzel, Ass't Professor, Geography Dept., MSU, East Lansing, MI

Activities:

Three fields were surveyed and soils identified with the GPR at the Michigan State University, Benton Harbor Experiment Station on 21 and 22 August 1989. Two of these fields (fields 25 & 26) were surveyed with the EM-38 on 22 August. An area of piping or preferential flow paths in Coloma soils was also studied with the GPR and a pit was excavated to verify interpretations on 22 August. Areas of ortstein soils were surveyed with the GPR near Agnew (Ottawa County) on 23 August, near Rothbury (Oceana County) and Ludington (Mason County) on 24 and 25 August.

Results and Discussion:

<u>MSU Experiment Station at Benton Harbor</u>

An earlier study by Mokma et al., (1989)* had demonstrated that GPR techniques could be used to identify and map soils in western Michigan. The Benton Harbor site represents the first mapping experience with the GPR. With a grid spacing of 120 by 50 feet, 8 transect lines were established in field 25, 6 transect lines in field 26, and 7 transect lines in field 28. Transect lines varied in length from 400 to 700 feet and provided 3.06 miles of continuous radar profiles. Soils were identified at only the 289 grid intersects.

The Benton Harbor study provided a dramatic "proof of concept" that with a knowledge of the unique graphic signatures of soils, soils can be identified and mapped using systematic radar sampling with little or no ground-truth auger borings. Considering the extent of soils, even the volume of soils observed by the most demanding soil scientist is extremely small. In areas where detailed soils information is needed, such as in the research fields of experiment stations, closely spaced soil borings must be made to map the patterns of soils. Limited by available resources (time, manpower, and money), the GPR can provide an expedient and effective tool to map soils.

The radar interpretations developed in the paper by Mokma et al. (1989) were used to identify the soil at each of the 210 grid intersect in fields 25 and 26. Numerical values were assigned to each soil. Values assigned to the Coloma (mixed, mesic Alfic Udipsamments), Spinks (sandy, mixed, mesic Psammentic Hapludalfs), Metea (loamy, mixed, mesic Arenic Hapludalfs), and Marlette (fine-loamy, mixed, mesic Glossoboric Hapludalfs) soils were 1, 2, 3, and 4. This data was feed into the SURFER software program developed by Golden Software, Inc. Gridding was completed using kriging with an octant search.

Figure 1 is a computer simulated map of soil delineations based on an interpretation of the GPR profiles for fields 25 and 26. In Figure 1, a road and the field boundary which separates fields 25 and 26 occurs between columns 840 and 960. All measurements along the margins are in feet. The numerical values for the soil occurring at each grid intersect have been posted in red. These values can be used to estimate taxonomic composition of the delineated areas. This computer simulated diagram corresponds exceptional well with the detailed soil survey of the area. In addition, the GPR survey identified a significant included area of Spinks, Metea, and Marlette soils in the central portion of the study site which was missed during the detailed survey.

An electromagnetic induction survey was conducted with the EM-38 in the vertical coplanar mode on a portion of the study area. It was hoped that a correlation between conductivity and clay or volumetric water content (each reflected by the soil type) would be observed. No correlation (-0.077) was found to exist between the soil patterns identified through the GPR survey and the EM data (in

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* Mokma, D. L.,R. J. Schaetzl, E. P. Johnson, and J. A. Doolittle. 1989. Assessing Bt horizon character in sandy soils using ground-penetrating radar: implications to soil survey. Soil Survey Horizon in preparations.

mS/m). The study site is located in an area of stratified deposits of sandy and loamy water reworked materials. Soils are differentiated based on the depth to and the thickness of loamy sediments. However, it must be assumed that variations in the clay and volumetric water contents were not sufficient enough to significantly influence the electrical conductivity of the upper 1.5 m of these soils.

The radar interpretations and EM data are displayed in Figure 2. A background value of 9.0 mS/m was arbitrarily selected. EM values have been posted and isolines based on magnitude above the background reading have been constructed on the lower diagram in Figure 2. Two zones having electrical conductivities greater than 1.4 X above the background value of 9.0 mS\m can be observed. One of these zones (between columns 960 and 1200, and rows 0 and 350) corresponded with a vineyard and the higher relative electrical conductivities may be related to management practices.

Water does not percolate uniformly through sandy soils but tends to become concentrated in pipes or preferential flow paths. These paths for throughflow are areas where chemicals can also become concentrated. In an area of Coloma soils, these pathways were studied with the GPR. A pit was excavated to verify the presence of a preferential flow path following an interpretation of the radar profile. The GPR can be used to identify, locate, and quantify preferential flow paths. This information can be used to help locate monitoring wells for ground water contamination studies.

Ortstein Study

Areas of ortstein soils were surveyed with the GPR within delineated areas near Agnew in Ottawa County; near Rothbury in Oceana County; and Ludington in Mason County.

Two transects were completed within a forested area near Agnew. These transects provided 1952 feet of continuous radar profiles with 124 equally spaced (16 foot intervals) observation sites. Based on these 124 observation points, the composition was 57% and 59% Saugatuck (sandy, mixed, mesic, ortstein Aeric Haplaquods) soils, and 43% and 41% Pipestone (sandy, mixed, mesic Entic Haplorthods) and Covert (sandy, mixed, mesic Entic Haplorthods) soils for transects 1 and 2, respectively.

Along each transect, discrete areas of Saugatuck soils, Saugatuck and Pipestone or Covert soils, and Pipestone and Covert soils were identified. These areas are intricately intermingled and are not separable in mapping. Areas of Saugatuck soils were identified by continuous, black, multiple radar reflections from the E/Bs and the Bs/Bsm interfaces. Continuous areas of Saugatuck soils occupied about 35% of the transected area, with an average extent of about 31 feet and a range (recognizable on the radar profiles) of 8 to 129 feet. Saugatuck soils occurred in 94% and Pipestone and Covert soils in 6% of these areas.

Areas of Saugatuck and Pipestone or Covert soils were identified by segmented patterns of black to light gray, multiple radar reflections from the E/Bs and the Bs/Bsm interfaces. Saugatuck and Pipestone or Covert soils occupied about 39% of the transected

area, with an average extent of about 38 feet and a range (recognizable on the radar profiles) of 10 to 89 feet. Saugatuck soils occurred in 56% and Pipestone and Covert soils in 44% of these areas.

Areas of Pipestone and Covert soils were identified by the absence of black and dark gray, multiple radar reflections from the E/Bs and the Bs/Bsm interfaces. Continuous areas of Pipestone and Covert soils occupied about 26% of the transected area, with an average extent of about 50 feet and a range (recognizable on the radar profiles) of 12 to 121 feet. Saugatuck soils occurred in 17% and Pipestone and Covert soils in 83% of these areas.

Several sites were examined in detail with a penetrometer at the Agnew study area. At these sites, the soil was excavated to the top of the Bsm horizon and multiple penetrometer measurements were made. It was hoped that the penetrometer readings could be correlated with the gray-scale of the radar's profile. Unfortunately, the Bsm horizon is commonly not the first horizon within the subsoil, and strong and variable reflections from the E/Bs interface often masked reflections from the Bs/Bsm interface. Also, these interfaces vary in their abruptness (the more abrupt an interface the greater the reflection of electromagnetic energy). Therefore, correlations between the gray scale intensity and penetrometer measurements must be suspected and relationships will be difficult to derive. However at one site, in areas of black, continuous images for the bsm horizon, penetrometer readings averaged 163 psi and ranged from 95 to >300 psi over short distances. Readings averaged 102 psi and ranged from 80 to 120 psi in areas where the image of the E/Bs interface was light gray.

Graphic signatures from areas of ortstein soils surveyed near Rothbury in Oceana County and near Ludington in Mason County were significantly different and caused initial interpretative problems. In each of these areas the ortstein layer was continuous but was extremely variable in degrees of cementation over short distances. Cementation ranged from weakly cemented to indurated. Generally "chunks" of strongly cemented ortstein were included within a weakly cemented matrix. However, no zones of indurated, continuous ortstein was observed. As these sites were cultivated, the effects of management practices upon the ortstein layer may have produced changes in the expression of the ortstein layer which are reflected in the radar profiles. In areas of weakly cemented ortstein, temporal variations in soil moisture content will effect the consistency of the ortstein layer and may influences its discernment by soil scientists.

An area of Wallace (sandy, mixed, frigid, ortstein Typic Haplorthods) soils was investigated on a dunal landscape in western Mason County. The ortstein layer was well expressed, not continuously cemented, and varied in degrees of induration over short distances. The site was about 70% Wallace soils and 30% Groton (?)(sandy-skeletal, mixed mesic Typic Eutrochrept) soils. The potential for a future (1990), detailed soil-landscape study at this site was discussed by the participants.

These study provide insight into the variable nature and expression of ortstein layers in Michigan. Further studies are recommended.

A detailed GPR survey of the Wallace site is encouraged as it would provided greater understanding of soil-landscape relationships within an area of ortstein.

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