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Subject: GEO- Geophysical Assistance **Date:** 26 November 1995

To: Douglas Burns
US Geological Survey
Water Resources Division
425 Jordan Road
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Purpose:
To assess the suitability of using ground-penetrating radar to estimate the thickness of till deposits and the depth to bedrock within a small watershed in the Catskill Mountains.

Participants:
Doug Burns, Hydrologist, USGS, Troy, NY
James Doolittle, Research Soil Scientist, NRCS, Chester, PA

Activities:
The survey was completed on 19 and 20 October 1995. The study site was located in northwest Ulster County near Frost Valley.

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc. (GSSI).* The use and operation of GPR have been discussed by Morey (1974), Doolittle (1987), and Daniels and others (1988). The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. The system was powered by a 12-VDC battery. A model 3105 (300 mHz) antenna was used in this investigation.

Survey Area:
The study area was located within the greater Neversink River watershed. The watershed of a small subsidiary tributary to the West Branch Neversink River is being studied by the principal investigator. Within this watershed, the principal soil map units include the Oquaga-Arnot-Rock outcrop complex, moderately steep, and the Arnot-Oquaga-Rock outcrop very steep (Tornes, 1979). These map units consist of shallow (0 to 50 cm) to moderately deep (50 to 100 cm), moderately well to excessively drained soils and areas of exposed bedrock. The very bouldery soils formed in till over sandstone and conglomerate bedrock. Arnot is a member of the loamy-skeletal, mixed, mesic Lithic Dystrochrepts family.

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* Trade names are used to provide specific information. Their mention does not constitute endorsement by USDA-NRCS.

Oquaga is a member of the loamy-skeletal, mixed, mesic Typic Dystrochrepts family.

Field Methods:
Five survey lines were established across the watershed. One line (#3) was established parallel with and along the drainageway. The four other line were established perpendicular to the principal drainageway. Lines 1 and 2 were located on south-facing slopes; lines 4 and 5 were located on north-facing slopes. Each line was cleared of brush and fallen tree limbs and branches. Along each survey flags were inserted in the ground at a paced interval of approximately 15 meters. The number of observations along each survey line are listed in Table 1.

Table 1

Number of Observations along Survey Lines

Line	Observations	File #
1	24	1 & 4
2	15	2 & 5
3	45	3 & 8
4	17	6 & 7
5	13	9 & 10

Radar transects were completed by hand-towing the antenna along each survey line. Two radar passes were completed along each survey line; one with a scanning time of 250 nanoseconds (ns), and one with a scanning time of 150 ns. Different scanning times were used to increase either the observation depth (250 ns) or the resolution of subsurface features (150 ns).

Interpretations:
Ground-penetrating radar provided interpretable images of several subsurface interfaces. As no auger observations were made during this investigation, the depth to and identity of subsurface interfaces are conjectural. In general, with the 300 mHz antenna, the depth of observation was restricted to a range of about 100 to 150 nanoseconds.

Figure 1 is a representative, processed radar profile from the watershed. This profile has been processed through the RADAN software package. Processing was limited to signal stacking, horizontal scaling, color transform and table customizing, and annotations. The horizontal scale is in meters and measures distances along the transect line. The vertical scale is in nanoseconds and measures relative scanning time or depth.

In Figure 1, the upper-most, continuous interface represents the soil surface. Immediately below the surface interface are a series of segmented interfaces (see A in Figure 1) believed to represent discontinuous soil horizons or features (roots and rock fragments). The interface representing the inferred bedrock surface (see B in Figure 1) has been highlighted with a dark line. In Figure 1, the bedrock interface ranges from about 15 to 30 ns. The depth of observation has been restricted to the upper part of a lower-lying, continuous, contrasting strata (see C in Figure 1). This interface appears variable in expression and is presumed to represent a contrasting lithologic layer.

For each transect, the scanning times to the inferred bedrock interface at each observation point has been listed in Tables 3 to 7. Assuming a dielectric constant of 6 for the dry mineral soil materials, the anticipated depth to bedrock has been estimated for each observation point in column 3 of Tables 3 to 7.

Results:

1. This reconnaissance survey attempted to assess the potentials for using GPR techniques for bedrock investigations within the Catskill Mountains. Time did not permit satisfactory calibration of the system, experimentation with additional antennas, nor verification of the interpretations.

2. The performance of the radar was considered good. Depths of consistent observation consistently exceeded 100 to 150 ns. Radar imagery can be improved through selection of the most suitable antenna and adjustments to the settings on the digital control unit. Antenna selection could be varied. The 300 mHz antenna was selected because of its size (maneuverability in a forested environment) and anticipated observation depths.

3. Returning to the site at a more moist time of the year could produce greater clarity of some subsurface interfaces and increased interpretability of radar profiles. Conducting GPR surveys when soils are moist to saturated could increase the contrast or dielectric gradient between the overlying till and underlying sandstone bedrock.

4. In the absences of ground-truth auger observations, the results of this survey are speculative. Based on a theoretical value of 6 for the dielectric constant of dry mineral soils and with no ground-truth observations to confirm radar interpretations, Table 2 summarizes the anticipated depths to bedrock for each transect line.

Table 2

Basic Statistics
for
Depth to Bedrock along Radar Traverses

(all measurements are in meters)

				Quartiles		
Traverse	**Min.**	**Max.**	**Avg.**	**1st**	**2nd**	**3rd**
1	0.42	1.65	1.17	1.00	1.16	1.41
2	0.89	2.73	1.36	1.10	1.21	1.36
3	0.73	2.58	1.39	1.13	1.32	1.58
4	0.97	1.73	1.34	1.12	1.24	1.58
5	0.87	1.97	1.30	1.10	1.23	1.36

Based on interpretations and assumptions made at one hundred and fourteen observation points, the depth to bedrock within the watershed ranged from 0.42 to 2.73 m. Within the watershed, the average depth to bedrock was about 1.32 m. One-half of the observations had depths to bedrock between 1.12 and 1.48 cm.

5. Radar profiles can be used to partition the landscape and to test hypotheses concerning the depth to and the configuration of the underlying bedrock. Gross patterns and distinct areas of similar and dissimilar subsurface graphic signatures are apparent on the collected radar profiles. These profiles should be reviewed and compared with existing bedrock/landscape models.

6. Hard copies of all radar profiles have been returned with this report.

With kind regards.

James A. Doolittle

cc:
J. Culver, Assistant Director, NSSC, NRCS, Lincoln, NE
C. Holzhey, Assistant Director, NSSC, NRCS, Lincoln, NE

References:

Daniels, D. J., D. J. Gunton, and H. F. Scott. 1988. Introduction to subsurface radar. IEE Proceedings 135F(4):278-320.

Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. IN Soil Survey Techniques, Soil Science Society of America Special Publ. No 20. pp. 11-32.

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.

Tornes, L. A. 1979. Soil survey of Ulster County, New York. USDA Soil Conservation Service. U.S. Government Printing Office, Washington, D.C. p. 273.

Table 3

Line 1		
Observation	**Time**	**Depth**
0	7.76	0.56
15	16.11	1.09
30	5.42	0.42
45	8.50	0.61
60	21.97	1.45
75	17.28	1.16
90	17.87	1.19
105	21.39	1.41
120	13.62	0.93
135	8.79	0.63
150	21.83	1.44
165	25.19	1.65
180	19.04	1.26
195	16.26	1.09
210	16.70	1.12
225	24.32	1.59
240	14.79	1.00
255	20.51	1.36
270	24.02	1.58
285	16.11	1.09
300	21.39	1.41
315	24.32	1.59
330	20.51	1.36
345	16.85	1.13

Table 4

Line 2		
Observation	**Time**	**Depth**
0	42.63	2.73
15	23.88	1.57
30	17.87	1.19
45	18.31	1.22
60	16.55	1.11
75	17.58	1.17
90	18.16	1.21
105	19.04	1.26
120	17.72	1.18
135	16.70	1.12
150	24.90	1.63
165	13.04	0.89
180	19.92	1.32
195	19.34	1.28
210	22.41	1.48

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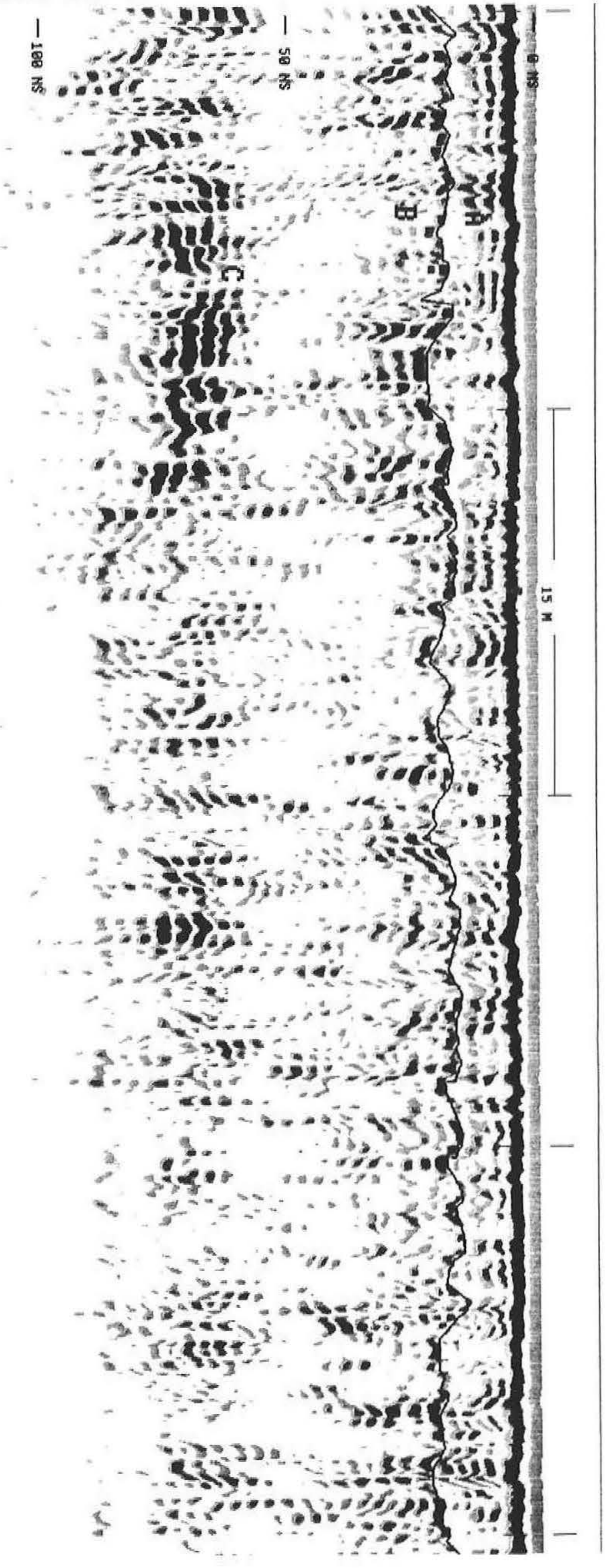

Table 5

Line 3

Observation	Time	Depth
0	18.46	1.23
15	12.45	0.86
30	15.82	1.07
45	15.53	1.05
60	22.26	1.47
75	21.24	1.40
90	25.19	1.65
105	14.94	1.00
120	16.70	1.12
135	27.10	1.77
150	19.77	1.31
165	17.43	1.16
180	12.16	0.84
195	18.02	1.20
210	19.04	1.26
225	24.61	1.61
240	24.76	1.62
255	14.50	0.98
270	20.65	1.37
285	20.07	1.33
300	24.02	1.58
315	30.47	1.98
330	36.62	2.36
345	24.02	1.58
360	28.27	1.84
375	14.21	0.97
390	20.80	1.37
405	17.14	1.15
420	17.28	1.16
435	18.46	1.23
450	10.40	0.73
465	25.49	1.67
480	36.77	2.37
495	20.95	1.38
510	22.56	1.48
525	20.51	1.36
540	19.92	1.32
555	18.02	1.20
570	16.85	1.13
585	25.19	1.65
600	18.02	1.20
615	14.79	1.00
630	20.51	1.36
645	40.48	2.58
660	22.70	1.49

Table 6

Line 4		
Observation	Time	Depth
0	18.02	1.20
15	16.26	1.09
30	14.21	0.97
45	17.87	1.19
60	23.14	1.52
75	24.46	1.60
90	26.51	1.73
105	17.44	1.14
120	19.34	1.28
135	24.90	1.63
150	25.19	1.65
165	19.92	1.32
180	16.55	1.11

Table 7

Line 5		
Observation	Time	Depth
0	15.38	1.04
15	17.58	1.17
30	24.61	1.61
45	15.97	1.08
60	17.28	1.16
75	20.80	1.37
90	19.19	1.27
105	19.34	1.28
120	19.92	1.32
135	19.04	1.26
150	15.38	1.04
165	17.58	1.17
180	18.02	1.20
195	30.32	1.97
210	21.68	1.43
225	29.30	1.90
240	12.60	0.87