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

Subject: Soils – Geophysical Field Assistance **Date:** 31 August 2001

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Purpose:
This report supplements my report of 20 July 2001 concerning the ground-penetrating radar (GPR) surveys that were completed within Juniper Bay, North Carolina. Radar data were processed through the RADAN NT and the 3D QuickDraw software module developed by Geophysical Survey Systems, Inc., and three-dimensional block and fence diagrams of the survey area were created.

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Activities:
All activities were completed during the period of 11 to 14 June 2001.

Equipment:
The radar unit is the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-2000 consists of a digital control unit 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. A 120 MHz antenna was used in this study. The scanning time was 170 nanoseconds (ns).

The RADAN NT (version 2.0) software program was used to process the radar profiles (Geophysical Survey Systems, Inc, 2001a). Processing was limited to signal stacking, distance normalization, color transforms, and table customization. The 3D QuickDraw module for RADAN NT was used to construct and analyze three-dimensional displays of the radar data. This module permits the viewing of all radar profiles from the survey area at the same time. With the 3D QuickDraw module, three-dimensional displays of radar data can be rapidly created, displayed, and adjusted to observe subsurface features at different depths or from different perspectives.

A file was created from the seventeen radar profiles collected within a grid area. This file consists of the orderly succession of parallel radar profile lines that are processed together into one file. A macro was created to further process this radar file. The data were migrated to reduce hyperbolic diffraction patterns in the data set. These unwanted reflections often clutter radar

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

images. To create a three-dimensional display, radar profiles are appended to one another in order of increasing Y-coordinates. A cube is created from this file having its X-axis parallel, and its Y-axis orthogonal to the radar survey lines.

Study Site:

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 planted to cotton last year. This year, the land is idle.

Juniper Bay has been extensively drained for agriculture. Principal soils that have been mapped within Juniper Bay are Leon fine sand, Pantego fine sandy loam, Ponzer muck, and Rutlege loamy sand (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.

Background:

Two-dimensional radar profiles have been used to identify soil horizon, bedrock, and stratigraphic features (Davis and Annan, 1989; Beres and Haeni, 1991; Doolittle, 1987; Collins et al., 1989; Jol and Smith, 1991;and Morey, 1974). Many complex stratigraphic features cannot be resolved in sufficient detail on the basis of a few random two-dimensional radar profiles. A major constraint of two-dimensional radar profiling has been its inability to adequately resolve and disclose the often complex, three-dimensional geometries of these features. The comparison of multiple, adjacent parallel radar traces are a time consuming task. The recent advancements in processing technologies have facilitated the manipulation of large sets of radar data and the creation of three-dimensional radar images. These displays have provided unique, multiple viewpoints in which to analyze the subsurface.

Three-dimensional images provide multiple perspectives from which to view and analyze the subsurface. Junck and Jol (2000) noted that, with 3-D images. "The internal stratigraphy and geometry of geomorphic environments can be interpreted in more detail than with widely spaced 2D transects and reflection patterns can be compared with better spatial awareness." Three-dimensional images have facilitated the interpretations of stratigraphic and lithologic features by associating images that appear on different radar profiles and characterizing spatial variation in geometric form within survey areas (Beres et al., 1995). Three-dimensional radar images have improved interpretations of fault-related structures (Gross et al., 2000), bedding planes, and fractures in bedrock (Asprion and Aigner, 1997; Pipan et al., 2000). These images have been used to plot the internal geometry of glaciofluvial (Asprion and Aigner, 1997; Beres et al., 1999; Lehmann et al., 2000), glacio-lacustrine (Asprion and Aigner, 1999) deposits and coastal and eolian stratigraphic features (Junck and Jol, 2000).

The objectives of this study were to see if three-dimensional displays of GPR data provide a more useful way to view and analyze the subsurface stratigraphy and geometry of the bay than with two-dimensional radar profiles.

Field Procedures:

A 320 by 1200 ft grid (8.3 acres) was established in the northwest portion of the bay. The grid consisting of 17 parallel lines spaced about 20 feet apart. Survey flags were inserted in the ground at intervals of about 100 feet along each line and served as observation points. Pulling the 120 MHz antenna along the 17 traverse lines completed radar surveys. As the radar antenna was pulled passed each observation point, the operator impressed a vertical mark on the radar record. Daniels and others (1998) remarked on the need for high spatial density to obtain accurate three-dimensional presentations of GPR data. Accurate location of each trace on the radar record is critical to producing good quality three-dimensional images (Daniels et al., 1997). Reference flags spaced at 100-foot intervals along each traverse line controlled the location of individual traces. The spacing is determined primarily by the size of the smallest subsurface feature to be detected. In this study, only major subsurface interfaces and gross spatial patterns were of interest.

Survey procedures are modified to facilitate the construction of 3-D images and the interpretation of subsurface features. To construct three-dimensional displays, the imagery between adjoining radar profiles is interpolated. As a consequence, the quality and detail of a three-dimensional display will increase as the number of lines is increased or the spacing between survey lines is decreased (Geophysical Survey Systems, Inc., 2001b). As a general rule, lines should be spaced so that the radar beams from adjacent lines overlap at the depth of interest. (Geophysical Survey Systems, Inc., 2001b).

The size, depth, and presumed spatial variability of subsurface features influences survey designs. Because of setup time and the intensity of sampling, areas surveyed for 3D imaging have been typically small. The use of three-dimensional images has been restricted because of the time required to conduct fieldwork over limited areas and image processing (Binningsbo et al., 2000). Generally small grids with small line spacings are desired. Whiting and others (2000) and Junck and Jol (2000) used a 25 cm line spacing with control points spaced at 1.0 m intervals along each line to identify prehistoric burials, middens, post-holes, and pit structures and stratigraphic features, respectively. Gross and others (2000) used a 25 by 50-cm interval over a 50 by 35-m grid to identify principal fault planes. Pipan and others (2000) surveyed a 200 square m area using a 1-m line spacing to identify features within limestone. Beres and others (1995) used a 0.5 by 0.25-m line spacing to cover a 15 by 20-m area of glaciofluvial sediments. In a similar investigation, Beres and others (1999) used a 5 by 10-m line spacing to cover a more extensive, 60 by 100-m area. Versteeg and Birken (1998) used 0.5 and 1 m line spacings to profile deltaic deposits within a 42 by 35-m grid area.

Processing:
Initial processing typical consists of data inspection and editing. All station marks were confirmed and basic data (scans/meter, meters/mark, dielectric constant) inputted. Signal processing is used to remove or minimize background noise and clutter in the radar data. As noted by Daniels and others (1997), while processing tends to improve the appearance of the data, it rarely changes the interpretation of the data. Simplifying the radar profile through the elimination of noise and clutter is a prerequisite for achieving favorable interpretations (Daniels et al., 1997). Steps for simplifying images have been listed by Daniels and others (1997).

Interpretations:
Interpretations are biased towards high amplitude in-line reflectors. Reflectors that are out of line from the original radar traverse are minimized in three-dimensional images because they are not align horizontally and do not add constructively in the horizontal direction (Daniels et al., 1998). Lateral variations in the amplitude of the reflected signal make some interfaces difficult to identify and trace laterally. By selecting a higher amplitude range, these interfaces may be more easily identified and traced. However, higher amplitude ranges increases the amplitudes of other, perhaps less desirous reflectors as well. These added reflectors are clutter that can complicate interpretations.

In the accompanying figures, the program assumed a constant velocity for electromagnetic waves traveling through soils. Data have been displayed opaquely rather transparently. As a consequence only the data on the sides of the cube are visible. An optimum viewing angle of the cube was chosen. The viewing angle will vary with the complexity and orientations of the subsurface features. Care must be exercised in selecting the amount of data that is displayed. Often, interpreters chose to show more detail than is necessary. As a consequence, images contain excessive clutter that masks many desired features. Daniels and others (1997) extol the axiom "less is more" when it comes to displaying three-dimensional data. Features with complicated shapes and subsurface geometries produce complex scattering of electromagnetic energy that can result in awkward and difficult to interpret three-dimensional displays. Showing a smaller subset of the display or decreasing the thickness of the time slice (finite-width slice) may improve the visual presentation and interpretations by isolating and defining select features in greater detail.

The displays show a complex history of erosion and deposition within this portion of the bay. A well defined, trough-shaped, erosion surface overlain by extensive lateral and more constricted inclined beds of sediment.

Conclusions:
A new era of soil and stratigraphic investigations with GPR has begun. This study marks the first attempt by USDA-NRCS to create tree-dimensional images of radar profiles. Compared with two-dimensional radar profiles, three-dimensional images provide appear to provide a more acceptable means for characterizing a Carolina Bay and interpreting some complex subsurface features images. Enjoy the images.

With kind regards,

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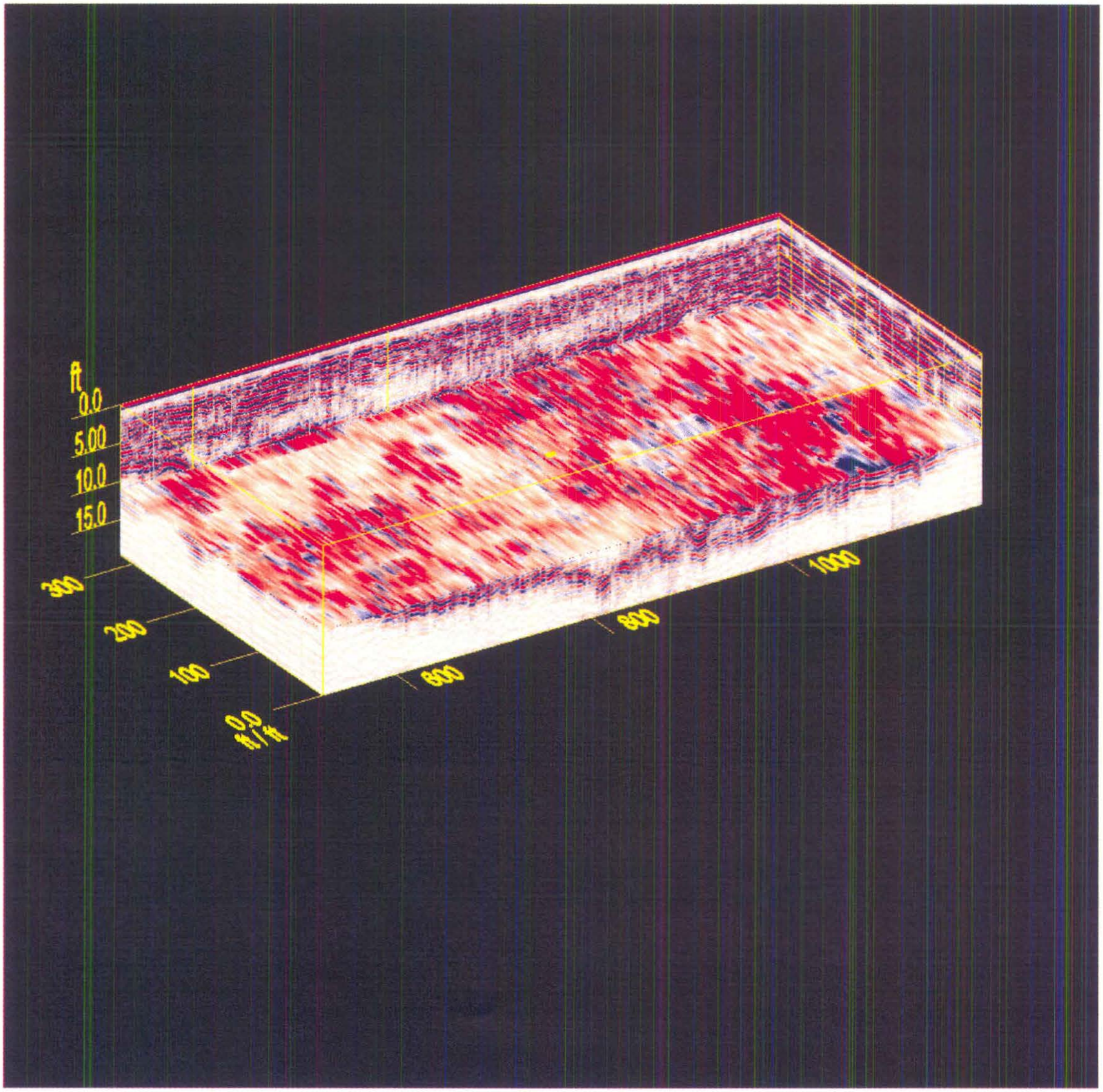

Figure 1. Three-dimensional cube of the survey area with time slice (z-slice) taken out. All measurements are in feet.

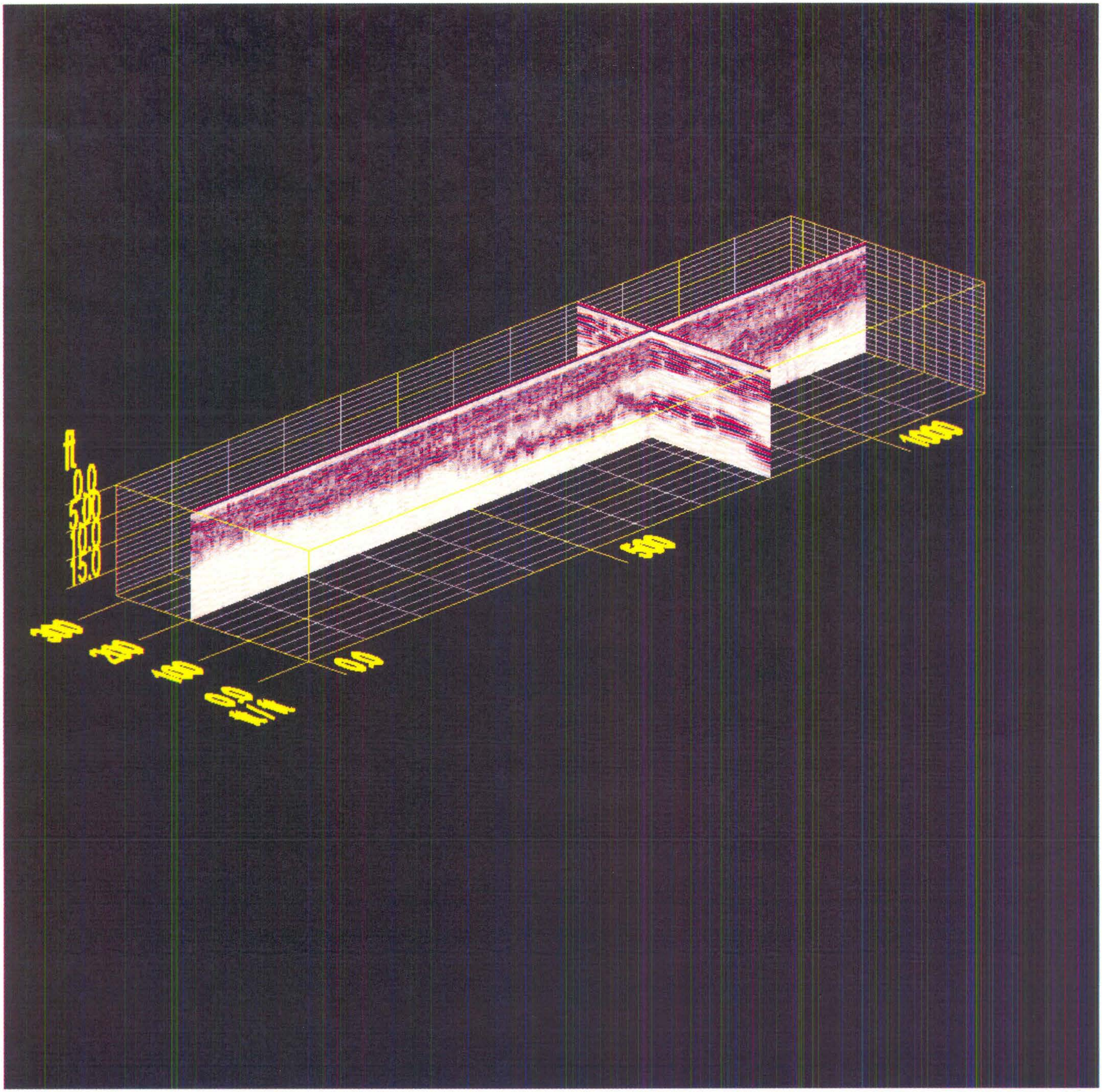

Figure 2. Three-dimensional cube of the survey area with XY Fence displayed. All measurements are in feet.

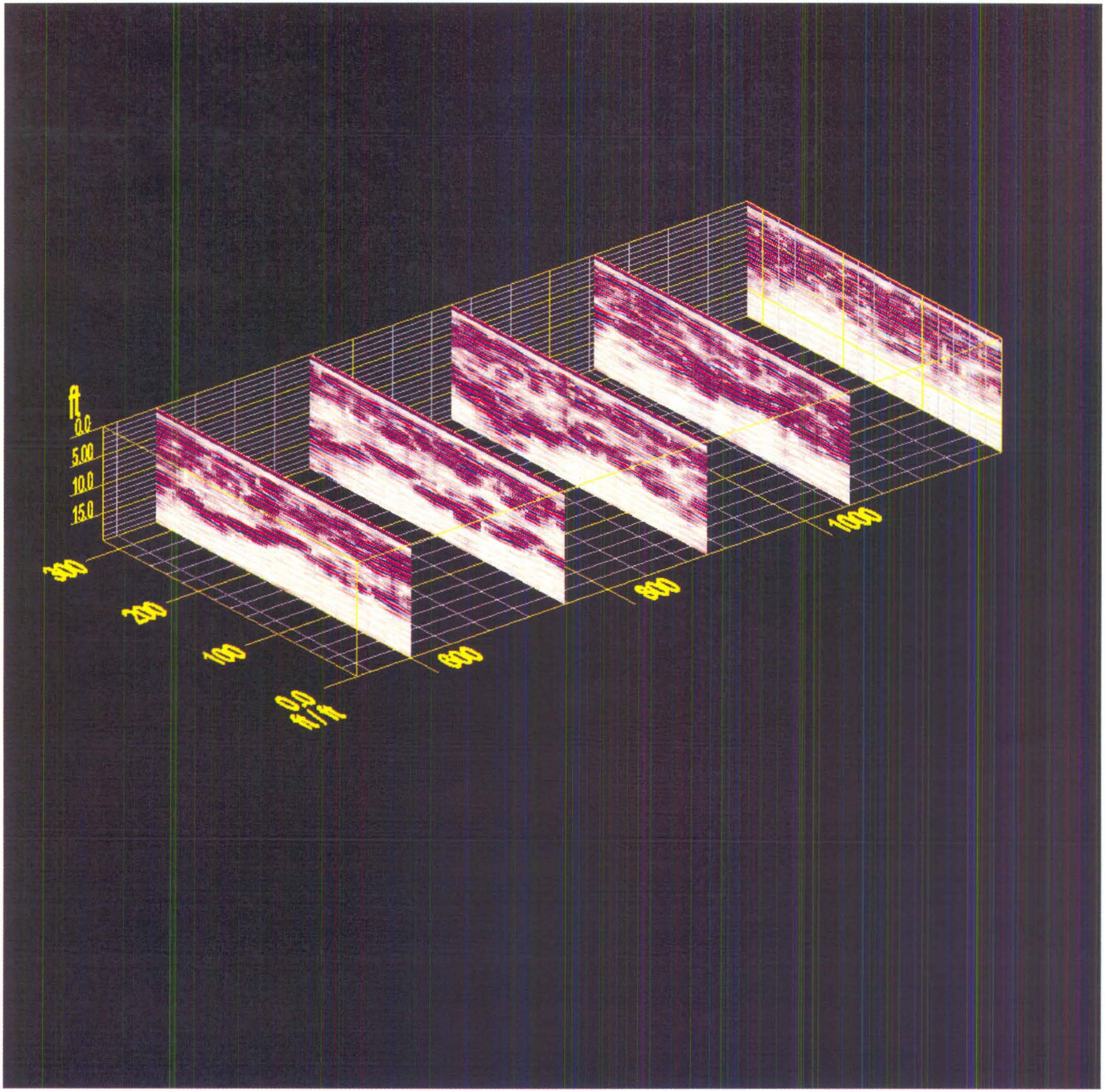

Figure 3. Three-dimensional cube of the survey area with multiple X-slices displayed. All measurements are in feet.

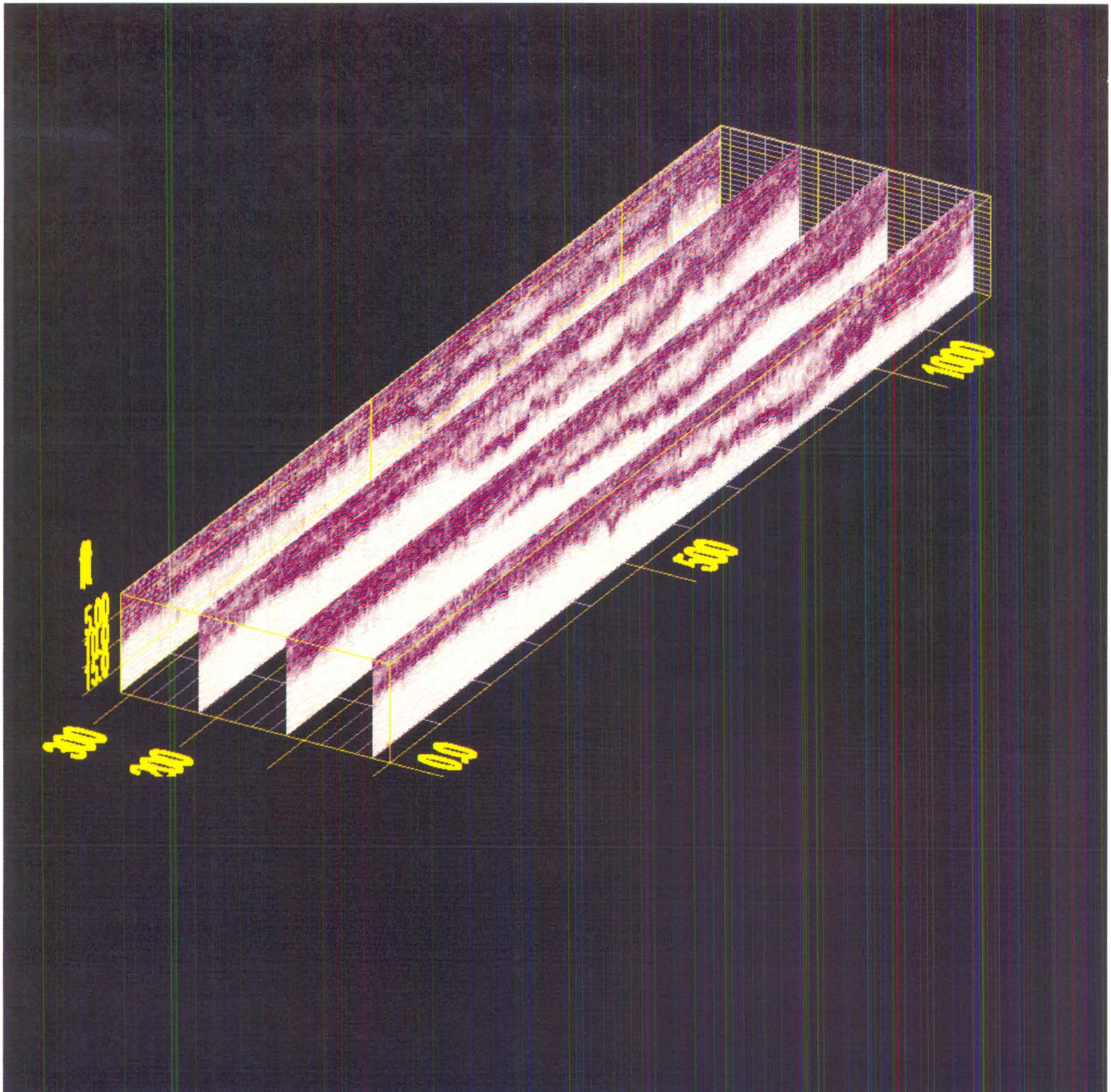

Figure 4. Three-dimensional cube of the survey area with multiple Y-slices displayed. All measurements are in feet.

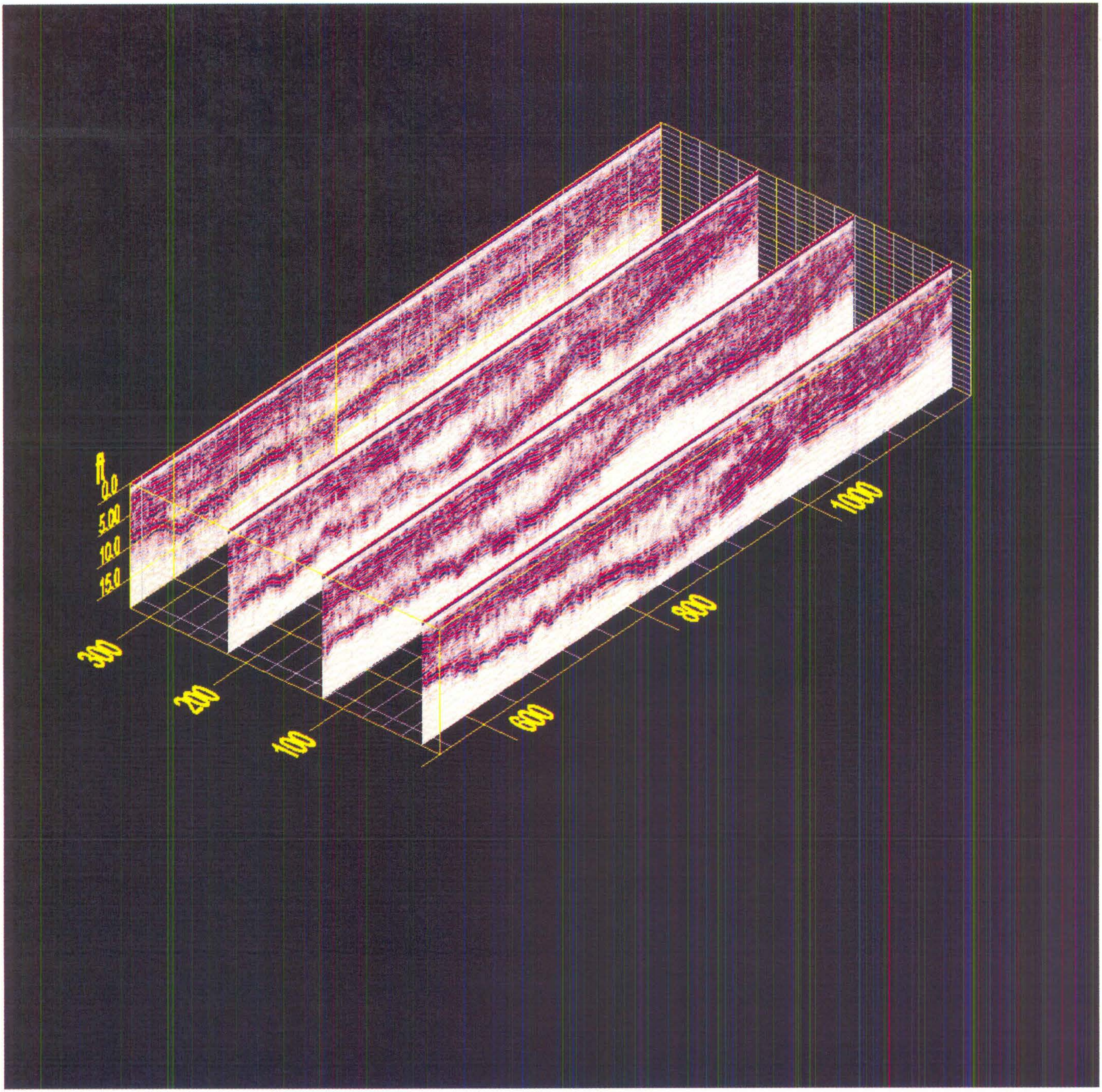

Figure 5. Three-dimensional cube of a portion of the survey area with multiple Y-slices displayed. All measurements are in feet.

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