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

Subject: SOI -- Ground-Penetrating Radar Assistance **Date:** February 27, 2001

To: Russell A. Collett
State Conservationist
USDA-NRCS
967 Illinois Avenue, Suite #3
Bangor, Maine 04401

PURPOSE:
The purpose of this study was to use ground-penetrating radar (GPR) to help characterize the depth of organic materials and the composition of soil map units within peatlands.

PARTICIPANTS:
Jim Doolittle, Research Soil Scientist, NRCS, Newtown Square, PA
Wayne D. Hoar, State Soil Scientist, USDA-NRCS, Dover-Foxcroft, ME
Amy Jones, Soil Scientist, USDA-NRCS, Dover-Foxcroft, ME
Steve Mierzyskowski, U.S. Fish & Wildlife Service, Sunkhaze Meadows NWR, Milford, ME
Ronald W. Olson, Soil Resource Specialist, USDA-NRCS, Bangor, ME
Laurie Osher, Assistant Professor, Soil and Environmental Sciences, Univ. of Maine, Orono, ME
David E. Turcotte, Soil Project Leader, USDA-NRCS, Dover-Foxcroft, ME
Rick Vollick, U.S. Fish & Wildlife Service, Sunkhaze Meadows NWR, Milford, ME

ACTIVITIES:
All field activities were completed during the period of 5 to 8 February 2001.

RESULTS:

1. Transect work is infrequently carried out in areas of organic soils because of wet and often ponded soil conditions that provides poor footing and little support to soil scientists. This was the first attempt to survey the thickness of organic materials within northern New England during winter months. Work the following week in New Hampshire proved the utility of using snowshoes. With good snowshoes, the speed and quantity of data increased greatly. Snowmobile trails were not followed and the ground was less frozen for easier observations. Sites were selected near roads for easier access.

2. In spite of the fact that weather conditions were poor and this was our first attempt at surveying peatlands under deep snow conditions, the goals of this field study were met. Six transects were completed with GPR. These transects provided a total of 156 observations. The average thickness of the organic deposits was about 4.0 m, with a range of 0.47 to 7.85 m.

3. The 70 MHz antenna, which was graciously loaned to the USDA-NRCS by Geophysical Survey Systems, Inc. (North Salem, NH), was immeasurably easier to operate and provide superior penetration depths than the 120 MHz. Based on this study, the 70 MHz antenna is considered highly suitable for the determinations of organic thickness. Without this antenna, fieldwork would be decidedly more arduous, requiring more people and producing less data. This antenna should be well suited to bedrock, geomorphic and stratigraphic investigation. It is recommended that the National Soil Survey Center purchase a 70 MHz antenna.

It was my pleasure to work in Maine and with members of your fine staff.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:
R. Ahrens, Director, USDA-USDA, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
W. D. Hoar, State Soil Scientist, USDA-NRCS, 1073 West Main Street, Suite #7, Dover-Foxcroft, ME 04426-3717
C. Olson, National Leader for Soil Investigations, USDA-USDA, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
H. Smith, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
B. Thompson, MO Team Leader, USDA-NRCS, 451 West Street Amherst, MA 01002-2995
D. Turcotte, Soil Project Leader, USDA-NRCS, 1073 West Main Street, Suite #7, Dover-Foxcroft, ME 04426-3717

STUDY SITES:

All study sites were in wetlands located within southern Penobscot County, Maine. The wetlands were located in areas that have not been mapped as part of the update of Penobscot County. These wetlands are in areas that had previously been mapped as Bucksport and Wonsqueak soils. The Bucksport and Wonsqueak series consist of very deep, very poorly drained soils that formed in well-decomposed organic soil material. Bucksport soils have a mantle of organic materials more than 51 inches thick. Bucksport is a member of the euic, frigid Typic Haplosaprists family. The Wonsqueak soils have a mantle of organic materials less than 51 inches thick over loamy mineral material. The Wonsqueak is a member of the loamy, mixed, euic, frigid Terric Haplosaprists family.

Site 1 was located on the east side of Highway 15 near the boundary of Penobscot and Piscataquois counties. The trail was over a former roadbed that contained large amounts of fill materials. These materials weakened the radar signal and severely limited observation depths. Data from this site was of poor interpretative quality and was not analyzed.

Other sites were more appropriate for GPR. Sites 2, 3, and 4 were located in Hermon Township. Site 2 was in a wetland near Pug Pond. Site 3 and 4 were located in Hermon Bog. Sites 5 and 6 were located in Greenbush Township. Both sites were located with Sunkhaze Meadow Wildlife Preserve. Site 7 was also located in Greenbush Township. It was located on the north side of Cards Ridge Road along a power line.

MATERIALS AND METHODS

Equipment:

The radar unit is the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-2000 consists of a digital control unit (DC-2000) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. This unit is backpack portable and, with an antenna, requires two people to operate. The 120 MHz and 70 MHz antennas were used in this study. The 70 MHz antenna was graciously loaned to us from Geophysical Survey Systems, Inc. This antenna is more portable and suited to forested conditions than the 120 MHz antenna. The 70 MHz antenna provides greater depths of penetration, but poorer resolution of near surface features. A scanning time of 270 nanoseconds (ns) was used with the 120 MHz antenna. A scanning time of 340 ns were used with the 70 MHz antenna. The scanning rate was 32 scan/second.

Field Methods:

Areas of organic soils are considered most crossable for soil transects work during winter months when the upper part of the soil is frozen. However, as witnessed during this survey, a deep snow cover makes radar work impractical unless a mode of rapid convenience is obtained (snowmobiles) or suitable snowshoes are available. This was not possible for this survey. Most sites were located along snowmobile trails where the snow was more compacted and passable for survey work. However, a heavy snowstorm occurred the night before the investigation was to begin. This storm dumped about 1.5 to 2 feet of snow across the area making survey work most difficult and exhausting. However, GPR surveys were completed at all sites.

A radar traverse was conducted across each study site. Along each traverse line, observation points were spaced at an interval of about 50 feet. As studies were conducted through wooded areas, all traverses were completed with the GPR control unit carried in a backpack. Carrying the 70 MHz or pulling the 120 MHz antenna along each traverse line completed a radar transect. As the antenna passed each observation point, the operator impressed a dashed vertical line on the radar record.

CALIBRATION OF GPR

Ground-penetrating radar is a time scaled system. This system measures the time it takes electromagnetic energy to travel from an antenna to an interface (i.e., soil horizon, water table, stratigraphic layer) and back. To convert travel time to depth requires knowledge of the velocity of pulse propagation. Several methods are available to determine the velocity of propagation. These methods include use of table values, common midpoint calibration, and calibration over a target of known depth. The last method is considered the most direct and accurate method to estimate

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

propagation velocity. The procedure involves measuring the two-way travel time to a known reflector on the radar profile and calculating the propagation velocity by following equation (after Morey, 1974):

$$V = 2D/T \quad [1]$$

Equation [1] describes the relationship of the average propagation velocity (V) to the depth (D) and two-way pulse travel time (T) to a reflector. At one observation point the depth to the organic mineral interface was measured at a depth of 47 inches. This observation point was covered with about 9 inches of snow. In addition, the upper 16 inches of the soil profile was frozen. The measured depth (D) and the two-way radar pulse travel time to the organic/mineral interface were used to estimate the velocity of propagation. The estimated velocity of propagation through the upper part of this profile was 0.0463 m/ns. Unquestionably, this velocity is greater than the average velocity through unfrozen organic materials (about 0.0375 m/ns). It would have been preferable if several observations each to greater depths were made. However, frozen soil conditions along the snowmobile trails made digging very difficult and the depth of observation was limited to a six-foot auger.

Considering existing conditions along traverse lines, the estimated velocity of propagation provided a fairly accurate measure to the taxonomically critical depth of 51 inches (1.3 m). At each observation point, the two-way travel time to the organic/mineral interface and the estimated velocity of propagation were used to determine the thickness of organic materials. Within the study sites, the velocity of propagation decreased with soil depth and principally reflects increased soil water contents. Because of this variability it is impossible to accurately predict depths to the organic mineral interface across these sites using a single velocity of propagation. Because of this, deeper depth measurements (> 2 m) given in this report err by as much as 0.5 to 1 m.

RESULTS

Compared with the 120 MHz antenna, the 70 MHz antenna was easier to carry across sites and provided improved penetration depths and comparable resolution.

Six transects were completed with GPR. These transects provided a total of 156 observations. The average thickness of the organic deposits was about 4.0 m, with a range of 0.47 to 7.85 m. On half of the observations had organic materials between 2.1 to 6.1 m thick. A recorded depth of 7.85 m represents the maximum depth of penetration with the 70 MHz antenna and a scanning time of 340 ns. Because of this factor, a recorded depth of 7.85 m at an observation point signifies that the depth to the organic/mineral interface was equal to or (most likely) greater than 7.85 m.

Table 1 shows the frequency distribution of peat thickness within each study site. The critical depth of 1.3 m separates the Terric from the Typic taxonomic subgroups. For the areas traversed with GPR, peatlands are predominantly composed of organic soils with organic layers greater than 1.3 m (51 inches) thick. Table 2 lists the interpreted depth to the organic/mineral soil interface at each observation point. The UTM coordinates of each observation point are also given in Table 2.

References:

Daniels, D. J. 1996. Surface-Penetrating Radar. The Institute of Electrical Engineers, London, United Kingdom. 300 p.

Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. pp. 11-32. In: Reybold, W. U. and G. W. Peterson (eds.) Soil Survey Techniques, Soil Science Society of America. Special Publication No. 20. p. 98

Morey, R. M. 1974. Continuous subsurface profiling by impulse radar. pp. 212-232. IN: Proceedings, ASCE Engineering Foundation Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, held at Henniker, New Hampshire. Aug. 11-16, 1974.

Table 1

Distribution of depths to the organic/mineral interface in selected peatlands as interpreted with GPR.

SITE 2	Depth (m)	Number	Frequency
	0 TO 1.3	7	0.21
	1.3 TO 2	3	0.09
	2 TO 3	3	0.09
	3 TO 4	9	0.26
	4 TO 5	8	0.24
	>5	4	0.12

SITE 3	Depth (m)	Number	Frequency
	0 TO 1.3	1	0.04
	1.3 TO 2	0	0.00
	2 TO 3	1	0.04
	3 TO 4	9	0.33
	4 TO 5	5	0.19
	5 TO 6	7	0.26
	>6	4	0.15

SITE 4	Depth (m)	Number	Frequency
	0 TO 1.3	0	0.00
	1.3 TO 2	0	0.00
	2 TO 3	0	0.00
	3 TO 4	0	0.00
	4 TO 5	0	0.00
	5 TO 6	4	0.10
	6 TO 7	28	0.72
	>7	7	0.18

SITE 5	Depth (m)	Number	Frequency
	0 TO 1.3	0	0.00
	1.3 TO 2	1	0.10
	2 TO 3	2	0.20
	3 TO 4	7	0.70
	4 TO 5	0	0.00
	5 TO 6	0	0.00
	6 TO 7	0	0.00
	>7	0	0.00

Site 6	Depth (m)	Number	Frequency
	0 TO 1.3	0	0.00
	1.3 TO 2	4	0.50
	2 TO 3	3	0.38
	3 TO 4	1	0.12
	4 TO 5	0	0.00
	5 TO 6	0	0.00
	6 TO 7	0	0.00
	>7	0	0.00

SITE 7	Depth(m)	Number	Frequency
	0 TO 1.3	12	0.32
	1.3 TO 2	10	0.27
	2 TO 3	7	0.19
	3 TO 4	3	0.08
	4 TO 5	5	0.14
	5 TO 6	0	0.00
	6 TO 7	0	0.00
	>7	0	0.00

Table 2

Thickness of Organic Materials as interpreted with GPR along each Traverse Line

Site	Easting	Northing	Depth(m)
2	508210	4960154	1.19
2	508194	4960158	1.80
2	508175	4960146	2.09
2	508172	4960137	1.86
2	508133	4960115	2.30
2	508117	4960115	2.63
2	508096	4960108	3.69
2	508072	4960075	3.93
2	508073	4960072	4.36
2	508026	4960048	4.81
2	508033	4960039	4.77
2	508023	4960030	5.40
2	508005	4960016	5.39
2	508018	4960012	4.80
2	508002	4960010	4.80
2	507993	4959998	5.20
2	507987	4959994	5.36
2	507974	4959990	4.82
2	507970	4959967	3.66
2	507957	4959956	4.18
2	507964	4959932	4.24
2	507926	4959934	3.85
2	507938	4959934	3.87
2	507940	4959952	3.56
2	507942	4959942	3.68
2	507934	4959928	3.68
2	507926	4959915	3.37
2	507920	4959902	1.98
2	507916	4959886	1.27
2	507914	4959869	0.75
2	507910	4959855	0.70
2	507905	4959840	1.13
2	507902	4959823	1.20

Site	Easting	Northing	Depth(m)
3	509633	4961894	1.15
3	509649	4961890	2.88
3	509661	4961888	3.32
3	509674	4961884	3.15
3	509687	4961881	3.39
3	509701	4961879	3.60
3	509713	4961876	3.54
3	509726	4961872	3.39
3	509738	4961868	3.21
3	509750	4961865	3.27
3	509766	4961859	3.39
3	509775	4961862	4.36
3	509790	4961857	4.36
3	509803	4961852	4.44
3	509818	4961849	4.48
3	509832	4961845	5.00
3	509847	4961841	5.38
3	509858	4961839	5.41
3	509869	4961837	5.50
3	509881	4961834	5.88
3	509893	4961832	5.65
3	509906	4961829	5.66
3	509917	4961827	5.90
3	509929	4961824	6.04
3	509940	4961821	6.29
3	509954	4961817	6.29
3	509966	4961814	6.29

Site	Easting	Northing	Depth(m)
4	509977	4961811	6.29
4	509992	4961808	6.90
4	510003	4961806	6.90
4	510016	4961801	6.97
4	510027	4961799	6.97
4	510038	4961797	7.09
4	510049	4961794	7.22
4	510062	4961791	7.31
4	510073	4961788	7.12
4	510085	4961784	7.11
4	510098	4961781	7.07
4	510111	4961777	7.24
4	510122	4961774	7.46
4	510133	4961771	7.85
4	510147	4961769	7.85
4	510158	4961766	7.85
4	510169	4961762	7.85
4	510181	4961760	7.85
4	510192	4961757	7.51
4	510203	4961754	7.28
4	510216	4961752	7.22
4	510227	4961749	7.26
4	510238	4961746	7.22
4	510251	4961743	7.28
4	510262	4961741	7.22
4	510273	4961739	7.19
4	510285	4961735	7.19
4	510296	4961733	7.22
4	510309	4961728	7.16
4	510322	4961724	6.92
4	510335	4961721	6.90
4	510347	4961719	6.89
4	510360	4961717	6.75
4	510372	4961714	6.43
4	510383	4961711	6.51
4	510395	4961708	6.12
4	510406	4961705	6.11
4	510419	4961702	5.70
4	510431	4961703	5.56

Site	Easting	Northing	Depth(m)
5	535122	4980209	1.81
5	535115	4980200	2.36
5	535116	4980189	2.58
5	535117	4980171	3.14
5	535114	4980164	3.21
5	535111	4980150	3.24
5	535111	4980145	3.39
5	535111	4980129	3.22
5	535114	4980114	3.26
5	535111	4980101	3.19

Site	Easting	Northing	Depth(m)
6	535168	4980472	1.31
6	535174	4980484	1.93
6	535179	4980498	1.70
6	535183	4980512	1.87
6	535186	4980528	2.66
6	535188	4980543	2.54
6	535189	4980559	2.85
6	535193	4980572	3.12

Site	Distance(m)	Depth(m)
7	0	0.81
7	15	0.68
7	30	0.78
7	45	0.47
7	60	0.68
7	75	0.66
7	90	1.09
7	105	1.61
7	120	2.10
7	135	2.32
7	150	1.85
7	165	2.15
7	180	3.54
7	195	4.68
7	210	4.65
7	225	4.29
7	240	4.19
7	255	4.12
7	270	3.75
7	285	2.97
7	300	2.12
7	315	1.73
7	330	1.63
7	345	1.46
7	360	2.34
7	375	1.53
7	390	1.39
7	405	1.41
7	420	2.36
7	435	3.02
7	450	1.54
7	465	1.15
7	480	1.59
7	495	1.10
7	510	0.70
7	525	0.60
7	540	0.83