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

Subject: SOI -- Ground-Penetrating Radar (GPR) Assistance **Date:** 19 October 2002

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PURPOSE:
Ground-penetrating radar (GPR) was used to help characterize the stratigraphy of mineral deposits in selected wetlands of the Catskill. The US Environmental Protection Agency (EPA), Pennsylvania State University (PSU) and State University of New York at Cortland are participating in a study of wetlands. The study is being conducted in New York, Pennsylvania, and Virginia. This study is designed to test a modified hydrogeomorphic model (HGM) that has been developed by PSU. The present investigation uses noninvasive GPR methods to characterize subsurface deposits and look for communalities in substrate formations and sequences, which may be used for hydrologic classifications of wetlands.

PARTICIPANTS:
Christopher P. Cirmo, Associate Professor, State University of New York College at Cortland, Cortland, NY
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ACTIVITIES:
All field activities were completed during the period of 15 to 17 October 2002.

STUDY SITES:
The first study site, the *Meyers Road Site*, was located just to the northeast of the intersection of State Road 55 and Meyers Road, near the Neversink Reservoir in Sullivan County. The site includes Hollow Brook, several seeps and road drains. The site is located in a wooded area of Scriba loam, 3 to 8 % slopes (Seifried, 1989). The very deep, somewhat poorly drained Scriba soil formed in loamy glacial till. Scriba has a dense fragipan layer that restricts root penetration and water movement. Scriba is a member of the coarse-loamy, mixed, active, mesic Aeric Fragiaquepts family. Included with Scriba soils in mapping are small areas of Neversink soil. The very deep, poorly drained Neversink soil formed in depressional areas and along small drainageways. Neversink is a member of coarse-loamy, mixed, active, acid, mesic Aeric Epiaquepts family.

The second site, the *Biscuit Brook Site*, is just upstream from the junction of Biscuit Brook and the West Branch of Neversink River in Ulster County. The site is located on the east side of Ulster Route 47. The site is located in a relatively open area of Menlo very bouldery soils (Tornes, 1979). The very poorly drained Menlo soil formed in subglacial till. Menlo soil is very deep to bedrock and moderately deep to dense soil materials. Menlo soil is in depressions and drainageways. Menlo is a member of the coarse-loamy, mixed, active, nonacid, mesic Histic Humaquepts. Based on field observations, the *Biscuit Brook Site* contains large areas of Canandaigua soil. The very deep, poorly and very poorly drained Canandaigua soil formed in silty glacio-lacustrine sediments in depressional areas on glaciated uplands. Canandaigua is a member of the fine-silty, mixed, active, nonacid, mesic Mollic Endoaquepts family.

The third site, *Frost Valley Seep Site*, is located just north of the *Biscuit Brook Site* and is on the east side of Ulster Route 47. A large seep is conspicuous along the more steeply inclined slopes that bound the west side of the site. The area has been mapped within a broader unit of Wellsboro and Wurtsboro very bouldery soils, gently sloping (Tornes, 1979). The very deep, moderately well and somewhat poorly drained Wellsboro and Wurtsboro soils formed in till derived from conglomerate and sandstone. Both the Wellsboro and Wurtsboro soils are members of the coarse-loamy, mixed, active, mesic Typic Fragiudepts family. Included with Wellsboro and Wurtsboro soils in mapping are small areas of Atherton and Canandaigua soils in depressions. Based on field observations, the *Frost Valley Seep Site* consists principally of Canandaigua soil.

The Fourth site, *Ashoken Reservoir Site*, is located on a peninsula jutting out from the north shore of Ashoken Reservoir, south of Shokan in Ulster County. The area has been mapped as Canandaigua loam (Tornes, 1979). This poorly and very poorly drained site contains a small stream.

MATERIALS AND METHODS

Equipment:

The radar unit is the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974) and Doolittle (1987) 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 70, 120, and 200 MHz antennas were used in preliminary calibration trials at the *Meyers Road Site*. The 120 MHz antenna provided the best balance of penetration depth and resolution of subsurface features and was used in all subsequent fieldwork. For most radar profiles, a scanning time of 100 nanoseconds (ns) was used.

Field Methods:

Traverse lines were established across wetlands. Along each line, survey flags were inserted in the ground at either 5-m or 10-m intervals and served as reference points. Pulling the 120 MHz antenna along each traverse line completed a radar survey file. As the radar antenna was pulled passed each flagged reference point, the operator impressed a vertical reference line on the radar profile to identify the reference point. The coordinates of these observation points will be measured with a GPS receiver. Table 1 provides a summary of the radar traverses.

Table 1. Record of GPR Traverses

Site	File #	Length	Interval	General Direction
Meyers Road	1	60m	5m	From Stream toward West
Meyers Road	2	60m	10m	North to South
Meyers Road	3	60m	10m	from road into wetland
Meyers Road	4	60m	10m	from wetland to road
Biscuit Brook	5	60m	10m	From road into wetland
Biscuit Brook	6	55m	5m	Cross wetland west to East
Frost Valley Seep	7	40m	5m	North to South
Ashoken Reservoir	8	45m	5m	North to South across stream

CALIBRATION OF GPR

Ground-penetrating radar 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. In this study, tabled values were used to provide an approximate depth scale for the radar imagery.

For all depth calculations, a dielectric permittivity of 24 and a velocity of pulse propagation of 0.06 m/ns were used. Using a velocity of 0.06 m/ns, a two-way scanning time of 100 ns provided a penetration depth of about 3.0 m.

Ground-Penetrating Radar:

Ground-penetrating radar operates by transmitting pulses of radio-frequency electromagnetic energy into the subsurface. A receiving antenna records the energy that is reflected from subsurface boundaries or interfaces that separate layers of contrasting dielectric permittivity. The more abrupt and contrasting the difference in dielectric permittivity, the greater the amount energy that is reflected off an interface and the stronger the amplitude of the

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

reflected signal. Subsurface layers with the same or similar dielectric properties reflect little electromagnetic energy and are often indistinguishable with GPR. Dielectric permittivity is principally controlled by the water content (Davis and Annan, 1989).

Ground-penetrating radar is not equally suited to use in all earthen materials. Materials that have high electrical conductivity rapidly attenuate radar energy, restrict penetration depths, and severely limit the resolution and effectiveness of GPR (Davis and Annan, 1989). Electrical conductivity increases with increases in water, clay, and soluble salt contents. Because of their high adsorptive capacity for water and exchangeable cations, clays produce high attenuation losses. As a consequence, the penetration depth of GPR is inversely related to the clay content of soils. Doolittle and Collins (1998) noted that, depending on antenna frequency and the chemistry of the soil materials, penetration depths could range from 5 to 30 m in sandy (>85 % sand), 1 to 5 m in loamy (7 to 35 % clay), to less than 0.5 m in clayey (>35 % clay) soils. Soils that average less than 18 percent clay are considered favorable to deep penetration with GPR.

INTERPRETATIONS:

Figure 1 is a representative radar profile collected with the 120 MHz antenna from the *Biscuit Brook Site* (radar File #6). The radar profile is 55 m in length. The short, vertical lines at the top of the radar profile represent twelve, equally spaced (5-m), and flagged referenced points. The depth scale (in meters) along the left-hand side of the radar profile is based on an estimated velocity of propagation was 0.06 m/ns and a scanning time of 100 ns.

Figure 1 can be interpreted using the concept of *radar facies*. A radar facies is defined as a "mappable three-dimensional sedimentary unit composed of reflections whose parameters differ from adjacent units" (Jol and Smith, 1991). Parameters used in interpretations include the amplitude, continuity, and configuration of radar reflections. In radar facies analysis a portion of a radar profile that has a unique and identifiable graphic signature (a distinct, aggregate configuration, appearance, or pattern) is used to identify a stratigraphic units composed of like materials and distinguishable sedimentary structure or geometry.

Four distinct radar facies are evident in Figure 1. The upper-most facies (A) consists of horizontally continuous, parallel reflectors. These reflectors have moderate signal amplitudes suggesting modest dielectric gradients across interfaces. Because of moderate signal amplitudes, these layers are believed to reflect the interface separating silty glacio-lacustrine sediments from loamy till. Differences in clay and moisture contents exist across this interface. In the left-hand portion of Figure 1, multiple high amplitude reflections make up a distinct radar facies (B). This facies is believed to represent ledge rock composed of sandstone or conglomerate. Numerous, chaotic point reflectors are apparent between reference points 15 and 30 m. The reflectors that comprise this radar facies are believed to represent concentrations of cobbles and stones in the till. Between reference points 30 and 50 m, the radar signal appears to be more strongly attenuated. In general, subsurface reflectors are absent and parallel bands of noise dominate the lower part (below 1.5 m) of this portion (and facies) of the radar profile. The absence of subsurface interface in this portion of the radar profile denote either (1) rapid attenuation of radar signals caused by soil horizons with higher clay contents, or (2) the absence of contrasting soil horizons and subsurface reflectors.

In other profiles at other sites, planar near surface reflections are believed to represent the denser fragipan and/or texturally contrasting layers of soil materials. Most soils have a dense fragipan layer that restricts root penetration and water movement. At the time of this investigation, surface layers were typically saturated while the substratum was moist.

RESULTS:

Eight transects were completed with GPR at the four sites listed in Table 1. These transect were variable in length and ranged from 45 to 60 m. Measurable layers of peat were not encountered in any of the wetland sites. Organic deposits were too thin to be profiled with the 70, 120, or 200 MHz antennas.

It is desirable to profile peat deposits in the Catskills and compare these radar images with images obtained in the Adirondacks (see my trip report to Joseph R. DelVecchio, State Conservationist, New York of July 20, 2002). A review of the published Ulster County Soil Survey report, disclosed several large peat deposits mapped along the flanks of Wildcat Mountain and within the Frost Valley YMCA boundaries. These sites should be surveyed with GPR and results compared those of peat deposits that were surveyed within the Adirondacks this summer.

It was my pleasure to have this opportunity to work in New York.

With kind regards,

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