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SUBJECT: SOI – Geophysical Assistance

November 1, 2011

TO: Denise C. Coleman
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NRCS, Harrisburg, Pennsylvania

File Code: 330-7

Purpose:
The purpose of this investigation was to collect supporting geophysical data on soil moisture status and movement across different landscapes. This information will be use to more correctly document soil property fields in NASIS and to improved soil interpretations.

Participants:
Tim Craul, MLRA Soil Survey Project leader, USDA-NRCS, Mill Hall, PA
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA

Activities:
Field activities were completed on 14 March 2011.

Summary:

1. Baseline EMI data were collected at three sites in Centre County. This data will be to evaluate temporal and spatial variations in soil moisture contents, fluctuations, and movement across different landscapes in Pennsylvania.

2. In cultivated areas of Hublersburg and Nolin soils, apparent conductivity increased with increasing soil depth. Spatial apparent conductivity (EC_a) patterns principally reflect differences in clay content, soil depth, and management. However, the relative EC_a values and spatial patterns are also impacted by differences in soil moisture.

3. In cutover areas of Laidig soil, apparent conductivity decreased and became less variable with increasing soil depth. Surface layers appear to have higher and more variable EC_a than deeper soil layers. This relationship is attributed to increased soil moisture in surface layers caused by recent thawing and the present of a fragipan. Apparent conductivity is lower on higher-lying than on lower-lying slope components of Laidig soil. The lower values on higher-lying slope positions suggest lower moisture contents.

4. Returning to these site at a drier time of the year, and repeating an EMI survey, should, through comparisons, provide insight into changes in soil moisture status.

/s/ Jonathan W. Hempel

JONATHAN W. HEMPEL

Director

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Technical Report on the Use of Geophysical Methods for the Evaluation of Soil Water and Moisture Status at selected Sites in Centre County, Pennsylvania, on 15 March 2011.

James A. Doolittle

Background:
There is a recognized need for additional and improved data on seasonal soil moisture contents, duration of saturation, and depths to *high* water table in Pennsylvania soils. Currently, soil moisture conditions and water table depths in the National Soil Information System (NASIS) database are either estimated, or derived from very periodic (monthly or weekly) data. Data on soil water status are used for soil interpretations, conservation practices, risk management, and identifying hydric soils. In addition, hydrological models require more accurate information on temporal and spatial variations in soil moisture and flow patterns. To accommodate these needs, a study, entitled *Evaluating Soil Water and Moisture Status,* has been implemented to improve soil water status data in NASIS. This study is designed to collect data on soil moisture contents, fluctuations, and movement across different landscapes in Pennsylvania. Graphs from data loggers on water table depths, analysis of Pennsylvania's Soil Climate Analysis Network (SCAN) data, and geophysical methods will be used to revise, correct, and update the soil moisture status data in NASIS.

Equipment:
An EM38-MK2 meter (Geonics Limited; Mississauga, Ontario) was used in this study. [1] Operating procedures for the EM38-MK2 meter are described by Geonics Limited (2007). The EM38-MK2 meter operates at a frequency of 14,500 Hz and weighs about 5.4 kg (11.9 lbs). The meter has one transmitter coil and two receiver coils, which are separated from the transmitter coil at distances of 1.0 and 0.5 m. This configuration provides two nominal penetration depths of 1.5 and 0.75 m in the vertical dipole orientation (VDO), and 0.75 and 0.40 m in the horizontal dipole orientation (HDO). In either dipole orientation, the EM38-MK2 meter provides simultaneous measurements of both apparent conductivity (EC_a) and magnetic susceptibility (χ_m) over two depth intervals. Apparent conductivity is typically expressed in milliSiemens/meter (mS/m). Susceptibility is the ratio of the secondary to primary magnetic fields and is expressed in parts per thousand (ppt).

A Trimble AG114 L-band DGPS (differential GPS) antenna (Trimble, Sunnyvale, CA) was used to georeferenced EC_a data collected with the EM38-MK2 meter. [1] An Allegro CX field computer (Juniper Systems, North Logan, UT) was used to record and store both GPS and EC_a data[1]. The RTM38MK2 program (Geomar Software, Inc., Mississauga, Ontario) was used with the EM38-MK2 meter to display and record both GPS and EC_a data on the Allegro CX field computer. [1]

To help summarize the results of the EMI surveys, the SURFER for Windows (version 9.0) software (Golden Software, Inc., Golden, CO) was used to construct the simulations shown in this report. [1] Grids were created using kriging methods with an octant search.

Field Sites:
During this investigation, three different landscapes were surveyed in Centre County. Each site contained a PVC pipe (Size DN32, Class PN12, with an inside diameter of 37.5mm), which was installed upright in the soil. This PVC pipe served as an observation well for an Odyssey capacitance water level probe (Christchurch, New Zealand). [1] The Odyssey probe can be lowered inside these PVC pipes to measure the water level.

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[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

Site 1 is located in cultivated fields (about 40.80715 N. latitude and 77.6982 W. longitude) on either side of Whiteman Drive. The site is located about 2 kilometers northwest of Tusseyville. Relief is about 3 meters at this site. Soil map units recognized at this site include Hublersburg silt loam on 0 to 3 % slopes (HuA), and Nolin silt loam, local alluvium on 0 to 5 % slopes (No). These very deep, well drained soils formed in residuum (Hublersburg) or alluvium (Nolin) weathered from limestone.

Site 2 is located in a clear-cut area (about 40. 75419 N. latitude, and 77. 7181 W. longitude) on a solifluction lobe on the north side of Treaster Kettle Road about 5.75 kilometers southwest of Tusseyville on First Mountain. Relief is about 30 meters at this site. Soil map units recognized at this site include Laidig extremely stony loam on 8 to 15 % slopes (LcD), and Buchanan extremely stony loam on 8 to 25 % slopes (BxD). The very deep, well drained Laidig, and somewhat poorly and moderately well drained Buchanan soils formed in colluvium weathered from sandstone on uplands.

Site 3 is located in a scrubby, debris-laden forested area (about 40. 77508 N. latitude, and 77. 6475 W. longitude) along Krise Valley Road about 2.5 kilometers southeast of Colyer on First Mountain. The soil map unit is Ungers very stony loam on 0 to 8 % slopes (UnB). The deep and very deep, well drained Ungers soils formed in residuum weathered from red sandstone and shale on uplands.

TABLE 1 - TAXONOMIC CLASSIFICATION OF THE SOILS RECOGNIZED AT THE THREE CENTRE COUNTY ODYSSEY WELL SITES.

Soil Series	Taxonomic Classification
Buchanan	Fine-loamy, mixed, semiactive, mesic Aquic Fragiudults
Hublersburg	Clayey, illitic, mesic Typic Hapludults
Laidig	Fine-loamy, siliceous, active, mesic Typic Fragiudults
Nolin	Fine-silty, mixed, active, mesic Dystric Fluventic Eutrudepts
Ungers	Fine-loamy, mixed, semiactive, mesic Typic Hapludults

Field Methods:
Pedestrian surveys were completed with the EM38-MK2 meter across each site. The EM38-MK2 meter was operated in the deeper-sensing, vertical dipole orientation (VDO). The meter was operated in the continuous mode with measurements recorded at a rate of 1/sec. The meter was orientated with its long axes parallel to the direction of traverse, and held, where possible about 5 cm (about 2 inch) above the ground surface. While EC_a data were recorded for both the 50 and 100 cm intercoil spacings, data recorded for the 50-cm (0 to 75 cm depth interval) displayed extremely low (often negative) and unstable values (suggesting the presence of background and equipment noise) and were not used. All EC_a data discussed in this report were temperature corrected.

At Sites 2 and 3, terrain conditions were very unsuited to EMI. Steep and slippery slopes, dense undergrowth, and numerous trees, hanging and felled limbs, and debris piles interfered with the completion of systematic surveys. In addition, terrain obstructions, satellite shading, and multipath reception reduced the accuracy and reliability of GPS. Site conditions were so poor at Site 3, that the EMI data were considered too corrupted for use. As a consequence, no results are reported from this site.

Results:
Site 1 – Hublersburg and Nolin soils
Soils were moist at the time of this survey as the recent snow cover had just melted. The EC_a was low and relatively invariable at this site. Table 2 provides basic statistics for the EC_a data that were collected at this site with the EM38-MK2 meter. In general, EC_a remained relatively uniform with depth (comparison of measurements obtained in the deeper-sensing, 100-cm intercoil spacing with measurements obtained in the shallower-sensing, 50-cm intercoil spacing). For measurements obtained in

the shallower-sensing (0 to 75 cm), 50-cm intercoil spacing, EC_a averaged about 9.8 mS/m, and ranged from about 0.1 to 23.5 mS/m. One-half of these measurements were between about 6.9 and 15.4 mS/m. For the deeper-sensing (0 to 150 cm), 100-cm intercoil spacing, EC_a averaged about 11.7 mS/m and ranged from about 1.7 to 25.3mS/m. One-half of these measurements were between about 8.5 and 14.3 mS/m.

TABLE 2. APPARENT CONDUCTIVITY DATA FROM SITE 1 – HUBLERSBURG AND NOLIN SOILS

	50 cm intercoil spacing 0 to 50 cm	100 cm intercoil spacing 0 to 150 cm
Observations	695	695
Minimum	0.07	1.74
25%-tile	6.94	8.46
75%-tile	15.44	14.26
Maximum	23.47	25.28
Mean	9.75	11.71
Std. Dev.	4.38	4.15

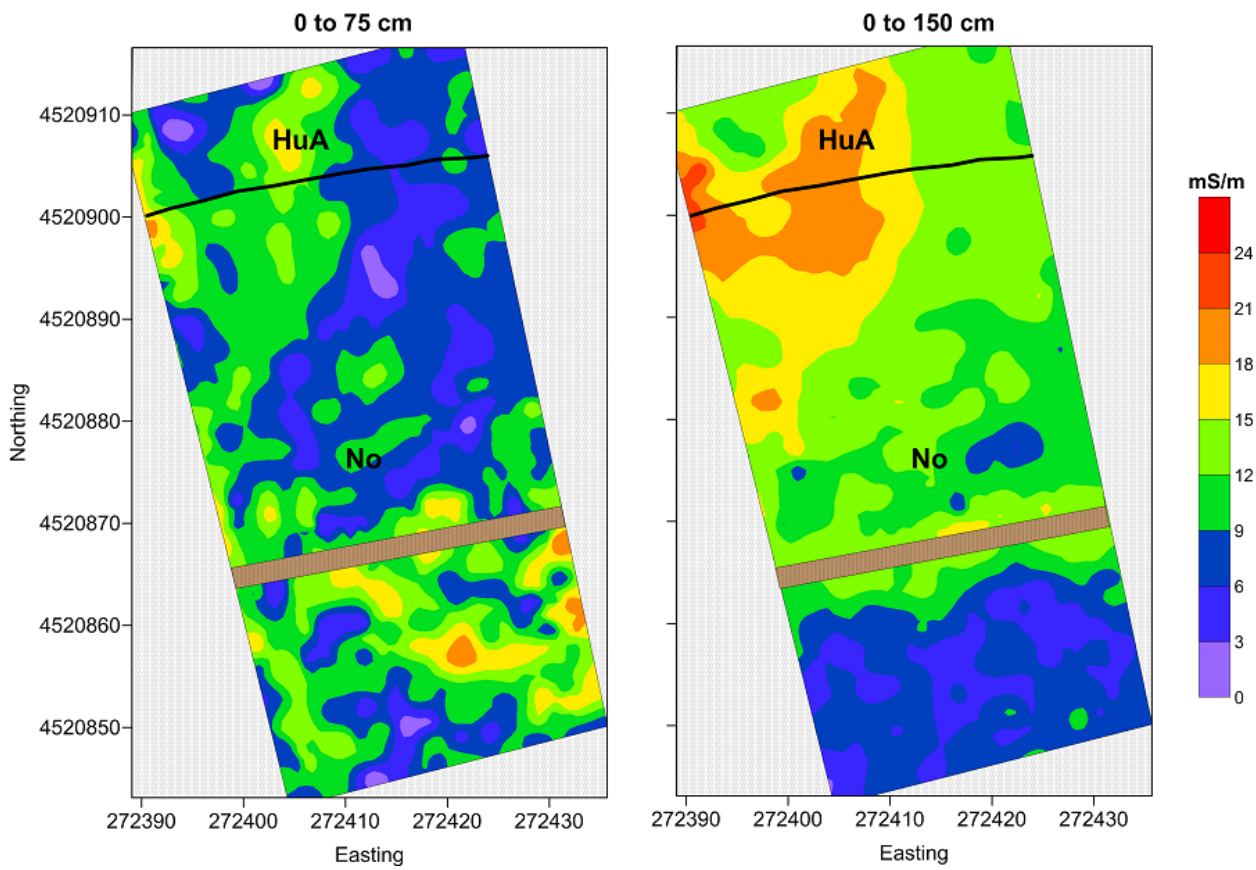

Figure 1. These plots of spatial EC_a patterns were generated from data collected with the EM38-MK2 meter at Site 1. The depth of effective penetration is shown above each plot.

Figure 1 contains plots of the EC_a data collected at Site 1. The same color scales and ramps have been used in both plots shown in Figure 1. Soil boundary lines have been digitized from Web Soil Survey

data.[2] The narrow, darken rectangle that cross each plot represents the location of Whiteman Drive. For the 0 to 150 cm depth interval (Figure 1, right-hand plot), the field south of Whitman Drive has noticeably lower EC_a. Fields on either side of Whiteman Drive have been managed differently and spatial EC_a patterns appear to reflect this difference. The field on the south side of Whiteman Drive has been in no-till for the last four years. The field on the north side of the road has been chiseled plowed for the last three years. Also, the field on the south side of the road was recently fertilized.

The zone of higher EC_a in the northwest corner of the site is believed to reflect the higher clay content and shallower depth to limestone of Hublersburg soil. Higher clay contents are associated with reduced permeability and increased soil water storage capacity. Spatial EC_a patterns evident in Figure 1 are believed to principally reflect differences in clay content, soil depth, and management. However, the relative EC_a values and spatial patterns are also impacted by differences in soil moisture. Returning to this site at a drier time of the year, and repeating an EMI survey, should, through comparisons, provide insight into changes in soil moisture status.

Site 2 – Laidig soils

Soils were moist at the time of this survey as the recent snow cover had just melted. Apparent conductivity was low and invariable at both sites located on this solifluction lobe. Table 2 provides basic statistics for the EC_a data that were collected at the two solifluction lobe sites with the EM38-MK2 meter. The lower-lying grid site displayed relatively higher and slightly more variable EC_a than the higher-lying grid site. This difference is attributed to greater moisture and/or clay contents on the lower-lying grid site. In general, for both sites EC_a decreased with increasing soil depth (compare measurements obtained in the deeper-sensing, 100-cm intercoil spacing with measurements obtained in the shallower-sensing, 50-cm intercoil spacing). This relationship is attributed to increased soil moisture in surface layers caused by recent thawing and the present of a fragipan, which restricts the downward flow of soil moisture.

TABLE 2. APPARENT CONDUCTIVITY DATA FROM SITE 2 – SOLIFLUCTION LOBE OF LAIDIG SOILS

	Lower Grid 0 to 50 cm	**Lower Grid 0 to 150 cm**	**Upper Grid 0 to 50 cm**	**Upper Grid 0 to 150 cm**
Observations	318	318	273	273
Minimum	0.13	0.00	0.13	0.07
25%-tile	7.27	4.02	3.88	2.27
75%-tile	14.97	7.45	9.52	5.44
Maximum	34.63	23.80	25.41	9.15
Mean	11.52	5.95	7.10	3.97
Std. Dev.	6.43	2.81	4.31	2.01

At both grid sites, EC_a decreased and became less variable with increasing soil depth. For the lower-lying grid site, for measurements obtained in the shallower-sensing (0 to 75 cm), 50-cm intercoil spacing, EC_a averaged about 11.5 mS/m, and ranged from about 0.1 to 34.6 mS/m (the anomalous, maximum EC_a was attributed to the meter passing too near a discarded metallic artifact). One-half of these measurements were between about 7.3 and 15.0 mS/m. For the deeper-sensing (0 to 150 cm), 100-cm intercoil spacing, EC_a averaged about only 5.9 mS/m and ranged from about 0.0 to 23.8 mS/m. One-half of these measurements were between about 4.0 and 7.4 mS/m.

For the higher-lying grid site, for measurements obtained in the shallower-sensing (0 to 75 cm), 50-cm intercoil spacing, EC_a averaged about 7.1 mS/m, and ranged from about 0.1 to 25.4 mS/m (once again,

[2] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/ accessed [3/17/2011].

the anomalous, maximum EC_a was attributed to the meter passing too near a metallic artifact). One-half of these measurements were between about 3.9 and 9.5 mS/m. For the deeper-sensing (0 to 150 cm), 100-cm intercoil spacing, EC_a averaged only about 4.0 mS/m and ranged from about 0.1 to 9.2 mS/m. One-half of these measurements were between about 2.3 and 5.4 mS/m.

Spatial EC_a patterns for the lower-lying area are shown in Figure 2. The area is mostly mapped as Laidig extremely stony loam on 8 to 25 % slopes (LcD). However, the lower portion of the grid area may contain a small segment of Buchanan extremely stony loam on 8 to 25 % slopes (BxD). This grid area represents a potential seepage area. Apparent conductivity is higher at this site than at the nearby, higher-lying grid site. The higher values could be indicative of higher moisture contents. However, no spatial patterns are evident in these plots that suggest a seepage area or differences in soil types. A comparison of the two plots shown in Figure 2 reveals that surface layers to have a higher and more variable EC_a than deeper soil layers. Once again, this relationship is attributed to increased soil moisture in surface layers caused by recent thawing and the present of a fragipan.

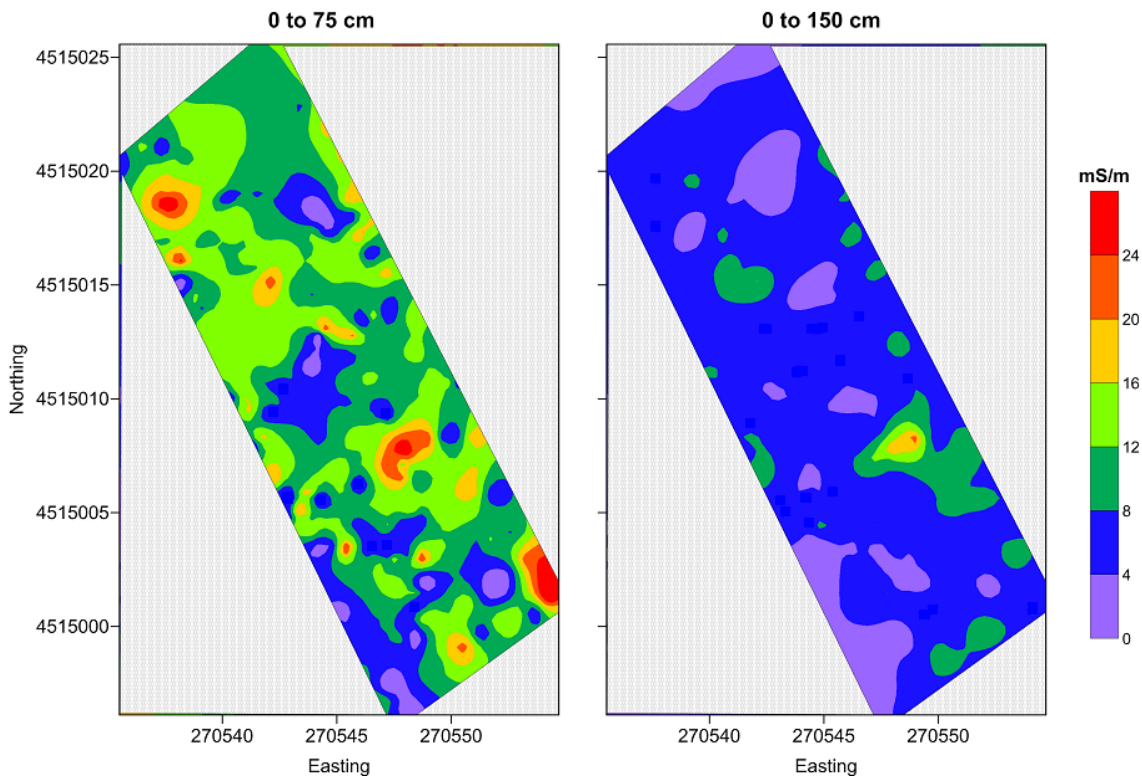

Figure 2. These plots of apparent conductivity were generated from data collected over the lower-lying grid area at Site 2. The depth of effective penetration is shown above each plot.

The spotty, discontinuous EC_a patterns evident at this site, especially in the surface layers, is considered noteworthy. These patterns may reflect variations in soil physical properties (clay and moisture contents, density, rock fragments) and/or the meter's varying height above the surface, which was caused by cutover debris, rocks, and undergrowth. Returning to this site at a drier time of the year, and repeating the EMI survey, should, through comparisons, provide insight into changes in soil moisture status.

Spatial EC_a patterns for the higher-lying area are shown in Figure 3. The area is mapped as Laidig extremely stony loam on 8 to 25 % slopes (LcD). Apparent conductivity is lower at this site than at the nearby, lower-lying grid site. As the soil types are considered the same at each site, lower values suggest lower soil moisture contents at this site than the lower-lying site. A comparison of the two plots shown in Figure 3 reveals that surface layers have higher and more variable EC_a than deeper soil layers. Once again, this relationship is attributed to increased soil moisture in surface layers caused by recent thawing and the affects of a fragipan on the vertical flow and distribution of soil moisture.

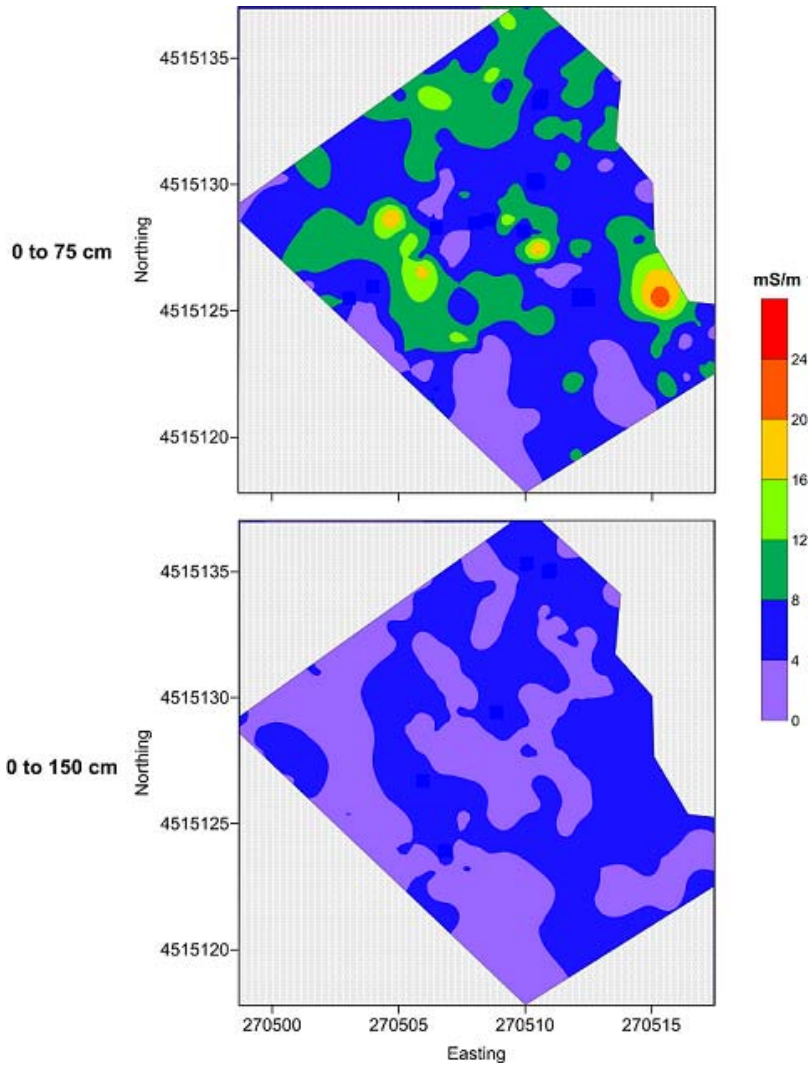

Figure 3. These plots of apparent conductivity were generated from data collected over the higher-lying grid area at Site 2. The depth of effective penetration is shown above each plot.

References:

Geonics Limited, 2007. EM38-MK2 ground conductivity meter operating manual. Geonics Ltd., Mississauga, Ontario.