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

**Subject:** Soils – Ground-Penetrating Radar (GPR) Assistance **Date:** 4 February 2008

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**Purpose:**
The Massachusetts staff has recently upgraded its ground-penetrating radar (GPR) to a SIR-3000 system, and obtained the most recent version of RADAN (version 6.6) processing software. The Rhode Island staff has recently received older SIR-2, SIR-3, and SIR-2000 GPR systems from USDA-NRCS staffs in Massachusetts and New York. The primary purpose of this visit was to provide GPR training, and to insure that the Massachusetts's GPR units, global positioning systems (GPS), and processing software programs were synchronized and operating properly. A visit to Geophysical Survey Systems, Inc. (GSSI), (Salem, New Hampshire) was arranged in order to review the newest software, compatibility of the SIR3000 system with this agency's GPS receivers, and to observe new antenna systems.

**Principal Participants:**
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Robert Tunstead, Resource Soil Scientist, USDA-NRCS, West Wareham, MA
Jim Turenne, Assistant State Soil Scientist, USDA-NRCS, Warwick, RI

**Activities:**
All activities were completed during the period of 22 to 24 January 2008.

**Summary:**

1. During the visit to GSSI, Jim Doolittle, Rob, Tunstead, and Jim Turenne were instructed on how to setup a GPS receiver with the serial data recorder (SDR) and SIR3000 system. This setup will allow the automatic integration of GPR and GPS data. In addition, using the *Interactive 3D Module* to the RADAN processing software, depth to soil horizons and features can be a quickly, automatically, and accurately picked and outputted to worksheets (X, Y, Z format; containing latitude, longitude, and depths to soil, stratigraphic, and/or bedrock features). Using this module, data can be easily exported into GIS for plotting and visualization. Although, components of this software are still in the developmental stage, the integration of GPR with GPS, and the potentials of the *Interactive 3D Module* are collectively the greatest advancement in GPR technology that I have witness.

2. While Massachusetts has the most advanced GPR system and processing software that is available on the market today, components of these technologies can not be integrated with GPS because of the limitations of the Garmin Map76 GPS receiver that is presently being used by USDA-NRCS. In light of state-of-the-art GPR systems and processing technologies, the lack of a suitable GPS receiver severely restricts the effectiveness of these tools.

3. A suitable GPS receiver is necessary for the integration of GPS with GPR data. The Garmin Map76 GPS receiver that is extensively used within USDA-NRCS, while still very functional for most field office

applications, has outlived its intended lifecycle. This relatively old, inexpensive GPS receiver cannot be used with modern GPR systems and has become increasingly difficult to interface with modern electromagnetic induction (EMI) meters and software used by this agency. The Garmin Map76 GPS receiver simply outputs too many different strings of unnecessary NMEA data. EMI and GPR units require only strings of GGA NMEA data. With the Garmin, the string of GGA data occur only once in every 12 to 15 strings. It is not possible to eliminate the reception of these unnecessary and conflicting strings of NMEA information on the Garmin Map76 receiver. A new generation of more sophisticated GPS receivers is needed that can be earmarked for use with modern ground-penetrating radar systems and electromagnetic induction meters.

1. The most recent revision to the RADAN processing software is presently in the experimental phase and is still being tested by GSSI. Presently, this version does not communicate well with all GPS receivers, and setup procedures can be involved and time consuming. As a consequence, this "beta version" (RADAN6600 Beta6.exe) is not recommended for use by USDA-NRCS at this time.

It was my pleasure to work and to be of assistance to your staffs.

With kind regards,

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**What is possible?**
With further refinements to the RADAN (version 6600 Beta6) and the availability of a compatible GPS receiver, each scan on radar records can be quickly geo-referenced. A geo-referenced radar record can be quickly imaged using the *3D QuickDraw Module* of RADAN (version 6.6) as shown in Figure 1. Figure 1 is a geo-referenced radar record that was collected in the parking lot at GSSI. The depth scale is in meters. The radar record is positioned on a Universal Transverse Mercator (UTM) grid.

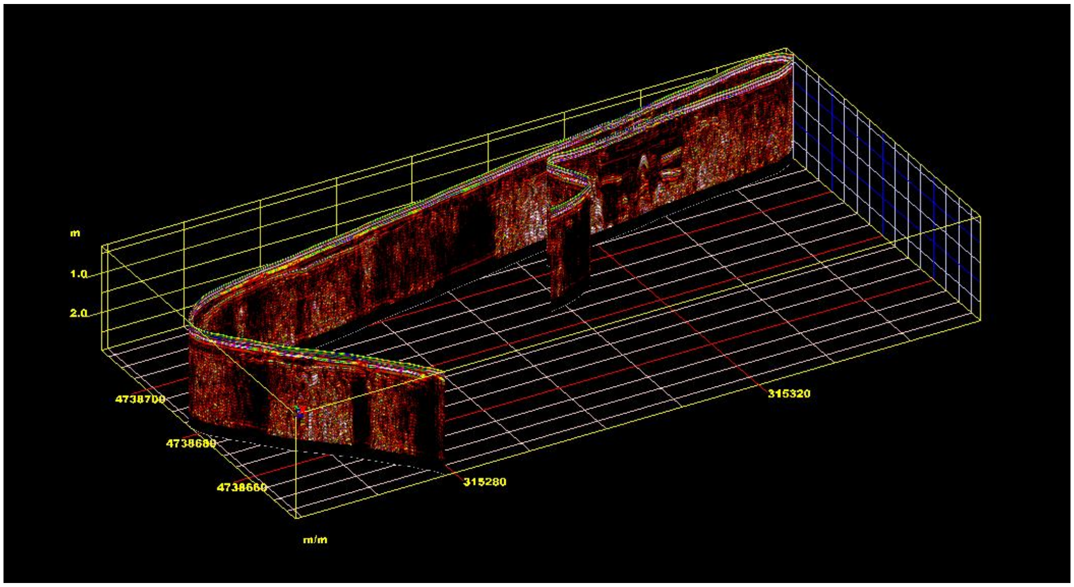


*Figure 1. This geo-referenced radar record has been imaged in a 3D perspective using the 3D QuickDraw Module of RADAN*

As mentioned in the summary, using the *Interactive 3D Module* to RADAN (version 6.6), depth to subsurface horizons and features can be a quickly, automatically, and accurately picked and exported to a worksheet (X, Y, Z format; containing latitude, longitude, and depth to soil, stratigraphic, and/or bedrock features). Table 1 is an example of a portion of this output. The depth of fill material (Layer 1) was picked from the radar record shown in Figure 1. The data shown in Figure 1 was collected at a rate of 120 scans/sec. This resulted in over 15,380 depth measurements (one for each scan) for the radar record shown in Figure 1. The radar record was obtained in a little over 2 minutes. The data were interpreted, and measurements of the thickness of the fill layer were obtained in less than 10 minutes. The 15,380 geo-referenced depth measurements from this one radar record can be exported in various file formats (an example of a portion of the data set is shown in Table 1).

| Scan# | Longitude | Latitude | Layer 1 | Depth (m) |
|---|---|---|---|---|
| 4 | -71.258128 | 42.7780553 | Layer 1 | 0.641 |
| 5 | -71.258128 | 42.7780553 | Layer 1 | 0.641 |
| 6 | -71.2581279 | 42.7780553 | Layer 1 | 0.641 |
| 7 | -71.2581279 | 42.7780553 | Layer 1 | 0.641 |
| 8 | -71.2581279 | 42.7780553 | Layer 1 | 0.641 |
| 9 | -71.2581278 | 42.7780553 | Layer 1 | 0.641 |
| 10 | -71.2581277 | 42.7780554 | Layer 1 | 0.641 |
| 11 | -71.2581277 | 42.7780554 | Layer 1 | 0.641 |
| 12 | -71.2581277 | 42.7780554 | Layer 1 | 0.641 |
| 13 | -71.2581276 | 42.7780555 | Layer 1 | 0.641 |
| 14 | -71.2581276 | 42.7780555 | Layer 1 | 0.641 |
| 15 | -71.2581276 | 42.7780556 | Layer 1 | 0.641 |
| 16 | -71.2581275 | 42.7780557 | Layer 1 | 0.641 |
| 17 | -71.258128 | 42.7780561 | Layer 1 | 0.635 |
| 18 | -71.2581281 | 42.7780562 | Layer 1 | 0.635 |

*Table 1. An example of the data that can be exported to a worksheet using the Interactive 3D Module to RADAN.*

Table 1 shows a very small portion of the data exported using the *Interactive 3D Module*. In this example, *Layer 1* is the fill layer, depths are presented in meters, and coordinates in latitude and longitude expressed in decimal degrees. At a rate of 120 scans per second, it is obvious from the data that the GPR hardly moves in the time that it takes to record 16 scans (data can be reduced).

Based on 15,380 depth measurements, the thickness of the fill layer averaged 82 cm with a range of 60 to 167 cm. This information can be easily scaled and exported into GIS for display (in this example from GSSI, *Goggle Earth* was used). In Figure 2, the location of the radar traverse line has been superimposed on an image of the parking lot at GSSI. The track of the GPR traverse is evident. Along the GPR traverse line, different colors are used to represent different thickness of fill materials: 0 to 50 cm (white); 50 to 100 cm (red); >100 cm (green). The synergism of GPR, GPS, and advanced processing techniques is very impressive and should greatly improve the collection of soil data and the quality of soil survey information.


*Figure 2. Depth scaled radar data of the thickness of fill materials superimposed on a Goggle Earth image.*