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

Subject: Soils – Geophysical Field Assistance **Date:** 19 December 2003

To: Dr Mike Vepraskas
Professor
Department of Soil Science
North Carolina State University
Campus Box 7619
3404 Williams Hall
Raleigh, NC 27695-7619

Roy Vick
State Soil Scientist
USDA-NRCS,
4405 Bland Road, Suite 205
Raleigh, North Carolina 27609

Purpose:
The purpose of this investigation was to characterize the stratigraphy and detect possible breaches in a medium textured aquitard within Juniper Bay in Robeson County with ground-penetrating radar (GPR).

Participants:
Alex Adams, Technician, Department of Soil Science, North Carolina State University, Raleigh, NC
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Brian Roberts, Technician, Department of Soil Science, North Carolina State University, Raleigh, NC
Wes Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, Wilkesboro, NC
Jeff White, Assistant Professor, Department of Soil Science, North Carolina State University, Raleigh, NC

Activities:
All activities were completed during the period of 8 to 9 December 2003.

Background:
Juniper Bay, a Carolina bay, will be restored to its original wetland conditions by the North Carolina Department of Transportation. This action is being undertaken to receive wetland credits. Within Juniper Bay, soils are diverse and highly stratified. In earlier GPR investigations of Juniper Bay, the depth and extent of permeable and impermeable layers were documented with GPR. Within much of the interior portion of the bay, an extensive layer of medium textured materials restricts the movement of water and limits the penetration depth and effectiveness of GPR. This layer is detectable with GPR. However, because of rapid attenuation of the radar's transmitted energy in the upper part of this layer, its thickness and the nature of the underlying materials cannot be interpreted from radar records. In this study, GPR was used to assess whether drainage ditches within Juniper Bay breach this relatively shallow (generally less than 2 m) aquitard.

Equipment:
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR System-3000), manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels

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

(1996) have discussed the use and operation of GPR. The SIR System-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. This unit weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, this system requires two people to operate. A 70 MHz antenna was used in this study. This antenna was selected because of its low frequency (greater penetration depth) and portability.

The RADAN for Windows (version 5.0) software program was used to process the radar records (Geophysical Survey Systems, Inc, 2003). Processing included setting the initial pulse to time zero, color transformation, marker editing, distance normalization, and range gain adjustments. All radar profiles were converted into bitmap images using the Radan to Bitmap Conversion Utility (version 1.4) developed by Geophysical Survey Systems, Inc.[2]

Study Sites:
Juniper Bay is an exceeding large Carolina bay located near Lumberton, Robeson County, North Carolina. The bay is about 1.5 miles long and 1.0 mile wide. The bay has an extensive system of open drainage ditches and covered drain lines. The bay was formerly cultivated. At the time of this survey, the land was being disked and prepared for the planting of trees.

Juniper Bay has been extensively drained for agriculture. Principal soils that have been mapped within Juniper Bay are Leon, Pantego, Ponzer, and Rutlege (McCachren, 1978). The very deep, poorly drained and very poorly drained Leon and the very poorly drained Rutlege soils formed in sandy coastal plain sediments. Leon soil is a member of the sandy, siliceous, thermic Aeric Alaquods family. Rutlege soil is a member of the sandy, siliceous, thermic Typic Humaquepts family. The very deep, very poorly drained Pantego soil formed in medium textured coastal plain sediments. Pantego soil is a member of the fine-loamy, siliceous, semiactive, thermic Umbric Paleaquults family. The very poorly drained Ponzer soil formed in highly decomposed organic materials that are underlain by medium textured marine and fluvial sediments. Ponzer soil is a member of the loamy, mixed, dysic, thermic Terric Haplosaprists family.

Survey Procedures:
Traverse lines were located adjacent to several interior and perimeter ditches as well as in several portions of the bay that had not been previously surveyed with GPR. Most survey flags were inserted in the ground at intervals of 100 feet along each traverse line. However, along a portion of the Southern Main Drain, survey flags were inserted in the ground at intervals of 100 feet and also on either side of lateral drainage ditches. [This uneven spacing would prevent the *distance normalization* of these radar records during processing.] The flags served as reference points. Carrying the 70 MHz antenna along each traverse line completed a radar survey. As the radar antenna 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 were measured with a GPS receiver.

The Main Ditch was also surveyed with GPR. The purpose of this survey was to determine whether this major drainage ditch had breached a medium textured aquitard that is continuous and extensive across much of the bay's interior section. For this survey, the 70 MHz antenna was mounted in an inflatable raft and the raft was pulled along the ditch. Survey flags had been placed along a farm road that bordered the southeast side of the Main Ditch. Small trees and underbrush lined the banks of the Main Ditch obstructing the survey and making it difficult to pull the inflatable raft along the ditch. Frequently, radar records would have to be closed as the raft and towing lines were moved around these obstructions. In addition, the vegetation obscured several survey flags making position referencing difficult.

Multiple transects were conducted within Juniper Bay. The Appendix to this report provides a summary of the radar traverses. A "lift" tests was conducted to confirm the identity of the surface pulse. This test consisted of raising and lowering the antenna off of the ground surface to about head height.

CALIBRATION OF GPR

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

Ground-penetrating radar is a time scaled system that measures the time it takes electromagnetic energy to travel from an antenna to an interface (i.e., soil horizon, stratigraphic layer) and back. To convert travel time into a depth scale 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 propagation velocity (Conyers and Goodman, 1997). 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):

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

Equation [1] describes the relationship of the propagation velocity (V) to the depth (D) and two-way pulse travel time (T) to a subsurface reflector. The velocity of propagation and the dielectric permittivity are known to be spatiotemporally variable across the bay.

In this study, few ground-truth observations and depth calibrations over know reflectors were made. However, using Radan for Windows (version 5.0) and through a process known as *hyperbola matching*, the average propagation velocity through the upper part of the soils within Juniper Bay was estimated to be 0.065 m/ns (dielectric permittivity of 21). This velocity of propagation was obtained over areas of Pantego and Ponzer soils near the edges of major drainage ditches. Though not calculated, the velocity of propagation is slower through the water column (velocity of 0.03 m/ns; from a table value) and saturated coarse textured sediments (velocity of 0.05 m/ns; from a table value) that filled the Main Ditch.

Interpretations:

The 70 MHz antenna was relatively easy to carry along traverse lines and provided good radar imagery of the subsurface. Figure 1 is a representative radar record from a portion of a traverse that was conducted in an area of Ponzer soil adjacent to the Main Ditch. The short, white, vertical lines at the top of the radar record represent equally spaced (30.5 m) reference points along the radar traverse. The vertical scale along the left-hand margin of this figure is a depth scale that is based on a velocity of pulse propagation of 0.065 m/ns. Note that the depth scale is exaggerated relative to the horizontal scale by almost a factor of 6.

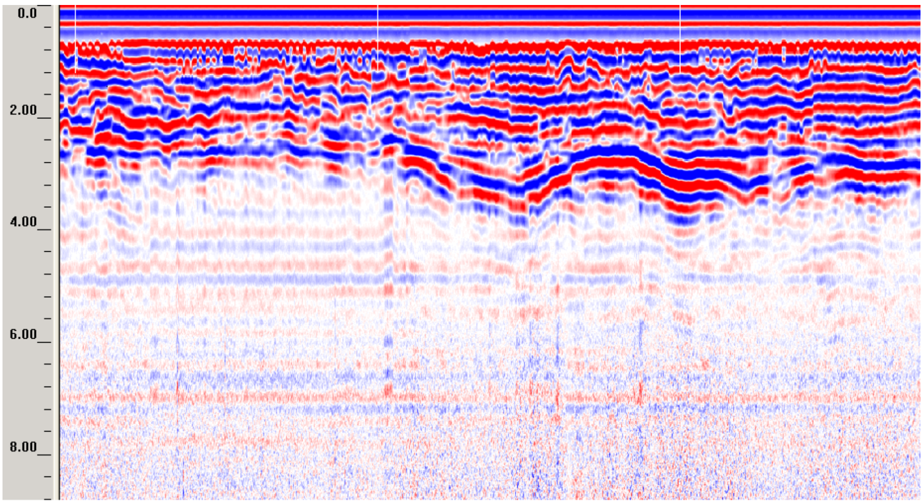

Figure 1. Radar record obtained with 70 MHz antenna over representative soils in Juniper Bay. Depth scale is in meters.

As evident in Figure 1, the upper 2 to 3 m of the soil profile appears to be composed of multiple, discontinuous planar reflectors. These reflectors represent mineral and organic layers. A highly attenuating, continuous layer restricts GPR signal penetration. The depth to this interface ranges from about 2.5 to 3.2 m. This layer is believed to represent the medium textured marine and fluvial sediments that form the aquitard.

Figure 2 is a representative radar record from a portion of a traverse that was conducted over the Main Ditch. The short, white, vertical lines at the top of the radar record represent equally spaced (30.5 m) reference points along the radar traverse. The vertical scale along the left-hand margin of this figure is a depth scale that is based on a velocity of pulse propagation of 0.065 m/ns. Note that the depth scale is exaggerated relative to the horizontal scale by almost a factor of 5.

As evident in Figure 2, the radar is profiling to depths as great as 10 m over the Main Ditch. [Even with a slower velocity of penetration of 0.05 m/ns for saturated sands, the effective penetration depth ranges from 4 to 8 m.] The highly attenuating layer that is so evident in Figure 1 is absence in Figure 2. The greater penetration depths within the Main Ditch are attributed to the absence of the medium textured aquitard that is apparent in Figure 1. Less conductive materials underlie the Main Ditch. These materials have lower clay and higher sand contents. These radar records suggest that the relatively shallow (2 to 3 m) medium textured aquitard that is ubiquitous beneath most interior sections of Juniper Bay has been breached by the drainage ditches.

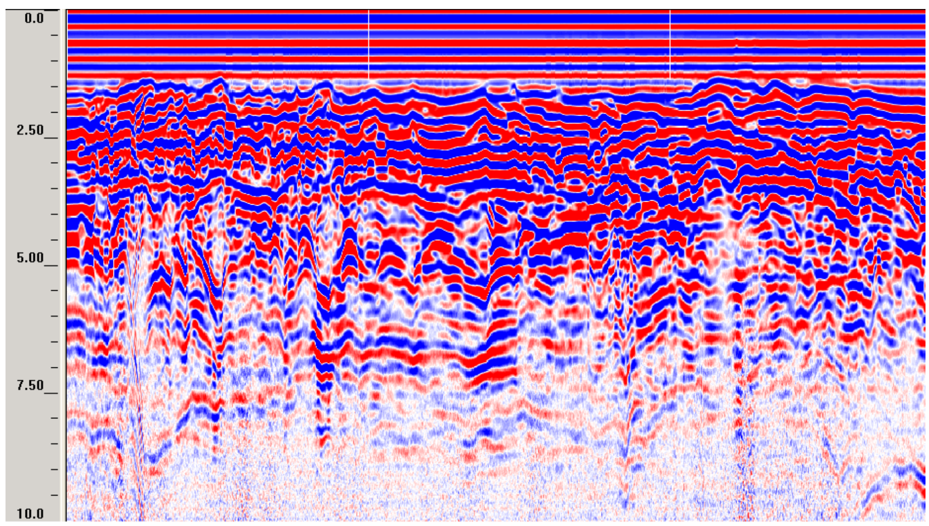

Figure 2. Radar record obtained with 70 MHz antenna over the Main Ditch in Juniper Bay. Depth scale is in meters.

Results:

1. Results of the GPR survey suggest that the relatively shallow (2 to 3 m), medium textured aquitard, which is ubiquitous beneath most interior sections of Juniper Bay, is breached by the drainage ditches.

2. All radar files have been stored on disks. All radar profiles have been processed through WINRAD NT software and converted into bitmaps. A CD containing the bitmap files has been forwarded with a copy of this trip report to Dr Jeff White at North Carolina State University.

3. Two additional surveys were completed along the east and west sides of Juniper Bay. These profiles will be used to characterize the hydrogeology of these areas.

It was my pleasure to work in North Carolina and assist North Carolina State University.

With kind regards,

James A. Doolittle
Research Soil Scientist
National Soil Survey Center

cc:
B. Ahrens, Director, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
C. Olson, National Leader, Soil Investigation Staff, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
M. Golden, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250
W. Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, P.O. Box 974, Federal Building, Room 206, 207 West Main Street, Wilkesboro, NC 28697
J. White, Assistant Professor, Department of Soil Science, North Carolina State Univ, Box 7619, 3404 Williams Hall, Raleigh, NC 27695

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Appendix - Summary of GPR transects.

File #	Time (ns)	Remarks
File 1	300	Road culvert at 89 inches
File 2	300	Southeast side of Main Ditch going from west to east. First traverse leg.
File 3	300	Southeast side of Main Ditch going from west to east. Second traverse leg.
File 4	300	Northwest side of Main Ditch going from east to west. First traverse leg. Skipped first flag. Ended at concrete bridge.
File 5	300	Crossed Main Drain from northwest to southeast across concrete bridge. Buried culvert at 42 inches.
File 6	300	Lift test.
File 7	300	Northwest side of Main Ditch going from east to west. Began at concrete bridge. Second traverse leg.
File 8	300	Northwest perimeter Ditch going from east to west. Started at telephone pole on the south side of ditch.
File 9	300	Traverse extended into field from the western end of the Northwest perimeter Ditch. Going from northwest to southeast.
File 10	300	Northwest corner of Juniper Bay. Traverse going from west to east.
File 11	300	Southeast side of Secondary Main Ditch going from east to west. Traverse conducted along field road to intersection with north – south trending ditch.
File 12	300	Northwest side of Secondary Main Ditch going from east to west. Traverse conducted in field adjoining ditch.
File 13	300	Southeast side of Secondary Main Ditch going from east to west. Traverse conducted from intersection with north – south trending ditch.
File 14	300	Northwest side of Secondary Main Ditch going from west to east. Traverse conducted back to the intersection with north – south trending ditch.
File 15	300	Traverse conducted on northwest side of the Southeast Perimeter Ditch. Traverse conducted from west to east.
File 16	300	Traverse conducted on northeast side of north –south trending field ditch. Traverse conducted from field road adjoining Main Ditch and extending from north to south.
File 17	340	70 MHz antenna in raft. Main Ditch. First leg. Traverse from northeast to southwest along the northwest side of Main Ditch.
File 18	340	70 MHz antenna in raft. Main Ditch. Second leg. Traverse from northeast to southwest along the northwest side of Main Ditch.
File 19	340	70 MHz antenna in raft. Main Ditch. Third leg. Traverse from northeast to southwest along the northwest side of Main Ditch.
File 20	340	70 MHz antenna in raft. Main Ditch. Fourth leg. Traverse from northeast to southwest along the northwest side of Main Ditch.
File 21	340	70 MHz antenna in raft. Main Ditch. Fifth Leg. Traverse from northeast to southwest along the northwest side of Main Ditch.
File 22	340	70 MHz antenna in raft. Main Ditch. Sixth leg. Traverse from northeast to southwest along the northwest side of Main Ditch.
File 23	340	Field adjoining field 13 in the southeast corner of Juniper Bay. Traverse conducted into the field from southeast to northwest.