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United States Department of Agriculture

Soil Conservation Service

401 SE First Avenue, Room 248
Gainesville, FL 32601

Subject: SOILS - Ground-Penetrating Radar (GPR) Trip Report - South Carolina

Date: February 27, 1984

To: Billy Abercrombie, State Conservationist
SCS, South Carolina

File Code: 430

The Gardner Smith Pond in rural Orangeburg County, near Salley, South Carolina, was constructed with technical assistance by the Soil Conservation Service (SCS). It was inferred from standard site assessment and sampling techniques that the site was suitable for construction of an earthen dam to retain water within a defined pool area. After completion of all necessary structures, water was pumped into the pool area. At this time, it was observed that the pool area would not retain water. The pool area was constructed in an area of loamy fluvial and marine sediments. These sediments are often stratified, but the extent and variability of the strata could not be adequately defined by standard investigative techniques. The actual source(s) of leakage were not disclosed during repeated investigations.

Ground-penetrating radar (GPR) assistance was requested. It was felt that the GPR could provide meaningful graphic profiles which would help to characterize the bottom sediments and perhaps to identify and delimit potential problem areas. Field investigations with the GPR were conducted on the afternoon of February 21, 1984.

Participants were:

Grady Adkins, Asst. State Conservation Engineer, Columbia, South Carolina
Wilbur Campbell, State Geologist, Columbia, South Carolina
Frank Collins, Soil Conservation Technician, Orangeburg, South Carolina
Dennis DeFrancesco, Soil Scientist, Orangeburg, South Carolina
Jim Doolittle, Soil Specialist (GPR), Gainesville, Florida
Frank Roe, Soil Conservation Technician, Aiken, South Carolina
Bobby Thompson, Area Engineer, Walterboro, South Carolina
W. Burton Wells, State Conservation Engineer, Columbia, South Carolina

The equipment utilized during this field trip was the SIR System-8 with an ADTEK SR-8004H Graphic Recorder. The 120 MHz antenna was the only transducer utilized during this field study. The equipment operated exceptionally well at the pool area. Signal processing and background removal with the Model 30 Microprocessor were not required as a result of the excellent quality of the graphic profiles.

GPR transects indicated that large areas of the pool are underlain by seemingly coherent and relatively impervious clays. Smaller, but disproportionately more siginificant areas are underlain by zones of more pervious materials or solution pipes. These more permeable areas provide the rapid avenues for water to pass through. These seepage areas are numerous, variable in size, and characterize the bottom of the pool area.

I appreciated the opportunity to work in your state. I wish to pass along a special "Thanks" for the cooperation and enthusiasm that all members of your staff extended to me.

James A. Doolittle
JAMES A. DOOLITTLE
Soil Specialist (GPR)

Attachments

cc:
James W. Mitchell, SCS, Gainesville (w/attachments)

PRINCIPLES OF OPERATION

The GPR is a broad-band width, pulse-modulated radar system that has been specifically designed to penetrate earthen materials. Relatively high frequency, short-duration pulses of energy are transmitted into the ground from a coupled antenna. When a pulse strikes an interface (boundary) separating layers of differing electronmagnetic properties, a portion of the pulses energy is reflected back to the receiving antenna. The reflected pulse is received, amplified, sampled and converted into a similarly shaped waveform in the audio frequency range. The processed reflected signal is displayed on the graphic recorder or is recorded and stored on magnetic tape.

The graphic recorder uses a variable gray scale to display the data. It produces images by recording strong signals as black, intermediate signals in shades of gray, and weak signals as white. As a general rule, the more abrupt the interface and the greater the difference in electromagnetic properties across the interface, the stronger the reflected signal and the darker the generated image.

The graphic profile is developed as electrosensitive paper moves under the revolving styli of the graphic recorder. Reflections above a preset threshold level are "burned" onto the electrosensitive paper. Each scan of a stylus draws a line across the paper in the direction of increasing signal travel time (depth). The intensity of the images printed along each line is dependent upon the amplitude of the processed signals. By towing the antenna along the ground surface, a continuous profile of subsurface conditions is "burned" onto the paper by the graphic recorder.

Figure 1 is an example of a graphic profile. The horizontal scale represents unit of distance traveled along the transect line. This scale is dependent upon the speed of antenna advance along the transect line, the rate

of the paper advance through the graphic recorder, and the playback speed of data recorded on magnetic tape. The vertical scale is a time or depth scale which is based upon the velocity of signal propogation. The dashed vertical lines are event markers, inserted on the graphic profile by the field operator to indicate known antenna positions, or reference points, along the transect line. The evenly-spaced horizontal lines are scale lines. Scale lines provide reference planes for relative depth assessments.

Most graphic profiles consist of four basic components: the start of scan image (A), inherent system images (B), surface images (C), and subsurface interface images (D). With the exception of the start of scan image, all of these components are generally displayed in groups of three dark bands unless limited by high rates of signal attenuation or the proximity of two or more closely spaced interface signals. These bands, which are produced by oscillations in the reflected pulses, limit the ability of the GPR to discriminate shallow or closely spaced interfaces. The dark bands occur at both positive and negative signal amplitudes. The narrow white line(s) separating the bands represent the neutral or zero crossing between the polar amplitudes.

The start of scan image (A) is a result of the direct coupling of the transmit and receive antennas. Though a source of unwanted clutter, the start of scan image is often used as a time reference line.

Reflections inherent in and unique to each of the systems antennas are the first series of multiple bands on graphic profiles. Generally, the number and width of these bands increase with decreasing antenna center-carrier frequency. These reflections (B) are a source of unwanted "noise" in graphic profiles.

The surface images (C) represent the first major interface signal. The first zero crossing of the surface images is normally selected as a matter of

its convenience and repeatability, as the soil surface for depth calibrations and measurements.

Below the images of the surface reflection are the images from subsurface interfaces (D). Interfaces can be categorized as being either plane reflectors or point objects. Most soil horizons and geologic layers will appear as continuous, parallel, multiple bands, similar to those appearing in the left-hand portion of Figure 1. Small objects, such as rocks, or buried pipes, will appear as point objects and will produce hyperbolic patterns similar to those appearing in the right-hand portion of this figure. Hyperbolic patterns are a function of the radar's conical area of radiation which enables the antenna to receive echoes even though it is not directly over the object.

INTERPRETATIONS

The pool area is situated in an area of stratified fluvial and marine sediments. Generally, it may be characterized as having a 7 to 10 foot mantle of sands overlying a 3 to 7 foot "clay" layer. The materials underlying the "clay" layer are sands. At one boring site within the pool area, the clay layer was not encountered within a recorded depth of 19 feet.

As the clay layer represents the effective bottom seal to the pool areas, the investigative approach was to use the GPR to provide a "graphic picture" of this layer. The "graphic picture" would hopefully express the layers lateral extent, continuity, and variability. All interpretations presented in this report are based upon inferred characteristics from the graphic profiles of the clay layers.

Prior to the arrival of the GPR, a major portion of the pool area was grid at 100 foot intervals. The grid system facilitated the location of subsurface features in relationship to fixed reference points on the surface. The grid system consisted of essentially equidistant parallel lines laid-out in an east-west direction. Along each line, flags were pushed into the ground at 100 foot intervals and served as reference points. Slight detours were taken along some lines to avoid exceptionally wet areas, stumps, or mounds of fill.

The GPR was calibrated and interpretative skills developed while conducting several trial runs in the pool area. Based upon these trials, the 120 MHz antenna was determined to provide the most suitable balance between resolution and depth of penetration. A scanning time of 116 nanoseconds (ns) was selected and provided an effective probing depth of approximately 4 meters (based upon table values for the velocity of signal propagation through similar materials).

The graphic profile in Figure 2 is representative of the pool area. The reference points at the top of this figure are at 3 meter intervals. The vertical scale is approximately 4 meters.

Two of the black horizonatal bands (A) in the upper part of this profile represent the image from the strong surface reflection. The first zero-crossing (narrow white line between darker bands) was selected as the soil surface for depth measurements. Immediately below the surface reflections are numerous, closely-spaced subsurface reflections. These reflections were not adequately investigated to ascertain their exact identity, but are from overburden of fill material, buried surface layers, soil horizons and strata within the sand.

The strongly expressed subsurface layer (B) that extends midway across this figure is the clay layer. The clay layer will appear as multiple, similarly shaped dark bands. It must be remembered that these bands are produced by oscillations in the reflected signal, and, though multiple, represent a single interface.

At first glance, the clay layer appears continuous across the entire graphic profile, but a closer examination reveals that it is segmented, irregular in depth, and variable in composition. In some areas, it abruptly terminates or plunges to greater depths (D). In other areas (C), it appears as a diffuse and ill-defined zone.

In this figure, the upper boundary of the clay layer has an uneven subsurface topography and ranges in depth from 1 to 2.4 meters.

The amount of clay in the upper part of this layer can be inferred from the relative darkness of the interface bands and by the absence of underlying subsurface interfaces. The graphic recorder prints in 16 shades of gray, from white to black. Dark interface signals result from abrupt and strongly contrasting electromagnetic gradients. Within the pool area, the dark

interface signals indicate abrupt transitions from sand to clay. In Figure 2, the sand/clay interface signal appears relatively uniform in degree of darkness.

Clays rapidly dissipate radar signals. The rapid dissipation of radar signals produce "white-out" areas. "White-out" areas are zones of no signal return. These zones results from the rapid and completion dissipation of the radar signal, the absence of subsurface interfaces, or both. In this figure, areas having distinct subsurface interfaces below the clay layer (see below C and at D) are assumed to be overlain by thinner, coarser textured, or more stratified (with pockets or lenses of sand) clay layers.

At C, the absence of distinct, continuous multiple bands and the occurrence of numerous random, overlapping and converging patterns are believed to represent areas of segmented clay layers interfingered with sand lenses. These zones represent areas in which water will rapidly drain through the clay layer. Two of these areas were probed with a drill rig. The credibility of this interpretation was confirmed by samples taken from the probe.

Solution piping (D) it often evident in areas of denser clays. Seepage and piping are inferred from the drawdown of overlying horizons, the steeply inclined sidewalls, and zones of dissimilar materials at the base of the solution pipes.

Similar interpretation can be made on graphic profiles from each of the transects. All graphic profiles have been turned over to W. Burton Wells, State Conservation Engineer.

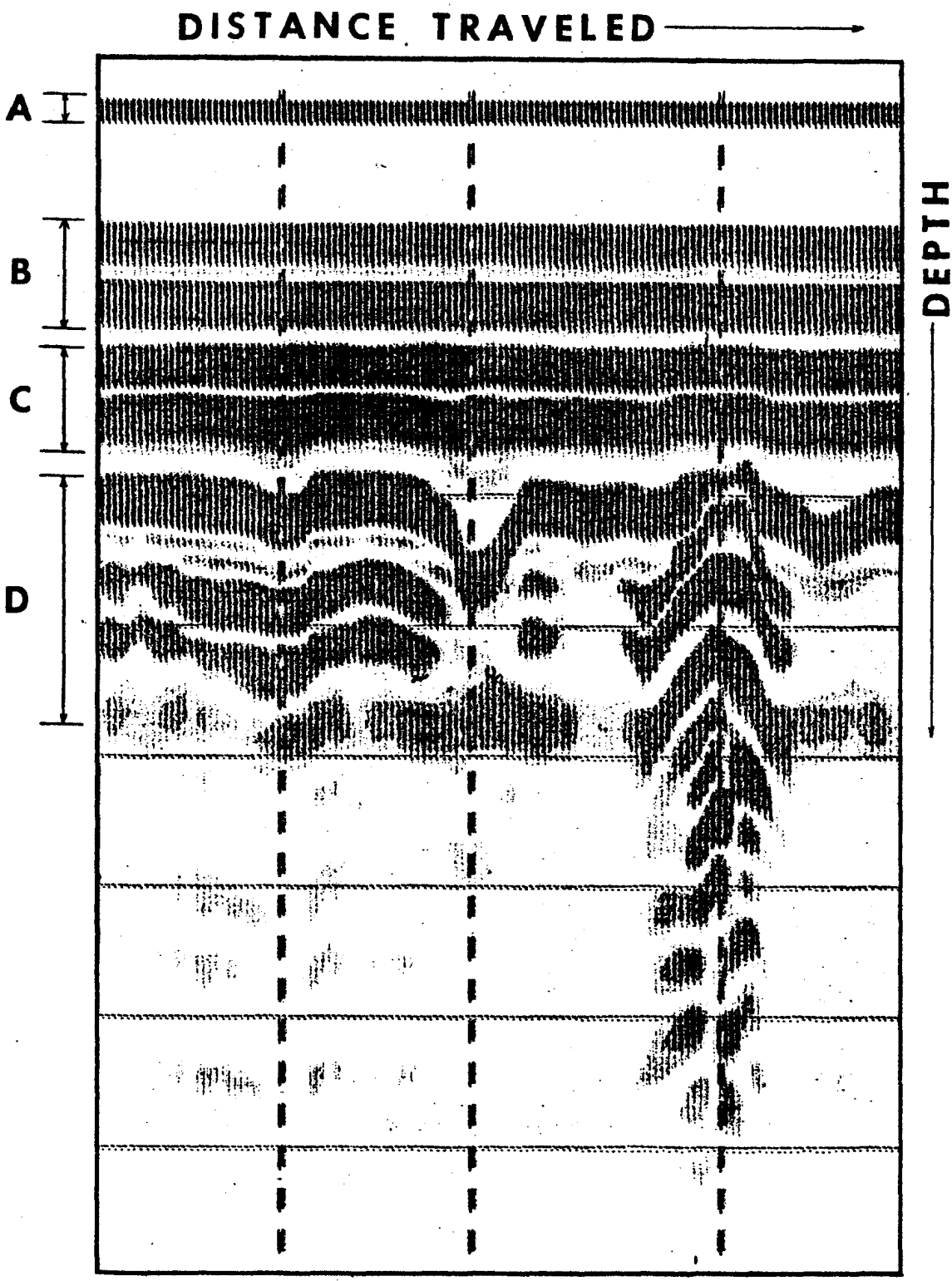
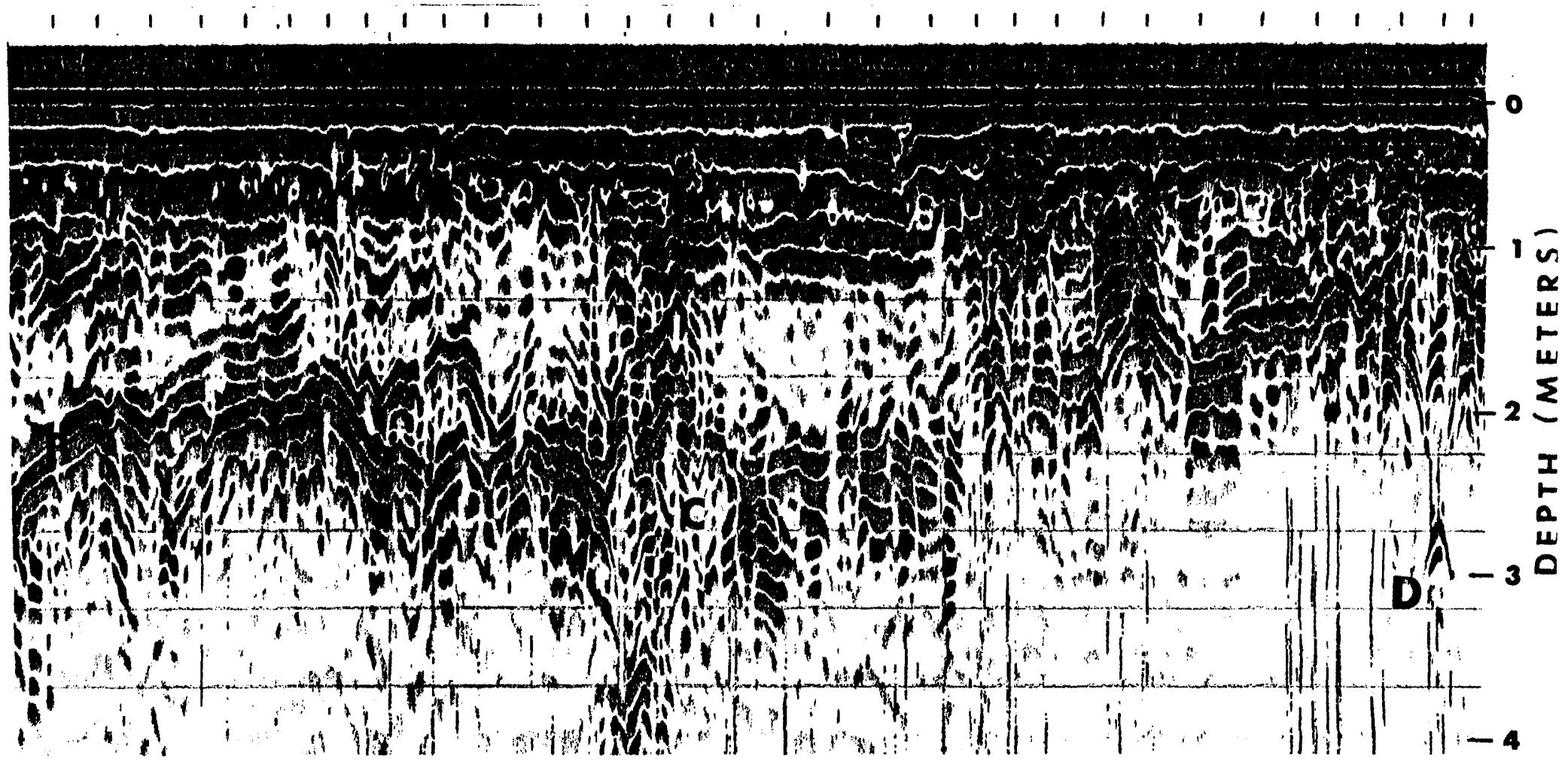


FIG. 1

A GRAPHIC PROFILE



TRANSECT ACROSS POOL AREA