Special Publication SJ92-SP13

FINAL REPORT

HIGH RESOLUTION SEISMIC REFLECTION PROFILING IN SELECTED LAKES IN THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

Prepared For

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

APRIL 1992

By

Subsurface Detection Investigations, Inc.

Revisions to Special Publication SJ92-SP12
Final Report
High Resolution Seismic Reflection
Profiling in Selected Lakes in the
St. Johns River
Water Management District

Page 1-1, second paragraph, last sentence should state:

> "Seismic reflection has been recently used to identify karst features beneath Lake Apopka in Orange and Lake Counties, Florida, and in several ponds along the Lake Wales Ridge in Polk County, Florida."

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Appendices can be consulted in the St. Johns River Water Management District library.

1.0 INTRODUCTION

1.1 Background

Subsurface Detection Investigations, Inc. (SDII) was contracted by the St. Johns River Water Management District (SJRWMD) to perform a high resolution seismic reflection profiling investigation of five selected lakes in the St. Johns River Water Management District. The project was performed in general accordance with Contract No. 91G146.

Seismic reflection is a standard geophysical method of determining deep subsurface stratigraphy and structural features. Seismic reflection has primarily been used for petroleum exploration, but is now being successfully applied to hydrogeologic studies. Seismic reflection has been recently used to identify karst features beneath Lake Apopka in Volusia County, Florida, and in several ponds along the Lake Wales Ridge in Polk County, Florida.

The five lakes in the study were chosen by SJRWMD to supplement studies related to the District's Mininum Flows and Levels Project. Each of the lakes has experienced varying degrees of water level decreases over the past 10 to 15 years. All of the lakes are located in areas where the Hawthorn Group is either thin, absent, or breached by sinkholes, which provide varying degrees of connection to the Upper Floridan aquifer. The results of this project will be used to help evaluate the relationship between water level decreases and the degree of connection with the Upper Floridan aquifer.

1.2 Purpose and Scope

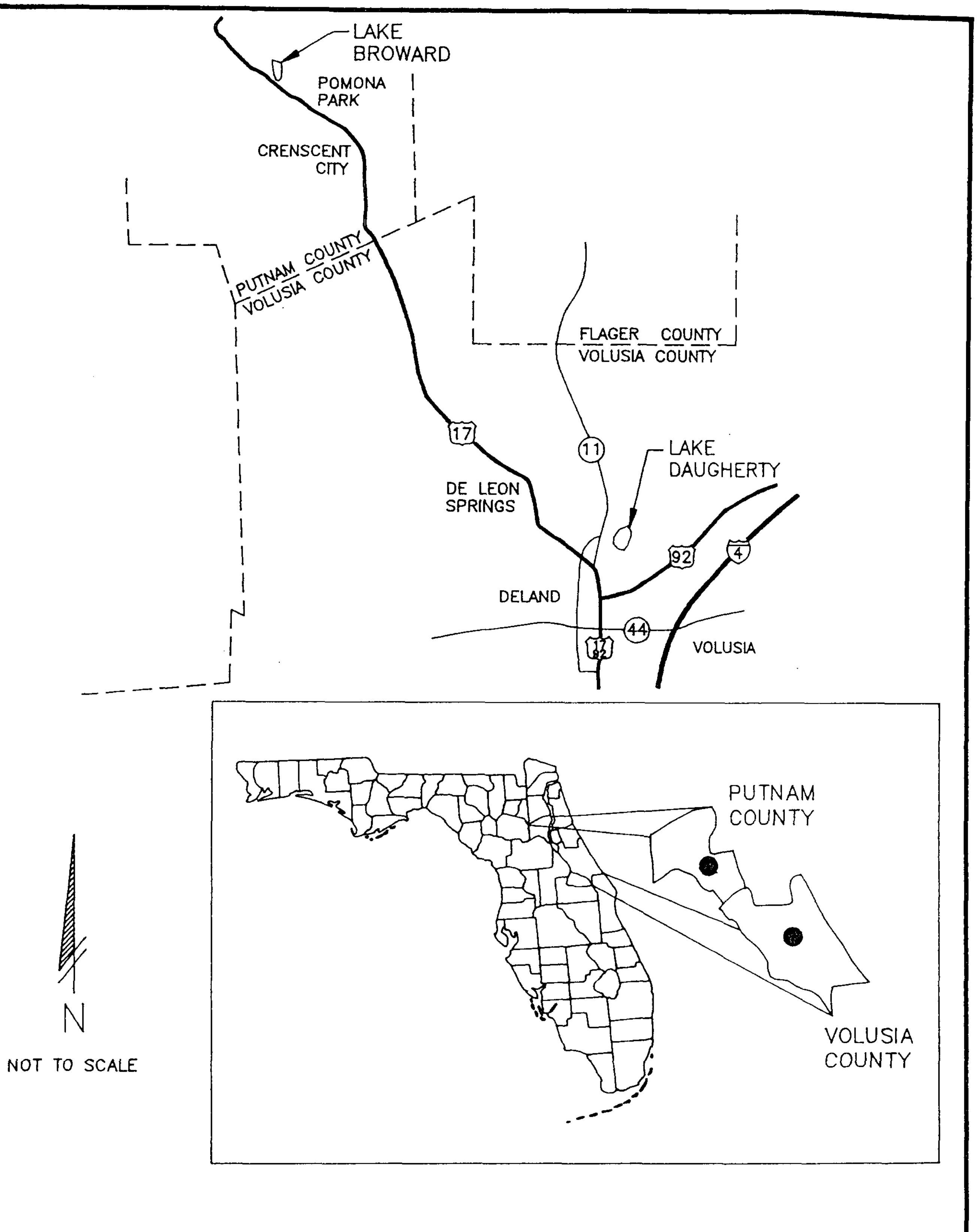
The purpose of this project is to identify the presence and areal extent of karst features in the strata below the selected lakes. The location and extent of these features could indicate whether these lakes are in direct hydraulic connection with various aquifers through large scale solution features, or are perched lakes that are mainly affected by water table and surface water features.

SDII implemented the following scope of work, as defined in the Contract Specifications, to perform this project:

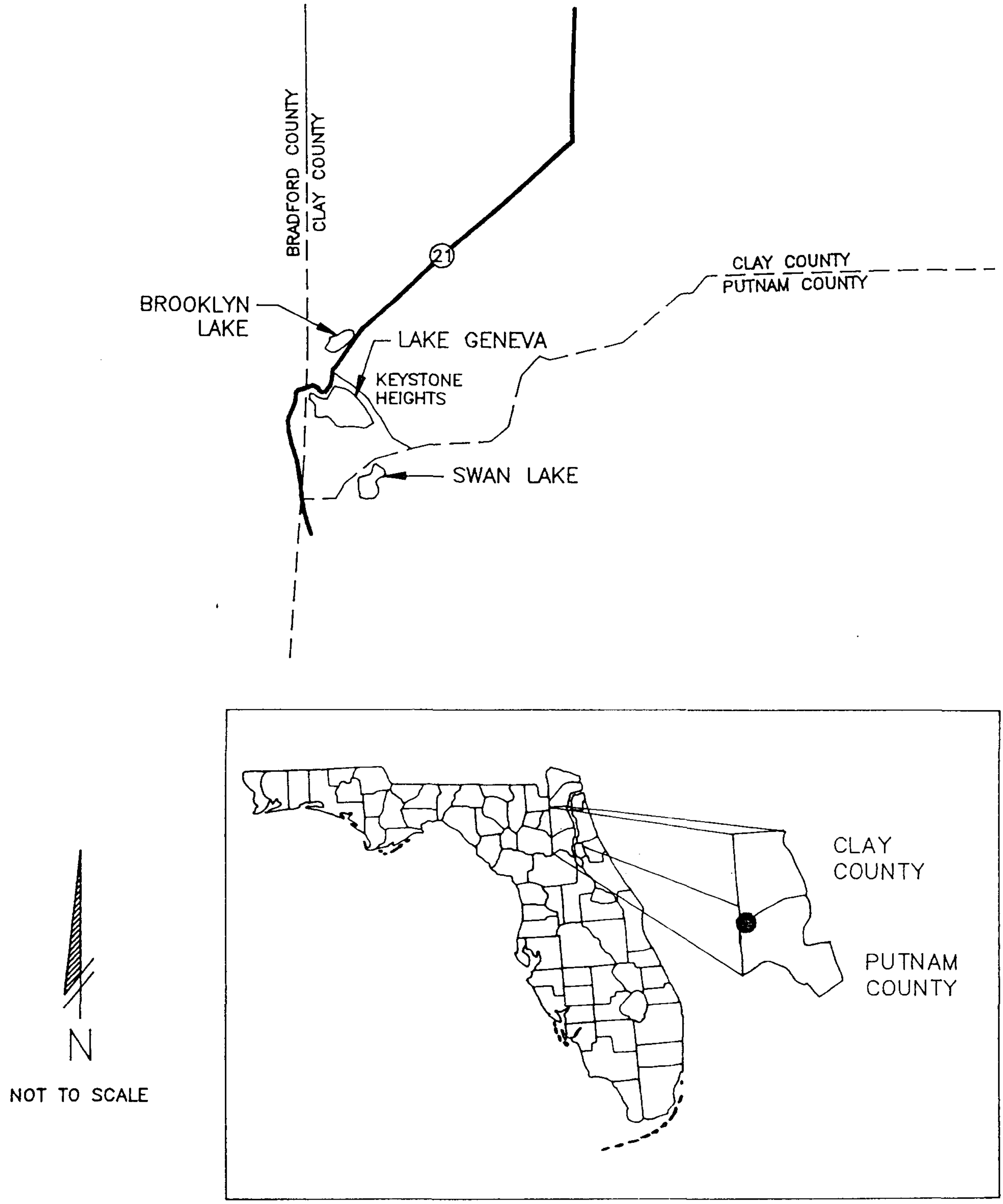
- Perform a high-resolution seismic profile survey in the five selected lakes.
- Record the position of each survey line with an accuracy of +/- 10 feet (ft), and report positions in latitude and longitude.
- Provide data interpretation including identification of stratigraphic units, karst structures, and areas of poor data resolution. Correlate seismic data to available nearby borehole gamma-ray and lithologic logs.
- Submit a final report that provides the reflection data and the results of the interpretations listed above.

1.3 Site Description

Figures 1-1 and 1-2 show the general locations of the five lakes that were surveyed during this study program. Lake Daugharty is in Volusia County, near the town of DeLand. Lake Broward is in southeast Putnam County, near the town of Pomona Park. Swan Lake is in Putnam County, and Lakes Geneva and Brooklyn are in Clay County, which are all near the town of Keystone Heights. The lakes have varying degrees of water level losses over the last 10 to 15 years with Lake Daugharty showing the least significant drop in level and Lake Brooklyn showing the most drastic drop in water levels (20 to 30 feet).



ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	LOCATION MAP OF LAKE BROWARD AND LAKE DAUGHERTY ST. JOHNS RIVER WATER MANAGEMENT DISTRICT		
		DESIGNED BY: J.M.T. CHECKED BY: R.J.W. DRAWN BY: R.L.K.	PROJECT NO.: 91668 DRAWING NO.: LOC-1 DATE: 12/5/91	FIGURE 1-1



ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
PALATKA, FLORIDA

SDII
SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED

LOCATION MAP OF BROOKLYN LAKE, SWAN LAKE, AND LAKE GENEVA
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

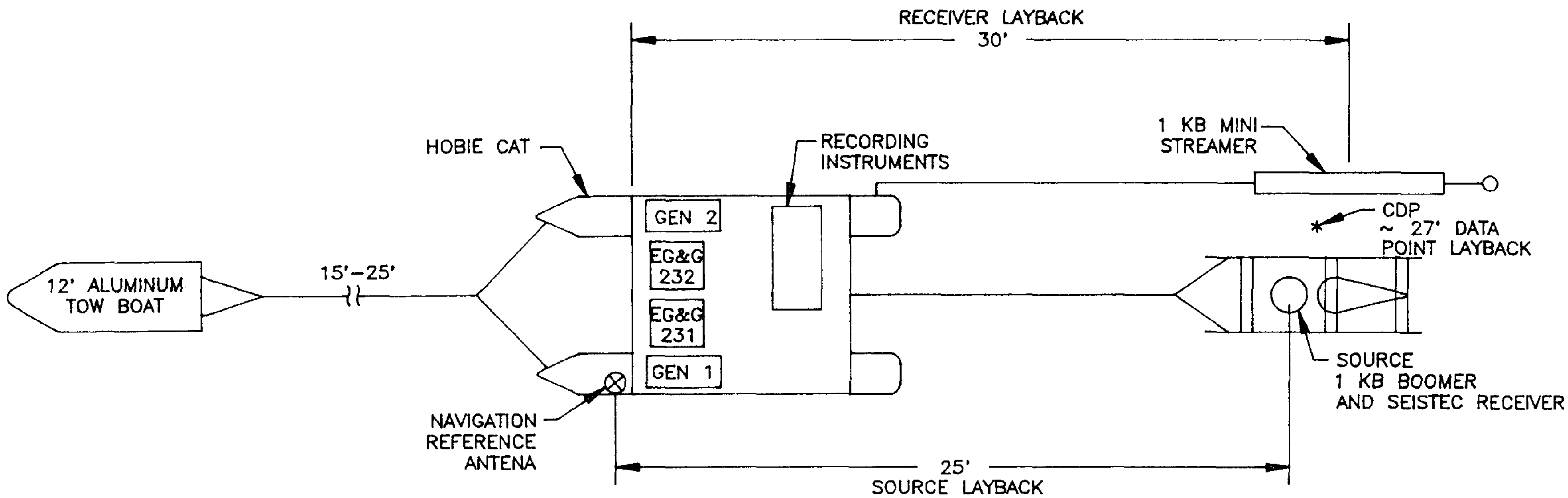
DESIGNED BY:	J.M.T.	PROJECT NO.:	91668	FIGURE
CHECKED BY:	R.J.W.	DRAWING NO.:	LOC-2	1-2
DRAWN BY:	R.L.K.	DATE:	12/5/91	

2.0 FIELD PROCEDURES

2.1 Survey Vessels

Two survey vessel configurations were employed to perform the study. Within Lakes Daugharty, Broward and Swan, a 16-foot catamaran with supplemented floatation was employed. This configuration was towed by a 12 foot aluminum boat with a 9.9 hp outboard motor. The catamaran provided an instrumentation platform for the power supplies and dry electronics of the seismic recording system. The source and receiver of the seismic system were towed behind the catamaran. Figure 2-1 is a sketch drawing of the first vessel arrangement showing the relative positions of the seismic source and receiver system to the navigation reference point.

For Lakes Geneva and Brooklyn, a 24-foot aluminum pontoon boat with a 40 hp motor and trailer was utilized. This combination was used here as reasonable access could be gained to the lake areas, and the ground surface of the dried up lakebed was firm enough to drive vehicles and trailers down to the water's edge and between the various isolated remnant mini-lakes that comprised these lake basins. Figure 2-2 shows the layout and towing configurations used with this vessel.

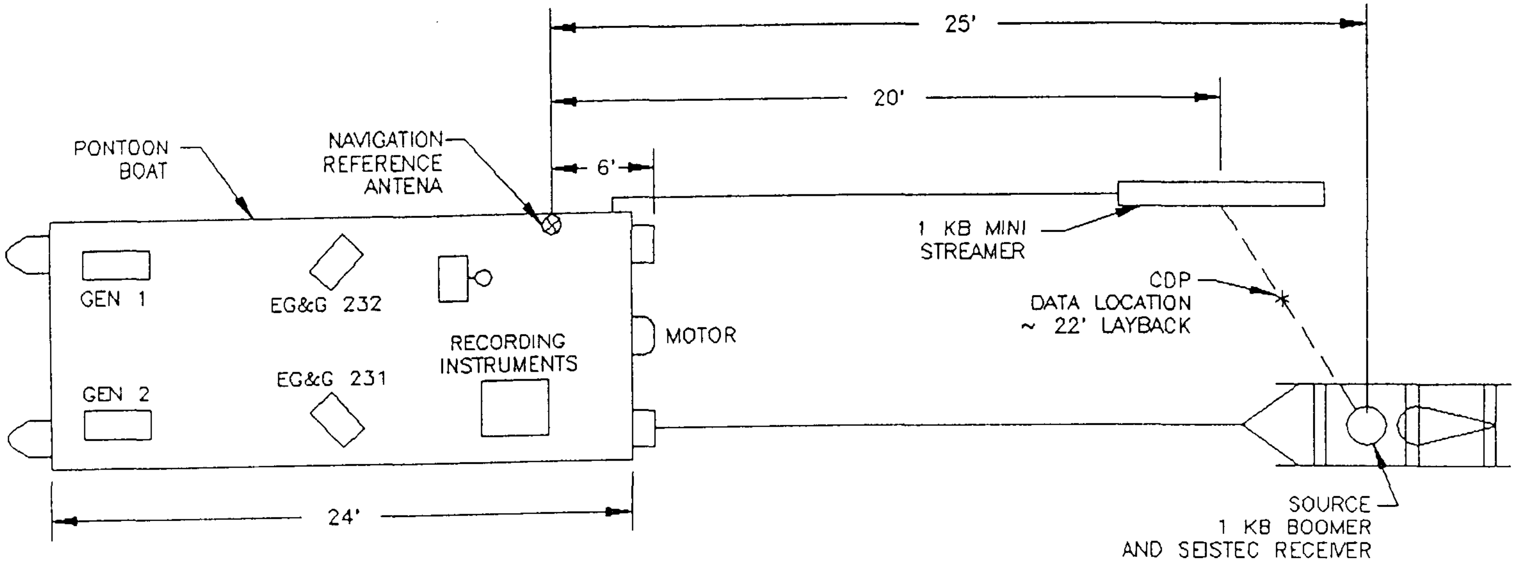


ST. JOHNS RIVER WATER
MANAGEMENT DISTRICT
PALATKA, FLORIDA

SDII
SUBSURFACE
DETECTION
INVESTIGATIONS
INCORPORATED

HOBIE CAT SURVEY VESSEL
TOWING CONFIGURATION
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

DESIGNED BY:	J.M.T.	PROJECT NO.:	91668	FIGURE
CHECKED BY:	R.J.W.	DRAWING NO.:	C-003	2-1
DRAWN BY:	R.L.K.	DATE:	12-2-91	



ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
PALATKA, FLORIDA

SDII
SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED

PONTOON BOAT SURVEY VESSEL
TOWING CONFIGURATION
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

DESIGNED BY:	J.M.T.	PROJECT NO.:	91668	FIGURE
CHECKED BY:	R.J.W.	DRAWING NO.:	C-002	2-2
DRAWN BY:	R.L.K.	DATE:	12-2-91	

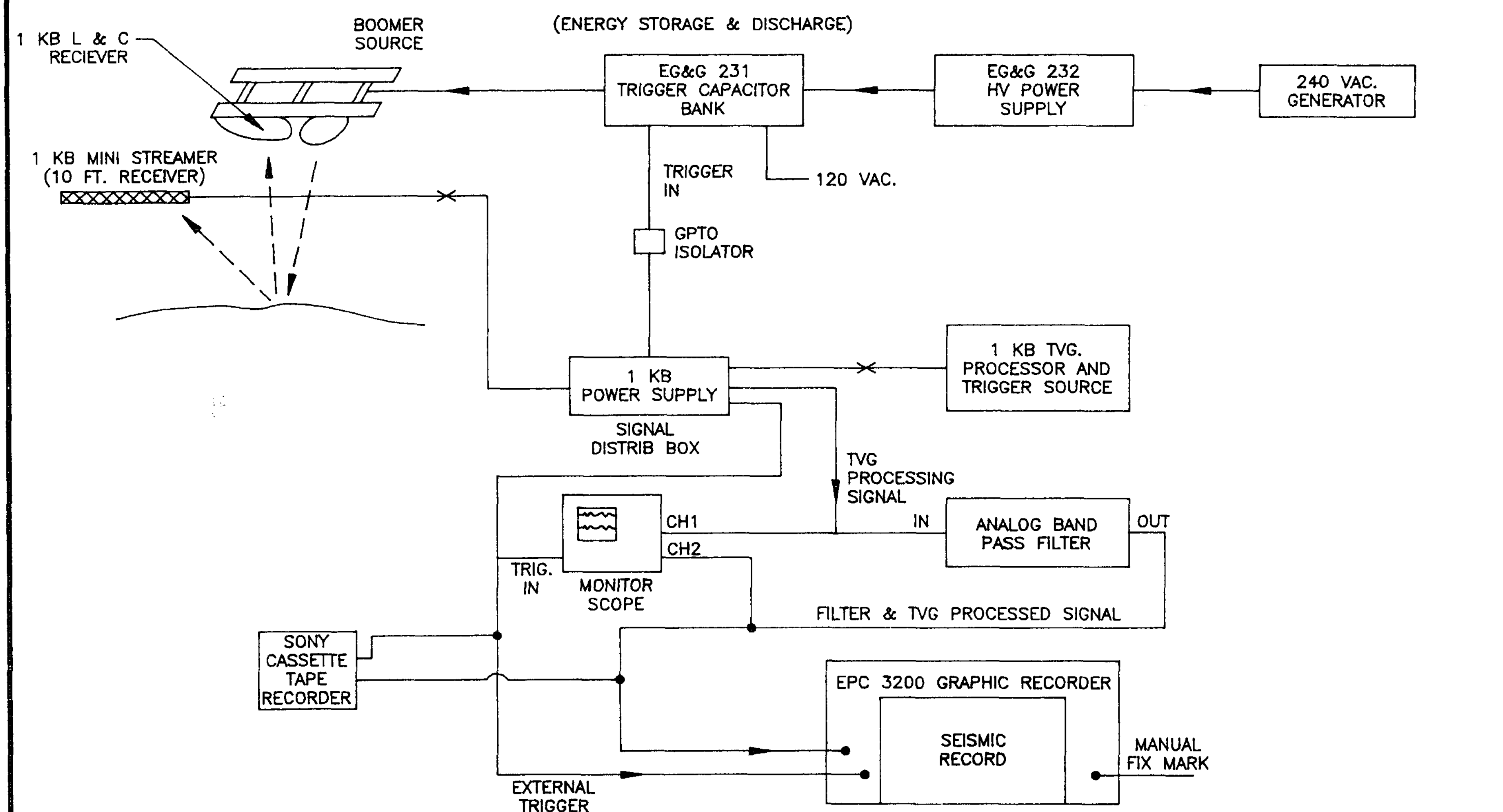
2.2 Navigation Control

During the field program the survey vessel was towed (catamaran) or driven (pontoon boat) along the proposed survey lines while the navigation shore control personnel laser tracked the antenna prism mounted on the vessel. At intervals of one minute (30 seconds on some short lines) as directed by radio from the survey vessel, the field crew logged the position of the survey vessel. The survey line coverage primarily followed the lake outline maps provided by SJRWMD, although on-site modifications were made in conjunction with Jeff Davis, the SJRWMD representative, related to the bathymetry of the lakes and geological features observed on the records. These modifications to the line orientations and positions were commonly based on limitations of vessel access in the lakes due to very shallow water depths. Also, geological features observed on the data during the trial and setup runs on the lakes occasionally resulted in modifications to, or additional survey lines being run to aid in definition of these geological features.

2.3 Marine Reflection Seismic Procedures

The Marine Reflection Seismic profiling technique is a vertical incidence acoustic profiling method involving the transmission of a short duration high amplitude sound pulse into the water column. This signal travels through the water and the sediments below the water where a portion of the outgoing signal energy is reflected off the lakebed and sublakebed sedimentary horizons. The return signal energy is received on a highly sensitive hydrophone receiver system which is towed in the water near the source unit. The amount of signal energy that is reflected from the various acoustic horizons is a function of the variations in the acoustic impedance of the sedimentary or rock layers (acoustic impedance is defined as the velocity of sound in the sediments times the density of the sediments). The source is repetitively fired at a high repetition rate (i.e. three times per second) along the survey line, and the return signals are filtered (for noise reduction) and ramp gained (corrections for signal attenuation due to spherical divergence losses and attenuation during travel through the sediments) before being printed on a line-scan graphic recorder. The line-scan recorder places adjacent shot records side by side on the paper in the form of an acoustic two way travel time, which creates a continuous cross-section of acoustic responses, which are based on geologic conditions. This record is then interpreted for reflector character and position, and best estimated velocity of sound in the sediments and rock materials so that an interpreted geologic cross-section can be generated for the data.

Appendix 1 (Volume 2) provides a basic description of the high resolution IKB Seistec system that was used on this project. The system was supplemented by the use of an IKB manufactured Mini-Streamer receiver to augment the lower frequency responses of the source which are attenuated by the high definition line and cone receiver system. The system was towed in the configurations shown on Figures 2-1 and 2-2 and fired at a rate of three shots per second during the survey program. Power settings on the system were set at 200 joules of electrical energy per shot, and return signals were filtered between a range of 250 Hz to 3.5 Khz throughout the survey program. Overall system gains were adjusted up or down as required to avoid signal limiting and to attempt to achieve the most interpretable data displays which indicated the geologic structures over the desired depth ranges in the site areas. Figure 2-3 is a block diagram schematic of the wiring configuration and signal flows of the seismic profiling system.



ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
PALATKA, FLORIDA

SDII
SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED

BLOCK DIAGRAM OF THE ACOUSTIC PROFILING SYSTEM COMPONENTS AND ELECTRICAL SIGNAL FLOWS
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

DESIGNED BY:	J.M.T.	PROJECT NO.:	91668	FIGURE
CHECKED BY:	R.J.W.	DRAWING NO.:	C-001	2-3
DRAWN BY:	R.L.K.	DATE:	12-2-91	

3.0 REGIONAL GEOLOGIC SETTING

3.1 Lakes Broward and Daugharty

Lake Broward is located in southern Putnam County near the town of Pomona Park. Lake Daugharty is located about 35 miles southeast of Lake Broward, in Volusia County near the city of Deland. Both lakes are located on physiographic ridges - Lake Broward on the Crescent City Ridge, and Lake Daugharty on the Deland Ridge. Both ridges consist of thick sand and shell deposits that are part of the Penholoway Terrace, which is a relict shoreline. The Penholoway Terrace is an area of extensive karst development, and contains numerous sinkhole lakes.

In general, the geologic formations present in this region include in descending order: undifferentiated recent and Pleistocene surficial sands; undifferentiated Pliocene sands and clays; the Miocene Hawthorn Group; and the Eocene Ocala Group and Avon Park Limestone. The geology of this area is described by Bermes, Leve, and Tarver, 1963; Wyrick, 1960; and Scott, 1988.

The undifferentiated sands and clays of recent to Pliocene age range from 40 to about 100 feet in thickness. The surficial deposits consist of fine to medium-grained sand, shell, silt, and inter-layered clays. These deposits are typically highly variable in composition and texture both laterally and vertically. In the Lake Broward area these undifferentiated deposits are underlain by the Hawthorn Group. The Hawthorn Group is the primary confining layer between the surficial aquifer and the Upper Floridan aquifer. It consists of gray to green clay, sandy clay, marl, with interbedded sand and limestone beds. The sediments of the Hawthorn Group contain abundant phosphorite sand and pebbles. The Hawthorn Group is up to about 75 feet thick in the Lake Broward area, but is shown to be absent due to erosion in most of Volusia County, including the Lake Daugharty area (Scott, 1988). In this area the undifferentiated surficial deposits lie unconformably on the Ocala Group. The Ocala Group is the top of the Upper Floridan aquifer in the area. It consists of white to tan, chalky to granular fossiliferous limestone. The mid to lower portion of the Ocala Group contains thin, interbedded dense, crystalline dolomite. The Ocala Group ranges in thickness from 50 feet in Volusia County to about 200 feet in southeast Putnam County. The Ocala Group is underlain by the Avon Park Limestone, which consists of white to brown crystalline limestone and dolomite. The Avon Park Limestone is over 600 feet thick in the area.

The Ocala Group and Avon Park Limestone generally dip to the north and east in this area. The top of the Ocala Group is about 50 feet below mean sea level in the Lake Broward area, to about sea level in the Lake Daugharty area.

3.2 Brooklyn Lake, Lake Geneva, and Swan Lake

Brooklyn Lake and Lake Geneva are located in southwest Clay County, and Swan Lake is located nearby in northwest Putnam County. The three lakes are located within five miles of each other near Keystone Heights. The lakes are in the Central Highlands physiographic province, which is characterized by high sand hills and low depressed areas due to extensive karst development. Many sinkhole lakes are located in this area.

The geologic units in this area are similar to those described above for the area around Lakes Broward and Daugharty. The undifferentiated surficial sands range from 20 to 90 feet thick. The Hawthorn Group ranges from 110 to 180 feet in thickness, but is known to be breached in many places by sand-filled sinkholes. The Ocala Group is between 200 and 250 feet thick.

3.3 Regional Hydrogeology

The region inclusive of both of the above described areas has primarily a two aquifer hydrogeologic system. The surficial aquifer system consists of the undifferentiated surficial sands. The bottom of the surficial aquifer system is generally at the top of the Hawthorn group, which separates the surficial aquifer system from the Upper Floridan aquifer. The top of the Upper Floridan aquifer is usually the top of the Ocala Group, or permeable limestone or dolomite at the base of the Hawthorn Group. In some areas, permeable limestone layers within the Hawthorn Group are productive enough to be classified as an intermediate aquifer. In this region an intermediate aquifer is discontinuous and local in nature.

Movement of water between aquifers is controlled by the head differential in the aquifers and the degree of confinement between the aquifers. In the area of all five lakes the water table of the surficial aquifer system is at a higher elevation than the potentiometric surface of the Upper Floridan aquifer (and the intermediate aquifer where it exists). Therefore water has the potential to move downward from the surficial aquifer system to the Upper Floridan aquifer. All five lakes are located in areas where the Hawthorn Group is either thin, absent, or breached by sinkholes, which provide varying degrees of connection to the Upper Floridan aquifer. All of the lakes are in areas considered recharge areas to the Upper Floridan aquifer. Movement of water between the lakes themselves and the Upper Floridan aquifer is controlled by the same mechanisms. Water levels in the five lakes are higher than the potentiometric surface of the Upper Floridan aquifer, therefore a downward flow potential exists. The magnitude of flow from the lakes will therefore depend on the vertical permeability of lake bottom sediments, and the occurrence of connections between the lake basins and Upper Floridan aquifer.

4.0 SURVEY PROGRAM AND NAVIGATION CONTROL

Field procedures, including survey vessels, navigation control, and marine reflection seismic procedures were summarized in Section 2.0. The following sections present a description of the survey programs performed in each of the five lakes.

4.1 Lake Daugharty, Volusia County

Lake Daugharty, located in Volusia County, was the first lake surveyed. This lake has shown the least overall water level drop of the lakes surveyed. The survey program included one lake subbasin and was performed on October 8, 1991. Figure 4-1-1 shows the lake outline and the survey track plots.

The navigation system was set up on two control points indicated as REF pt. 1 and REF pt. 2 on the track plot map. The laser ranging unit was established on pt. 1, and the backsite prism was established on pt. 2. While surveying within the western subbasin of the lake and out of site of the ranging station, navigation control was maintained using a portable Global Positioning System provided by SJRWMD. During this period, SJRWMD personnel surveyed the location of the seismic vessel with a transit and logged the values displayed on the GPS receiver at one minute intervals. The timing of navigation logging and marking of the seismic records were controlled by the seismic vessel and correlated with the navigation tracking crew by radio or visual communications methods.

N

EXPLANATION

——— SURVEY LINE POSITION DATA, REFERENCED TO UTM GRID

–––– SHORELINE AS DIGITIZED FROM A U.S.G.S. QUAD MAP

– – – HIGH FREQUENCY DEEP REFLECTIONS (POSSIBLE VOIDS OR FAULTS)

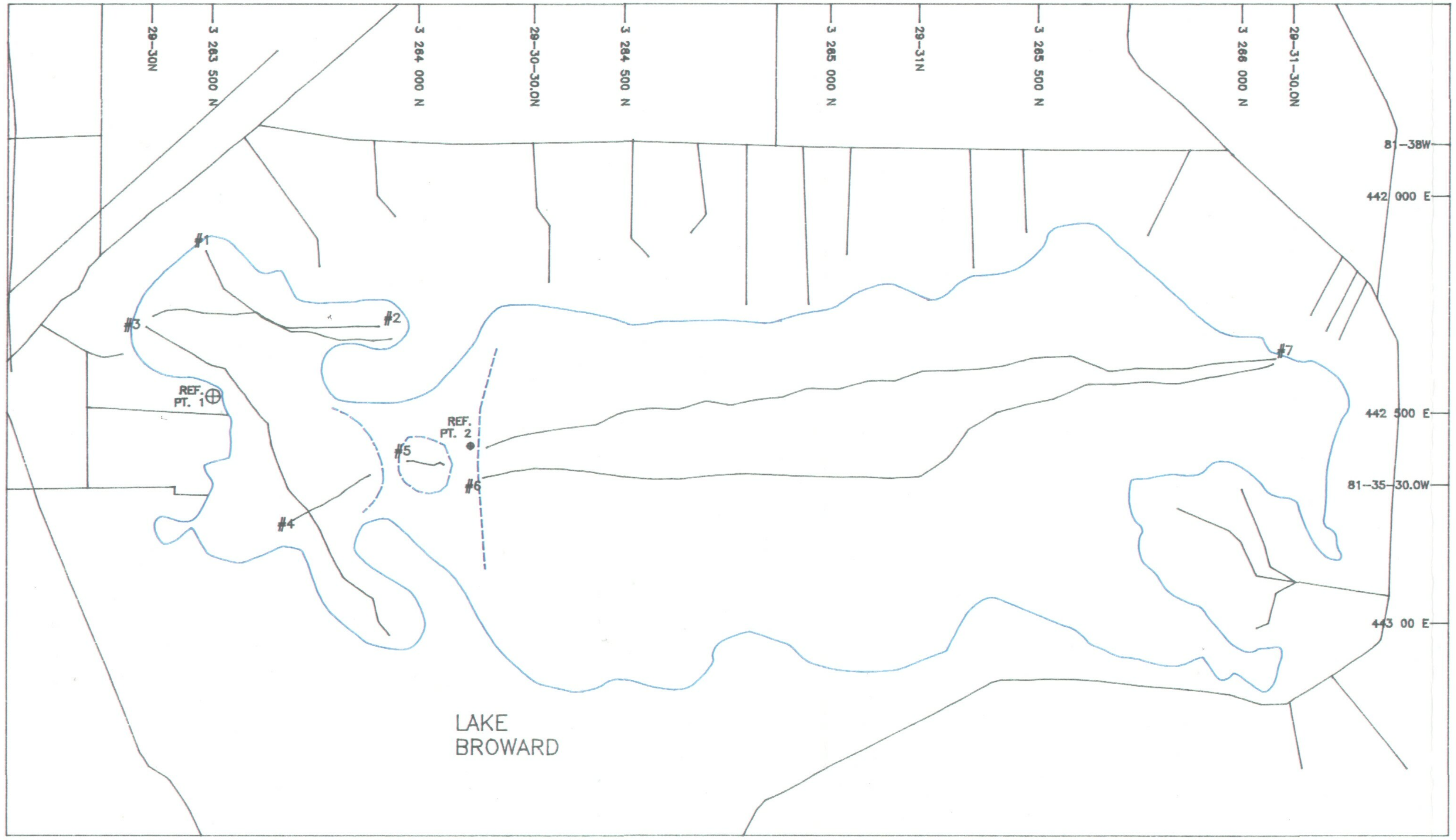
0 500' 1000'

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	LAKE DAUGHARTY NAVIGATION TRACK PLOT		
		DESIGNED BY: J.F.L. CHECKED BY: J.M.T. DRAWN BY: R.L.K.	PROJECT NO.: 91668 DRAWING NO.: S1–1 DATE: 1–6–92	FIGURE 4–1–1

Survey lines were completed after an initial setup and testing period on the lake. Initial testing was done using the Seistic Line and Cone receiver, which did not provide sufficient subbottom penetration within the sediments (due to an inherent limited low frequency response). Therefore, the IKB Mini-Streamer was used to extend the lower frequency response of the system and enhance penetration. This configuration reduces resolution and definition of shallow sediments and was used where increased depth of penetration was necessary. With this configuration Lines 1 and 2 were completed using a 62.5 millisecond sweep display. After completing these lines it was decided to rerun these lines at an expanded sweep speed of 125 millisecond as indications of possible features were observed beyond the scale range of the recording.

4.2 Lake Broward, Putnam County

Lake Broward, within Putnam County, was the second lake surveyed. The lake has experienced a moderate degree of water level drop and was divided into three subbasins by a sandbar. The lake was surveyed on October 9, 1991. Figure 4-2-1 shows the lake outline and the survey track plots. The dashed lines indicate the approximate location of the sandbar which separated the two main lake subbasins. A small pothole depression in the center of this sandbar was surveyed as the third Broward subbasin. The navigation system was set up on two control points indicated as REF pt. 1 and REF pt. 2 on the track plot map. The laser ranging unit was established on pt. 1, and the backsite prism was established on pt. 2 for survey of the southern basin. For the northern basin the



N

EXPLANATION

SURVEY LINE POSITION DATA, REFERENCED TO UTM GRID

APPROXIMATE LOCATION OF PRESENT SHORELINE

SHORELINE AS DIGITIZED FROM A U.S.G.S. QUAD MAP

0 500' 1000'

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	LAKE BROWARD NAVIGATION TRACK PLOT	
		DESIGNED BY: J.F.L. CHECKED BY: J.M.T. DRAWN BY: R.L.K.	PROJECT NO.: 91668 DRAWING NO.: S2-1 DATE: 1-6-92	FIGURE 4-2-1

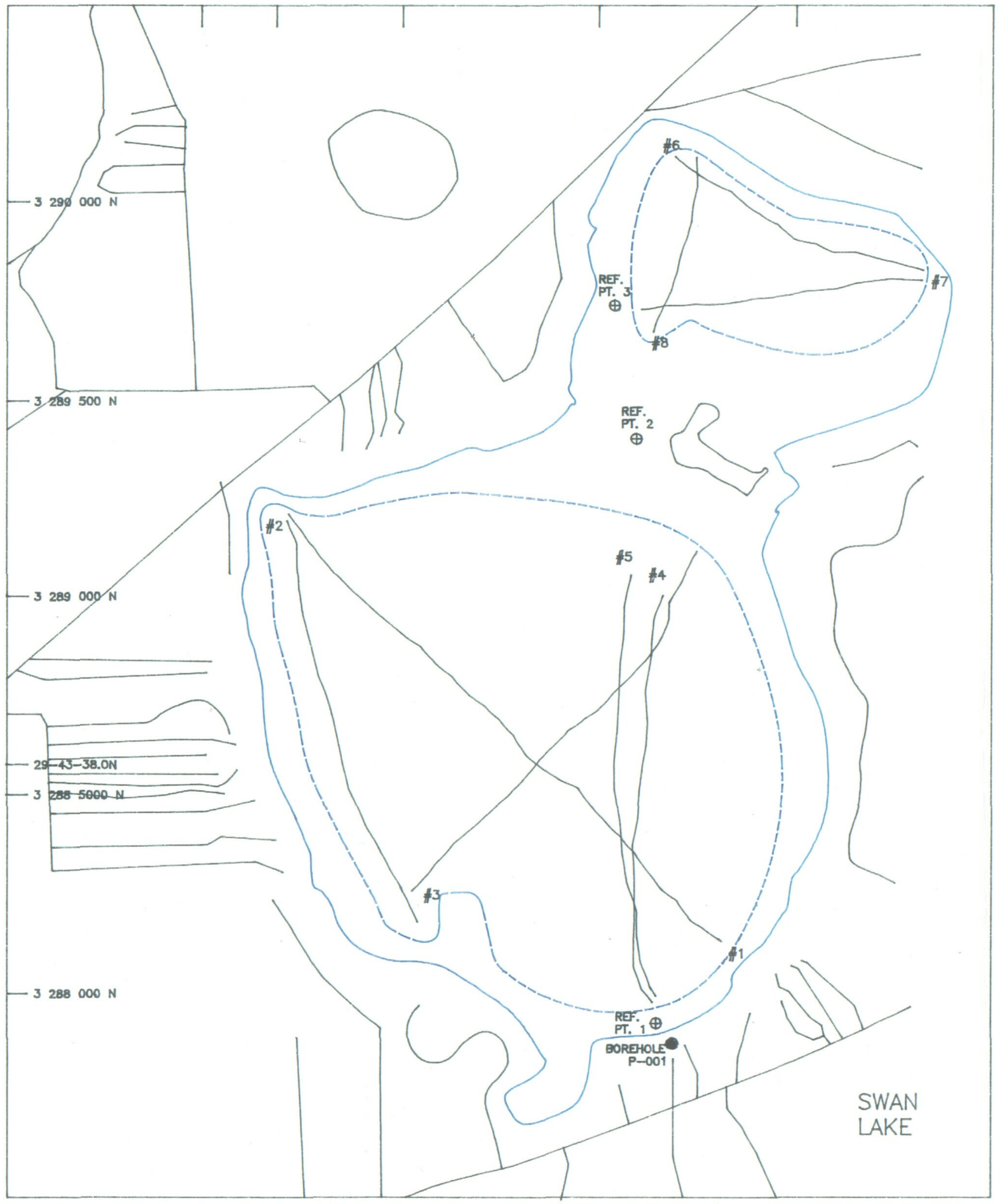
ranging unit was established on pt. 2, and pt. 1 was used as the location of the backsite prism.

Initial setup and testing showed that the equipment configuration used at Lake Daugharty was also appropriate for conditions at Lake Broward. All seismic lines were recorded on a 125 msec sweep display of the graphic recorder and on analog tape. System filters were nominally set between 500 Hz and 3 Khz throughout the duration of the survey.

4.3 Swan Lake, Putnam County

Swan Lake, near the border of Putnam and Clay Counties, was the third lake surveyed. Swan Lake has shown a considerable amount of water level drop (from 96 ft referenced on the USGS Melrose Quadrangle map to a present level of 84 ft). The lake basin was divided into two subbasins by a sandbar with a considerable elevation. The lake was surveyed on October 10th and 11th, 1991. Figure 4-3-1 shows the lake outline and the survey track plots. The dashed lines indicate the approximate location of the present shore line of the lake and the sandbar which separated the two main lake subbasins.

The navigation system was set up using three control points indicated as REF pt. 1, REF pt. 2, and REF pt. 3 on the track plot map. The laser ranging unit was established on pt. 1, and the backsite prism was established on pt. 2 for survey of the southern basin. For the northern basin the ranging unit was established on pt. 3, and pt. 2 was again used as the location of the backsite prism.



EXPLANATION

SURVEY LINE POSITION DATA, REFERENCED TO UTM GRID

APPROXIMATE LOCATION OF PRESENT SHORELINE

SHORELINE AS DIGITIZED FROM A U.S.G.S. QUAD MAP

0 500' 1000'

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA

SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED

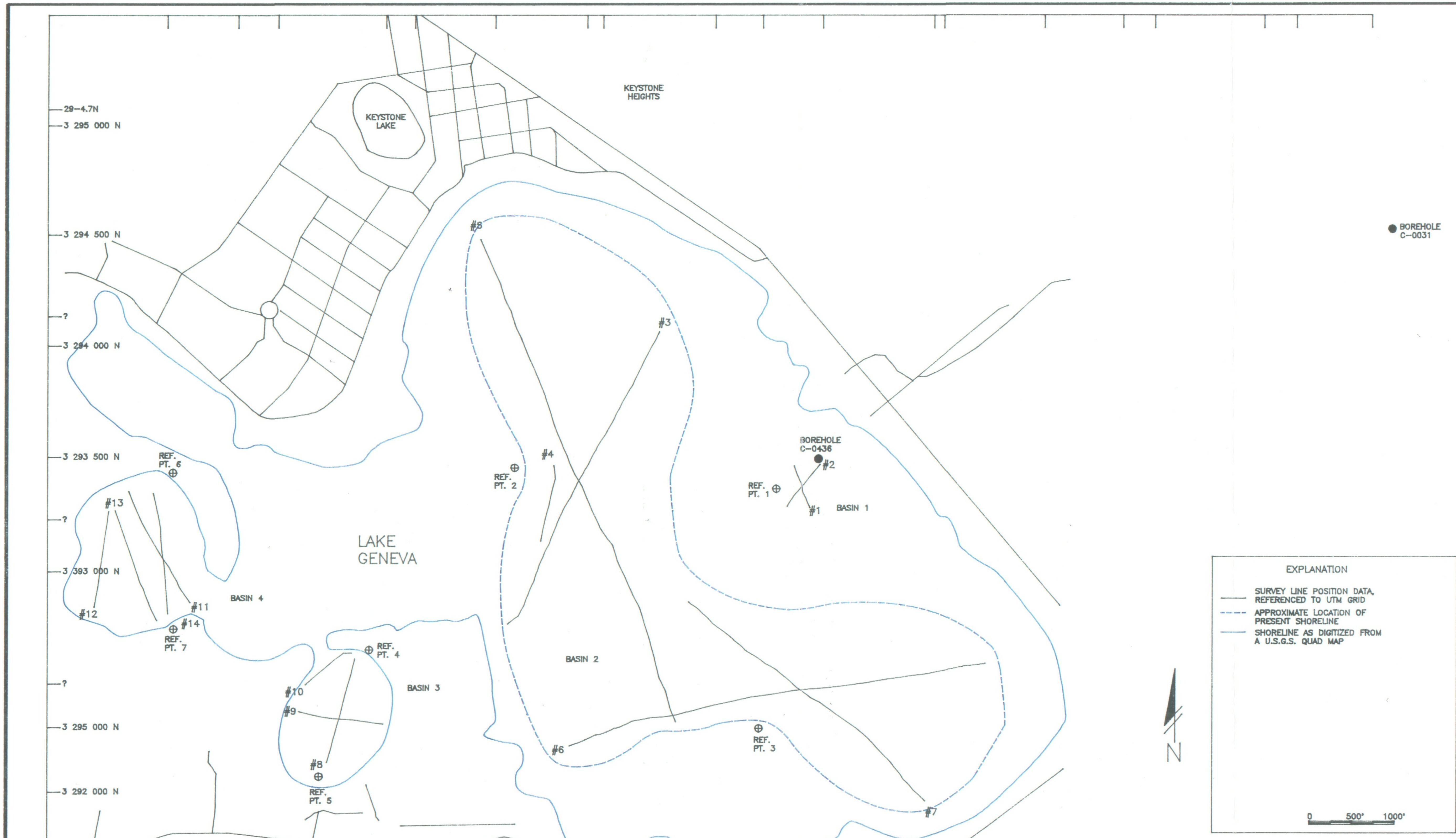
SWAN LAKE NAVIGATION TRACK PLOT

DESIGNED BY:	J.F.L.	PROJECT NO.:	91668	FIGURE
CHECKED BY:	J.M.T.	DRAWING NO.:	S3-1	4-3-1
DRAWN BY:	R.L.K.	DATE:	1-7-91	

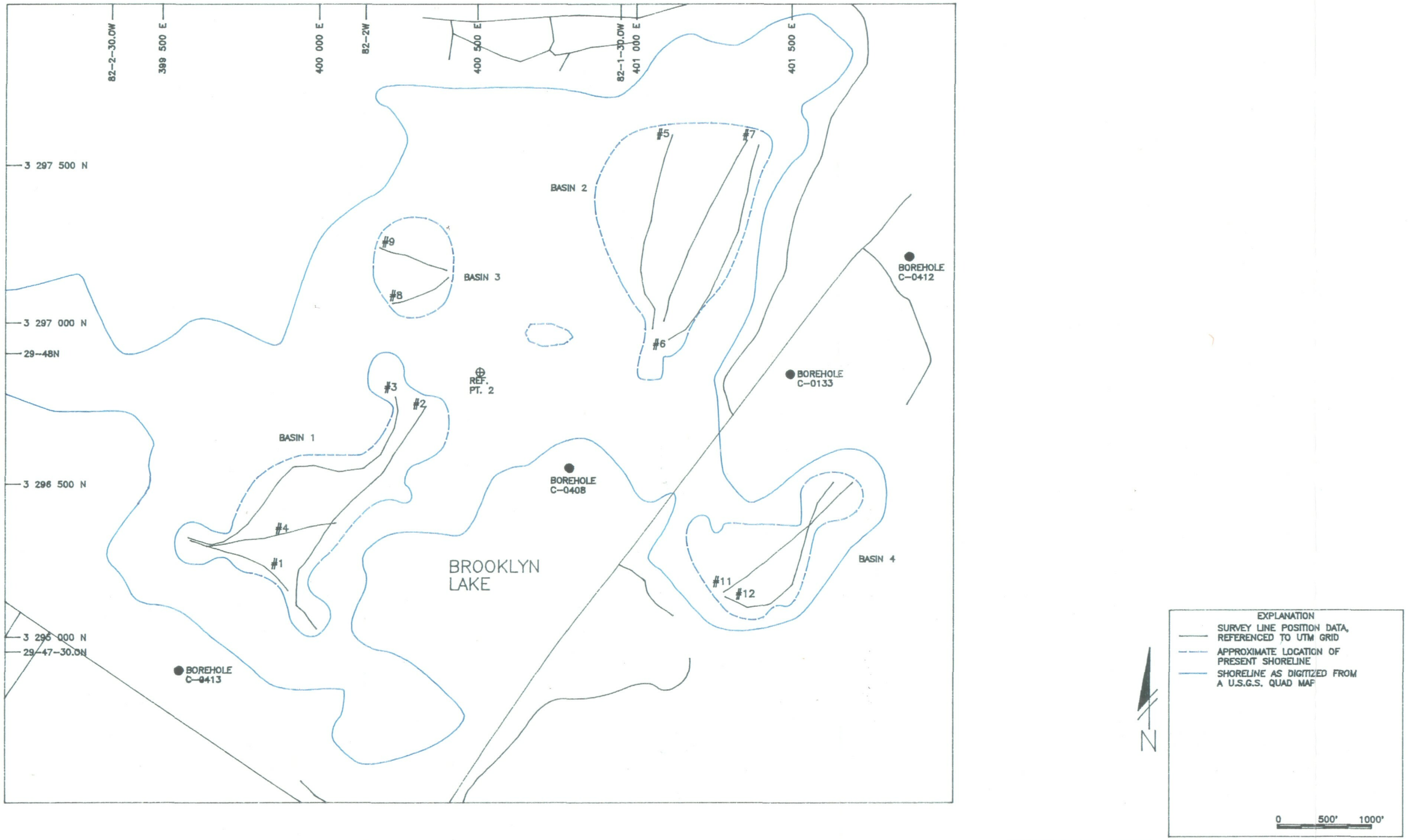
Initial setup and testing confirmed that the equipment configuration used on the previous lakes was suitable for use in Swan Lake. Seismic Lines 1-3 and 6 were recorded on a 125 msec sweep display of the graphic recorder and on analog tape. Lines 4, 7 and 8 were recorded on a 250 msec sweep as there were indications of possibly greater depths of penetration on the faster sweep records. System filters were nominally set between 500 Hz and 3 Khz throughout the duration of the survey.

4.4 Lake Geneva, Clay County

Lake Geneva is located approximately three miles to the north-northwest of Swan Lake near the border of Clay and Bradford Counties. This lake showed a considerable amount of water level drop (from 110 ft referenced on the USGS Keystone Heights Quadrangle map to a present level of 105 ft). The original lake has been divided into at least five subbasins by sandbars with elevations of 1 to 10 feet above lake level and in some cases with considerable areal extent. Lake Geneva was the fourth lake surveyed, with work performed on October 11th and 12th, 1991. Figure 4-4-1 shows the lake outline and survey track plot. The dashed lines indicate the approximate location of the present shore line of the lake and the sandbars which separate the lake subbasins that were surveyed. The subbasins have been labelled Basins 1 through 4 based on the order that they were surveyed. Each basin was surveyed using a 24 ft aluminum pontoon boat.



ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	LAKE GENEVA NAVIGATION TRACK PLOT		
		DESIGNED BY: J.F.L. CHECKED BY: J.M.T. DRAWN BY: R.L.K.	PROJECT NO.: 91668 DRAWING NO.: S4-1 DATE: 1-8-92	FIGURE 4-4-1



ST JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	BROOKLYN LAKE NAVIGATION TRACK PLOT

DESIGNED BY: J.F.L.	PROJECT NO.: 91668	FIGURE 4-5-1
CHECKED BY: J.M.T.	DRAWING NO.: S5-1	
DRAWN BY: R.L.K.	DATE: 1-8-92	

The navigation system was set up using seven control points indicated as REF pt. 1 through REF pt. 7 on the track plot map. The laser ranging unit was established on points 1, 3, 4 and 6, and the backsite prism was established on points 2 (used for survey of both areas 1 and 2), 5 and 7 for survey of their respective basins.

Initial setup and testing in Basin 1 showed no significant subbottom horizons. Trial lines were completed using the line and cone receiver with no improvements or clarifications discernable in the data. The testing indicated that the system configuration used for the previous lakes was suitable for use in Lake Geneva. Seismic Lines 1, 2, 3, and 5 were recorded on a 250 msec sweep to ensure that the greatest depths of penetration could be achieved. Line 4 was completed using a 125 msec sweep to show a greater detail over an anomalous feature that was encountered during transit between Lines 3 and 5. Lines 6 through 13 were recorded on the 125 msec sweep to provide more interpretable records as no deeper reflections were encountered on the earlier lines. System filters were nominally set between 500 Hz and 3 kHz throughout the duration of the survey.

4.5 Brooklyn Lake, Clay County

Brooklyn Lake is located 2.5 miles to the north of Lake Geneva near the border of Clay and Bradford Counties and was the fifth lake surveyed. This lake showed the most dramatic amount of water level drop (from approximately 120 ft referenced on the USGS Keystone Heights Quadrangle map to a present level of 92 ft). The original lake basin is currently only a remnant of four moderate to small subbasins separated by sandbars with considerable elevation, and a few even smaller basins that were considered too small to allow any realistic seismic survey coverage. This lake was surveyed throughout the day of October 13th, 1991.

Figure 4-5-1 shows the lake outline and the survey track plot. The dashed lines indicate the approximate location of the present shore lines of the lake and the sandbars which separated the lake subbasins that were surveyed. The subbasins have been labelled Basins 1 through 4 based on the order that they were surveyed. Each basin was surveyed using the 24 ft aluminum pontoon boat.

The navigation system was set up using four control points indicated as REF pt. 1 through REF pt. 4 on the track plot map. The laser ranging unit was established on points 1, 2 and 3, and the backsite prism was established on points 1, 2 and 4. For Basin 1, the ranging unit was on point 1 with the backsite on point 2 while for Basins 2 and 3 these positions were reversed. For Basin 4, the ranging unit was established on point 4 with the backsite on point 3. These positions provided the most unobstructed views of each of the subbasins.

All survey lines (Lines 1 through 12) were completed at a 125 msec sweep display with the data recorded to analog tape. System filters were nominally set between 500 Hz and 3 kHz throughout the duration of the survey.

5.0 SEISMIC SURVEY RESULTS

In general, the seismic survey program was very successful in that acoustic penetrations ranging from a few feet to over 300 feet were achieved throughout much of the study lakes. The geology as represented by the acoustic profiles within the lake basins appears to be highly contorted due to local karst collapse features. Correlations with borehole gamma-ray logs provided were difficult because many of the lake structures lay within karst collapse features while the boreholes were completed in uncollapsed areas on the shoreline and in some cases a considerable distance away from the actual lake basins. The following subsections on the regional seismo-acoustic characteristics describe each of the lake basins studied.

5.1 Regional Seismo-stratigraphy

Seismic data from each lake show numerous individual characteristics and structures, while at the same time showing some significant similarities in the acoustic response characteristics. The similarities are significant enough to develop a general regional seismo-stratigraphic correlation to the regional geology of the area. This regional seismo-stratigraphy is presented to aid in the following discussion, however absolute (time/lithologic stratigraphic) correlation of units between the individual lakes will necessitate more detailed direct sampling analysis at the sites.

Within each of the studied basins there have been localized areas that are minimally disturbed by the karst collapse activities that have formed the lake basins. These localized areas have been used as "type areas" for lake basins, from which a regional seismo-stratigraphic interpretation was developed for the overall study area. These local zones have also been used for comparison to the regional boreholes gamma-ray logs with the application of the estimated velocity functions described below. Overall, these undisturbed areas of the lakes constituted approximately 10% to 30% of the line lengths of survey completed.

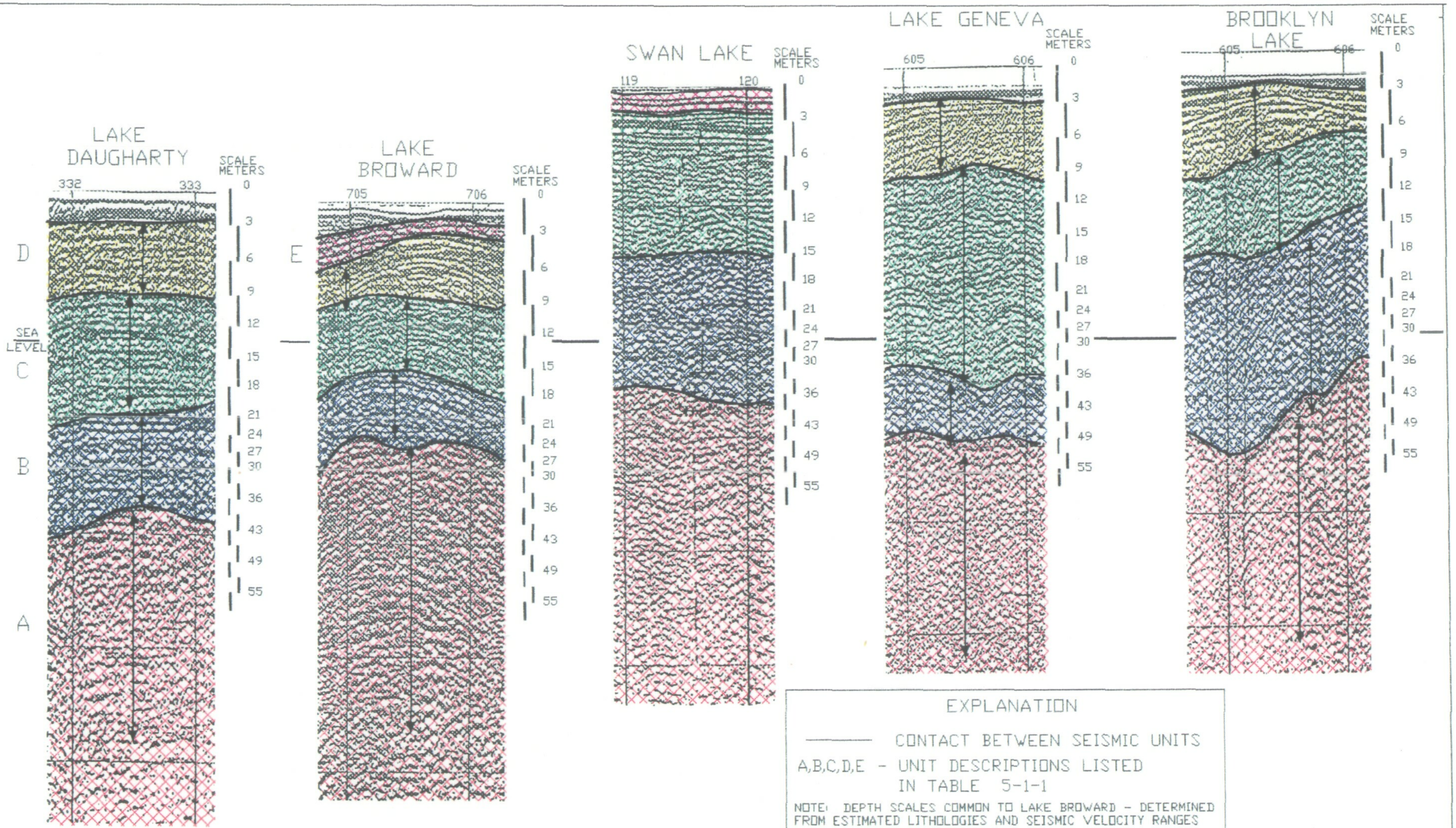
Figure 5-1-1 is composed of five short seismic sections, one from each of the "undisturbed" regions from the five lake basins. These sections and the original records were used to develop the following seismo-stratigraphic section.

There are essentially five seismically distinct acoustic units recognized throughout the separate lake basins. These units have been designated Units A (deepest) through Unit E (shallowest) within the basins. These acoustic units are most often separated by an unconformity surface which may or may not be angular at any site. The units are most often characterized by a visible change in acoustic signature of the seismic data ranging from homogeneous and acoustically transparent sediments with little or no observable internal bedding structures to highly banded, high amplitude zones of acoustic return with many complex internal bedding structures. At the base of the section, the deeper limestone units produce a relatively high amplitude return with a typically chaotic internal reflectivity signature, which occasionally show internal hyperbolic

TABLE 5-1-1 REGIONAL SEISMO-STRATIGRAPHY

UNIT NAME	BOUNDING HORIZONS	THICKNESS RANGE (estimated interval velocities)	SEISMO ACOUSTIC CHARACTERISTICS AND INTERPRETED LITHOLOGIC CORRELATION
E	Lakebed to D unconfined	0 to approximately 20 ft (v=1600 m/s)	Acoustically transparent occasionally fine conformable bedding horizons. When present the base of the unit lies unconformably on unit D. Recent aeolian and lacustrine infill - fine sands - lower boundary is a variable depth unconformity surface Primarily only observed as ponded deposits within topographic lows
D	D unconfined to C unconfined	typically 15 to 20 ft thick, locally thinner - much thicker within collapse features (v=1600m/s)	Acoustically transparent with typically a low amplitude acoustic response, often finely bedded materials with normally steeply dipping reflectors. Rests unconformably to paraconformably on C. Complex silt/clay and sand layering representing infill of sinkholes - undifferentiated sediments of Upper Pliocene to Recent age

C	C unconfined to B unconfined	20 to 100 ft thick (v=1700 m/s)	Moderate amplitude acoustic response with many closely spaced internal reflecting horizons. Horizons showing complex internal structures giving a twisted ropy like appearance to the data. Finely banded sand, silt and clay layering initially deposited conformable to lower sedimentary horizons, bedding is totally disrupted within some collapse features and conformable to other collapse features. Probably Miocene Aged Middle to Upper Hawthorn Group and Lower Pliocene aged undifferentiated sediments.
B	B to A	30 to 40 ft thickness (v=2000 m/s)	High amplitude banded reflections which are conformable to bedrock. Layered clays and interbedded silts/sands of the Lower Hawthorn Group, Miocene age
A	A1	90 to 110 ft in Daugharty and Broward - unknown elsewhere (v=3500 m/s)	High amplitude reflection with a low frequency characteristic response typical of consolidated bedrock reflections - chaotic internal reflections below the top of the unit normally associated with a rough bedrock surface. Limestone - Eocene Aged Ocala Group
	A2	unknown thickness to limit of penetration	Low frequency moderate to high amplitude reflection, not visible in many areas. Tentatively correlated to Avon Park Limestone (only seen in Lakes Daugharty and Broward)
voids/ fault planes	X	-370 to -600 ft below surface	High frequency variable discontinuous reflections - possible voids or subsurface fault planes



EXPLANATION

——— CONTACT BETWEEN SEISMIC UNITS

A,B,C,D,E - UNIT DESCRIPTIONS LISTED IN TABLE 5-1-1

NOTE: DEPTH SCALES COMMON TO LAKE BROWARD - DETERMINED FROM ESTIMATED LITHOLOGIES AND SEISMIC VELOCITY RANGES (after Grant and West, 1965)

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SEISMO-STRATIGRAPHIC COMPARISONS OF THE FIVE SURVEYED LAKES

DESIGNED BY:	JMT	PROJECT NO.:	91668	FIGURE
CHECKED BY:	RJW	DRAWING NO.:	STRAT	5-1-1
DRAWN BY:	SBG	DATE:	01/30/92	

reflectors that may be associated with void structures and/or fault planes within the limestones. Not all units are immediately recognizable within each of the lake basins. However, on close examination seismo-stratigraphically similar units are usually visible in some region of each data set and it appears that overall, the seismo-stratigraphic sequence is repeated and correlatable throughout the region. The seismo-stratigraphic correlations have been made solely on the basis of the acoustic signatures of these various sedimentary horizons within each lake. Therefore, stratigraphic projections of these acoustic units from lake basin to lake basin is conjectural at this time.

Table 5-1-1 provides a list of the individual units observed within the basins and a brief description of the identifying acoustic characteristics of the units. From the limited borehole information around the sites a speculative lithologic and geologic correlation has been developed.

5.2 Velocity Structures Used for Estimation of Depth

Figure 5-1-1 contains a non-linear depth scale which was constructed using the estimated velocity of sound in the sediments outlined in Table 5-1-1. These seismic velocities have been chosen based on the typical ranges of velocities for similar unconsolidated sands, silts and clays and for limestones and dolomites presented in numerous geophysical texts (Grant and West, 1965, Dobrin, 1976 and Telford et.al., 1976). The velocity ranges were further refined by iteration using projected depths to reflectors from the available borehole data and calculating seismic depths that agreed within reason assuming realistic velocity values for the sediments in the travel path. Though this procedure is not ideal (seismic data would ideally pass within a few meters of the borehole information) it is estimated that depths calculated using these values should be accurate to within 5% to 10% of the true depth to the reflecting structures.

5.3 Lake Daugharty, Volusia County

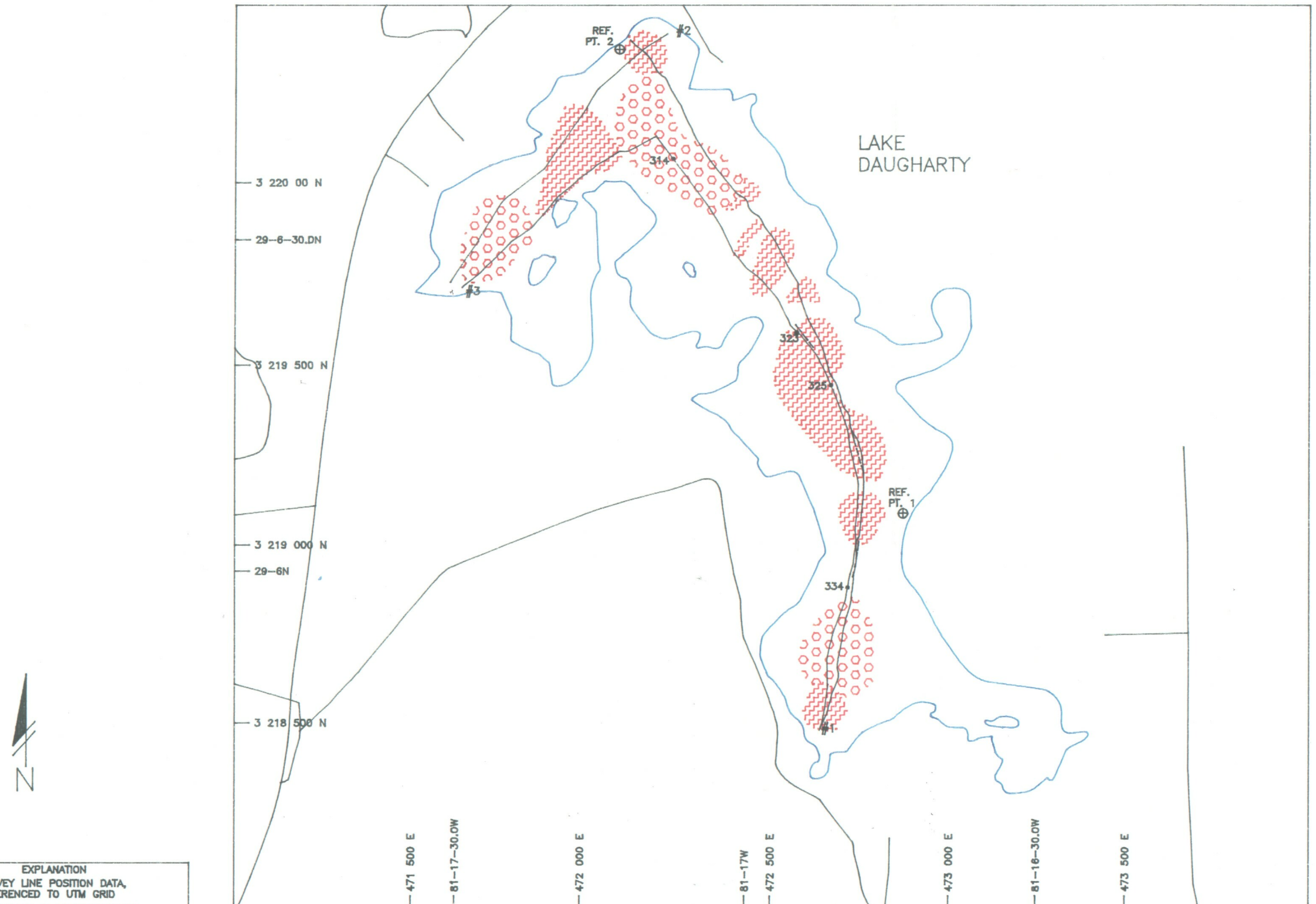
The three survey lines completed in this basin indicated eight local areas of karst collapse structure and three areas of seismic masking (Figure 5-3-1 and Volume 2, Appendix 2). Approximately 70% to 80% of the line transits were within these distorted or masked regions and even within the non-collapsed regions there was commonly some distortions or masking present which would not allow a clear definition of the regional seismo-stratigraphy. Within these relatively undistorted zones a small section on Line 3 between fixes 332 and 334 showed the clearest indication of the regional seismo-stratigraphic section. This portion of record is used in Figure 5-1-1, and is also shown in a more complete context in Figure 5-3-4. Table 5-3-1 provides a summary of the seismo-stratigraphic sequence for Lake Daugharty.

Seismic data from Lake Daugharty indicate three localized regions within the lake that are extremely reflective in nature. The records in these zones show numerous water bottom multiple reflections and no interpretable subbottom reflecting horizons. This response indicates that virtually all of the acoustic energy was being reflected from the lakebed or a reflector very near to the lakebed, and is reverberating within the water column with little or no energy being transmitted into the subbottom sediments. These regions are located in the three deeper basins of the lake. Figure 5-3-2 shows a portion of the calibration seismic recording using the high resolution IKB line and cone receiver array over the most southerly of these acoustic masking zones. This record clearly displays a phase reversal of the acoustic bottom return signal. This phase reversal indicates that the seismic signals are passing from a higher velocity media into a significantly lower velocity media (causing the very high amplitude reflection), which can be caused by gaseous materials within the sediments. This is probably the result of a peat layer of unknown thickness on the lakebed. The same non-penetration results were observed when using the lower frequency streamer receiver system though the phase reversals at the lakebed are less obvious on these records.

Within the remaining regions of the lake, acoustic penetrations of as much as 100 msec. (over 300 ft) were observed. From the lakebed to a depth of approximately 12 msec (9.6m or 31.5 ft) there are few reflecting horizons identifiable on the low resolution Mini-Streamer records. When the higher resolution line and cone receiver were used, some finely banded weak reflectors were detected in this zone (Figure 5-3-2). In many cases these sediments were contorted and deformed, and are interpreted to be loosely packed sands with occasional clay/silt interbeds. These near-surface sediments were likely deposited by aeolian and fluvial run-off processes since the lake basin was formed. These units are believed to correlate with Unit D and/or Unit E outlined on the

TABLE 5-3-1 LAKE DAUGHARTY - SEISMIC CORRELATIONS

UNIT NAME	HORIZON	DEPTH RANGE ELEVATION FT (relative to msl)	INTERPRETED LITHOLOGIC CORRELATION
D/E	Lakebed to top of C unconformity	+45 top +13 ft bottom	Upper Pliocene to Recent undifferentiated surficial sands - aeolian and lacustrine infill.
C	C to top of B disconformity	+13 ft top -23 ft bottom	Middle to Upper Hawthorn Group and Lower Pliocene undifferentiated layered clays and interbedded silts/sands - unconsolidated to semi-consolidated
B	B to top of bedrock unconformity	-20/-37 ft top undisturbed	Lower Hawthorn Group layered clays, silts and sands - semi-consolidated ??
A	A1 to A2 A2	-37/-47 ft top undisturbed -210/-230 ft to limit	Limestone - Ocala Group unconformity surface to unknown unit tentatively Avon Park Limestone
voids	X	-370 to -600	high frequency variable discontinuous reflections - possible voids



EXPLANATION

SURVEY LINE POSITION DATA, REFERENCED TO UTM GRID

SHORELINE AS DIGITIZED FROM A U.S.G.S. QUAD MAP

HIGH FREQUENCY DEEP REFLECTIONS (POSSIBLE VOIDS OR FAULTS)

REGIONS OF PALEOKARST COLLAPSE INDICATING SIGNIFICANT INFILL, SOME OF WHICH IS CONFORMABLE TO THE COLLAPSE STRUCTURES

REGIONS OF SHALLOW GAS MASKING DEEPER REFLECTIONS, CONFIRMED BY PHASE REVERSAL OF LAKEBED REFLECTING HORIZON

0 500' 1000'

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
PALATKA, FLORIDA

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LAKE DAUGHARTY NAVIGATION TRACK PLOT AND LOCATIONS OF ANOMALOUS FEATURES

DESIGNED BY:	J.F.L.	PROJECT NO.:	91668	FIGURE
CHECKED BY:	J.M.T.	DRAWING NO.:	S1-1	5-3-1
DRAWN BY:	R.L.K.	DATE:	1-6-92	

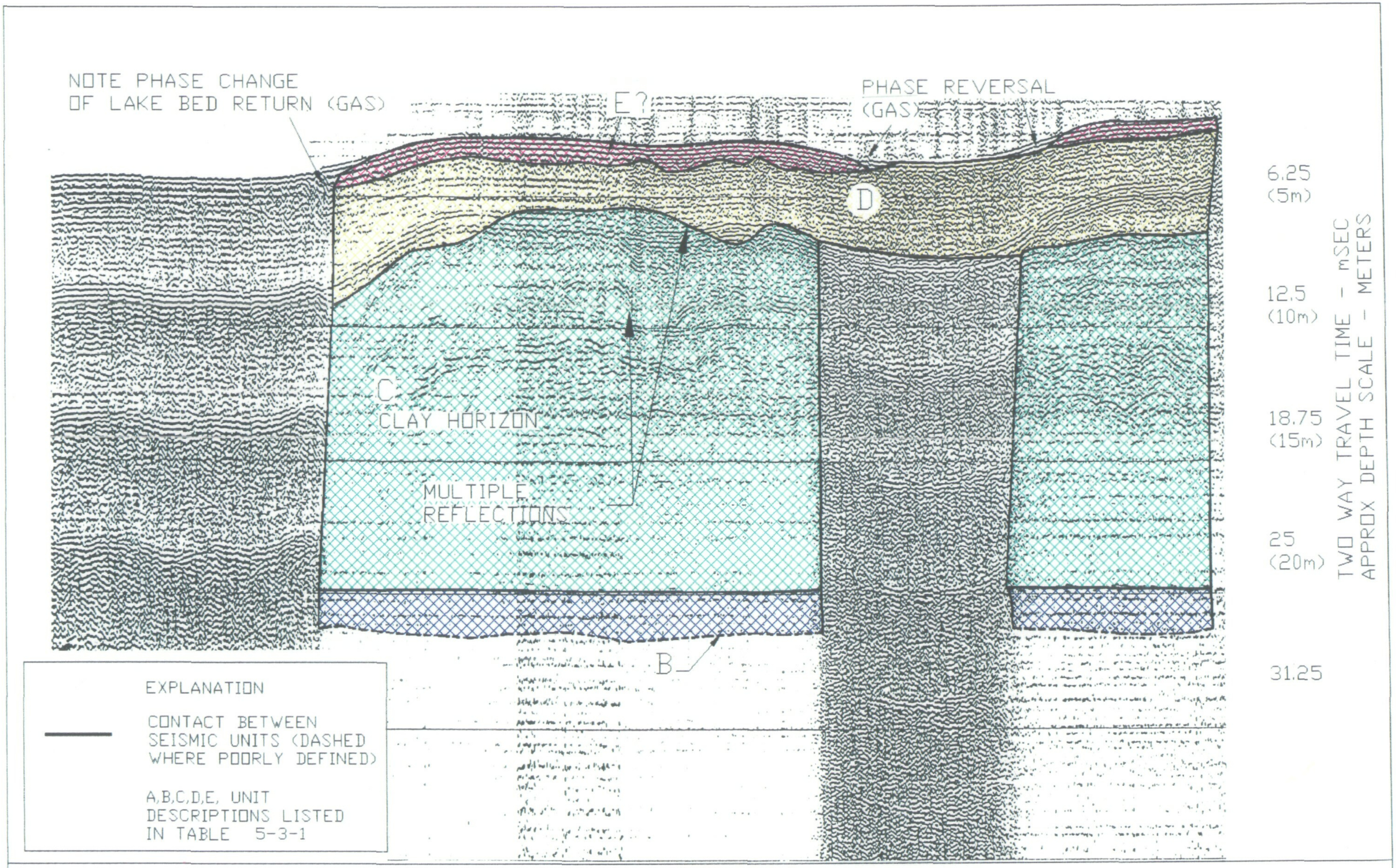


FIGURE 5-3-2 IKB Seistec Line and Cone receiver record from a calibration run (no survey fix points) indicating the acoustic phase reversal associated with the impenetrable zone in the southern portion of Lake Daugharty.

regional seismo-stratigraphy above. A horizon D unconformity reflector was not apparent on the records, therefore definite discrimination of Units D and E was not possible.

A repetitive series of moderately strong acoustic reflectors were observed within the undisturbed areas between depths of approximately 12.5 and 25 msec (10-21 m or 33-68 ft) below the lakebed. These reflecting horizons are nearly flat-lying and often show a banded character with four or five individual reflecting horizons (Figures 5-3-3 and 5-3-4). This moderately higher amplitude type of flat-lying reflector sequence is usually associated with banded and moderate to loosely compacted clays with possible interbeds of silt or sand. The reflectors are virtually flat-lying in some locations but are noted to be highly discontinuous with apparent down-drops that have disrupted the reflector sequence. These reflections are ascribed to Unit C within the regional seismo-stratigraphic outline.

At the base of the Unit C sequence a reflector was noted, which is conformable but significantly higher in amplitude and lower in frequency response than the overlying banded reflections. This reflector has been interpreted as the top of Unit B. The internal acoustic response of the Unit B sediments is generally lower frequency in character though still banded in nature which is most likely indicative of a more consolidated sequence of banded clays and silts. This unit has been assigned a higher acoustic velocity (2000 m/s) than the overlying sediments because the acoustic response suggests an apparent older and possibly more consolidated material. Through the central (non-collapsed) regions

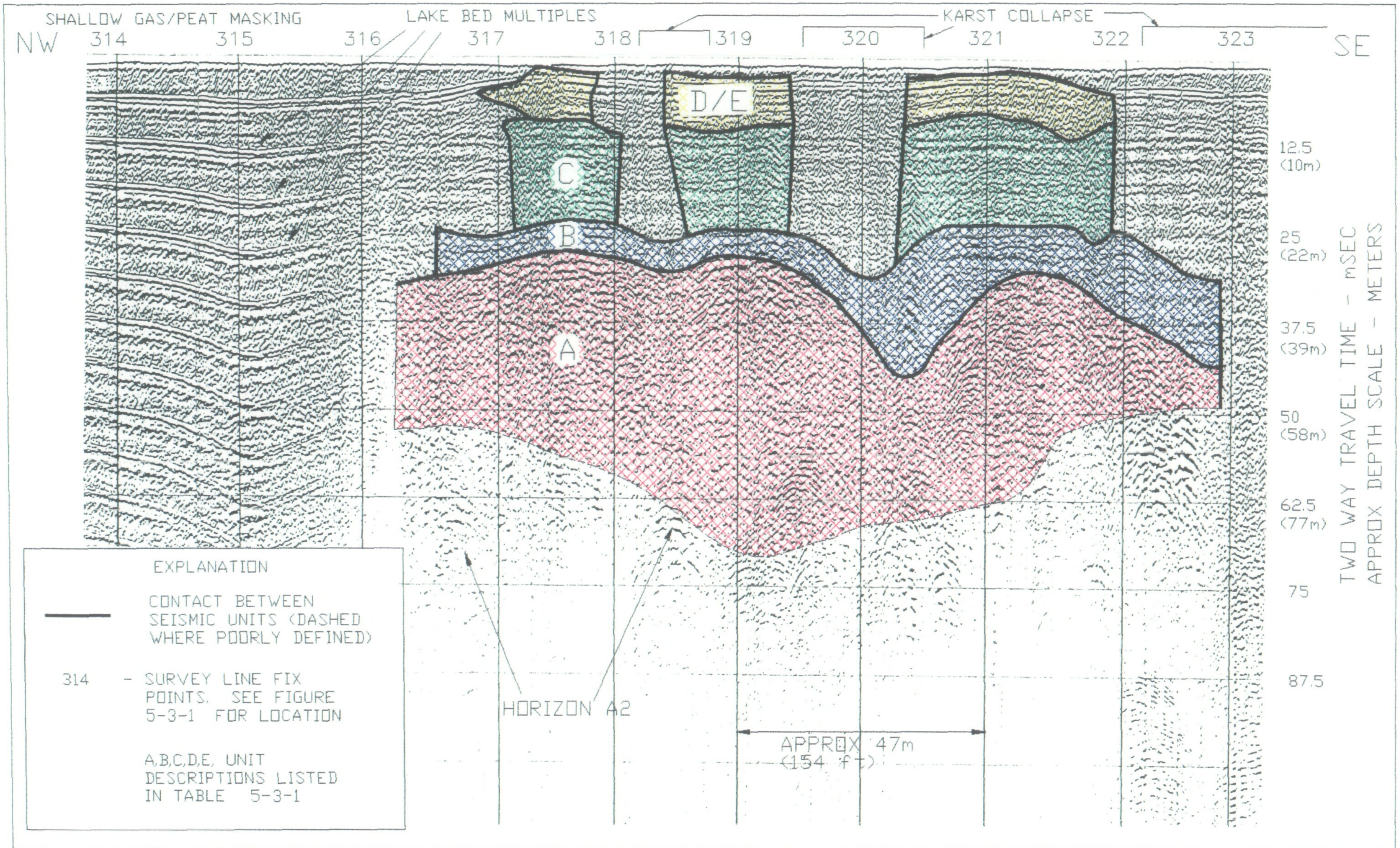


FIGURE 5-3-3 IKB Boomer and Mini Streamer record from survey line 3 in Lake Daugharty showing the acoustic character and acoustic horizon designations of the sediments below the lake.

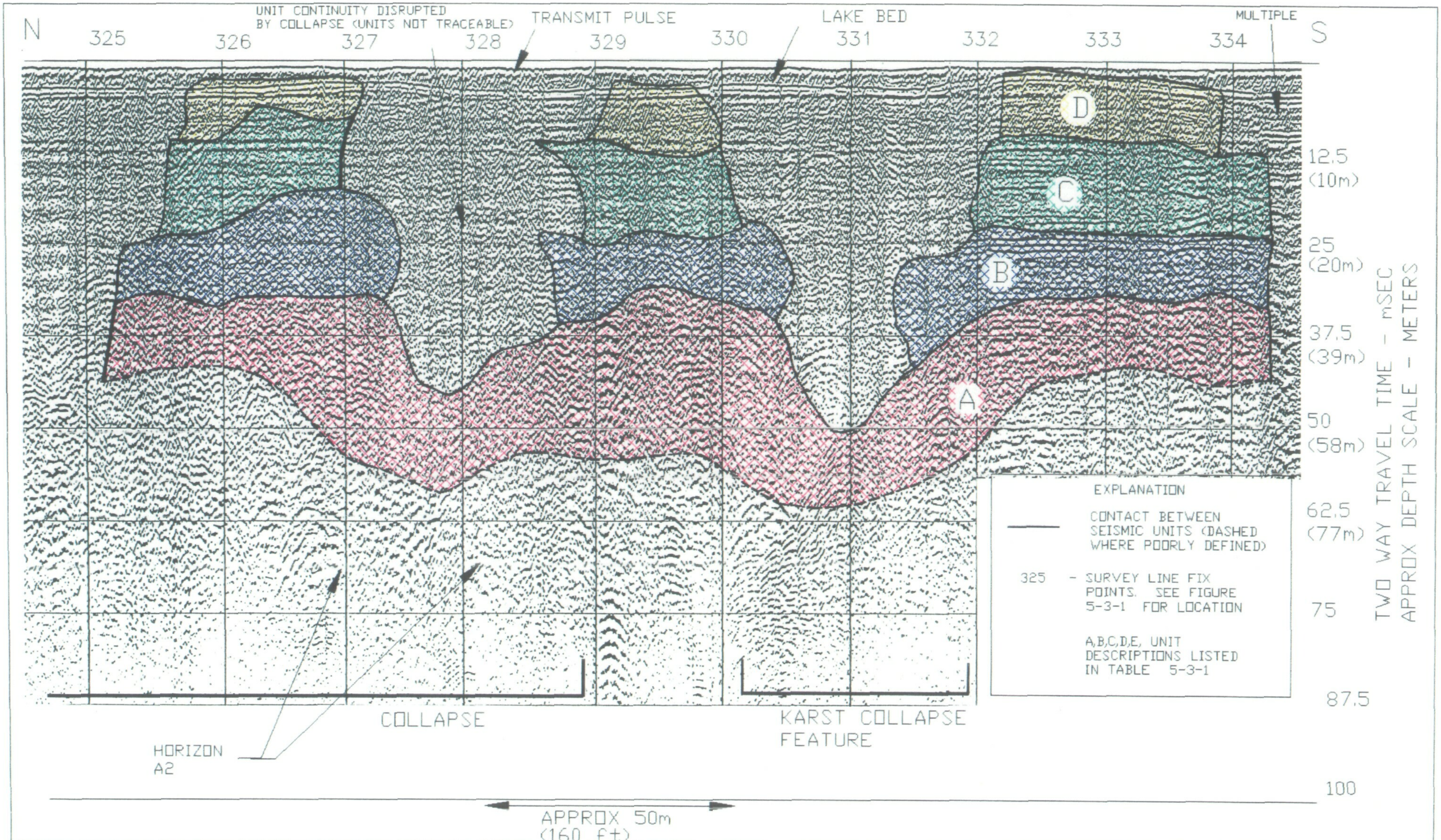


FIGURE 5-3-4 Example record from survey line 3 in Lake Daugharty showing the irregular A2 reflecting horizon and the local down-drop features associated with horizon A.

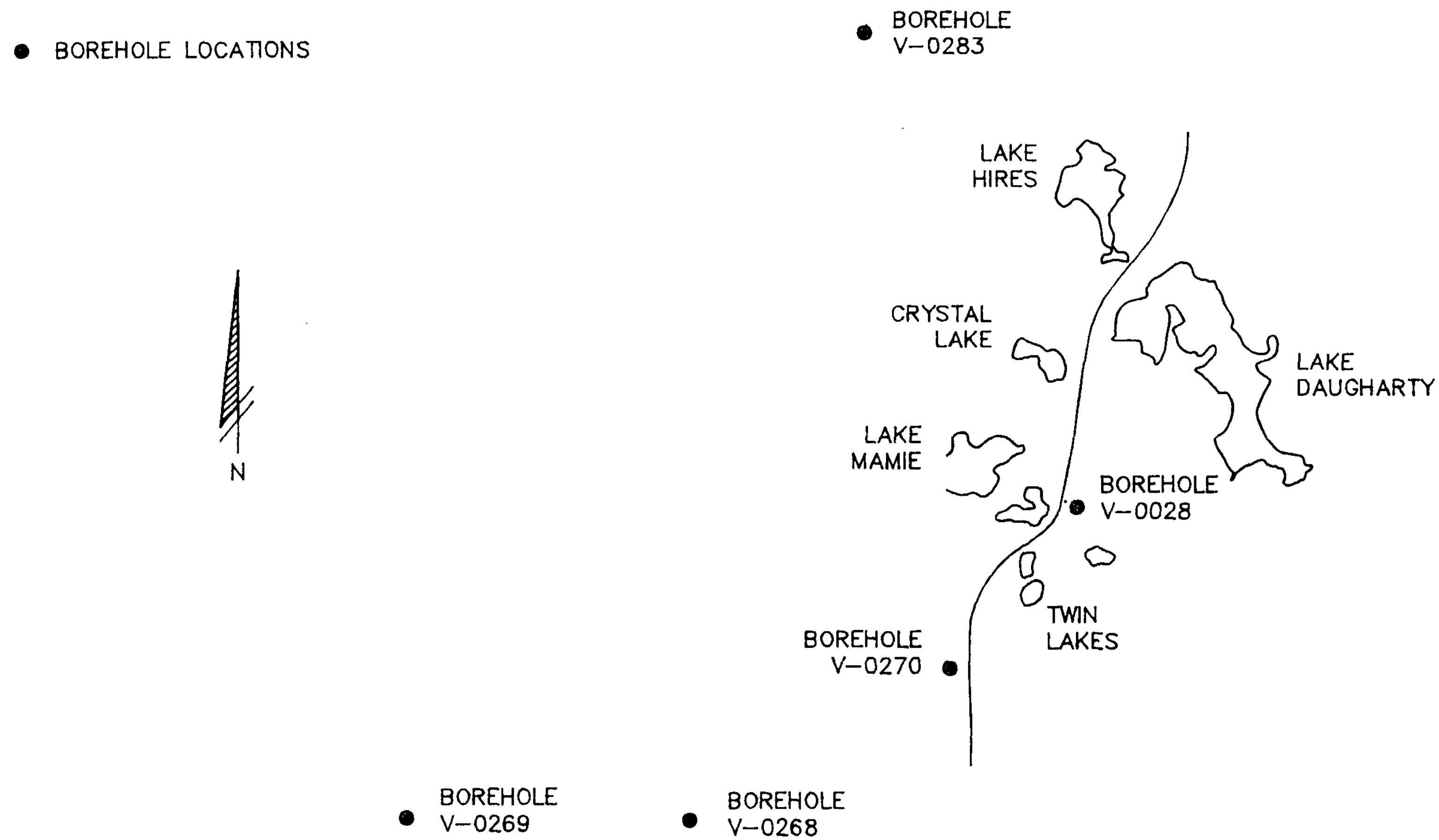
of the lake, the unit lies at a depth of 25 to 33 msec below the lake surface (65 to 92 ft) dipping and thickening toward the south.

A high amplitude reflector is present at the base of these banded horizons which exhibits a lower frequency type ringing response with a chaotic internal reflective character to the underlying sequence. This reflector has been interpreted to be the top of limestone in the region. The reflector was noted to be nearly flat-lying with small scale local irregularities on the bounding surface in the undisturbed areas referred to above, but appears to have dropped significantly in local areas associated with the karst collapse regions. This reflecting horizon has been designated reflector A1 and is observed at depths of from 29/33 msec (25/28 m - 82/92 ft or an elevation of -37/-47 ft) (undisturbed regions) to 60/65 msec (54/59m - 177/191 ft or an elevation of -132/-146 ft relative to msl) (down-dropped regions) over the main lake body.

The clay and limestone seismic character and structures are shown in Figure 5-3-3, which is a section from Line 3 in the longer north-south section of the lake. Through the central portion of the lake region (N-S profile), a deeper, more topographically irregular reflection is observed within the limestone sequence. This horizon is noted approximately 30 msec below the interpreted top of limestone, which would equate to approximately 52.5 m (172 ft) below the top of limestone (assuming a velocity of sound in the limestones of 3500 m/s) (Figure 5-3-4). These deeper reflections (designated Horizon A2) are often hyperbolic in nature which suggests that they could be caused by deep point reflectors that may be associated with void spaces in the limestone, or an older angular unconformity surface. There is insufficient data coverage to map these small scale irregularities, which would help to distinguish if they are roughly circular (void or collapse features) or linear (ridge and trough) in nature. The highs and lows on this horizon appear to be separated horizontally by about 250 -350 ft, and vary in elevation by 5-7 msec (9-12 m., 29-40 ft. re: 3500 m/s velocity).

The seismic recordings also exhibit deeper irregular reflections in the range of 75 to 115 msec depth (125 - 200 m., 410 - 650 ft or elevations of approximately -370 to 600 ft relative to msl). These reflections are discontinuous, highly variable in depth, often hyperbolic in nature, and sometimes exhibiting an upper and a lower hyperbolic reflection. These reflections are believed to be from water or gas filled void features, or alternately, deep fault planes within the limestone. Locations and depth postings (in msec) of these possible voids have been marked on Figure 5-3-1 by a thick solid line overlying the profile tracks. The acoustic character of these features is also shown in Figures 5-3-3 and 5-3-4.

Gamma-ray logs from six boreholes located in the vicinity of Lake Daugharty were provided by SJRWMD and used to attempt to correlate regional geology with the seismic data (Volume 2, Appendix 3). Of these wells only borehole V-0028 is located within one mile of the lake itself (Figure 5-3-5) and penetrated to a depth of only -195 ft relative to mean sea level (msl). The gamma-ray log of borehole V-0028 shows a general drop in gamma-ray counts



ST JOHNS RIVER WATER MANAGEMENT DISTRICT

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MAP SHOWING WELL LOCATIONS IN RELATION TO LAKE DAUGHARTY

Designed By:	J.M.T.	Proj. No:	91668	Fig. No.
Checked By:	R.J.W.	Scale:	N.T.S.	
Drawn By:	K.L.K.	Date:	1/30/92	5-3-5

at a depth of -25 to -30 ft msl. This depth appears to correlate reasonably well with the depth of the interpreted top of limestone (A1 horizon) in non-collapsed areas (-45/-70 ft), particularly when accounting for the apparent southerly rise of the limestone reflector, and the distance of the borehole from the lake. The deeper A2 horizon (assumed velocity of 3500 m/s in limestones may be underestimated) is beyond the depth of penetration of any of the well information presently available and cannot be correlated on the gamma-ray logs to any of the regional boreholes.

Based on the gamma-ray log correlations and the regional geology outlined in Section 3.0, similarities with the acoustically derived units suggest that the A1 bedrock reflector is most likely associated with the top of the Ocala Group. The lower A2 horizon may be associated with the Avon Park limestone although additional borehole log and lithologic data are needed to confirm this correlation. Unit B correlates with sediments of the lower Hawthorn Group. The lesser consolidated banded clay materials of Unit C are likely associated with the middle to upper portion of the Hawthorn Group and the overlying Lower Pliocene undifferentiated sands and clays of the region. The surficial, basically unstratified, Unit D/E materials are believed to be associated with the Upper Pliocene to Recent surficial sands in the region.

5.4 Lake Broward, Putnam County

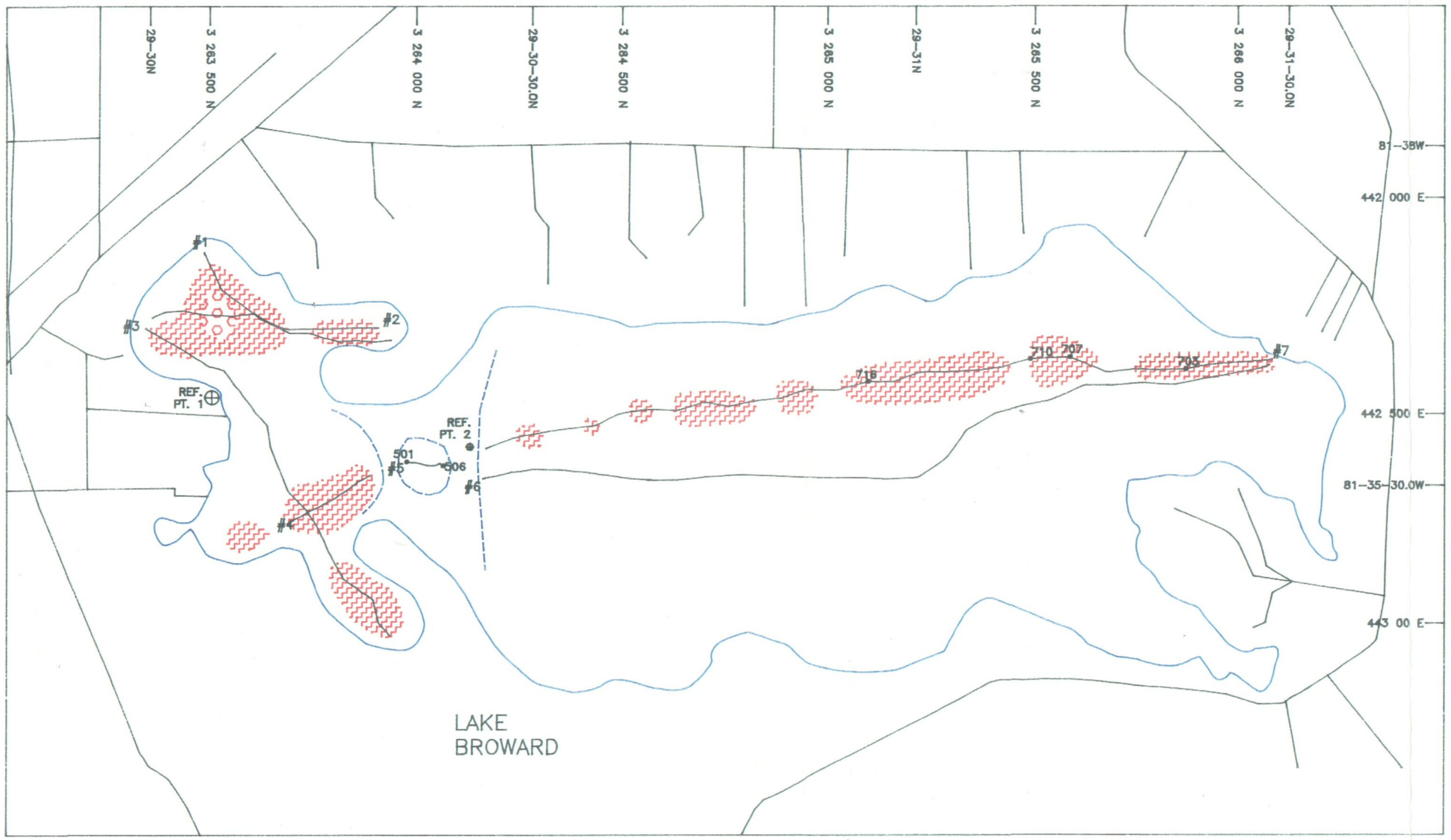
The seismo-acoustic units observed within the profile data from Lake Broward show a more complete seismo-stratigraphic sequence than observed in the Lake Daugharty area. There are significant similarities of acoustic Units A, B and C, which suggests that the primary units are present at both sites. Lake Broward data provided increased detail over that observed in the Lake Daugharty data set, as evidenced by the differentiation of Units D and E within the northern sub-basins. Unit E unconformably overlies Unit D within discontinuous depressions in the lake bed.

The seismic section from the northern end of the lake (fixes 702 to 709) shown on Figure 5-4-2 clearly displays all of the observed units. A portion of this section (fixes 705 to 706.2) was used to provide the type section geologic descriptions in the Lake Broward area. The seismo-stratigraphic interpretations for Units A through E at Lake Broward are identical to those provided in Section 5.3 for Lake Daugharty. Table 5-4-1 provides a summary of the seismo-stratigraphic sequence for Lake Broward.

A total of 14 local areas of probable karst collapse were observed on six seismic lines completed within Lake Broward. Five collapse features were identified in the southern basin. The entire sand bar mini basin is considered a collapse zone, and eight apparently isolated collapse zones were observed in the northern basin (Figure 5-4-1 and Volume 2, Appendix 2). An area in the southwestern embayment of the southern basin was masked, probably by shallow gas related to peat formation. Mapping of the areal extent of the collapse features in the northern basin was limited

TABLE 5-4-1 LAKE BROWARD - SEISMIC CORRELATIONS

UNIT NAME	HORIZON	DEPTH RANGE ELEVATION FT (re mean sea level)	INTERPRETED LITHOLOGIC CORRELATION
E	Lakebed to D unconfined	39 - 9.5 ft ponded v=1600 m/s	Recent aeolian and lacustrine infill, lower boundary is a variable depth unconformity surface, or in some areas lakebed.
D	D unconfined to C unconfined	approximately +40 ft to -39ft v=1600 m/s	Upper Pliocene to Recent undifferentiated complex silt/clay and sand layering representing infill of sinkholes.
C	C unconfined to B unconfined	approximately +13 to -11 undisturbed up to -80 ft in collapse v=1700 m/s	Finely banded silt and clay layering initially deposited conformable to lower sedimentary horizons, bedding is totally disrupted within some collapse features and conformable to other collapse features. Probable Middle to Upper Hawthorn Group to Lower Pliocene undifferentiated sediments.
B	B to A	-17 to -41 ft v=1800 m/s	Miocene - Lower Hawthorne Group layered clays and interbedded silts/sands - high amplify reflections conformable to bedrock.
A	A1 A2	-41 undisturbed to -190 collapsed v=3500 m/s -189 to limit	Limestone - Eocene Ocala Group high amplify low frequency response characteristic of consolidated bedrock reflections. unknown unit tentatively Avon Park Limestone.
voids	X	-370 to -600	High frequency variable discontinuous reflections - possible voids or subsurface fault planes.



EXPLANATION

- SURVEY LINE POSITION DATA, REFERENCED TO UTM GRID
- APPROXIMATE LOCATION OF PRESENT SHORELINE
- SHORELINE AS DIGITIZED FROM A U.S.G.S. QUAD MAP
- REGIONS OF PALEOKARST COLLAPSE INDICATING SIGNIFICANT INFILL, SOME OF WHICH IS CONFORMABLE TO THE COLLAPSE STRUCTURES
- REGIONS OF SHALLOW GAS MASKING DEEPER REFLECTIONS, CONFIRMED BY PHASE REVERSAL OF LAKEBED REFLECTING HORIZON

0 500' 1000'

N

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	LAKE BROWARD NAVIGATION TRACK PLOT AND LOCATIONS OF ANOMALOUS FEATURES	
		DESIGNED BY: J.F.L. CHECKED BY: J.M.T. DRAWN BY: R.L.K.	PROJECT NO.: 91668 DRAWING NO.: S2-1 DATE: 1-6-92 — FIGURE 5-4-1

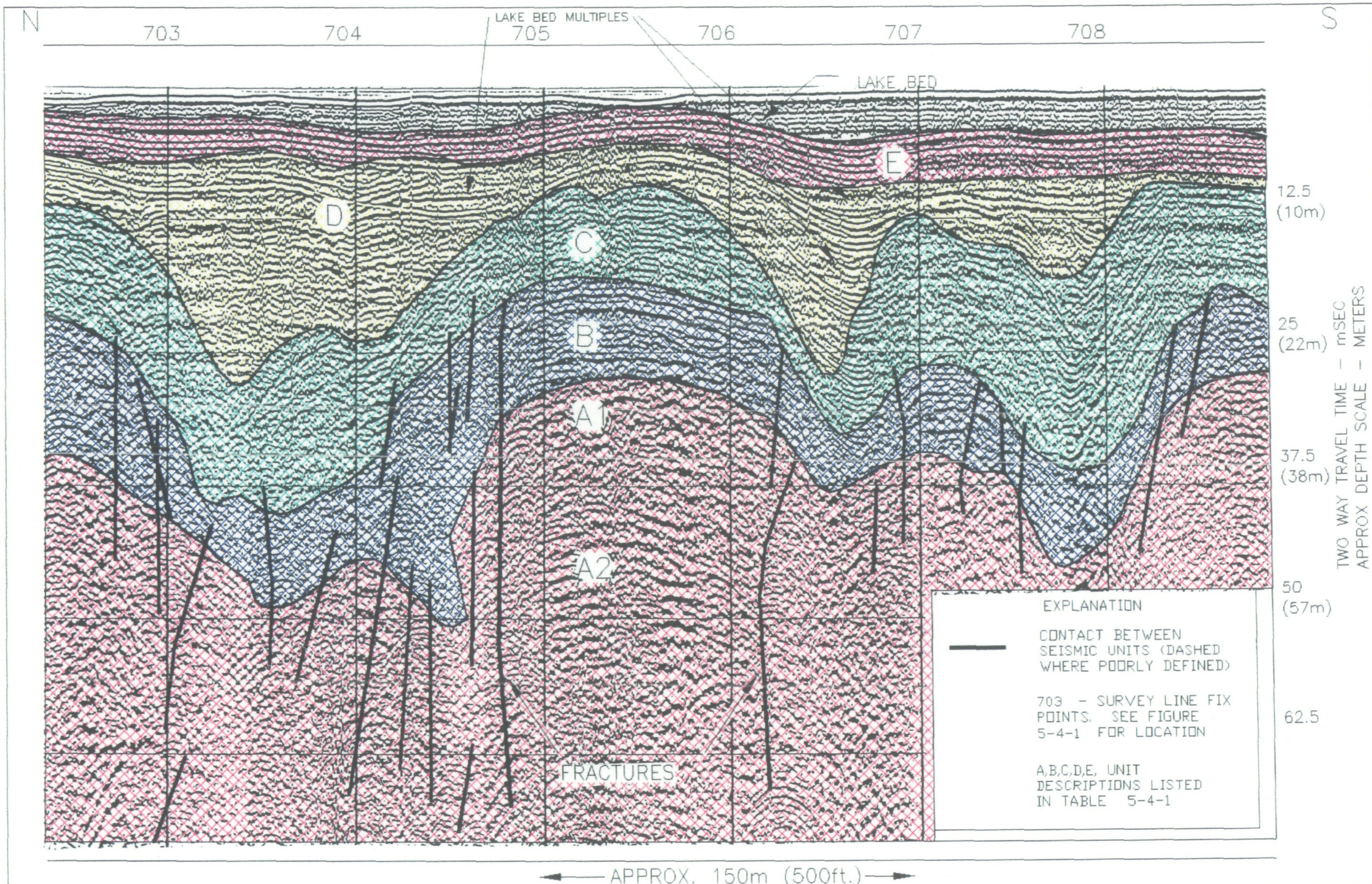


FIG 5-4-2 Seismic section from survey line 7 in northern end of Lake Broward showing the representative type section including units A through E.

because clearly interpretable data were only available along one survey line.

Figure 5-4-3 shows the seismic record from a region within the central part of the northern subbasin (710 to 716). The record shows a collapse feature in which the bedding planes of Units B and C have been disrupted and broken by the collapse. Unit D has infilled the collapse, as the bedding planes are generally not disrupted (fixes 712.8 to 713.7). There are a few apparent disruptions of lakebed sediments which may be associated with very recent minor readjustments and further settlement associated with the collapse, or possibly very recent (<1,000 years) additional karst collapse activity. The term "very recent" refers to karst collapse that has occurred within the last 1,000 years. This time-frame is defined by the occurrence of disruption of Unit E sediments. An older collapse located to the north (fixes 710.6 to 712.8) disrupts the reflectors of Unit A, but Units B and C conformably drape the irregular bedrock surface. A small hyperbolic reflection just below horizon A1 (30-35 msec) at fix 712.4 may be indicative of a shallow void feature within the limestone that remains intact.

Within these seismic sections, unconformities are noted between Units C and D, and between Units D and E. The nature of these unconformities indicates that Unit D was deposited conformably onto the irregular and locally collapsed Unit C surface, which results in the variable thickness of Unit D. The D-E discontinuity is erosional and angular in nature. The erosional character of the D-E unconformity suggests that the

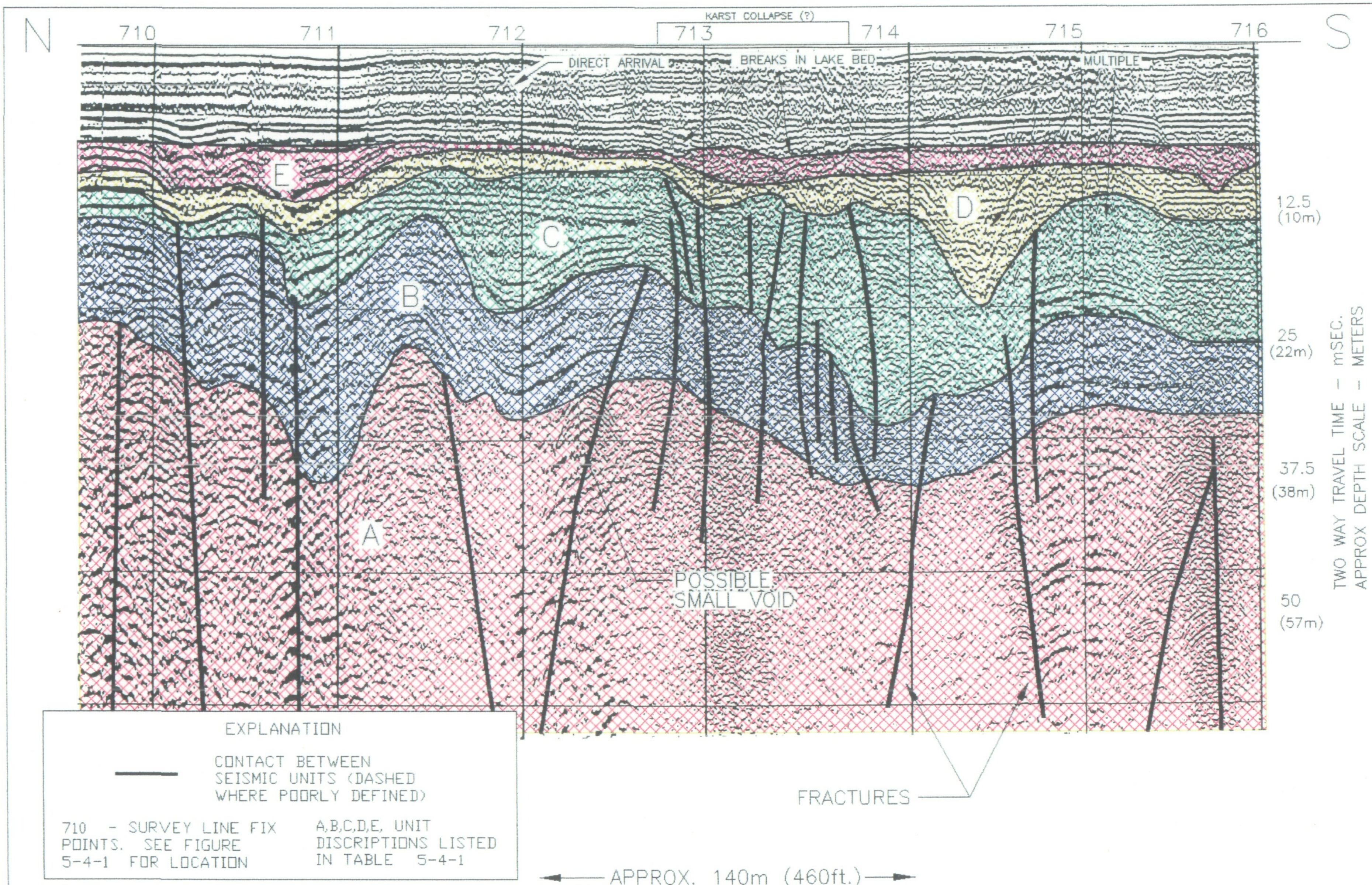


FIGURE 5-4-3 Seimic profile from survey line 7 in Lake Broward showing collapse features and the complex relationships to units B and C. Disruption on the lake bed suggests there may still be some minor adjustments occurring in this collapse feature.

lakebed had been exposed for some period in the recent past as there is not a significant accumulation of the recent Unit E materials on the lakebed.

Figure 5-4-4 shows the acoustic profile across the small subbasin within the sandbar area separating the two larger basins. An apparent positive elevation feature located between fixes 502 and 503 is probably an artifact of the fault planes associated with a minor collapse beneath the basin. The deeper Horizons A1 and B have apparently only been depressed 3 to 4 msec (9 to 12 ft) in the collapse process. In this process the overlying Unit C materials have fractured and collapsed into this void with the edges of the fractured region (faults) creating a series of near vertical point reflectors that appear to converge at a depth of approximately 12 msec. At this depth the water bottom multiple reflections converge with the fracture hyperbola reflections and obscure the true reflecting character, which limited additional interpretation of Units D and E.

Within the southern basin, five zones of paleokarst collapse are apparent (Figure 5-4-1). The data suggest that these areas are relatively older (>10,000 years) collapse features (infill and draping of the sediments into the collapse features). The region in the northern portion of the southwestern bay (reported by local residents to be a spring area, verbal communication from Jeff Davis) showed poor quality records, which may be due to disruption of all acoustic reflecting horizons from recent (<10,000 years) karst collapse. The term "recent" refers to karst collapse that has occurred in the last 10,000 years. This time-frame is defined

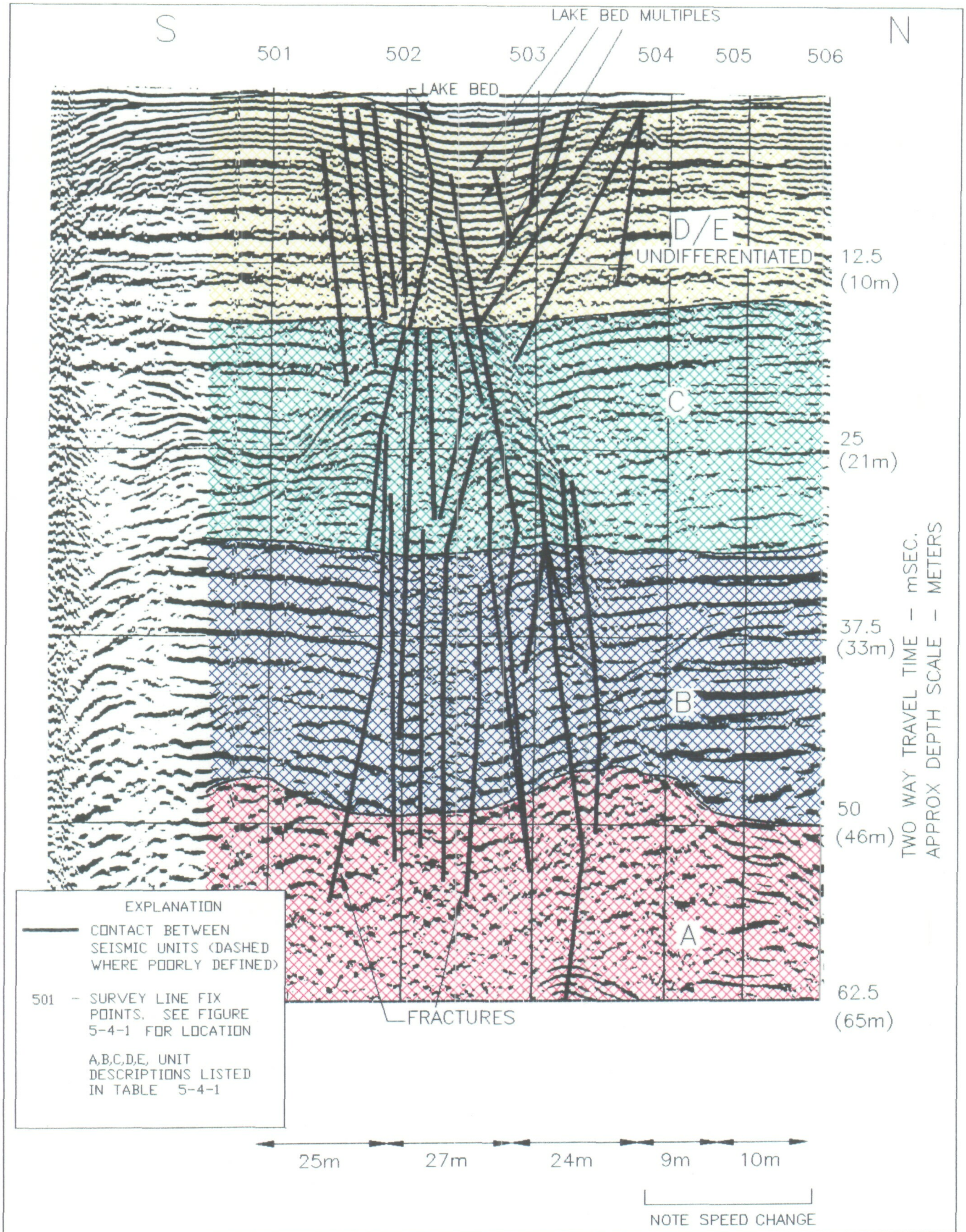
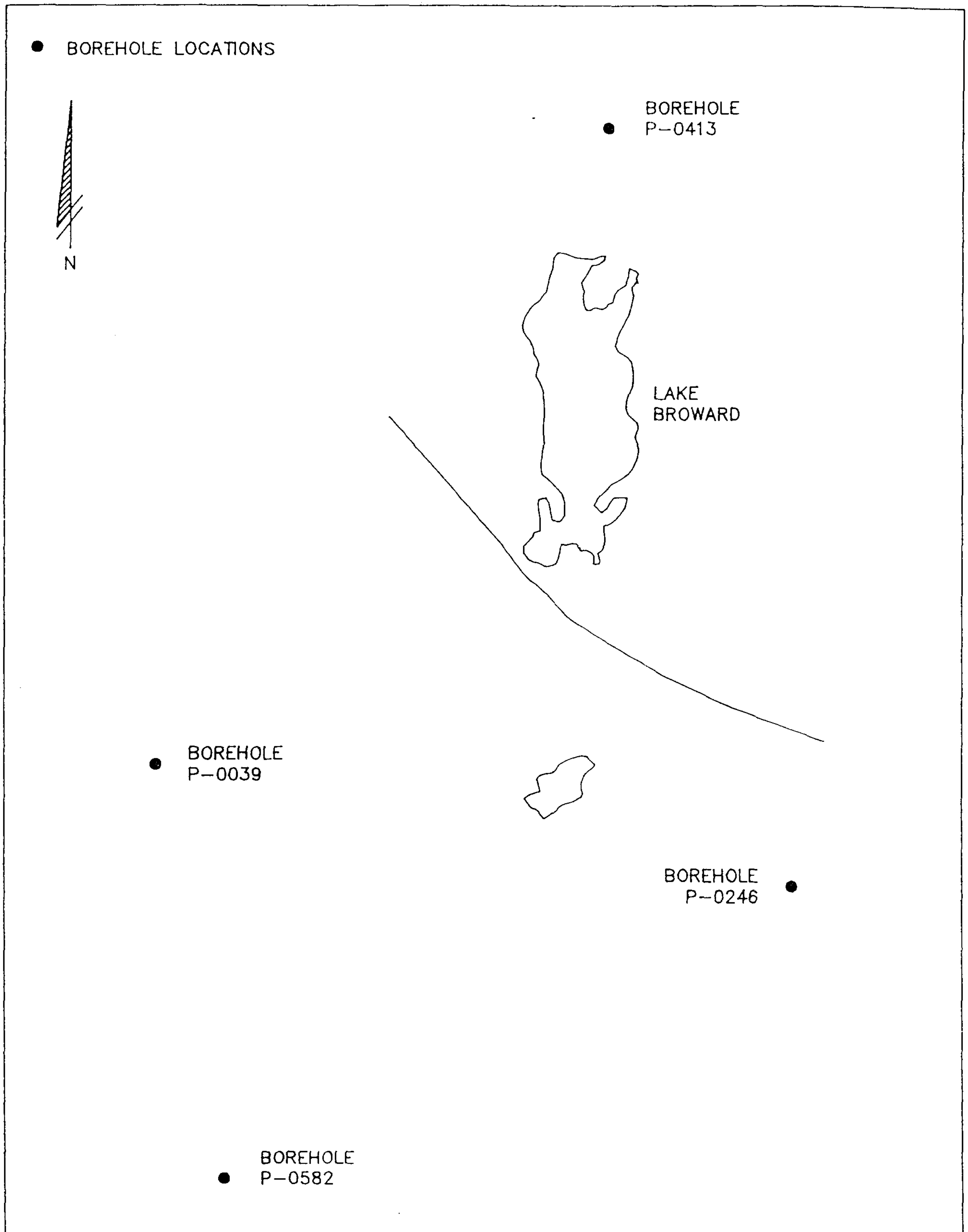


FIGURE 5-4-4 Seismic profile from survey line 5 across the mini basin feature within the sand bar of Lake Broward.

by the occurrence of disruption of Unit D sediments, which were deposited prior to 10,000 years ago. The poor quality data may also be due to parts of the seismic system (Streamer) dragging on the lake bed because of the shallow water in the basin. As a result, conclusions on this part of the bay are tentative and not supported by good quality data. The apparent collapse zone in the eastern bay is also indicated solely by a disruption in continuity of the acoustic reflectors with no strong indications of significant collapse at depth observed on the data. This region is also interpreted as a possible recent (<10,000 years) collapse feature.

Available borehole gamma-ray logs for the Lake Broward region were used to attempt to correlate regional geology to the seismo-stratigraphic units (Volume 2, Appendix 3). Locations of the boreholes relative to Lake Broward are shown on Figure 5-4-5. Based on these logs the top of the Ocala Group appears to be at an elevation of between -40 and -60 ft msl in the region of the southern end of Lake Broward, dipping gently toward the south-southeast. A 1,300 to 1,600-foot portion of undisturbed section between fixes 306 and 315, shows the top of Unit A1 between 32.5 and 42.5 msec. Using an average velocity through Units B - E of 1800 m/s, this horizon is calculated to be at an elevation of -57 to -86 ft msl, with an apparent dip of approximately 1.4° to the east-northeast. This supports the correlation of Unit A1 from the seismic data with the Ocala Group. The top of Unit B correspondingly is observed at a depth of 22.5 to 26.25 msec over this same transect. Using an estimated velocity of 1700 m/s for



ST JOHNS RIVER WATER MANAGEMENT DISTRICT	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	LOCATION MAP OF THE BOREHOLE CONTROL PROVIDED FOR THE LAKE BROWARD AREA	
		Designed By: J.M.T. Checked By: R.J.W. Drawn By: K.L.K.	Proj. No: 91668 Scale: N.T.S. Date: 1/30/92
			Fig. No. 5-4-5

the overlying sediments results in this horizon having an elevation of -24 to -34 ft msl. Gamma-ray logs from boreholes in the vicinity of the southern end of the lake display major peaks from -10 to -20 ft msl. These data suggest that Unit B correlates with the major clay layers in the Hawthorn Group. The borehole logs do not provide sufficient evidence for correlation of the overlying Units C, D, and E.

5.5 Swan Lake, Putnam County

The seismic character of the Swan Lake area shows similarities to the two preceding lakes although the area tends to be more disturbed by collapse features. Therefore, not all of the units noted in Lake Broward could be clearly discriminated at any one location in this lake. Table 5-5-1 provides a brief summary of the units identified on these records. Correlation to the comparably named units within Lakes Broward and Daugharty are based on seismic character, structural relationships, and borehole gamma-ray log similarities.

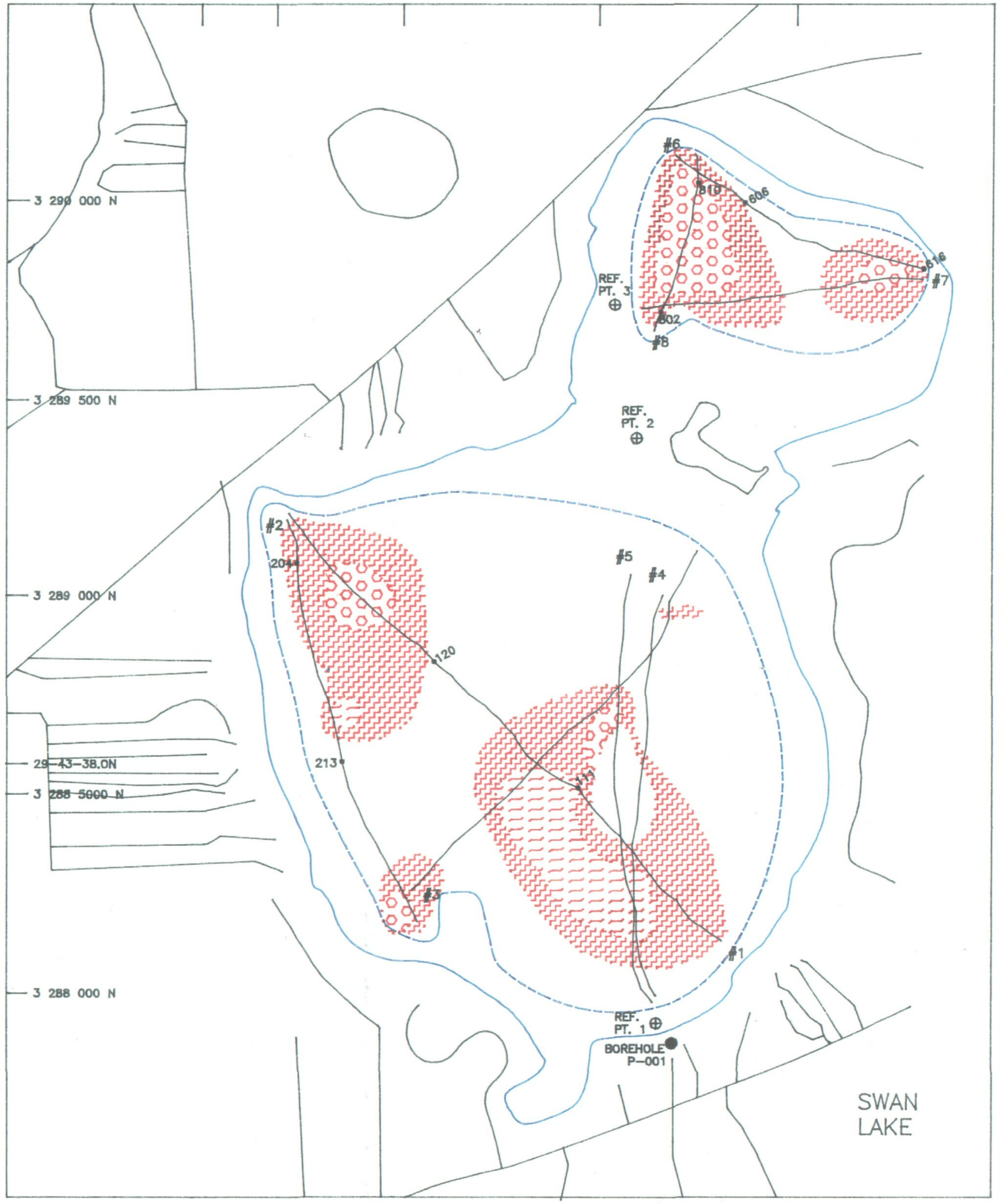
Within the Lake Swan basin a total of 6 local regions of karst collapse are observed on the seven interpretable seismic lines completed within the lake. Four local collapse areas were defined in the southern basin and two apparently isolated collapse zones were observed in the northern basin (Figure 5-5-1). Four local areas interpreted to be masked by shallow gas (peat) were observed within the collapse zone areas.

TABLE 5-5-1 LAKE SWAN - SEISMIC CORRELATIONS

UNIT NAME	HORIZON	DEPTH RANGE ELEVATION FT (re mean sea level)	INTERPRETED LITHOLOGIC CORRELATION
E	Lakebed to D unconfined	lakebed, ponded to 5 to 10 ft thickness v=1600 m/s	Recent aeolian and lacustrine infill, lower boundary is a variable depth unconformity surface when present.
D	D unconfined to C unconfined	lakebed to +61/67 ft v=1600 m/s	Upper Pliocene to Recent undifferentiated complex silt/clay and sand layering representing infill of sinkholes.
C	C unconfined to B unconfined	+67/61 ft to +48/+23 ft v=1700 m/s	Finely banded silt and clay layering initially deposited conformable to lower sedimentary horizons, bedding is totally disrupted within some collapse features and conformable to other collapse features. Probable Middle to Upper Hawthorn Group to Lower Pliocene undifferentiated sediments.
B	B to A	+58/+48 ft and lower in collapse -base -9/-33 ft north basin only v=1800 m/s	Miocene - Lower Hawthorne Group layered clays and interbedded silts/sands - high amplify reflections conformable to bedrock.
A	A1	-9/-33 ft north basin only v=3500 m/s	Limestone - Eocene Ocala Group high amplify low frequency response characteristic of consolidated bedrock reflections.
voids	X	-50 to -300	High frequency variable discontinuous reflections - possible voids or subsurface fault planes.

Figures 5-5-2, 5-5-3 and 5-5-4 are seismic sections showing the range of acoustic units observed in the Swan Lake basins. An area of very high internal reflectivity observed between fixes 111 and 113 (Figure 5-5-2) has the general appearance of shallow gas. However, deeper point reflectors below this zone suggest that this region is likely a zone of highly fractured or micro faulted and/or de-watered materials (hence the very high internal reflectivity). This feature is probably associated with more recent (<10,000 years) collapse activity.

The northwestern end of the line in Figure 5-5-2, from fixes 118 to 120, shows one of the few areas of the lake basin where the subbottom materials appear to be much less disturbed by collapse activities and may be representative of the regional seismo-stratigraphy. In this area a series of relatively flat-lying sedimentary reflectors is noted from approximately 6/8 msec on the record to about 15/22 msec below the lakebed (corresponding elevations of +67/61 ft to +43/+23 ft re msl). The internal reflectors of this unit are relatively flat-lying, with some local distortions that could be related to either depositional conditions, settlement adjustments, or movement from deeper karst activity. The top of this unit is marked by a clearly defined unconformity surface while the bottom of the unit rests on a higher amplitude reflector that is only clearly evident between fixes 119 and 120 of this line. From the acoustic response of this unit the sediments are interpreted to be composed of finely banded,



EXPLANATION

- SURVEY LINE POSITION DATA, REFERENCED TO UTM GRID
- APPROXIMATE LOCATION OF PRESENT SHORELINE
- SHORELINE AS DIGITIZED FROM A U.S.G.S. QUAD MAP
- REGIONS OF PALEOKARST COLLAPSE INDICATING SIGNIFICANT INFILL, SOME OF WHICH IS COMFORMABLE TO THE COLLAPSE STRUCTURES
- REGIONS OF SHALLOW GAS MASKING DEEPER REFLECTIONS, CONFIRMED BY PHASE REVERSAL OF LAKE BED REFLECTING HORIZON
- REGIONS OF RECENT (<10,000 YRS) KARST COLLAPSE INDICATING SIGNIFICANT RECENT FRACTURE OF SHALLOW REFLECTING HORIZONS NEAR TO THE LAKE BED

0 500' 1000'

N

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	SWAN LAKE NAVIGATION TRACK PLOT AND LOCATIONS OF ANOMALOUS FEATURES	
		DESIGNED BY: J.F.L. CHECKED BY: J.M.T. DRAWN BY: R.L.K.	PROJECT NO.: 91068 DRAWING NO.: S3-1 DATE: 1-7-91
		FIGURE 5-5-1	

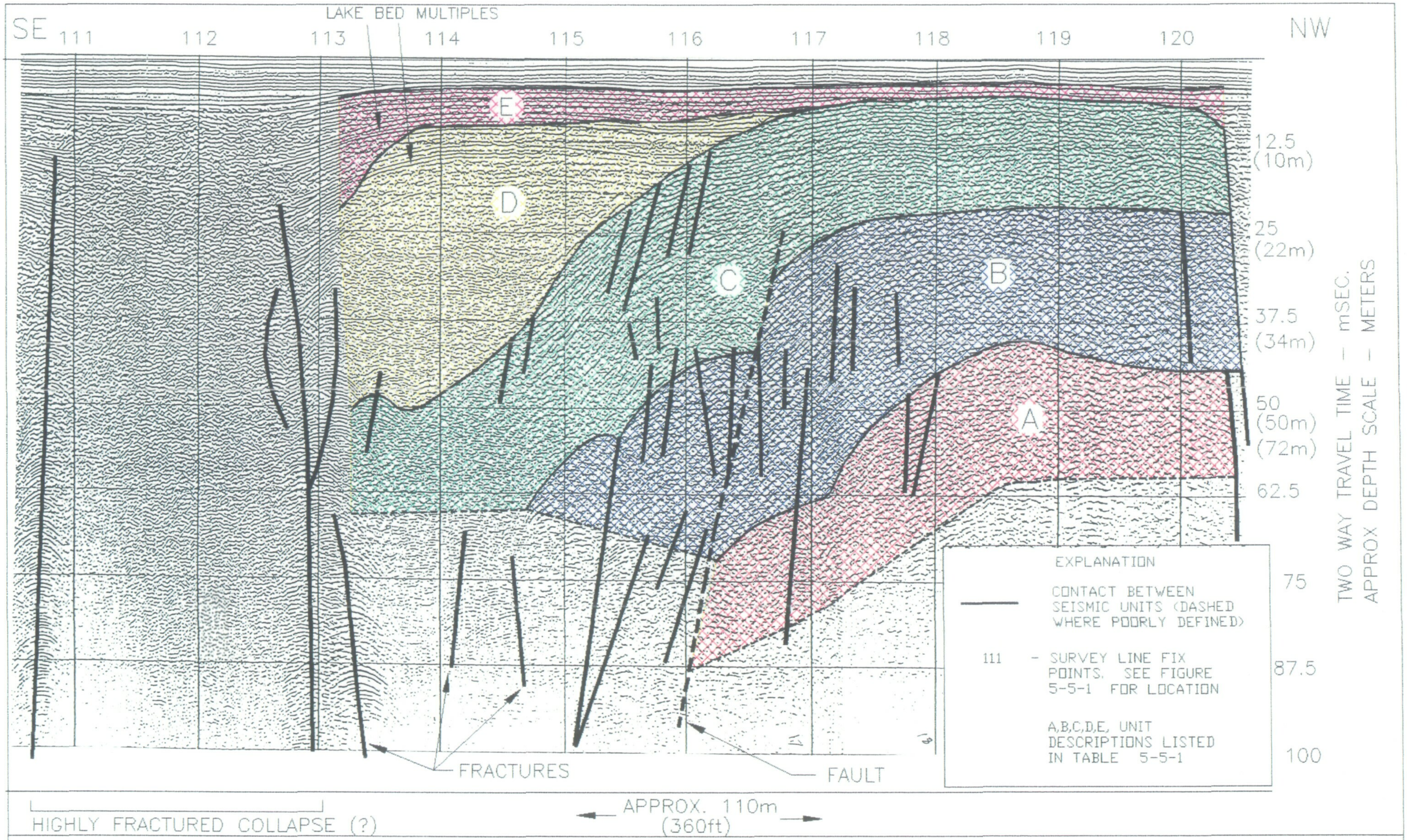


FIGURE 5-5-2 Example seismic record from survey line 1 within the southern basin of Swan Lake showing the range of observed acoustic units.

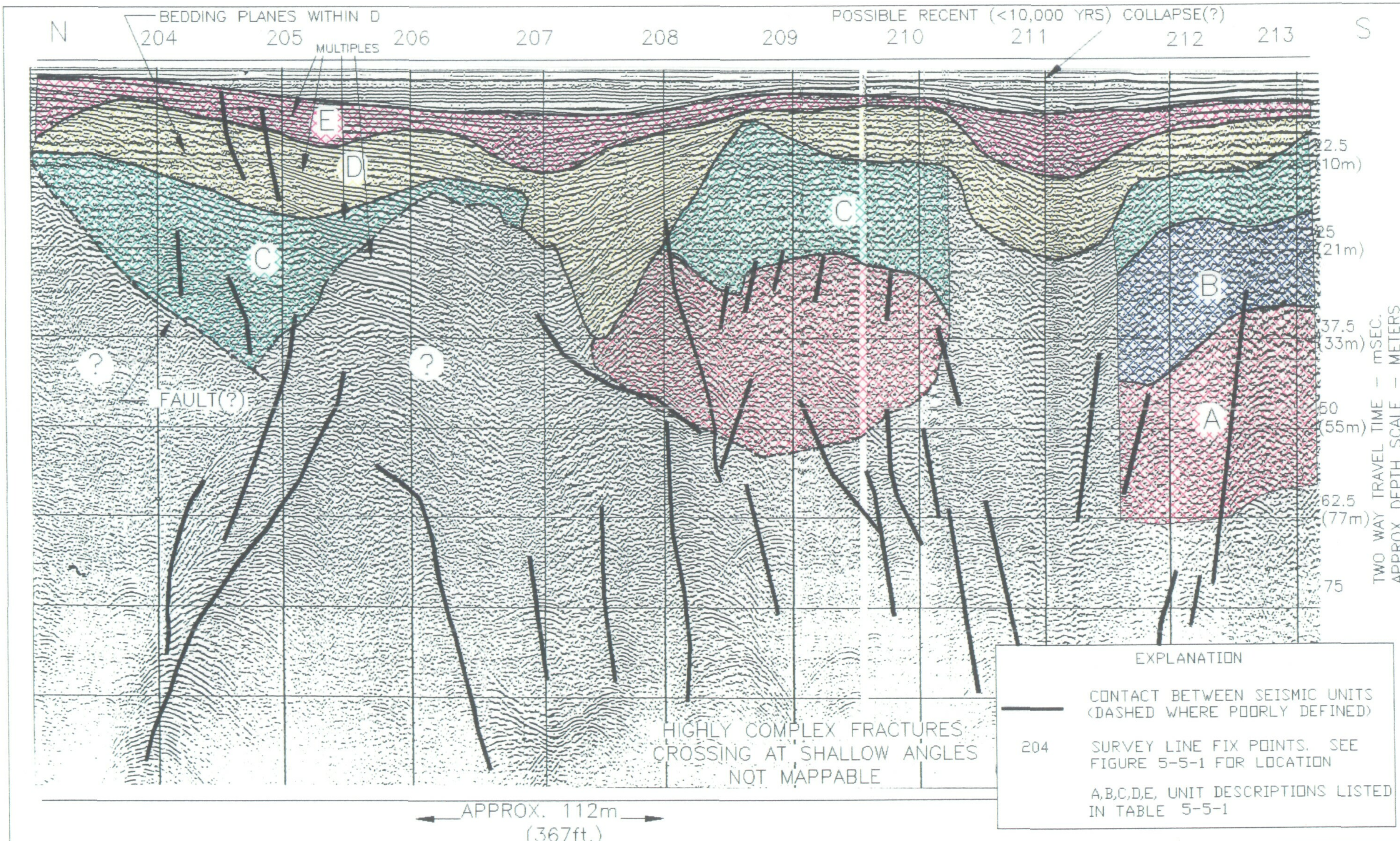


FIGURE 5-5-3 Example seismic record from survey line 2 in the southern basin of Swan Lake showing the range of acoustic units, complex fracture structures and some internal bedding planes within unit D.

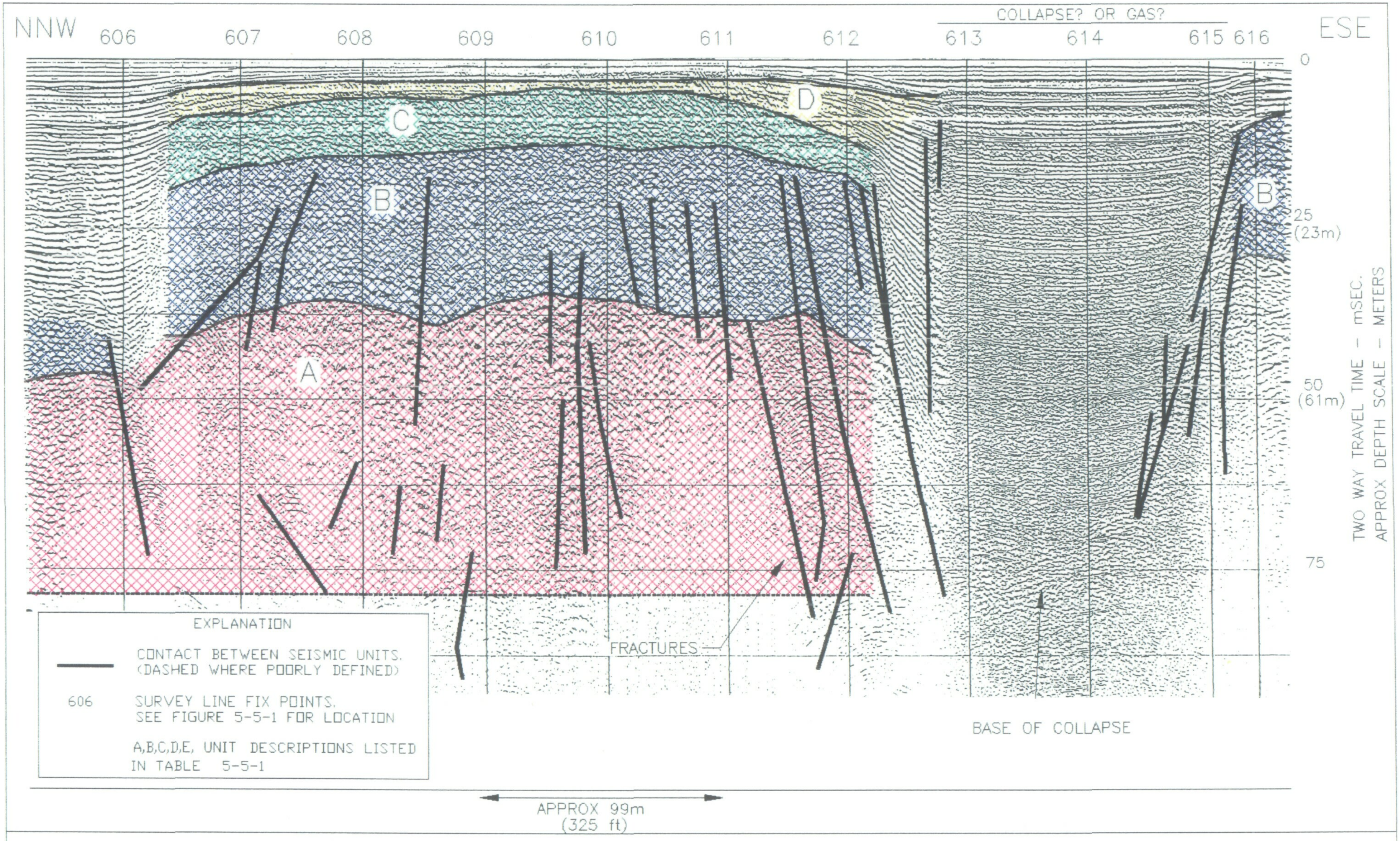


FIGURE 5-5-4 Example record from survey line 6 in the northern basin of Swan Lake apparent masking zone with deeper reflectors defining an apparent base of collapse zone.

unconsolidated to semi-consolidated silts and clays. This unit is interpreted to be related to the upper Hawthorn Group and Lower Pliocene silts and clays of Unit C.

Unit C lies conformably on a second silt and clay banded set of reflections that show a very slightly stronger acoustic return signature. This reflector is interpreted to represent the top of Unit B, and is at a depth of approximately 13 msec (11 m or 36 ft) below the lakebed (+48 ft msl). This reflector is believed to be associated with the Hawthorn Group which was identified at a slightly deeper position of +34 ft msl noted in the nearby C-0001 borehole. There were no clearly defined high amplitude reflections in this area that would be interpreted as the top of limestone, therefore the thickness of Unit B could not be determined from this section.

In the northern sub-basin, Line 6 (fixes 607 to 611.5) shown in Figure 5-5-4 contains a moderately high amplitude reflecting horizon with a characteristic low frequency "ringing" type response at a depth of 30 to 35 msec (28.5/33 m or 94/109 ft subsurface). This horizon is irregular and composed of a number of overlapping hyperbolic reflections indicative of a rough topographic surface, or one that has been broken by many small karst collapse features. This horizon is interpreted to be the A1 reflecting horizon representing the top of the Ocala Group. The surface lies at an elevation of -9 to -33 ft on this record and the overlying Unit B materials are observed to be approximately 46 ft thick.

Overlying these deeper seismo-stratigraphic units is a predominantly homogeneous sedimentary infill which varies in thickness from 6 msec to about 60-80 msec (15 ft to approximately 180-240 ft). These materials have been designated Unit D. The bottom of this unit is poorly defined within the central areas of the karst collapse features and accurate maximum thicknesses cannot be defined. Unit D commonly does not show internal reflectors, although in some regions (Figure 5-5-3) internal bedding reflections can be seen which suggest that these materials have infilled the collapse basins by aeolian and fluvial processes. Areas where these internal reflectors are totally absent may indicate regions of more recent (<10,000 years) minor collapse adjustments so that the acoustic reflectors have been disrupted and are subsequently not visible. Within some of the deeper basins (Figure 5-5-3) a six to 10-foot thick layer of sediment infill is present (fixes 206 - 208), which has been designated Unit E. These sediments are believed to be the most recent (<10,000 years) basin infill brought in by aeolian and fluvial processes. These sediments appear to be undisturbed except in the areas identified as possible recent (<10,000 years) collapse on Figure 5-5-1.

Figure 5-5-4 shows a good example of the apparent masking zone in the eastern end of the northern basin. This record is unusual in that the apparent masking zone shows no phase reversal at the lakebed (indicative of shallow gas) and shows a character change at depth which is interpreted to be the base of a collapse zone. The high internal reflectivity character of these materials just beneath the lakebed along with the strong multiples is interpreted to be the result of very recent (<1,000 years) collapse activity which has fractured these infill sediments and possibly compacting them such that a strong lakebed reflector is produced. Based on the patterns seen on this record, there has been little or no accumulation of Unit E materials over these disturbed materials which suggests that these re-adjustments have occurred very recently (i.e. from 0 to a few tens to hundreds of years ago; no sedimentation rate information was available for this lake basin). The data from the western portion of this subbasin shows similar characteristics and possibly even breaks in the lakebed where very recent (<1,000 years) faults adjustments may have extended to the lakebed (Figure 5-5-5, fixes 803.8, 807 and 810.3).

Borehole correlations with the observed reflecting horizons within Swan Lake are questionable because there is little undisturbed seismic data to correlate with the relatively undisturbed conditions at the boreholes. The nearest borehole to the lake is P-0001 located on the southern shore of the lake approximately 350 ft to the west of the end of lines 4 and 5. Line 4 ends on the edge of a major collapse structure with little interpretable record (for unit identification and correlations) at the end of the line. From this line, the top of Unit B is tentatively located at approximately 15 msec (about +42 ft elevation), and the top of Unit C is very tenuously interpreted to be at 10 msec depth (+58 ft msl). The borehole indicates a surficial sand cover overlying the Hawthorn Group at an elevation of approximately +36 ft msl. Based on this correlation the top of the Hawthorn Group is most likely associated with Unit B. Figure

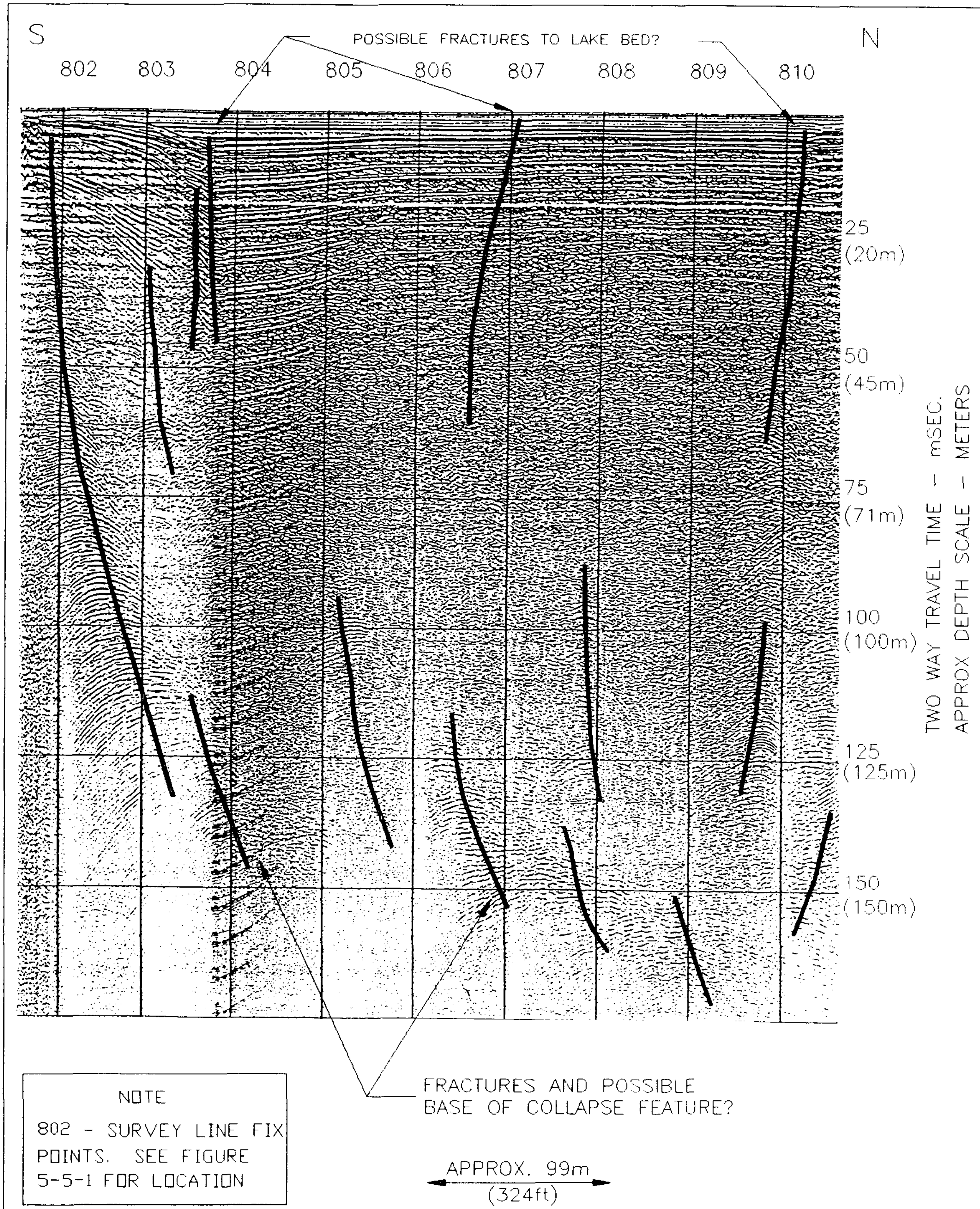
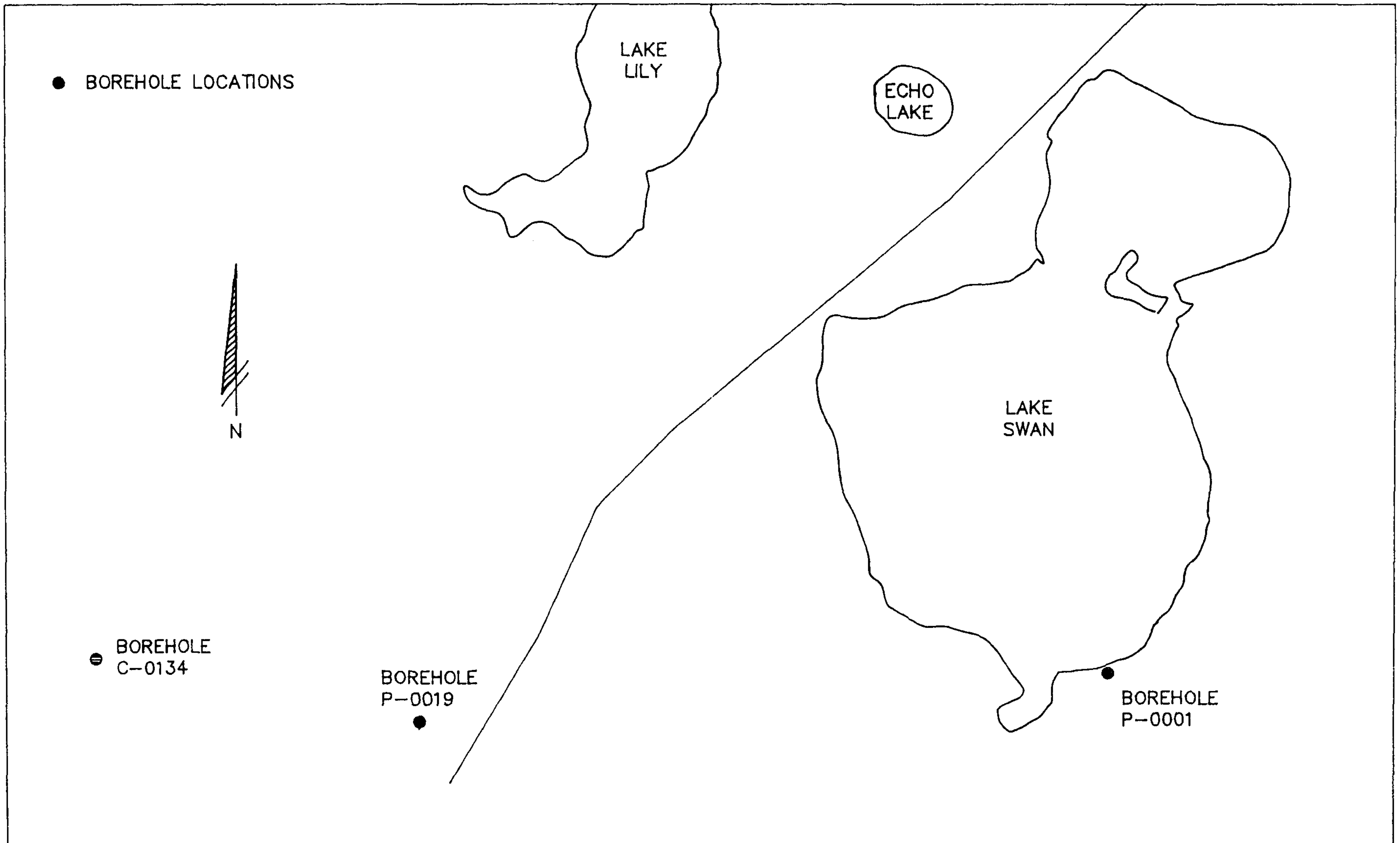


FIGURE 5-5-5 Example record from survey line 8 of the northern basin of Swan Lake showing a high reflectivity zone and minor lake bed displacement.

Boreholes P-0019 and C-0134 indicate the top of clays to be at +62 and +90 ft msl, respectively proceeding to the west. Only borehole C-0134 penetrated into the Ocala Group at an elevation of -25 ft re msl. This depth compares well with the interpreted elevation of -9/-33 ft msl for the A1 reflector within the northern lake basin area when the distance to the borehole site is taken into account. The locations of the boreholes have been shown on the larger scale map drawing of Figure 5-5-6, and their associated borehole logs are in Volume 2, Appendix 3.



ST JOHNS RIVER WATER MANAGEMENT DISTRICT	SDII SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED	**LOCATION MAP OF BOREHOLE CONTROL PROVIDED IN THE SWAN LAKE AREA**		
		Designed By: J.M.T. Checked By: R.J.W. Drawn By: K.L.K.	Proj. No: 91668 Scale: N.T.S. Date: 1/30/92	Fig. No. 5-5-6

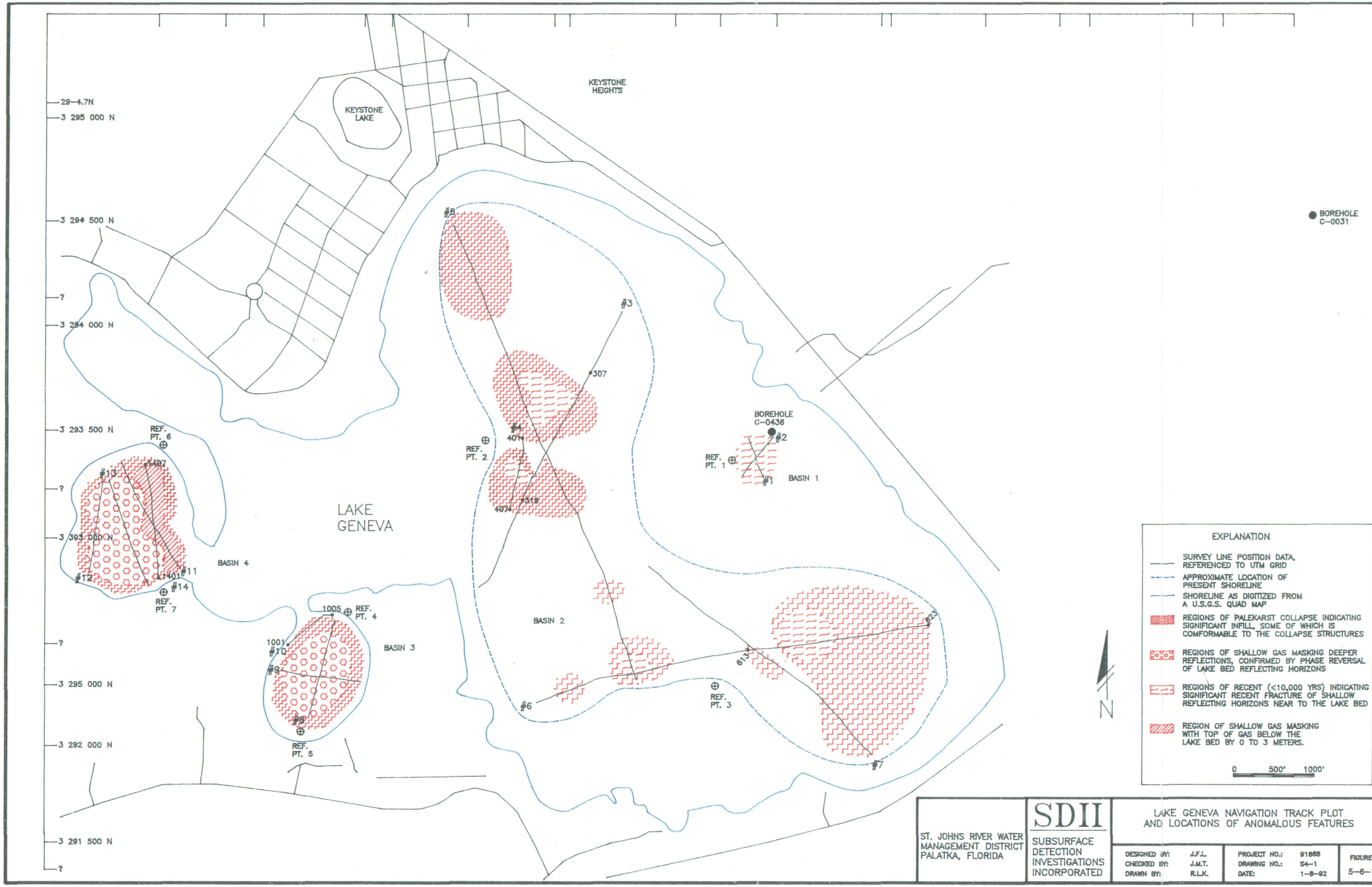
5.6 Lake Geneva, Clay County

The seismic character of the overall Lake Geneva regions shows similarities to the three preceding lakes. Absolute correlation of units could not be made from the seismic data alone although unit designations have been maintained based solely on acoustic and stratigraphic character. Table 5-6-1 provides a brief summary of the units identified on these records. Correlation to the comparably named units within Lakes Broward, Daugharty, and Swan are based on seismic character, structural relationships, and borehole gamma-log count similarities.

A total of 11 local regions of karst collapse activity were identified in the four sub-basins surveyed in the Lake Geneva area. Basins 1, 3 and 4 are individual collapse features, and the larger area of Basin 2 contained eight apparently isolated collapse zones. These collapse regions are outlined on Figure 5-6-1. Basins 3 and 4 were extensively masked by shallow gas (peat) reflections (Figure 5-6-1). A zone around the shorelines of both basins not masked by gas revealed data showing distorted and faulted bedding structures, which confirmed that the basins were karst collapse features. In addition to the 11 paleokarst features identified, five local areas interpreted to be relatively recent (<10,000 years) collapse activity were observed in Basins 1 and 2. These areas show chaotic internal reflection patterns that, although similar to the gassy peat reflections, show subsurface penetrations below these zones, which are more indicative of recently disturbed areas.

TABLE 5-6-1 LAKE GENEVA - SEISMIC CORRELATIONS

UNIT NAME	HORIZON	DEPTH RANGE ELEVATION FT (re mean sea level)	INTERPRETED LITHOLOGIC CORRELATION
E	Lakebed to D unconfined	lakebed, ponded to 5 to 10 ft thickness v=1600 m/s	Recent aeolian and lacustrine infill, lower boundary is a variable depth unconformity surface when present.
D	D unconfined to C unconfined	lakebed to +95/+84 ft v=1600 m/s	Upper Pliocene to Recent undifferentiated complex silt/clay and sand layering representing infill of sinkholes.
C	C unconfined to B unconfined	+95/+84 ft to +65/+50 ft - +15 to -200 ft within collapse features v=1700 m/s	Finely banded silt and clay layering initially deposited conformable to lower sedimentary horizons, bedding is totally disrupted within some collapse features and conformable to other collapse features. Probable Middle to Upper Hawthorn Group to Lower Pliocene undifferentiated sediments.
B	B to A	+65/+50 ft to -5/-35 ft v=1800 m/s	Miocene - Lower Hawthorne Group layered clays and interbedded silts/sands - high amplify reflections conformable to bedrock - often difficult to distinguish from Unit C in Geneva.
A	A1	-5 to -35 ft v=3500 m/s	Limestone - Eocene Ocala Group high amplify low frequency response characteristic of consolidated bedrock reflections - only occasionally seen within Basin 2.
voids	X	-100 to -300	High frequency variable discontinuous reflections - possible voids or subsurface fault planes.


KEYSTONE HEIGHTS
KEYSTONE LAKE
29–4.7N
3 295 000 N
3 294 500 N
3 294 000 N
3 293 500 N
3 293 000 N
3 295 000 N
3 292 000 N
3 291 500 N
?
LAKE GENEVA
BASIN 1
BASIN 2
BASIN 3
BASIN 4
BOREHOLE C–0031
BOREHOLE C–0436
REF. PT. 1
REF. PT. 2
REF. PT. 3
REF. PT. 4
REF. PT. 5
REF. PT. 6
REF. PT. 7
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
#13
#14
307
401
407
319
613
623
1001
1005
1401
1407
EXPLANATION
SURVEY LINE POSITION DATA, REFERENCED TO UTM GRID
APPROXIMATE LOCATION OF PRESENT SHORELINE
SHORELINE AS DIGITIZED FROM A U.S.G.S. QUAD MAP
REGIONS OF PALEKARST COLLAPSE INDICATING SIGNIFICANT INFILL, SOME OF WHICH IS COMFORMABLE TO THE COLLAPSE STRUCTURES
REGIONS OF SHALLOW GAS MASKING DEEPER REFLECTIONS, CONFIRMED BY PHASE REVERSAL OF LAKE BED REFLECTING HORIZONS
REGIONS OF RECENT (<10,000 YRS) INDICATING SIGNIFICANT RECENT FRACTURE OF SHALLOW REFLECTING HORIZONS NEAR TO THE LAKE BED
REGION OF SHALLOW GAS MASKING WITH TOP OF GAS BELOW THE LAKE BED BY 0 TO 3 METERS.
0 500' 1000'
N
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA
SDII
SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED
LAKE GENEVA NAVIGATION TRACK PLOT AND LOCATIONS OF ANOMALOUS FEATURES
DESIGNED BY: J.F.L.
CHECKED BY: J.M.T.
DRAWN BY: R.L.K.
PROJECT NO.: 91668
DRAWING NO.: S4–1
DATE: 1–8–92
FIGURE 5–6–1

On an individual basis, the separate lake sub-basins showed considerably different acoustic signatures. Basin 1 initially appeared to show no acoustic penetration. On closer examination a similarity was noted to the highly reflective, possibly recently (<10,000 years) collapsed zones within Swan Lake and in other areas of this lake. Though no data on the regional geological structure was apparent from Lines 1 and 2, this region is interpreted as a highly fractured collapse basin. Deep (65 to 150 msec) hyperbolic reflections were observed in the central regions of the basin that are most likely acoustic responses from a deep fault plane or a zone of large fractured blocks of bedrock.

Basin 2 was the largest of the basins and showed the most variety and detailed geologic structure in the lake area. Eight zones of karst collapse were observed (Figure 5-6-1) though the limited line coverage does not preclude additional zones within the areas not covered by the survey lines. Figure 5-6-2 shows that Units A, B, D and E can be readily identified on the records. Unit C was sometimes distinguishable from Unit B, but it could not be interpreted on a regular basis from the records. Four zones within Basin 2 were noted as high reflectivity, possibly recent (<10,000 years) karst collapse zones (example Figure 5-6-2 fixes 309-310 and 316.5-319 and Figure 5-6-3 fixes 615.7-618).

Two unusual plume-like anomalies (fixes 404 and 531) were noted at the lake bed that had the appearance of water or gas vent activity. Figure 5-6-4 shows one of these vent features located in the central area of the lake along Line 4. This feature is unusual in that the lake bed below the mid-water reflectors appears to be

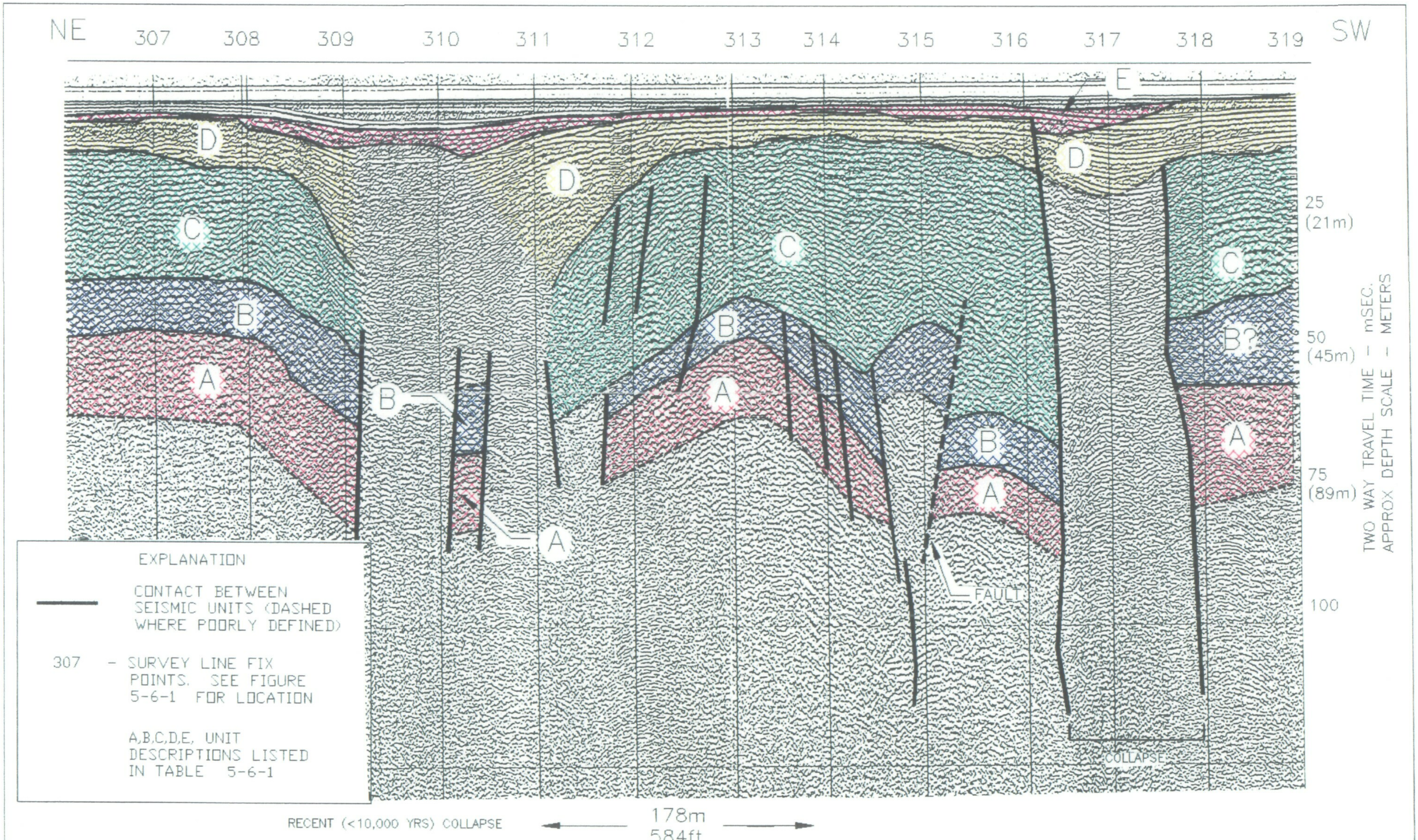


FIGURE 5-6-2 Example seismic record from survey line 3 in basin 2 of Lake Geneva showing the range of observed acoustic units.

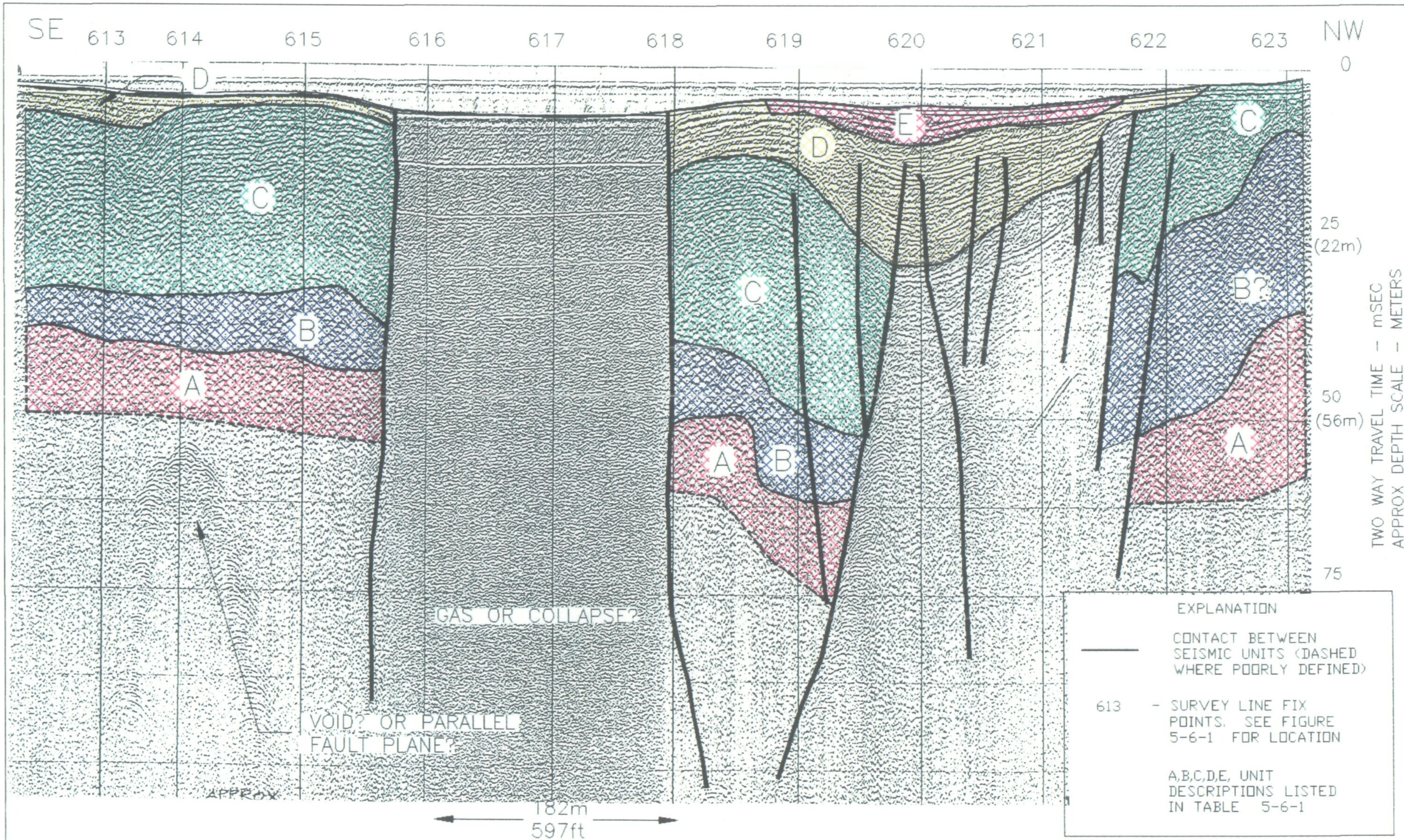


FIGURE 5-6-3 Example seismic record from survey line 6 in Basin 2 of Lake Geneva showing the range of acoustic units.

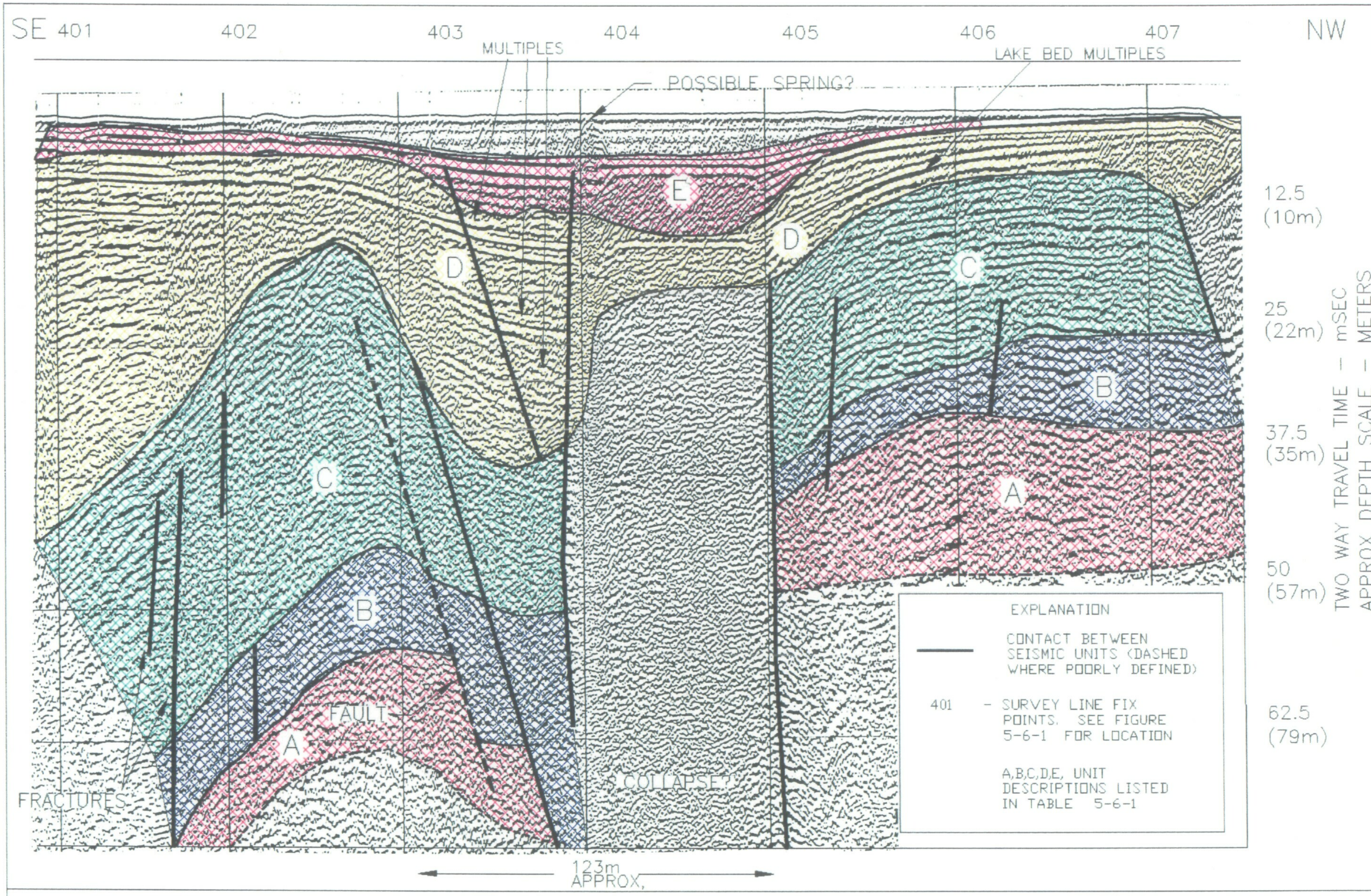


FIGURE 5-6-4 Example record from survey line 4 in Basin 2 of Lake Geneva showing one of the possible gas/water vent features within an apparent collapse feature.

depressed or broken which suggest that it represents a crack or vent type structure. A similar anomalous feature was also observed in the southern area of this basin. The strong mid-water reflections could be caused by gas bubbles or plumes in the water though no such bubbling was observed on the lake surface. In addition, as stated in Section 3.3, the potentiometric surface of the Upper Floridan aquifer is lower than the lake level, which precludes spring flow.

Basin 3 was acoustically masked by shallow gas or peat within the bottom sediments, as clearly shown by phase reversal of the bottom reflection and from 10 to 16 water bottom multiple reflections which indicated that virtually all of the acoustic energy was reflected from the lake bed. The only areas where subbottom penetration was achieved were adjacent to the shoreline on the slopes of the basin. Survey line 10 (shown in Figure 5-6-5), located along the shoreline of the northwestern side of the basin, showed seismic Units A, B, C and D to be present in the basin and indicated a significant unconformity (or possibly a fault bounded) surface between Units C and D. The significant undulations of the bedding planes and the abrupt thickening of Unit D on the southwestern end of this record strongly suggest that collapse had occurred within this basin prior to deposition of Unit D. Because of the circular nature of the entire basin structure it is assumed to be a karst feature but this could not be confirmed by the seismic study, and no estimation of current or recent karst activity could be made.

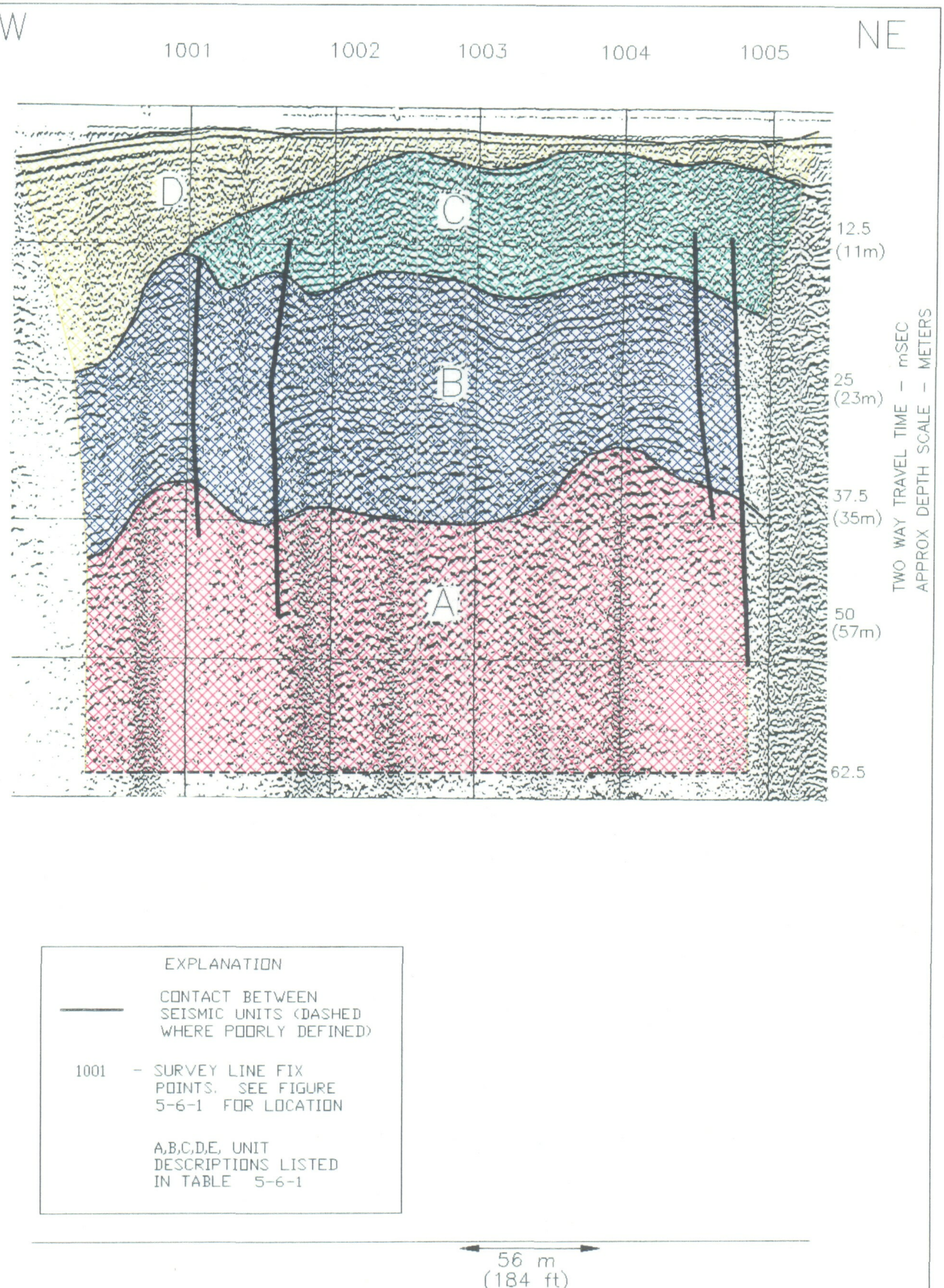


FIGURE 5-6-5 Example record from survey line 10 in Basin 3 of Lake Geneva showing units A?, B, C and D.

Basin 4 showed a similar though slightly different acoustic character to Basin 3. The western half of this basin showed phase reversals and complete masking of the subbottom reflections. In the eastern portion of the basin (Figure 5-6-6), line 14 indicates phase reversal in the south, and a two to four meter thick acoustically transparent zone just below the lakebed in the north. Within this acoustically transparent zone the top of gas horizon is irregular. A small zone in the center of the basin that shows an acoustic window to considerable depth within the section (fix 1403.7) with total masking on either side of this window. Gassy sediments were absent on the extreme edges of the basin, and acoustic penetrations of 40 to 60 msec (100 to 150 ft below lake surface) were achieved. There was insufficient continuity of the acoustic structures to make any definite conclusions concerning the geologic structures and karst activity within this basin. One small region along the western shore (line 12) showed some contorted and possibly faulted bedding which suggests possible karst related deformations. The 4-5 msec (3-3.75 m, 9.8-12 ft) thickness of soft clays and/or peats within this basin implies that the region has been stable for some duration as deformations would likely cause degassification of these sediments, which would be noted on the acoustic records.

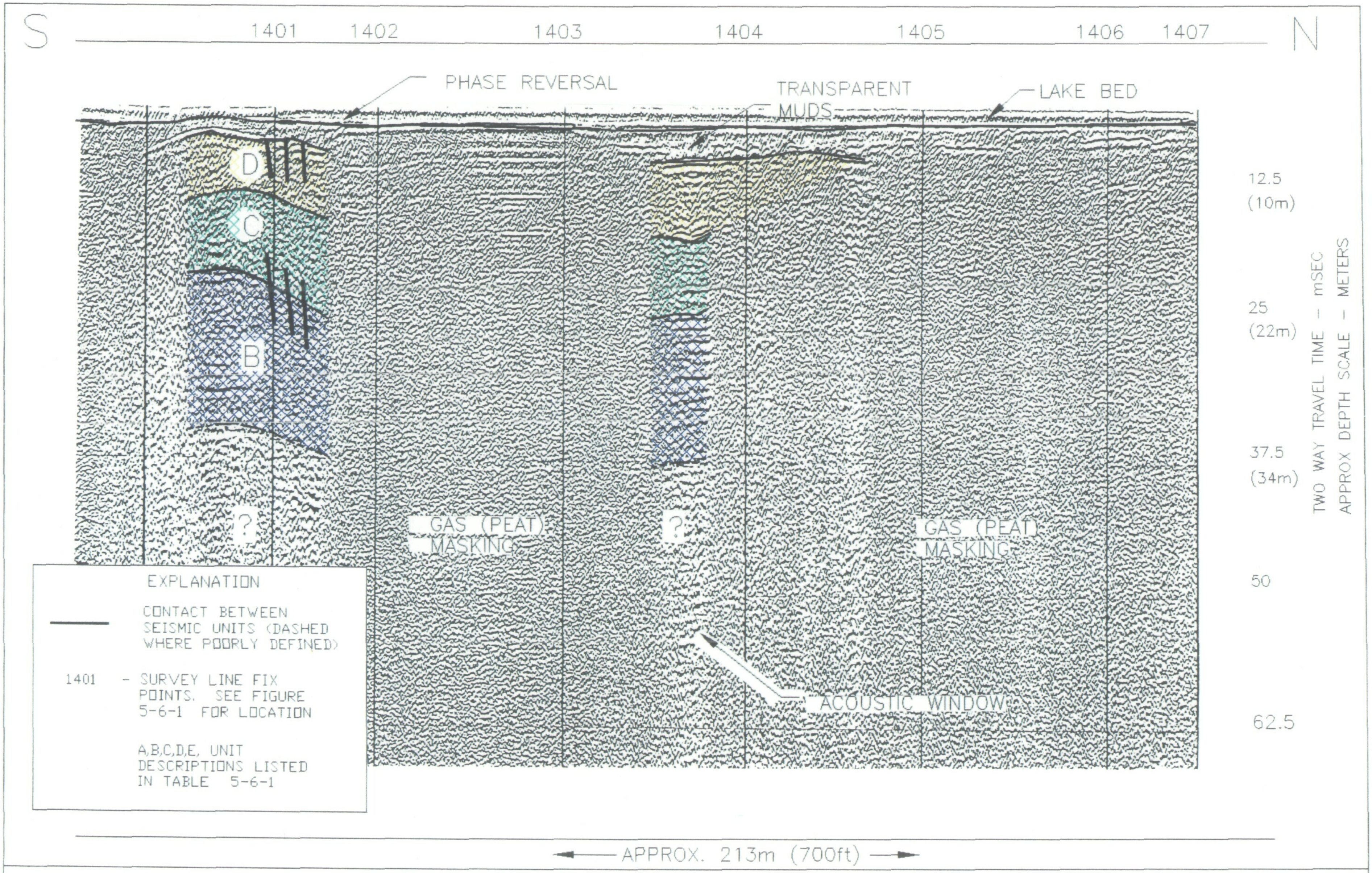


FIGURE 5-6-6 Example record from survey line 14 in Basin 4 of Lake Geneva showing the surficial clay/peat basin fill sediments, gas masking and acoustic window located in the central portion of the basin.

Gamma-ray logs from boreholes in the vicinity of Lake Geneva were used to attempt to correlate the seismic units with regional geology. Figure 5-6-1 shows the locations of the borehole control available in the Lake Geneva area, and the gamma-ray logs for these boreholes are in Volume 2, Appendix 3. This borehole profile indicates the top of the Hawthorn Group to be at a level of between +100 ft msl along the northeast shore of the lake and +70 ft msl slightly further to the northeast. Borehole C-0430 was the only borehole to penetrate into the Ocala Group and shows this unit to be at an elevation of approximately -40 ft msl along the northeast shore of the lake. This implies that the Hawthorn Group is 140 ft or more thick in the region. Figures 5-6-2, 3 and 4 show that the interpreted top of Unit C is often close to the lakebed in regions of no collapse. In these regions, 4 to 8 msec of sediments overly Unit C and the top of the unit is an unconformity surface at an elevation of +95 to +84 ft msl. Within collapse features, the top of the Unit C can be seen to be at depths of 30-40 msec and in some cases up to 70/100 msec (+16 to -200 ft msl) although identification of the units becomes difficult in these zones. From these records, Horizon A is often vague or poorly defined even within the un-collapsed areas though a reflector tentatively correlated to the top of the Ocala Group is occasionally noted at a depth of between 35 and 45 msec (-5 to -35 ft msl) which correlates reasonably well with the depth from the C-0430 borehole.

5.7 Brooklyn Lake, Clay County

The seismic character of the Brooklyn Lake region shows similarities to the four preceding lakes. The accessible survey areas of the lake were almost entirely within disturbed collapse features, and there were minimal areas of undisturbed seismostratigraphy. Absolute correlation of units could not be made from the seismic data alone, but unit designations have been maintained as much as possible based solely on acoustic and stratigraphic character. Table 5-7-1 provides a brief summary of the units identified on these records.

A total of seven regions of karst collapse were observed in the four sub-basin areas of Brooklyn Lake (Figure 5-7-1). Basin 1 in the southwest showed three apparently isolated collapse zones. Basins 2 and 3 were essentially single larger collapse zones. Basin 4 was essentially one collapse region though the shape of the basin suggested that there were two separate collapse features that merge together at a narrow neck in the basin structure. In addition to the seven paleokarst features, there were two local areas of relatively recent (<10,000 years) collapse in Basins 1 and 2. Within Basins 2 and 4, local regions of shallow gas masking (peats) were observed. No local breaks were observed in the lake bed sediments on any of the survey lines completed within these four sub-basins that might indicate unimpeded flow connection to the deeper aquifer systems.

TABLE 5-7-1 BROOKLYN LAKE - SEISMIC CORRELATIONS

UNIT NAME	HORIZON	DEPTH RANGE ELEVATION FT (re mean sea level)	INTERPRETED LITHOLOGIC CORRELATION
E	Lakebed to D unconfined	lakebed, ponded to 5 - 15 ft thickness v=1600 m/s	Recent aeolian and lacustrine infill, lower boundary is a variable depth unconformity surface, or in some areas lakebed.
D	D unconfined to C unconfined	lakebed to +66/+60 ft v=1600 m/s	Upper Pliocene to Recent undifferentiated complex silt/clay and sand layering representing infill of sinkholes.
C/B	C unconfined to B unconfined	+66/+66 ft v=1700 m/s Note: not distinguishable from Unit B in areas 1,3,4	Finely banded silt and clay layering initially deposited conformable to lower sedimentary horizons, bedding is totally disrupted within some collapse features and conformable to other collapse features. Probable Middle to Upper Hawthorn Group to Lower Pliocene undifferentiated seds.
B	B to A	? +60/+50 ft in Basin 2 only v=1800 m/s	Miocene - Lower Hawthorne Group layered clays and interbedded silts/sands - high amplify reflections conformable to bedrock.
A	A1	-17/-26 ft to limit of penetration v=3500 m/s	Limestone - Ocala Group high ampl low freq response characteristic of consolidated bedrock reflections.
voids	X	-50 to -400	High frequency variable discontinuous reflections - possible voids or subsurface fault planes.

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PALATKA, FLORIDA

SDII
SUBSURFACE DETECTION INVESTIGATIONS INCORPORATED

BROOKLYN LAKE NAVIGATION TRACK PLOT AND LOCATIONS OF ANOMALOUS FEATURES

DESIGNED BY:	J.F.L.	PROJECT NO.:	91668	FIGURE
CHECKED BY:	J.M.T.	DRAWING NO.:	S5-1	5-7-1
DRAWN BY:	R.L.K.	DATE:	1-8-92	

Figure 5-7-2 is an example record from Basin 1 that shows a section within the Brooklyn Lake basin where the seismo-stratigraphic units in the region can be reasonably interpreted. Within this section, Units A, B/C and D, and some of the recent infill materials that might be interpreted as Unit E can be identified. Horizon A is seen at a depth of approximately 37 to 40 msec (-17 to -26 ft msl), and the top of Unit B/C is noted at a depth of approximately 10 to 12 msec (+66 to +60 ft msl). A distinction between Units B and C is not clear from the seismic characteristics along this section. These units are step faulted down to the west into a basin just below the boat ramp launching area. Unit D overlies these deeper units and forms the conformably deposited infill materials of the collapse feature seen at the west-northwest end of this line. An unconformity surface seen at fix 103 at a depth of approximately 8 msec is interpreted to be the base of Unit E in this basin.

Basin 1 appears to consist of three separate collapse features. The northern and southern collapse areas appear to indicate older (>2 million years) paleokarst activity and showed virtually no fracture structures that extend upward beyond Unit B/C. The deep subsurface of the region is very highly faulted and fractured as shown in Figure 5-7-3. Unit D is conformably deposited infill material within the collapse basin. The thickness of Unit D increases due to infilling of the collapse basins in Unit C. The small western collapse area (Figure 5-7-2 fixes 101-102.5) at the foot of the launch ramp shows a high internal reflectivity character with no phase reversal at the lakebed, and

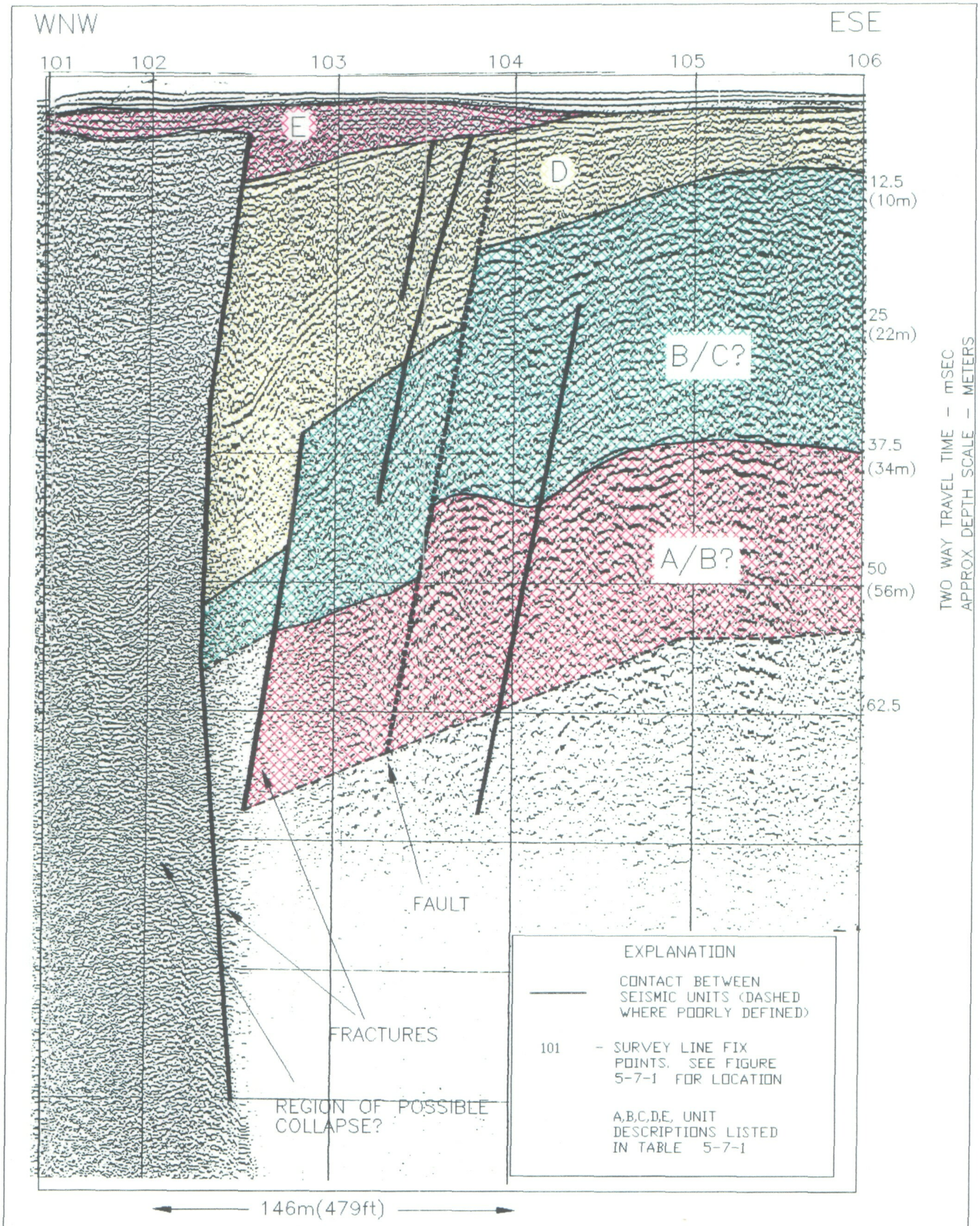

FIGURE 5-7-2 Example seismic record from survey line 1 in Basin 1 of Brooklyn Lake showing the range of observed acoustic units.

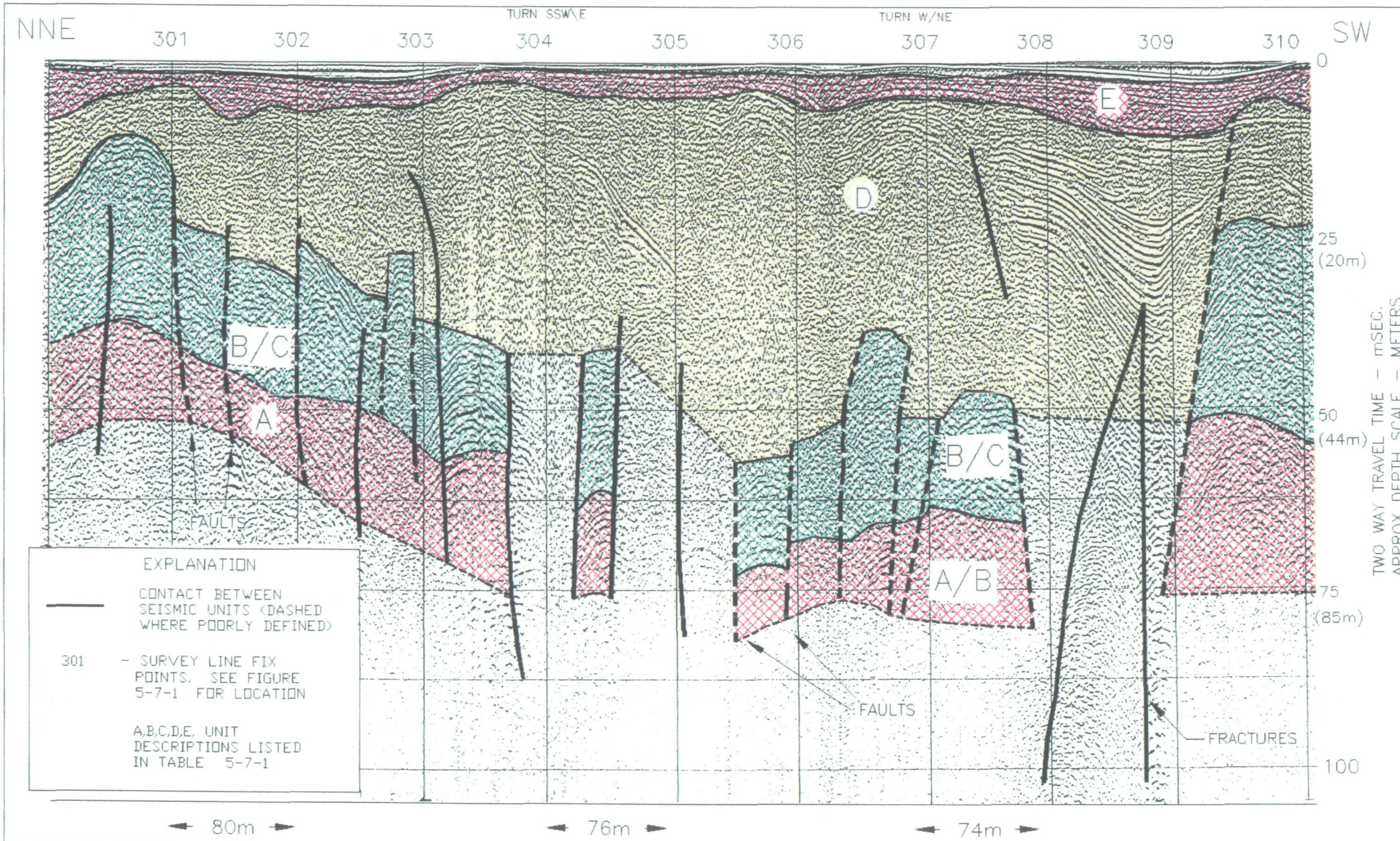

FIGURE 5-7-3 Example seismic record from survey line 3 in Basin 1 of Brooklyn Lake showing the highly faulted subsurface within the basin and the erosional surface at the base of unit E.

is interpreted to be a result of recent (<10,000 years) collapse disturbance of the sedimentary structures.

Basin 2 appears to be composed of one large collapse zone. The base of the collapse feature was poorly defined on the records, and a total depth of collapse could not be obtained. Figure 5-7-4 from Line 5 in the northern end of this basin shows an apparent vertical displacement on an identifiable reflector of at least 42 msec (34 m or 110 ft). Line 6, along the eastern shore of the basin, shows displacements to the base of the recognizable collapse zones of similar magnitude. Within the central region of Basin 2, the subsurface structures could not be identified on the records in two local regions of very high reflectivity at the lakebed (Figure 5-7-5 fixes 702.4 to 704 and fixes 705.2 to 705.8). The northern high reflectivity region (702.4-704) shows apparent phase reversal of the return signal at the lakebed and is interpreted to be associated with gas and or peat. The mid-basin zone (fixes 705.2-705.8) shows approximately three feet of acoustically transparent infill over the higher reflectivity zone and a series of small near vertical hyperbolic reflections that are characteristic of fault edges, which can be mapped virtually to the lakebed. Thus, this region is interpreted to be associated with recent (<10,000 years) collapse activity.

The subsurface seismo-acoustic units beneath Basin 3 are essentially uncorrelatable from the data due to extensive karst collapse. The edges of the karst features are presumably farther up the shore of this basin, beyond the water covered areas accessible to this survey program.

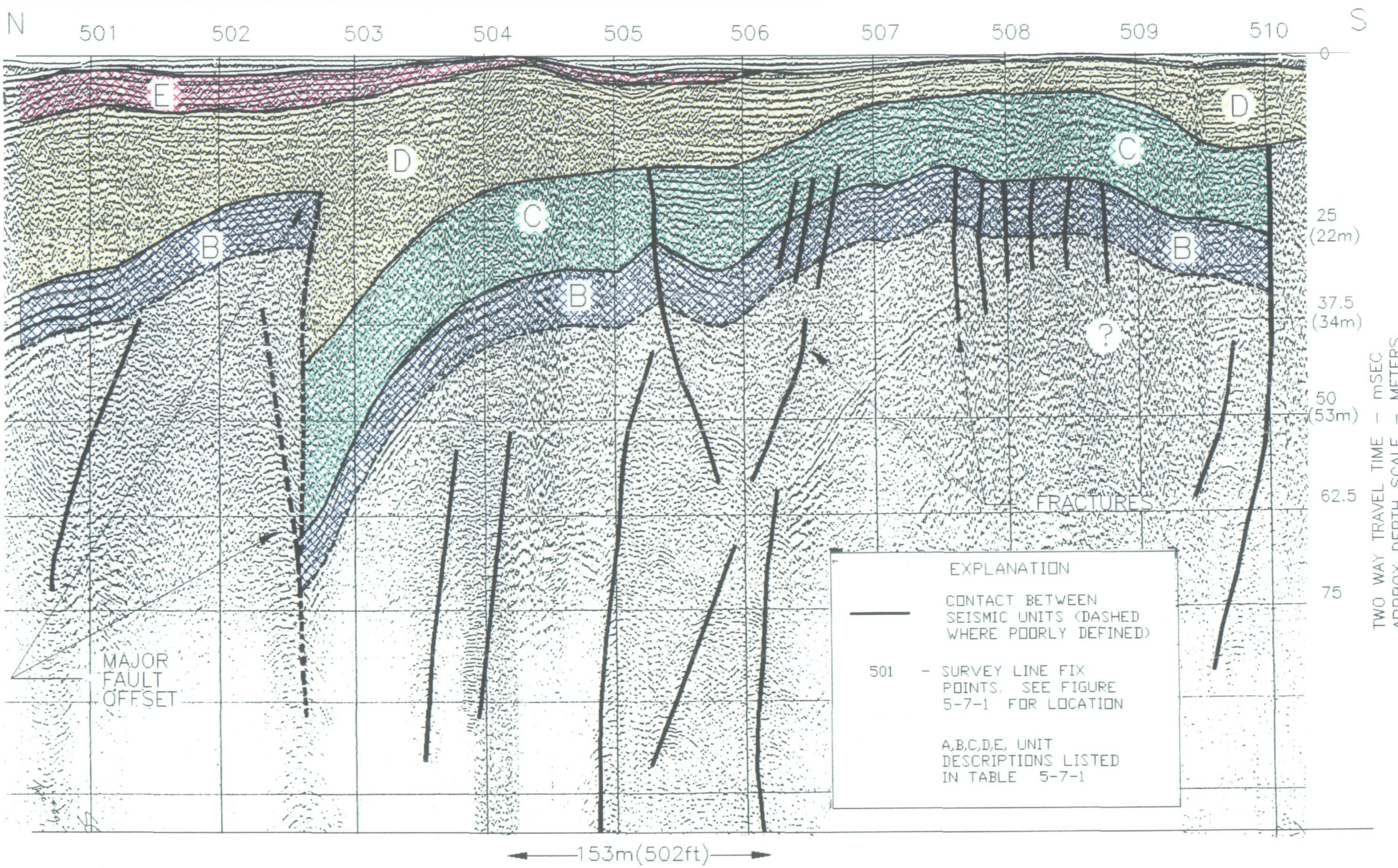

FIGURE 5-7-4 Example record from survey line 5 Basin 2 of Brooklyn Lake showing the highly faulted nature of the subsurface reflections and a major vertical displacement of over 100 ft on a reflecting horizon.

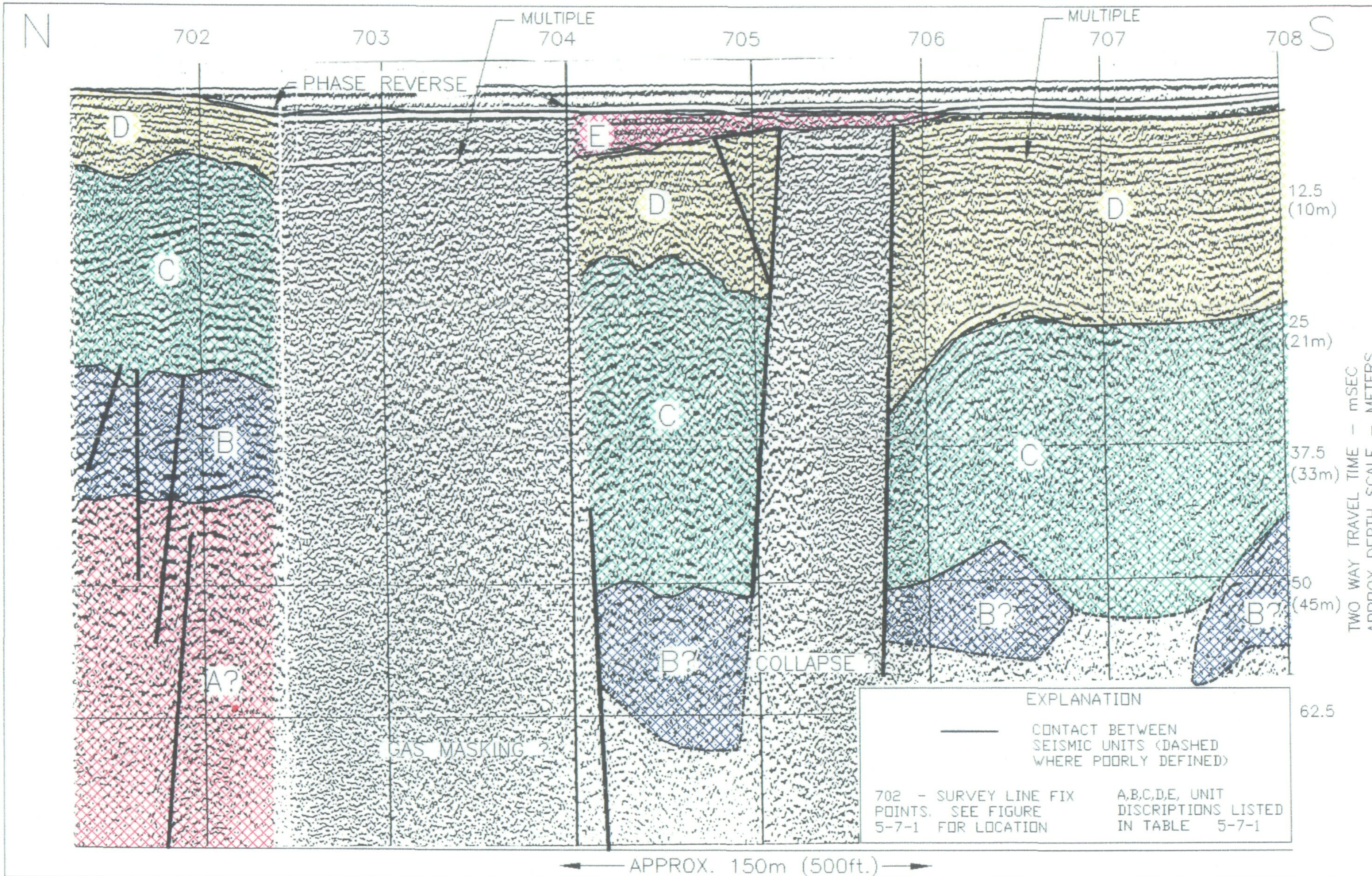

FIGURE 5-7-5

Example record from survey line 7 in Basin 2 of Brooklyn Lake, showing two high reflectivity masking zones. The northern zone shows apparent phase reversal (gas) while the southern zone shows infill possibly indicating collapse activity.

Data from Basin 4 showed two large regions of shallow gas or peat masking of the subsurface reflections (phase reversals seen at lakebed). The line completed around the circumference of the basin did show Units A through D to be distorted and faulted, however the relative age of the feature and degree of connectivity with the intermediate or Upper Floridan aquifers could not be determined.

Available gamma-ray logs from boreholes in the vicinity of Brooklyn Lake were used to attempt to correlate the seismic data with regional geology (Figure 5-7-1). The gamma-ray logs for these boreholes are in Volume 2, Appendix 3. Based on these borehole data, the top of the Hawthorn Group is at an elevation of approximately +80 to +90 ft msl in the region, and the top of the Ocala Group and the Upper Floridan aquifer is at an elevation of approximately -60 ft msl in the region. Based on these data, the top of the Hawthorn Group may correlate with the lower portion of Unit C, above the top of Unit B which was noted at an elevation of +50 to +60 ft msl in the northern part of Basin 2. From the borehole data it also may be concluded that the top of Unit A may not actually be the top of the Ocala Group but is a strong reflector within the Hawthorn Group such as was correlated to Unit B within Lakes Broward and Daugharty. If this is the case, a reflecting horizon correlating to the Ocala Group has not been identified in the Brooklyn Lake area.

6.0 CONCLUSIONS

In conclusion, the seismic study of these five lake basins has been generally quite successful. Acoustic penetrations of over 150 ft were achieved in some regions of all lakes, and in some areas penetration of up to 650 ft was achieved. Complex karst collapse features have been identified in all five lakes. Also, up to five seismo-stratigraphic units have been identified in most of the lake basins, and it appears that correlation of these units can be carried from lake to lake by their acoustic characters. Unit A (deepest) has been correlated to the Ocala Group in at least four of the basins. Units B correlates with the Hawthorn Group. Unit C appears to be correlated to the Upper Hawthorn Group and Lower Pliocene sediments. Unit D is probably Upper Pliocene to Recent infill material that has in some regions conformably infilled the older major collapse features and in some regions has been itself deformed by subsequent collapse activities. Unit E represents a thin veneer in most lakes that lies unconformably on the surface of the older units and is likely the recent aeolian and fluvial infill into these basins. Local areas of possible recent (<10,000 years) collapse activity have been identified in at least four of the lakes, and these regions may potentially provide direct connection to the intermediate or Upper Floridan aquifers, although the seismic method cannot confirm water flow through these possible paths.

The seismic method cannot confirm flows between the lake waters and the subsurface aquifers although it can delineate fractured materials and collapse features that may provide a flow path. Thus, different methods such as chemical tracer studies or direct lakebed flow studies would be required to confirm the presence or absence of actual transfer of fluids.

6.1 Lake Daugharty

The acoustic profiles discussed in Section 5.3 illustrate the complexity of the limestone surface and sedimentary structures in the Lake Daugharty area. This complexity is interpreted to be a result of a number of karst collapse areas within the Ocala Group limestone. In most cases the acoustic horizons associated with Hawthorn Group and overlying Pliocene to Recent sediments are completely disrupted (fractured) and cannot be mapped over these collapse features. This implies that the collapse activities have occurred since their deposition. The lack of mappable shallow reflectors that show sedimentary drape into the surficial depressions precludes the ability to define an accurate stratigraphic age to these collapse features. The lakebed shows no sharp (recent) breaks or down-drop features with the exception of a small steep depression in the northwestern basin which is possibly associated with a pump installation and boat ramp on the nearby shore that was noted while on site (fix 211). Major regions of relict karst collapse are common throughout most of the lake basin.

There were no direct indications such as vent or spring activity associated with the karst collapse features observed on the seismic sections that might indicate a conduit to the Upper Floridan aquifer. However, the fractured clays of the Hawthorn Group and overlying Pliocene sediments within any of the collapse structures would likely provide significant potential seepage paths for hydraulic connection between the lake and the Upper Floridan aquifer. Hydraulic heads in the surficial aquifer system and the Upper Floridan aquifer would most likely result in downward leakage of water from the lake to the Upper Floridan aquifer.

6.2 Lake Broward

The seismic profile data from Lake Broward shows considerable evidence of paleokarst collapse in the Ocala Group and Hawthorn Group within the lake basins. However, the predominantly smooth lakebed and generally undisturbed nature of Pliocene to Recent sediments show little evidence of recent (<10,000 years) collapse activity that would provide a high probability of hydraulic connection between the lake and the Upper Floridan aquifer. One exception to this may exist in the central region of the northern basin where a small perturbation on the lakebed could be interpreted to represent recent settlement over one of the younger appearing karst collapse features. The two possible recent (<10,000 years) collapse regions identified in the southern basin may provide some hydraulic connection through the observed subsurface fracture lines, although no direct evidence such as a fault scarp was observed on the lake bed. The very shallow lakebed section was masked by multiple reflections which precluded a definite correlation of extension of these fracture zones to the lakebed.

6.3 Swan Lake

The seismic data obtained within the Swan Lake basins show significant karst collapse activity. Much of this activity is interpreted to be paleokarst (Pliocene or older) although at least four regions of the lake, two in each of the northern and southern basins, show characteristics which might be interpreted as relatively recent (<10,000 years) in nature. The lakebed appears to be smooth and gently undulating over most of this area, which either implies that there are capping sands or silts that have infilled the rougher texture of the original collapse structure, or that the noncohesive Pliocene to Recent sands observed in the region may have been liquified during the collapse process and essentially flowed back into the smooth lakebed character that is observed on the records.

No features could be identified as being directly associated with conduit connection between the lake and underlying aquifers, although numerous zones of apparently fractured sediments could provide hydraulic connections between the lake and Upper Floridan aquifer. The potentiometric surface of the Upper Floridan aquifer is lower than the lake level, therefore water would leak downward from the lake if hydraulic connections existed. The major karst subsidence features observed indicate a high likelihood of connection with the intermediate and Upper Floridan aquifer as some of these features are seen to have vertical displacement extents of 200 feet or more.

6.4 Lake Geneva

The basins within Lake Geneva show considerable evidence of karst collapse activities. Some regions are highly faulted and may provide direct connection to the Upper Floridan aquifer. Within Basins 1 and 2, regions of high reflectivity are interpreted to be related to recent (<10,000 years) karst collapse activity and are considered to have a higher probability of direct connection. In particular, two anomalies resembling spring vents are noted within Basin 2. However, based on the hydraulic differential between the lake level and the potentiometric surface of the Upper Floridan aquifer, spring flow appears unlikely. Therefore, the interpretation of these anomalies requires further direct visual and/or chemical tracer confirmation. The subsurface of Basins 3 and 4 could not be mapped because of shallow gas or peat masking zones at and just beneath the lakebed. Within these two regions there was no indication of breaks observed in the lakebed and thus the capping clay/peats would likely inhibit flow of water through the lakebed. However, no clay/peat layer was noted along the sloping shores of these areas and some perimeter flow might occur within these regions.

6.5 Brooklyn Lake

Brooklyn Lake consists of a number of collapse features that show fractures and faulting in the Hawthorn Group and overlying Pliocene to Recent sediments that may provide some degree of hydraulic connection between the lake and the Upper Floridan aquifer. Most of the areas studied indicate at least a thin veneer of surficial sands that show no continuous breaks that would provide the final link to unimpeded flow. These unconsolidated sands showed no indications of clay horizons which would act as a seal and the highly permeable sands would likely provide hydraulic connection between the lake and deeper aquifers. Local regions within Basins 1 and 2 suggest relatively more recent (<10,000 years) collapse activity that would provide the most likely flow paths.

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