United States Department of Agriculture | **Natural Resources Conservation Service** | **11 Campus Boulevard, Suite 200 Newtown Square, PA 19073**

Subject: SOI – Geophysical Field Assistance **Date:** 22 February 2006

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Purpose:
Multiple electromagnetic induction (EMI) surveys have been completed of the Shale Hill Watershed in northern Huntingdon County, Pennsylvania. The purpose of these investigations is to assess spatial and temporal variations in apparent conductivity (EC_a) within a small, steeply-sloping, forested watershed in central Pennsylvania. This is a report on the latest investigation.

Activities:
All field activities were completed on 2 February 2006.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Bob Zhou, Postdoctoral Research Associate, Department of Crop and Soil Sciences, Pennsylvania State University, University Park, PA
Shujiang Kang, Candidate, PhD in Soil Science, Department of Crop and Soil Sciences, Pennsylvania State University, University Park, PA

Materials and Methods:
An EM38 meter, manufactured by Geonics limited (Mississauga, Ontario) was used in this study.[1] This meter weighs about 1.4 kg (3.1 lbs) and needs only one person to operate. No ground contact is required with this instrument. The EM38 meter has a 1-m intercoil spacing and operates at a frequency of 14,600 Hz. When placed on the soil surface, it has an effective penetration depth of about 1.5 m in the vertical dipole orientation.[2] The size and light weight of this instrument makes it suited for use in steeply-sloping, forested terrains.

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.
[2] Geonics Limited. 1998. EM38 ground conductivity meter operating manual. Geonics Ltd., Mississauga, Ontario.

The Geonics DAS70 Data Acquisition System was used with the EM38 meter to record and store both EC_a and position data (see Figure 1).[1] The acquisition system consists of the EM38 meter, an Allegro CE field computer (Juniper Systems, North Logan, UT), and a Garmin Global Positioning System (GPS) Map 76 receiver (with CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack)(Olathe, KS). When attached to the acquisition system, the EM38 meter is keypad operated and measurements can be automatically triggered.

To help summarize the results of this EMI survey, SURFER for Windows, version 8.0, developed by Golden Software, Inc. (Golden, CO), was used to construct the simulation shown in this report.[1] The grid of EC_a data was created using kriging methods with an octant search.

Survey Procedures:
The EM38 meter was operated in the vertical dipole orientation and continuous mode with measurements recorded at a 1-sec interval. The meter was generally orientated with its long axis parallel to the direction of traverse. Where possible, the meter was held about 5 cm (2 inches) above the ground surface. However, steep slopes, tree limbs, and fallen forest debris made walking difficult and caused the meter to vary slightly in height (see Figure 1). Where possible, traverses were conducted parallel with the slope contours. Multiple traverses were conducted across and along each swale. Horizon obstructions, satellite shading, and multipath reception reduced the accuracy and reliability of GPS positioning on lower slopes within the watershed especially beneath the evergreen canopy along the lower reach of the stream.

Figure 1. The EM38 meter and the DAS70 Acquisition system were used to complete the EMI survey of the Shale Hill Watershed.

Results:
The results of this study are considered invalid and have provided only for your information and future guidance. The EM38 meter was partially disassembled at the conclusion of the survey. An immediate field review of the data set disclosed that GPS signals had not been recorded during the latter portion of the survey because of a discharged battery. A new battery was installed in the backpack, and the affected portions of the watershed were resurveyed. Later, all data were reviewed in the office. At that time, it was noticed that inconsistent EC_a had been recorded in the resurveyed area (see Figure 2; Note data plotted in the northwest corner of the watershed).

A plot of the EMI data points revealed that the watershed had been inadequate covered (see Figure 2). Principally on the north-facing slopes, many EC_a measurements made were not effectively geo-referenced (terrain and vegetation interference) and therefore were not included in the data set. In addition, although setup procedures mimicked the procedures used in previous survey, a disproportion number (1342) of negative measurements were recorded. Several factors can be brought forward to explain these negative values; calibration site selection, difficulty traversing terrains, lifting the meter to variable heights above the surface, and failure to adequately monitor the meters responses. These factors will be addressed and corrected in future surveys.

Basic statistics for the three surveys that were completed with the EM38 meter in the vertical dipole orientation are listed in Table 1. All data have been temperature corrected to a standard temperature of 75^o F, and most data points with negative values have been omitted. Compared with the October 2005 survey, the EC_a was higher and more variable within the watershed. This reflects the moister soil conditions in February 2006 that in October 2005. At the time of the October 2005 survey, soils were noticeably droughty and stream flow was restricted to only the lowest portion of the watershed. In addition, EC_a was slightly more variable in February than in October. For the October 2005 survey, EC_a averaged only about 2.2 mS/m and ranged from about 0.0 to 23.8 mS/m across the watershed. One half the observations had values of EC_a between about 1.25 and 3.0 mS/m. For the February 2005 survey, EC_a averaged about 3.9 mS/m and ranged from about 0.0 to 20.5 mS/m across the watershed. One half the observations had values of EC_a between about 1.5 and 5.78 mS/m.

Table 1
Comparison of Basic Statistics for the Two EMI Surveys of the Shale Hills Watershed.

	March-2005	October-2005	February -2006
Number Observations	2226	5931	3448
Minimum	0.88	0.00	0.00
Maximum	18.38	23.75	20.50
25% Quartile	8.75	1.25	1.50
75% Quartile	10.00	3.00	5.78
Mean	9.31	2.22	3.94
Standard Deviation	1.33	1.38	3.20

A plot of the EC_a data collected during the February 2005 EMI survey is shown in Figure 2. This plot shows the spatial distribution of EC_a data collected with the EM38 meter in the deeper-sensing vertical dipole orientation. In Figure 2, the EC_a isoline interval is 2 mS/m. In Figure 2, the area with the erroneous measurements is evident in the northwest portion of the watershed. Here EC_a is atypically high. With the exception of this area, EC_a spatial patterns are consistent with previous surveys. The lowest EC_a is recorded on plane and convex shoulder and back slopes. Areas of higher EC_a are recorded along the stream channel. These soils have higher moisture contents. What may be a significant finding of this survey is that some of the swales appear to have slightly higher EC_a than the adjacent side slopes.

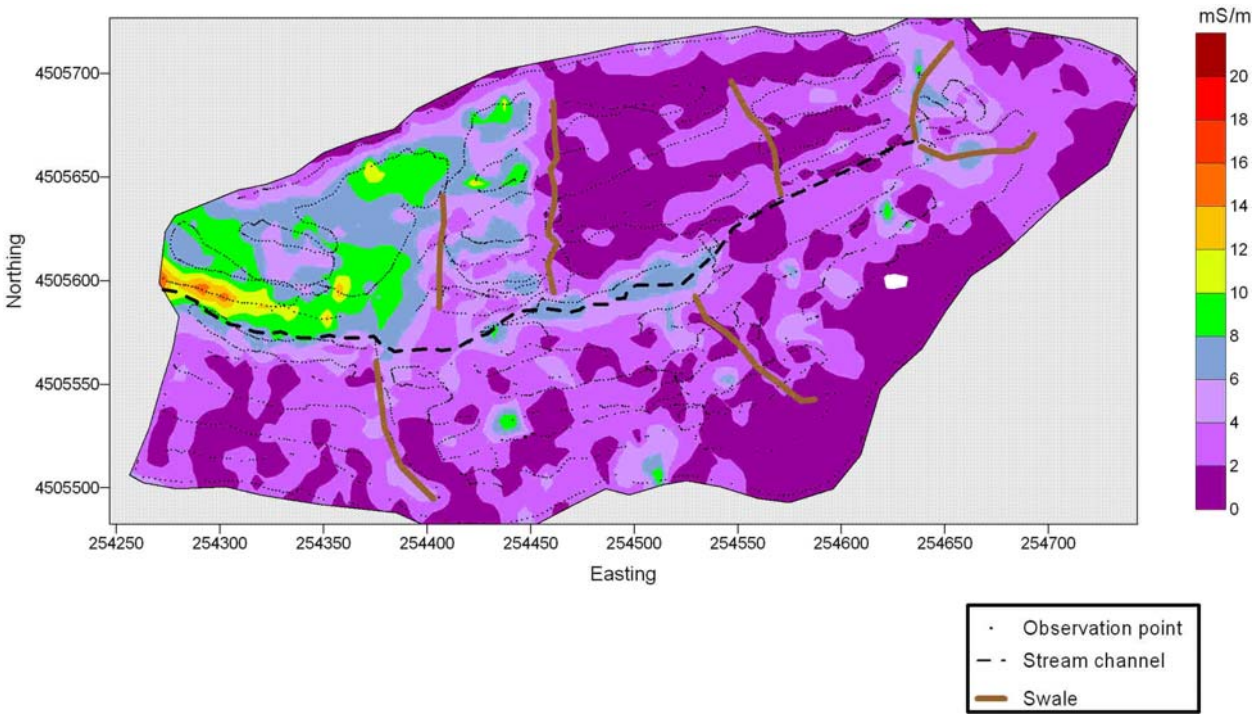

Figure 2. This map shows the spatial distribution of EC_a within the watershed at the time of the February2006 survey.

Summary:

The Shale Hills Watershed is composed of electrically resistive materials. Soils contain large amounts of shale fragments and have electromagnetic properties that are closely similar to the underlying shale parent rock. These electrically resistive and comparatively uniform materials result in low and relatively invariable EC_a across most of the watershed. This watershed offers several challenges to EMI, not the least of which is the steeply sloping and forested terrain. Because of similar electromagnetic properties, the use of EMI to differentiate soil from parent rock or to determine the depth to bedrock is not considered practical in this and similar watersheds.

Spatial EC_a patterns within the watershed are attributed principally to variations in soil moisture. The highest EC_a occurs along the stream channel. The lowest EC_a occurs on side slopes and summit areas. Results from the present survey indicate that while spatial patterns are indistinct, with increased soil moisture contents, some of the swales appear to have slightly higher EC_a than the adjacent plane and convex side slopes. The higher EC_a is attributed to greater soil depths and higher clay and moisture contents in the swales.

Because of surveying errors, it is recommended that the results of this survey be discarded. Wes Tuttle and I are scheduled to work at Pennsylvania State University in mid-March 2006. It is recommended that an EMI survey of Shale Hill Watershed be completed at that time.

It was my pleasure to participate in this study and to work with your research associates at Pennsylvania State University.

With kind regards,

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