United States Department of Agriculture

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SUBJECT: MGT – Trip Reports – Delayed Reports

June 25, 2012

TO: Maria Collazo
Acting State Conservationist
Natural Resources Conservation Service
Somerset, New Jersey

File Code: 330-20-7

The enclosed trip report is being distributed much later than it should have been according to our policy. I am offering no excuses, but processing and distribution of the trip reports were delayed because of changes to administrative assistant duties following the transfer of one of our administrative assistants to another office. All blame for the delay belongs to me for not following up on the proper processing and distribution of these reports.

Please let me assure you the issue has been resolved, and trip reports will be prepared, processed, and distributed as expediently as possible in the future.

Sincerely,

LARRY T. WEST
National Leader
Soil Survey Research and Laboratory

United States Department of Agriculture

NRCS

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SUBJECT: MGT – Geophysical Assistance

June 7, 2012

TO: Maria Collazo
Acting State Conservationist
Natural Resources Conservation Service
Somerset, New Jersey

File Code: 330-20-7

Purpose:
The objective of this study is to collect information on the depth to bedrock with ground-penetrating radar (GPR) in areas mapped as complexes of Nassau soils in northwestern New Jersey. This information will be used to justify changes in soil survey legend and interpretative data.

Participants:
Jim Doolittle, Research Soil Scientist, NSSC, NRCS, Newtown Square, PA
Edwin Muñiz, Assistant State Soil Scientist, NRCS, Somerset, NJ
Fred Schoenagel, Resource Soil Scientist, NRCS, Clinton, NJ
Richard Shaw, State Soil Scientist, NRCS, Somerset, NJ

Activities:
Field activities were completed on January 24-26, 2012.

Summary:

1. Thirty-nine radar records were collected in Warren County over a two day period. Ground-penetrating radar provided copious, georeferenced data needed to validate bedrock depths in areas of Nassau soils.

2. In the two areas surveyed in Warren County, based on 574,238 radar depth measurements, the distribution of soils according to soil depth classes is 9 % shallow(< 50 cm), 65 % moderately deep (50 to 100 cm), 23 % deep (100 to 150 cm), and 3 % very deep (> 150 cm).

It was the pleasure of Jim Doolittle and the National Soil Survey Center to be of assistance to your staff and cooperators.

JONATHAN W. HEMPEL
Director
National Soil Survey Center

Attachment (Technical Report)

cc: (see next page)

cc:
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David Clausnitzer, Acting MLRA Office Leader, NRCS, Amherst, MA
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Mike Wilson, Research Soil Scientist & Liaison for MO12, Soil Survey Research & Laboratory Staff, NSSC, MS 41, NRCS, Lincoln, NE

Technical Report on Ground-Penetrating Radar (GPR) Investigations conducted in areas of Nassau Soils on January 24-26, 2012

James A. Doolittle

Background:

Nassau (loamy-skeletal, mixed, active, mesic Lithic Dystrudepts) soils are relatively extensive in the northwest part of New Jersey and in MLRA 144A (New England and Eastern New York Upland, Southern Part) (see Figure 1). These somewhat excessively drained soils formed in glacial till (predominantly the *Kittatinny Mountain Till*) and are shallow to Martinsburg shale (Ordovician age). In New Jersey, Nassau soils have been mapped on approximately 75,910 acres. Previous field investigations have shown that the extent of Nassau soils were over estimated in some areas, especially where augers were used to collect data, due to the high percentage of coarse fragments in soil profiles, which often limits the depth and number of observations made. Ground-penetrating radar can provide copious, georeferenced data needed to overcome issues of data insufficiency and incorrectness, and validate differences in depths to bedrock. This information will be used to improve soil data for support of NRCS technical assistance.

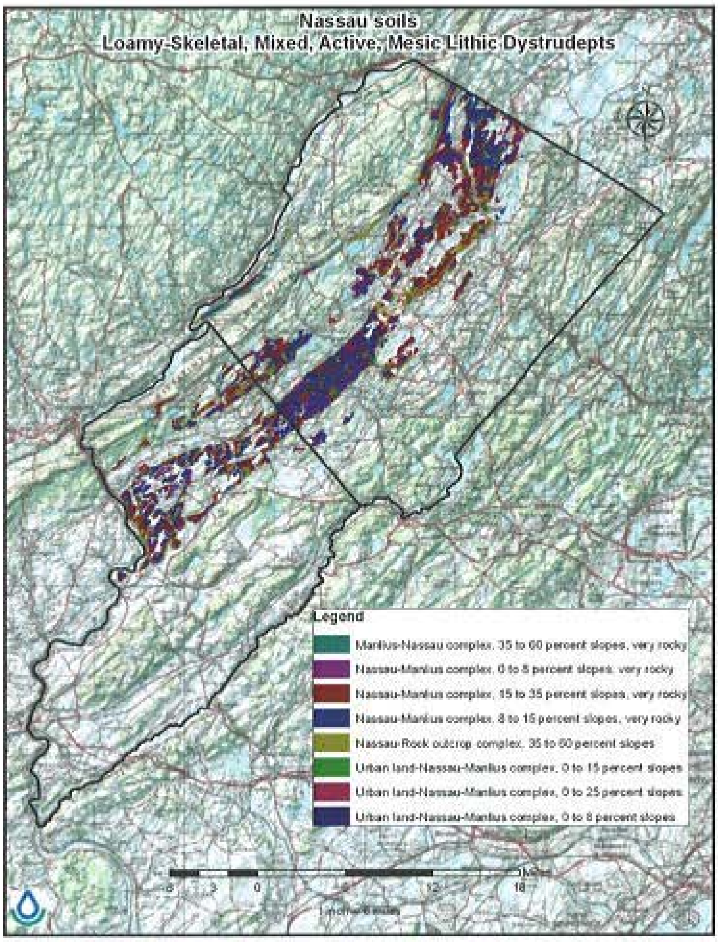

Figure 1. Areas that are mapped as complexes of Nassau soil in Warren and Sussex Counties, New Jersey, are shown on this map.

In northeastern New Jersey, Nassau is commonly mapped in complex with Manlius soils (Figure 1). The moderately deep, well drained to excessively drained Manlius soils formed in channery till. Manlius is a member of the loamy-skeletal, mixed, active, mesic Typic Dystrudepts taxonomic family.

Equipment:

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR-3000), manufactured by Geophysical Survey Systems, Inc. (GSSI; Salem, NH).[1] The SIR-3000 consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. A 10.8-volt, lithium-ion, rechargeable battery powers the system. The SIR-3000 weighs about 4.1 kg (9 lbs) and is backpack portable. With an antenna, the SIR-3000 requires two people to operate. Jol (2009) and Daniels (2004) discuss the use and operation of GPR. The 200, 400, and 900 MHz antennas were used in this study. However, after initial calibration trials, the 200 MHz antenna was selected as the most appropriate antenna, as it provided the best balance of exploration depth and resolution of the soil/bedrock interface.

The RADAN for Windows (version 6.6) software program (GSSI) was used to process the radar records.[1] Processing included: header editing, positioning the initial pulse to time zero, color table and transformation selection, horizontal high pass filtration, migration, and range gain adjustments (refer to Jol (2009) and Daniels (2004) for discussions of these techniques).

Recent technical developments allow the integration of GPR and global positioning system (GPS) data. The SIR-3000 system provides a setup for the use of a GPS receiver with a serial data recorder (SDR). With this setup, each scan on radar records can be georeferenced (position/time matched). During data processing, a subprogram within RADAN is used to proportionally adjust the position of each radar scan according to the time stamp of the two nearest positions recorded with the GPS receiver. A Garmin Global Positioning System Map 76 receiver (with a CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack) was used to georeferenced data collected with the SIR-3000 system.[1]

The *Interactive 3D Module* of RADAN was used to semi-automatically picked the depths to the soil/bedrock interface. The picked data were outputted to a worksheet (in an X, Y, and Z format; including longitude, latitude, and depth to bedrock data).

Calibration of GPR:

Ground-penetrating radar is a time scaled system. The system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., bedrock, soil horizon, stratigraphic layer) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships among depth (D), two-way pulse travel time (T), and velocity of propagation (v) are described in the following equation (after Daniels, 2004):

$$v = 2D/T \qquad [1]$$

The velocity of propagation is principally affected by the relative dielectric permittivity (E_r) of the profiled material(s) according to the following equation (after Daniels, 2004):

$$E_r = (C/v)^2 \qquad [2]$$

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[1] Trade names are used for specific references and do not constitute endorsement.

Where C is the velocity of propagation in a vacuum (0.299 m/ns). The velocity of pulse propagation is commonly expressed in meters per nanosecond (ns). In soils, the amount and physical state (temperature dependent) of water have the greatest effect on the E_r and v.

Based on the measured depth and the two-way pulse travel time to a known subsurface reflector (metallic plate), the velocity of propagation and the relative dielectric permittivity through the upper part of a soil profile were estimated using equations [1] and [2]. At the time of this study, soils were moist, but the upper 10 cm were frozen. The estimated E_r varied between 9.09 and 11.26. The estimated v ranged from 0.0891 to 0.1010 m/ns. Each of these parameters varied with the antenna being used. The estimated E_r (11.26) and v (0.0891 m/ns) for the 200 MHz antenna were used for soil depth estimations.

Survey Area:

Two study areas were selected in northwestern New Jersey. Each is in a major wildlife management area consisting of open fields and woodlands. All GPR surveys were restricted to open fields. Area 1 is located off of Sarepta Road about 2.7 km southeast of Ramseysburg and 3.8 km northwest of Buttzville. Area 2 is located off of Walnut Road about 0.5 km west-southwest of Knowlton.

GPR Survey Procedures:

At each site, multiple traverses were completed with a 200 MHz antenna (see Figure 2). The 200 MHz antenna provided excellent resolution of subsurface features and appropriate penetration depths. Each radar traverse was stored as a separate file. Surveys were conducted by pulling the 200 MHz antenna on the ground surface. Areas of high grass and shrubs were avoided as these features jarred and lifted the antenna producing poor antenna coupling with the ground, which resulted in inferior quality images.

Figure 2. Radar surveys were completed by pulling a 200 MHz antenna along the ground surface. In this photo, Edwin Muñiz closes out a radar file on the SIR-3000 control unit, which is suspended from a harness.

Interpretation of Radar Records:
The radar records collected during this investigation contained insignificant levels of background noise, were highly interpretable, and required little additional processing. Figure 3 is a portion of a radar record that was collected in an area of Manlius and Nassau soils. In Figure 3, the horizontal and vertical scales are expressed in meters. The incline beds of the Martinsburg shale are clearly evident in this image. The interpreted soil/bedrock interface is approximated with a green-colored, segmented line in Figure 3. This interface is defined by the nearest point that the inclined bedding planes approach the soil surface. In this radar image, the depth to bedrock is largely moderately deep and shallow.

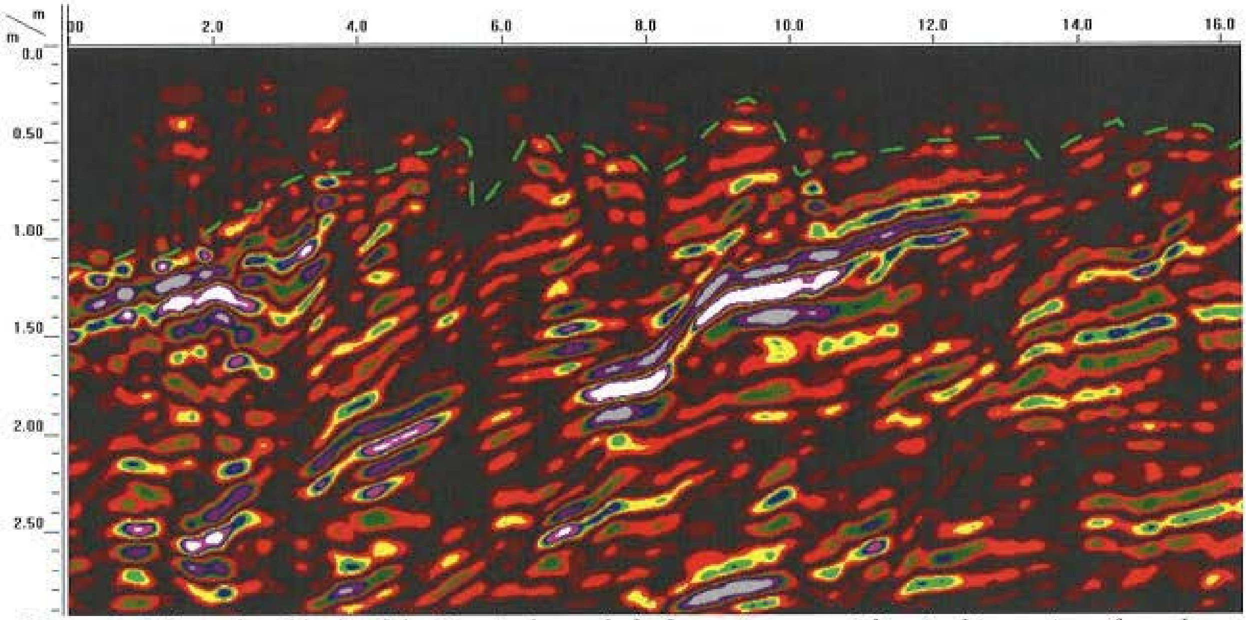

Figure 3. The inclined beds of the Martinsburg shale formation are evident in this portion of a radar record from an area of Nassau and Manlius soils.

The detection of fracture and bedding plane with GPR depends on their thickness and the material filling the discontinuity. High-amplitude radar reflections have been associated with abrupt changes in water content that occur in filled joints, fractures, and structural planes (Lane et al., 2000; Buursink and Lane, 1999; Olhoeft, 1998; Grasmueck, 1996). Scattering loss (a form of signal attenuation) from bedding and cleavage lanes is greater for reflectors with large dip-angles. Bedding and cleavage planes with dip-angles greater than about 45 ° are affected by spatial aliasing distortion and are not accurately imaged with GPR (Buursink and Lane 1999).

Processing was used to increase the interpretability of radar records. Processing steps that were used included: time zero adjustment, horizontal high pass filtration, migration, and range gain adjustments. These steps were sequentially applied to all radar records to improve the identification of the soil/bedrock interface.

The first processing step was to adjust the position of the surface pulse using the *time zero* adjustment (see Figure 4, top). As evident in Figure 4, the *horizontal high pass filter* is used to reduce the ringing noise of the surface pulse and to aid the identification of the soil/bedrock interface at very shallow depths. *Migration* is used to adjust inclined reflectors (such as bedding planes in Martinsburg shale) to their proper position and to remove hyperbolic diffraction tails (a source of unwanted noise). Processing techniques such as migration and high pass filtration reduce the amplitude of reflected radar signals appearing on radar records (see middle two images in Figure 4). The *range gain* function is used to selectively increase signal amplitudes (Figure 4, bottom).

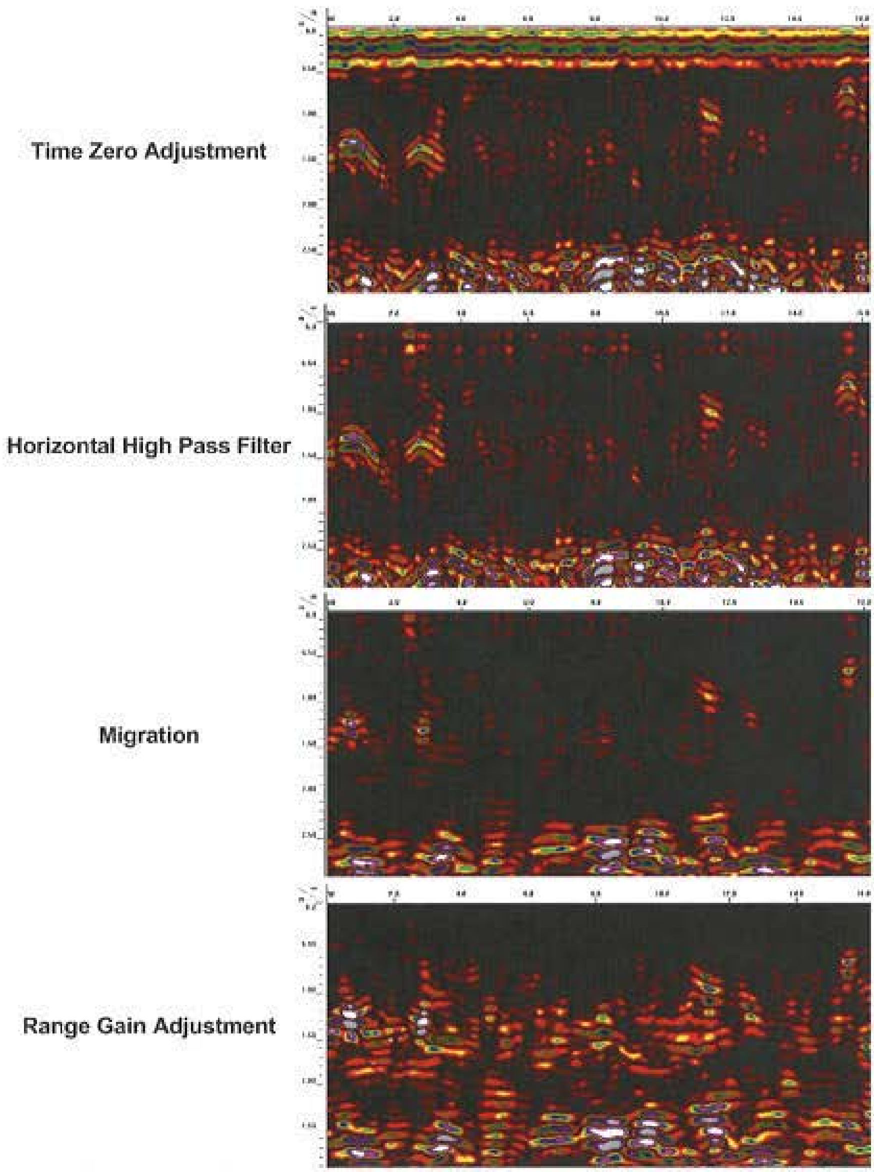

Figure 4. Sequential steps used to increase interpretability and identify the soil/bedrock interface on radar records.

The aforementioned processing steps were applied to all radar records. In areas that lacked inclined shale strata, the bedrock surface was often more difficult to indentify. As shown in Figure 4 (top), high amplitude reflectors occurred at the bottom of many radar records. On raw radar records, this zone was initially interpreted to be the soil/bedrock interface. However, as shown in Figure 4 (top), this zone of higher amplitude reflectors is overlain by an ill-defined zone consisting of discontinuous and lower amplitude reflections. This upper zone was initially interpreted as till on the raw radar records that were reviewed in the field. Till, however, is characterized on radar records by chaotic reflection patterns. The patterns evident on raw radar records were more linear with a rather discontinuous, but fairly distinct upper interface. Following processing, the radar signature of this overlying zone is more linear and closely corresponds to the signature of the lower lying zone (previously interpreted as the bedrock surface). The overlying zone is interpreted as bedrock. However, this overlying zone of bedrock was not confirmed in the field and is an enigma. Because of it weaker expression on raw radar records, it is possible that the apparent strata represent wetter, softer, and/or more weathered members of the Martinsburg shale. It is also possible that the weaker expression is attributed to inappropriate gain adjustments on the SIR-3000 for the traversed soils and terrain conditions.

Results:

<u>Area 1:</u>

Area 1 is located near the southern terminus of Wisconsin glaciations. Here, the till mantle is expected to be thin and discontinuous. In the traversed portions of Area 1, based on 337,349 radar measurements, soils are 12 % shallow, 67 % moderately deep, 18 % deep, and 3 % very deep. Within this area, depths to bedrock ranged from 0.01 to 2.89 m. Figure 5 is a *Goggle Earth* image of Area 1 showing the distribution of soils based on soil depth classes. In this image, the locations of the GPR traverse lines are shown. Colors have been used to identify the interpreted depth classes.

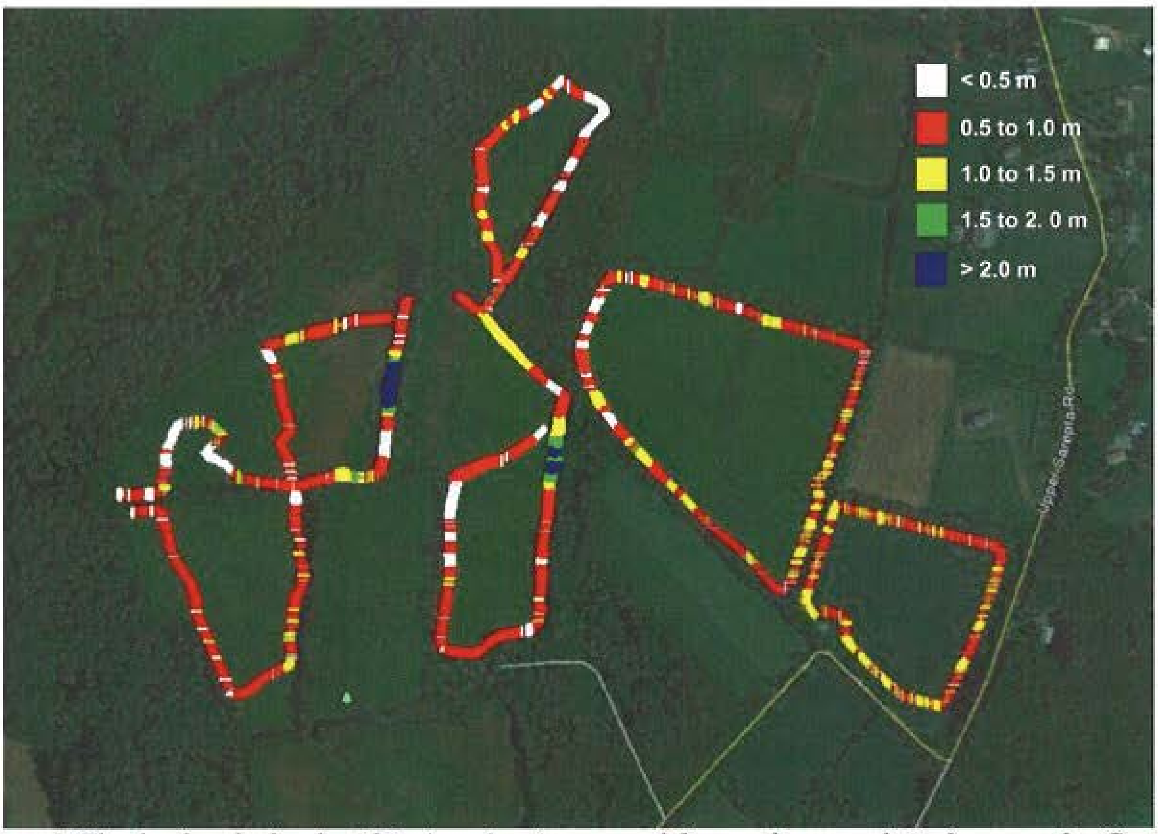

Figure 5. *The depth to bedrock within Area 1 as interpreted from radar records is shown on this Google Earth image (courtesy of Brian Jones of GSSI). All depths are expressed in meters.*

Tables 1 and 2 provide basic data and statistics for the twenty-two radar traverses completed in Area 1. Tables 3 and 4 list the frequency distributions of measurements by soil depth classes for each of the twenty-two radar traverses completed in Area 1.

Table 1. Basic Statistic for GPR Traverses 10 to 21 in Area 1.

	File 10	File 11	File 12	File 13	File 14	File 15	File 16	File 17	File 18	File 19	File 20	File 21
Shallow	225	244	201	2678	3215	5531	539	1034	3001	81	2976	6041
Mod Deep	7656	12404	18600	5737	8440	5834	18259	14292	13769	9488	8909	5210
Deep	4889	4152	13641	1121	3225	2398	1106	3440	1095	2174	805	0
Very Deep	10	67	155	3756	766	367	0	190	0	0	0	0
Mean	0.95	0.88	0.98	1.17	0.83	0.67	0.79	0.84	0.71	0.83	0.65	0.47
Minimum	0.30	0.40	0.44	0.28	0.31	0.12	0.30	0.32	0.01	0.34	0.09	0.01
Maximum	1.55	1.65	1.62	2.89	2.27	1.63	1.33	1.89	1.24	1.40	1.50	0.96
Number	12780	16867	32597	13292	15646	14130	19904	18956	17865	11743	12690	11251

Table 2. Basic Statistic for GPR Traverses 22 to 31 in Area 1.

	File 22	File 23	File 24	File 25	File 26	File 27	File 28	File 29	File 30	File 31	File 31
Shallow	2690	238	1126	592	4731	795	1749	258	176	648	783
Mod Deep	17577	3787	10178	7913	7543	7271	6381	7890	6681	9916	13314
Deep	2143	114	3282	1025	767	361	347	2952	1642	6223	4772
Very Deep	63	0	3348	0	0	0	0	0	87	120	145
Mean	0.74	1.23	1.04	0.74	0.62	0.77	0.66	0.90	0.84	0.92	0.87
Minimum	0.15	0.90	0.32	0.34	0.28	0.29	0.33	0.41	0.44	0.32	0.24
Maximum	1.52	1.57	2.26	2.22	1.36	1.15	1.21	1.44	1.60	2.02	1.68
Number	22473	4139	17934	9530	13041	8427	8477	11100	8586	16907	19014

Table 3. Frequency Distribution of Observations according to Soil Depth Intervals for GPR Traverses 10 to 21 in Area 1.

	File 10	File 11	File 12	File 13	File 14	File 15	File 16	File 17	File 18	File 19	File 20	File 21
Shallow	0.02	0.01	0.01	0.20	0.21	0.39	0.03	0.05	0.17	0.01	0.23	0.54
Mod Deep	0.60	0.74	0.57	0.43	0.54	0.41	0.92	0.75	0.77	0.81	0.70	0.46
Deep	0.38	0.25	0.42	0.08	0.21	0.17	0.06	0.18	0.06	0.19	0.06	0.00
Very Deep	0.00	0.00	0.00	0.28	0.05	0.03	0.00	0.01	0.00	0.00	0.00	0.00

Table 4. Frequency Distribution of Observations according to Soil Depth Intervals for GPR Traverses 22 to 32 in Area 1.

	File 22	File 23	File 24	File 25	File 26	File 27	File 28	File 29	File 30	File 31	File 32
Shallow	0.12	0.06	0.06	0.06	0.36	0.09	0.21	0.02	0.02	0.04	0.04
Mod Deep	0.78	0.91	0.57	0.83	0.58	0.86	0.75	0.71	0.78	0.59	0.70
Deep	0.10	0.03	0.18	0.11	0.06	0.04	0.04	0.27	0.19	0.37	0.25
Very Deep	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01

Area 2:

Area 2 is located north of Area 1 and is assumed to be covered by a thicker till layer. Based on 236,889 radar measurements, soils are 4 % shallow, 61 % moderately deep, 30 % deep, and 4 % very deep across Area 2. Within this area, depths to bedrock ranged from 0.2 to 2.45 m. Figure 6 is a *Goggle Earth* image of Area 2 showing the distribution of soils based on soil depth classes. In this image, the locations of the GPR traverse lines are shown. Colors have been used to identify the interpreted depth classes.

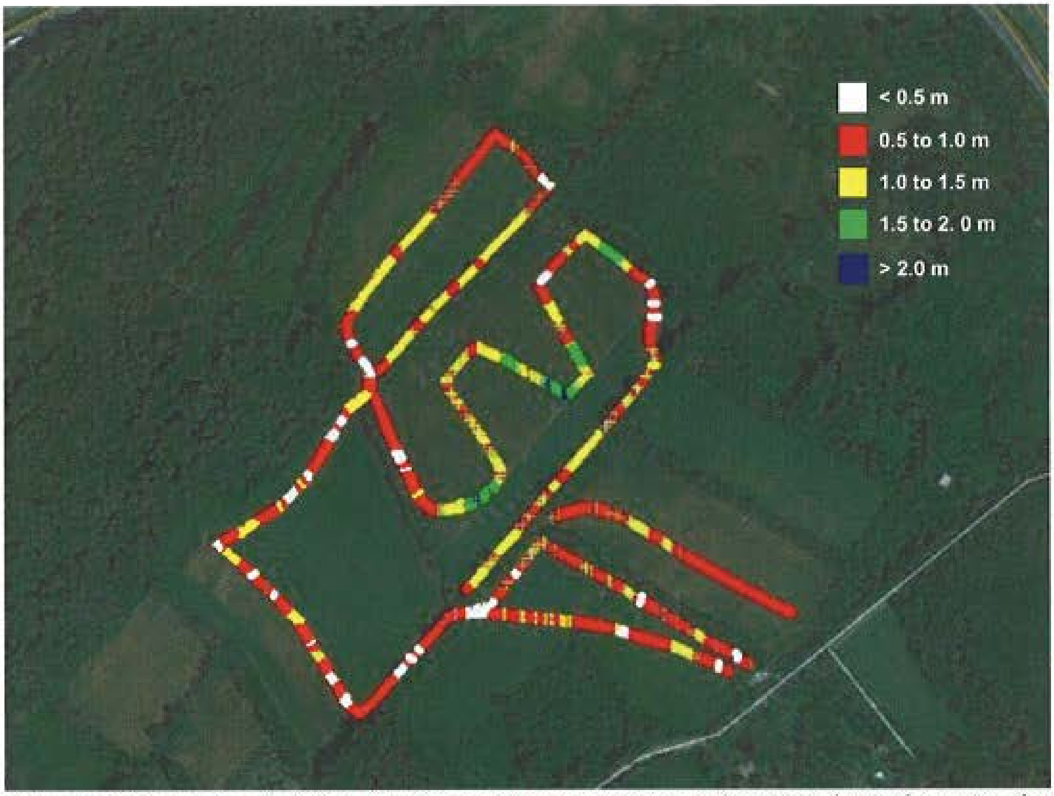

Figure 6. *The depth to bedrock within Area 2, as interpreted from radar records, is shown on this Google Earth image (courtesy of Brian Jones of GSSI). All depths are expressed in meters.*

Tables 5 and 6 provide basic data and statistics for the sixteen radar traverses completed in Area 2. Tables 7 and 8 list the frequency distributions of measurements by soil depth classes for each of the sixteen radar traverses completed in Area 2.

Table 5. Basic Statistic for GPR Traverses 33 to 41 in Area 2.

	File 33	File 34	File 36	File 37	File 38	File 39	File 40	File 41
Shallow	1304	126	2952	573	545	1658	1498	0
Mod Deep	12586	15521	13167	10874	2196	8731	15858	4492
Deep	3654	3324	1118	3796	280	2074	9005	869
Very Deep	43	66	0	77	0	0	0	0
Mean	0.83	0.84	0.70	0.88	0.72	0.78	0.91	0.84
Minimum	0.29	0.32	0.20	0.32	0.21	0.21	0.26	0.52
Maximum	2.05	1.54	1.22	1.72	1.18	1.44	1.44	1.44
Number	17587	19042	17237	15320	3021	12463	26362	5361

Table 6. Basic Statistic for GPR Traverses 42 to 49 in Area 2.

	File 42	File 43	File 44	File 45	File 46	File 47	File 48	File 49
Shallow	0	161	0	0	692	340	0	493
Mod Deep	8676	9756	4485	1520	6382	10935	6305	13097
Deep	9734	2435	7160	5455	5202	4958	7837	4988
Very Deep	89	3105	271	3768	734	1879	0	39
Mean	1.03	1.04	1.09	1.40	0.98	0.98	1.02	0.88
Minimum	0.54	0.37	0.53	0.55	0.15	0.31	0.59	0.31
Maximum	1.61	2.15	1.72	2.45	1.86	1.97	1.40	1.77
Number	18499	15457	11916	10743	13010	18112	14142	18617

Table 7. Frequency Distribution of Observations according to Soil Depth Intervals for GPR Traverses 33 to 41 in Area 2.

	File 33	File 34	File 36	File 37	File 38	File 39	File 40	File 41
Shallow	0.07	0.01	0.17	0.04	0.18	0.13	0.06	0.00
Mod Deep	0.72	0.82	0.76	0.71	0.73	0.70	0.60	0.84
Deep	0.21	0.17	0.06	0.25	0.09	0.17	0.34	0.16
Very Deep	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00

Table 8. Frequency Distribution of Observations according to Soil Depth Intervals for GPR Traverses 42 to 49 in Area 2.

	File 42	File 43	File 44	File 45	File 46	File 47	File 48	File 49
Shallow	0.00	0.01	0.00	0.00	0.05	0.02	0.00	0.03
Mod Deep	1.62	0.63	0.38	0.14	0.49	0.60	0.45	0.70
Deep	1.82	0.16	0.60	0.51	0.40	0.27	0.55	0.27
Very Deep	0.02	0.20	0.02	0.35	0.06	0.10	0.00	0.00

References:

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