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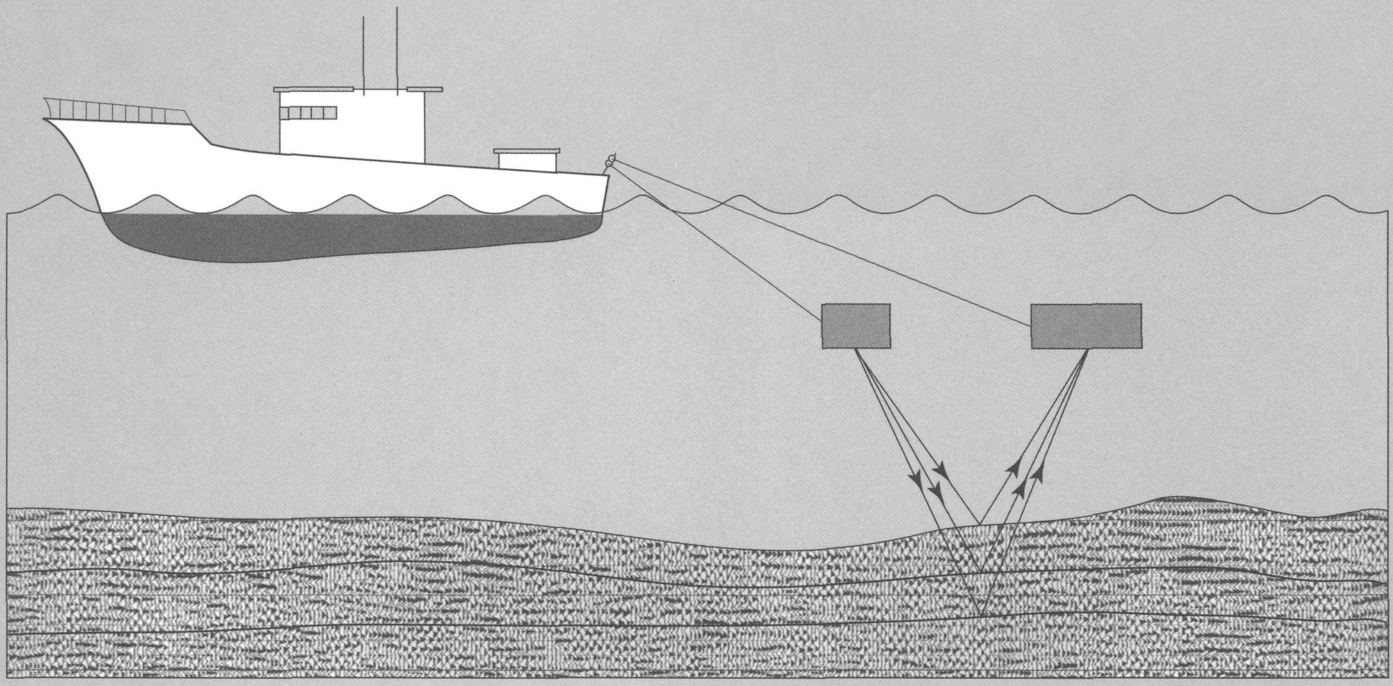
Application of Continuous Seismic-Reflection Techniques to Delineate Paleochannels Beneath the Neuse River at U.S. Marine Corps Air Station, Cherry Point, North Carolina

U.S. Geological Survey
Water-Resources Investigations Report 99-4099



Prepared in cooperation with Department of the Navy, U.S. Marine Corps

U.S. Department of the Interior
U.S. Geological Survey

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Raleigh, North Carolina
1999

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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CONVERSION FACTORS, TEMPERATURE, VERTICAL DATUM, AND ABBREVIATIONS AND ACRONYMS

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer
foot (ft)	0.3048	meter
	Flow Rate	
foot per second (ft/s)	0.3048	meter per second
	Energy	
kilowatt-hour (kWh)	3,600,000	joule

TEMPERATURE:

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

SEA LEVEL:

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

ABBREVIATIONS AND ACRONYMS USED IN THIS REPORT:

CDP	common depth point
Hz	Hertz
MCAS	Marine Corps Air Station
mg/L	milligram per liter
ms	millisecond
RASA	Regional Aquifer Systems Analysis
RMS	root mean square
USGS	U.S. Geological Survey
VSP	vertical seismic profile

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ABSTRACT

A continuous seismic-reflection profiling survey was conducted by the U.S. Geological Survey on the Neuse River near the Cherry Point Marine Corps Air Station during July 7–24, 1998. Approximately 52 miles of profiling data were collected during the survey from areas northwest of the Air Station to Flanner Beach and southeast to Cherry Point. Positioning of the seismic lines was done by using an integrated navigational system.

Data from the survey were used to define and delineate paleochannel alignments under the Neuse River near the Air Station. These data also were correlated with existing surface and borehole geophysical data, including vertical seismic-profiling velocity data collected in 1995.

Sediments believed to be Quaternary in age were identified at varying depths on the seismic sections as undifferentiated reflectors and lack the lateral continuity of underlying reflectors believed to represent older sediments of Tertiary age. The sediments of possible Quaternary age thicken to the southeast.

Paleochannels of Quaternary age and varying depths were identified beneath the Neuse River estuary. These paleochannels range in width from 870 feet to about 6,900 feet. Two zones of buried paleochannels were identified in the continuous seismic-reflection profiling data. The eastern paleochannel zone includes two large superimposed channel features identified during this study and in re-interpreted 1995 land seismic-reflection data. The second paleochannel zone, located west of the first paleochannel zone, contains several small paleochannels near the central and south shore of the Neuse River estuary between Slocum Creek and Flanner Beach. This second zone of channel features may be continuous with those mapped by the U.S. Geological Survey in 1995 using land seismic-reflection data on the southern end of the Air Station.

Most of the channels were mapped at the Quaternary-Tertiary sediment boundary. These channels appear to have been cut into the older sediments and deepen in a southerly or downgradient direction. If these paleochannels continue beneath the Marine Corps Air Station and are filled with permeable sediment, they may act as conduits for ground-water flow or movement of contaminants between the surficial and underlying freshwater aquifers where confining units are breached.

INTRODUCTION

The U.S. Marine Corps Air Station at Cherry Point is located in southeastern Craven County in the North Carolina Coastal Plain (fig. 1). Since 1941, activities at the Air Station have created

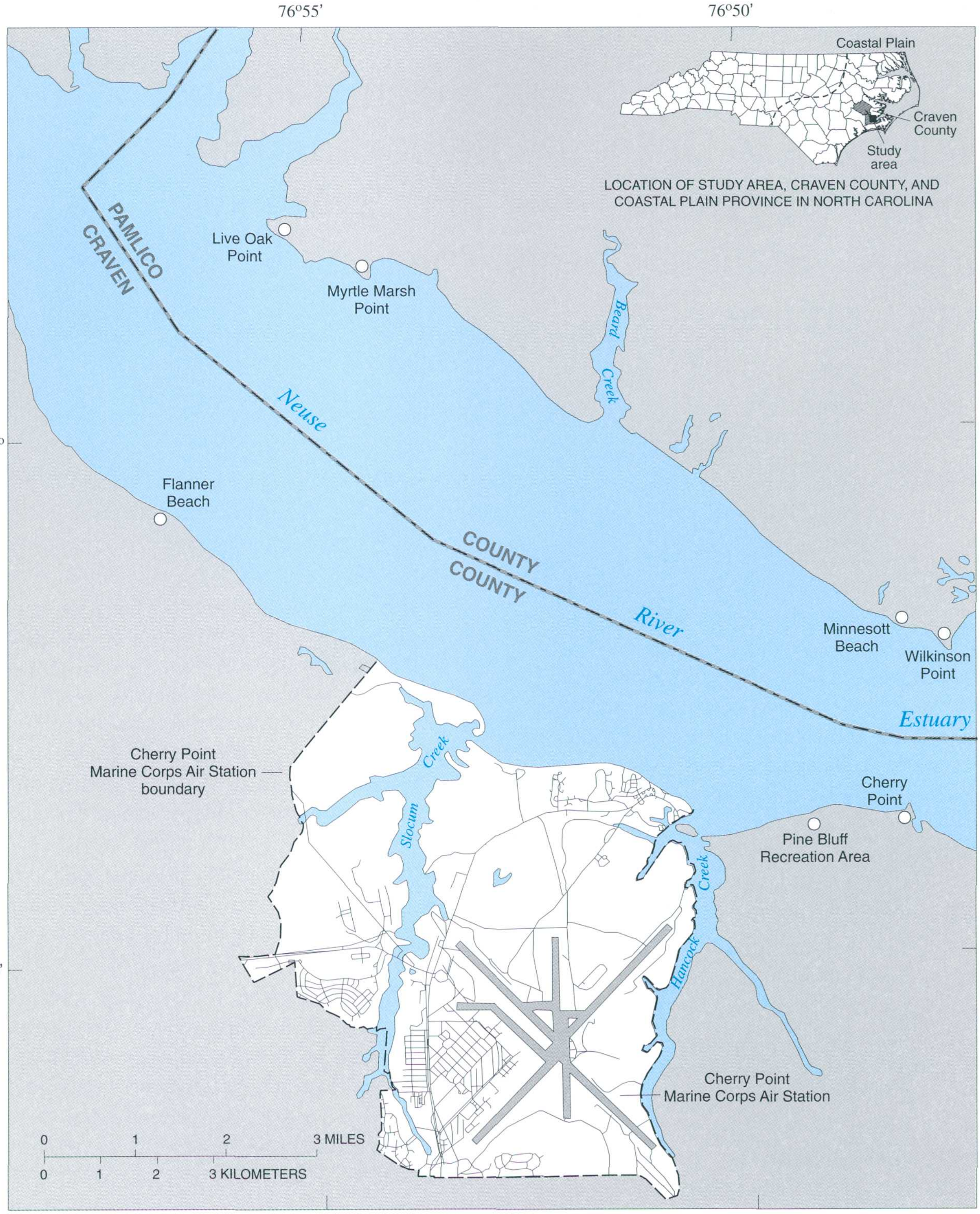

Figure 1. Location of the Cherry Point Marine Corps Air Station, North Carolina.

water-contamination problems for local ground-water and surface-water systems (Daniel and others, 1996). The potential for ground-water contamination is influenced by local hydrogeologic conditions, which recent studies have shown to be more complex than previously thought. The greatest potential for ground-water contamination occurs in areas where clay confining units that typically overly the Castle Hayne aquifer are thin or absent. The Castle Hayne aquifer is the principal water-supply source for the Air Station and surrounding communities (Daniel and others, 1996).

A multidisciplinary U.S. Geological Survey (USGS) study (Daniel and others, 1996), based on surface and borehole geophysics and lithologic borehole data, identified paleochannels (fig. 2) and cut-and-fill structures beneath the Air Station, some of which may have breached confining units in several areas. In the vicinity of these paleochannels, the regional confining unit over the River Bend limestone (part of the Castle Hayne aquifer) is absent or has been replaced by sand and shell layers and, thus, offers little confinement. The full extent of the paleochannels and missing confining unit beneath the Air Station currently (1999) is unknown. Delineation of areas where confining units are absent is of critical concern because this information may affect decisions regarding future well construction, waste handling, fuel storage, building construction, site remediation, and other activities at the Air Station.

Paleochannels at the south end of the Air Station and in part of the Neuse River next to the Air Station were mapped by Daniel and others (1996). However, the alignments of these paleochannels beneath the Air Station and the Neuse River are not well defined. This study was undertaken to help define the alignments of these paleochannels at the Air Station by using continuous seismic-reflection profiling techniques in the Neuse River estuary.

Purpose and Scope

The results of continuous, low-frequency, seismic-reflection profiling surveys conducted in the Neuse River estuary in July 1998 are presented in this report. These results are interpreted in conjunction with vertical seismic-profiling (VSP) surveys conducted in 1995 at the Air Station, and with other lithologic and borehole geophysical data collected at the Air Station. This report also describes additional paleochannel delineation and alignment, as well as the geophysical methods that were used to map the lateral extent, continuity, and depth of the paleochannels. In addition, the scope of work presented in this report includes the development of an average velocity curve from the 1995 vertical seismic-profiling data to convert time to depth.

Previous Studies

Several studies have been conducted to characterize the geology, hydrogeology, and hydrology of the study area. The lithology and extent of various geologic formations that make up the Coastal Plain aquifers were studied by Winner and Coble (1996) as part of the Regional Aquifer Systems Analysis (RASA). More localized studies have been conducted to characterize the hydrogeology, hydrology, and quantity and quality of water from supply wells at the Air Station. The general geology and ground-water resources of the Craven County area are discussed in reports by LeGrand (1960), Floyd (1969), and Floyd and Long (1970). Kimrey (1964, 1965) and Miller (1982) describe the Pungo River Formation of Miocene age, which constitutes an important part of the hydrogeologic framework at the Air Station.

Paleochannels have been identified previously beneath the Coastal Plain of eastern North Carolina (Riggs and O'Connor, 1974; Mixon and Pilkey, 1976; Daniel, 1981; Hine and Snyder, 1985; Hine and Riggs, 1986; Cardinell and others, 1990; Cardinell and others, 1993). Most of these studies were conducted near the study area discussed in this report.

Mixon and Pilkey (1976) outlined the base of the Quaternary deposits in the study area. Although Mixon and Pilkey (1976) suggested that a Neuse River paleochannel crossed the Air Station in a northwest to southeast direction, the location and depth of their proposed channel did not exactly coincide with the depth and location of missing confining units in borehole-geophysical and borehole-lithological data at the south end of the Air Station. These data suggest the presence of a Neuse River paleochannel at the Air Station, a potentially critical feature of the hydrogeologic framework of the area.

Several studies have been conducted on the Air Station, including one by Lloyd and Daniel (1988) who described the general hydrogeologic setting, distribution of hydraulic head within and between the freshwater aquifers, and the water quality from

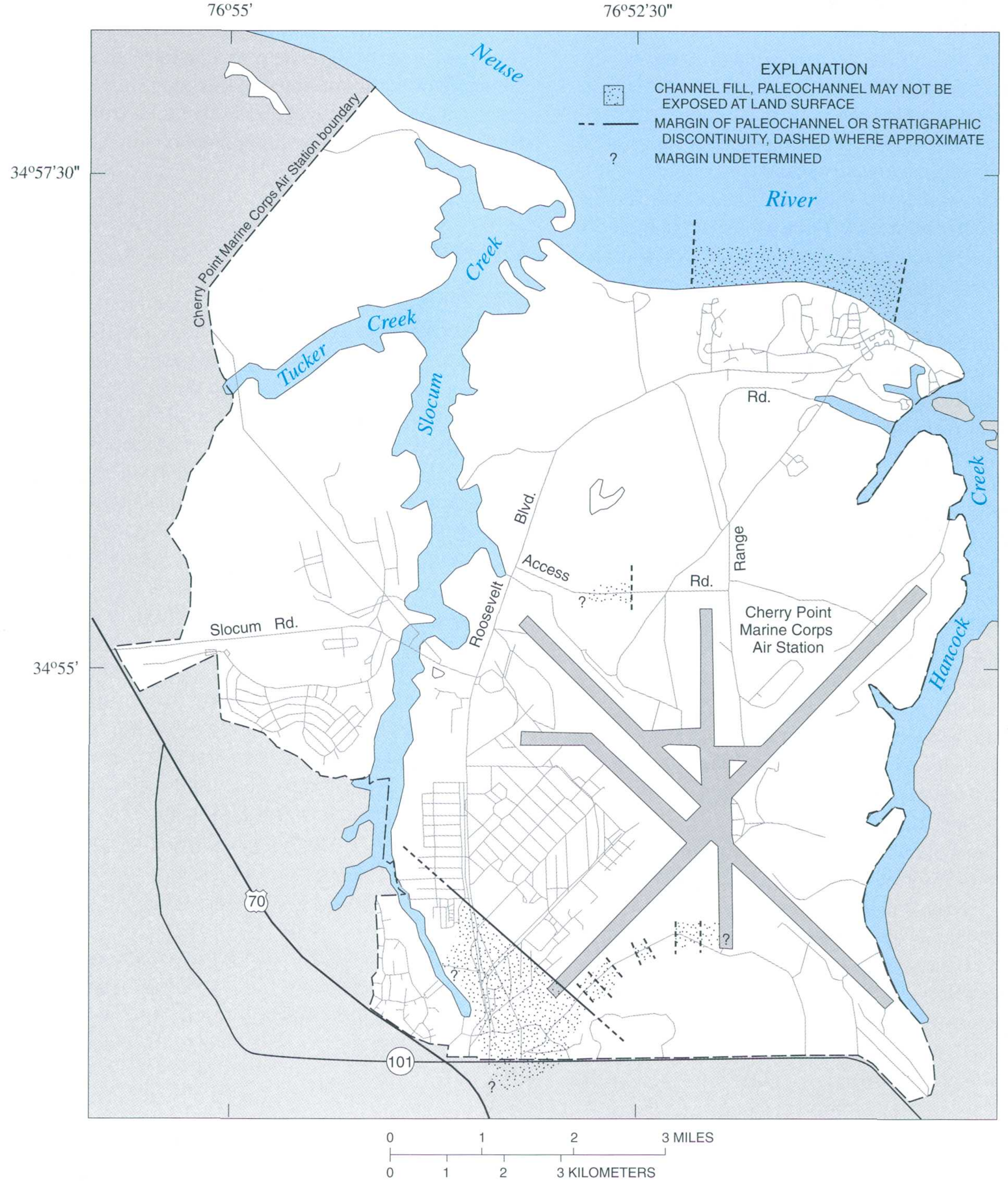

Figure 2. Locations of suspected paleochannels beneath Cherry Point Marine Corps Air Station, 1994–95 (modified from Daniel and others, 1996).

21 supply wells at the Air Station. Murray and Keoughan (1990) revised the hydrogeologic framework at the south end of the Air Station by re-mapping the Pungo River aquifer as the Yorktown aquifer. Eimers and others (1994) described the hydrogeologic framework, hydraulic properties of the aquifers and confining units, changes in the potentiometric surfaces of the aquifers since the Air Station opened in 1941, and simulation of ground-water flow beneath the Air Station with a three-dimensional ground-water flow model. Daniel and others (1996) identified areas where aquifers and confining units have been breached by paleochannels. The work of Daniel and others (1996) was done by using a combination of land and continuous seismic-reflection techniques, borehole geophysical data, and borehole-lithologic data. Daniel and others (1996) concentrated on the southern end of the Air Station where previous work by Mixon and Pilkey (1976), Lloyd and Daniel (1988), and Murray and Keoughan (1990) implies the presence of a large paleochannel that cuts the Yorktown and Pungo River aquifers and their confining units (when present).

The continuous seismic-profiling and paleontological data presented by Hine and Riggs (1986) provide evidence of a complex sequence of Cenozoic erosional and depositional events (as many as 18 depositional sequences identified within the composite Miocene section of Onslow Bay). These events appear to be related to multiple Cenozoic shoreline migration and sea-level fluctuations, many of which were high-amplitude events (greater than 300 feet [ft]). Most of the sea-level fluctuations caused the shoreline to migrate laterally across large areas of the ancestral North Carolina Coastal Plain, producing major changes in physical processes and depositional environments. Consequently, the Cenozoic stratigraphy of the area is not only characterized by numerous erosional surfaces but also by highly variable lithologies with complex relations in lateral and vertical facies. Work by Hine and Snyder (1985) and Hine and Riggs (1986) suggests that paleochannels of Pleistocene age might cross the study area in directions ranging from northwest to southeast or from north to south.

Similar work was done at a military base south of the Air Station, including the work of Cardinell and others (1990, 1993) in which paleochannels were mapped at Camp Lejeune Marine Corps Base, North Carolina. Several of these channels cut into older Tertiary sediments that underlie sediments of Quaternary age in the New River estuary, an estuary that bisects the Marine Corps Base.

As a result of the RASA study, Daniel and others (1996) presented a generalized relation between geologic and hydrogeologic units beneath the Air Station (fig. 3). Miller and Xia (1996) used shallow land seismic-reflection techniques and vertical seismic-profiling surveys to delineate some stratigraphic units, bedding geometries, and to map paleochannel features in the upper 195 ft of sediment that underlies part of the Air Station.

Hydrogeologic Framework

The Cherry Point Marine Corps Air Station is underlain by sedimentary Coastal Plain aquifers and attendant confining units that consist of interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone (Winner and Coble, 1996). Except where the units have been eroded, confining units separate all aquifers beneath the surficial aquifer. On a regional scale, the base of the Pungo River consists of a clay unit. This clay unit serves as the confining unit for the upper Castle Hayne aquifer. This basal clay of the Pungo River has undergone a facies change beneath part of the Air Station and has become sandy (Daniel and others, 1996). The freshwater aquifers (chloride concentrations less than 250 milligrams per liter [mg/L]) at the Air Station include the surficial aquifer, the Yorktown aquifer and confining unit, the Pungo River aquifer and confining unit, the upper Castle Hayne aquifer and confining unit, and the lower Castle Hayne aquifer and confining unit (fig. 3). These aquifers and confining units are of primary interest in this study.

The observed thickness of the surficial aquifer ranges from about 31 to 50 ft at the Air Station, and the aquifer is thickest at the southern part of the Air Station (Eimers and others, 1994). The surficial aquifer overlies the Yorktown confining unit, except where the unit is missing such as at the southern part of the Air Station. The Yorktown confining unit is estimated to range in thickness from 5 to 34 ft beneath the Air Station (Eimers and others, 1994).

The Yorktown aquifer underlies the Yorktown confining unit and consists of unconsolidated sand and

Era	Geologic units			Hydrogeologic units
	System	Series	Formation	Aquifer and confining unit
Cenozoic	Quaternary	Holocene	Undifferentiated	Surficial aquifer
		Pleistocene	Flanner Beach	
			James City	Yorktown confining unit
	Tertiary	Pliocene	Yorktown	Yorktown aquifer
				Pungo River confining unit
		Miocene	Pungo River	Pungo River aquifer
				[1]Upper Castle Hayne confining unit
		Oligocene	River Bend	Upper Castle Hayne aquifer
		Eocene	Castle Hayne Limestone	Lower Castle Hayne confining unit Lower Castle Hayne aquifer
		Paleocene	Beaufort	Beaufort confining unit Beaufort aquifer
Mesozoic	Cretaceous	Upper Cretaceous	Peedee	Peedee confining unit Peedee aquifer
			Black Creek and Middendorf	Black Creek confining unit Black Creek aquifer
			Cape Fear	Upper Cape Fear confining unit Upper Cape Fear aquifer
				Lower Cape Fear confining unit Lower Cape Fear aquifer
	Pre-Cretaceous crystalline basement rocks			

[1]Upper Castle Hayne confining unit may be sandy beneath parts of the Air Station and may not serve as a confining unit for the upper Castle Hayne aquifer.

Figure 3. Generalized relation between geologic and hydrogeologic units beneath Cherry Point Marine Corps Air Station (from Daniel and others, 1996).

clayey sand. The altitude of the top of the Yorktown aquifer ranges from less than 35 ft to more than 50 ft below sea level, and the aquifer averages 35 ft in thickness at the Air Station (Eimers and others, 1994). The Yorktown aquifer overlies the Pungo River confining unit (5 to 33 ft thick) except at the southern boundary of the Air Station where the confining unit is missing.

The Pungo River aquifer consists of fine- to medium-grained sand with some local beds of silt, clay, and phosphatic sand (Winner and Coble, 1996). The base of this aquifer consists of clay that, on a regional scale, serves as a confining unit for the upper Castle Hayne aquifer (Daniel and others, 1996). The altitude of the top of the Pungo River aquifer ranges from less than 85 ft to more than 128 ft below sea level (Eimers and others, 1994). The Pungo River aquifer is reported to be thickest (70 ft) at the southern part of the Air Station (Eimers and others, 1994). Daniel and others (1996) reported that the basal Pungo River clay is not present over parts of the Air Station due to a facies change from clay to sand. Where this facies change occurs, the Pungo River aquifer is hydraulically connected to the upper Castle Hayne aquifer. The Pungo River aquifer overlies the upper Castle Hayne confining unit (estimated to range in thickness from 12 to 45 ft by Eimers and others, 1994) except where the facies change from clay to sand has occurred.

The upper Castle Hayne aquifer is composed primarily of porous limestone, sandy limestone, and discontinuous beds of medium to fine sand (Winner and Coble, 1996). Eimers and others (1994) reported that the thickness of the upper Castle Hayne aquifer ranges from about 30 ft on the west side of the Air Station to about 85 ft on the east side of the Air Station. The altitude of the top of the upper Castle Hayne aquifer ranges from less than 155 ft in the north to nearly 200 ft below sea level at the southern boundary of the Air Station. The upper Castle Hayne aquifer overlies the lower Castle Hayne confining unit, a unit estimated to range in thickness from about 15 to 50 ft.

The lower Castle Hayne aquifer is composed of limestone, sandy limestone, calcareous sand, and clay beds (Winner and Coble, 1996). The altitude of the top of the lower Castle Hayne aquifer ranges from less than 220 ft to more than 320 ft below sea level (Eimers and others, 1994, fig. 17, table 2). Eimers and others (1994) estimated the thickness of the lower Castle Hayne aquifer to range from 465 to 500 ft. More detailed discussions on the hydrogeologic framework at the Air Station may be found in Eimers and others (1994) and Daniel and others (1996).

Acknowledgments

Mr. Ken Cobb, Environmental Specialist, Cherry Point Marine Corps Air Station, served as the program manager for this study and was instrumental in obtaining support for the study and in providing access to the study area. Thanks also to Ms. Kristine Kartman of the Cherry Point Environmental Branch and Mr. George Radford, Cherry Point Environmental Affairs Officer, who were supportive of this study.

DELINEATION OF PALEOCHANNEL FEATURES

Paleochannels underlying the Neuse River near the Cherry Point Marine Corps Air Station were delineated by using geophysical methods (continuous seismic-reflection profiling and re-evaluation of the 1995 vertical seismic-profiling (VSP) velocity analysis), and by comparing these data with the results of the paleochannel delineation study by Daniel and others (1996). Difficulties faced in identifying paleochannel features involve interpretation of seismic-reflection data collected over multiple depositional sequences that were deposited during high amplitude sea-level fluctuations. Much of the seismic record contains evidence of cut and fill features throughout.

Continuous Seismic-Reflection Profiling

During July 7–24, 1998, the USGS collected approximately 52 miles (mi) of continuous seismic-reflection profiling data along both sides of the Neuse River estuary near the Air Station (fig. 4). The data collected on the south side of the Neuse River included several near-parallel lines of data between Flanner Beach northwest of the Air Station and Cherry Point southeast of the Air Station. Data also were collected along one profile line between Live Oak Point and Minnesott Beach on the north side of the Neuse River estuary. The collection of usable data in the middle of the Neuse River estuary was limited by the hard river bottom. Additional data were collected along two northeast-southwest trending lines to enable correlation with the data collected on both sides of the estuary. The seismic survey boat location was determined throughout the survey with a Geolink navigational package that links a global positioning system and a geographic information system.

Survey Methodology

A variable power acoustic source and a single channel hydrophone array were combined in the low-frequency ORE Geopulse system that was used in this seismic survey. The acoustic source and the hydrophone array were towed behind a 25-ft boat (fig. 5). Data were recorded on digital tape for playback

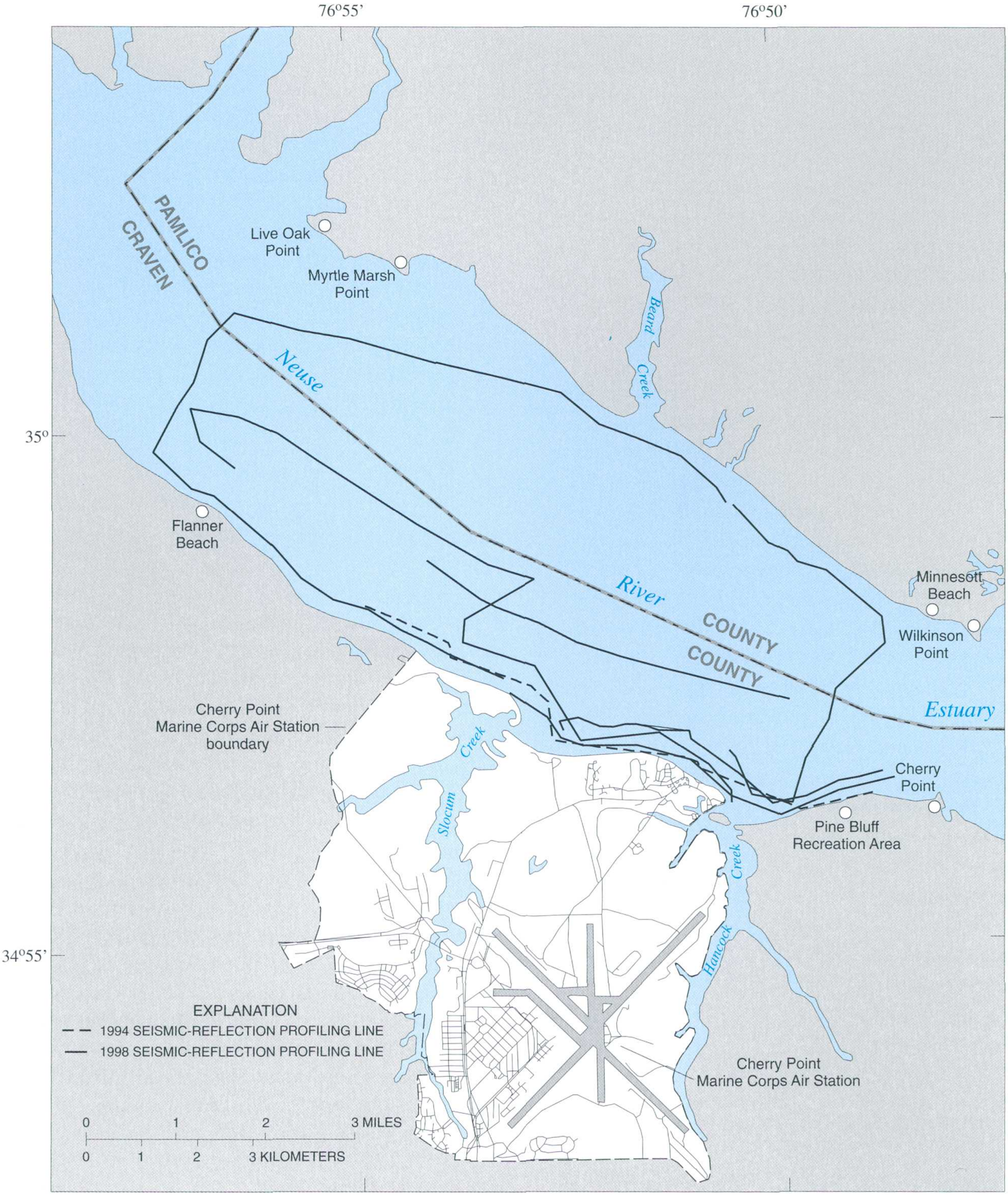

Figure 4. Locations of continuous seismic-reflection profiling lines for the 1994 and 1998 studies along the Neuse River estuary, N.C.

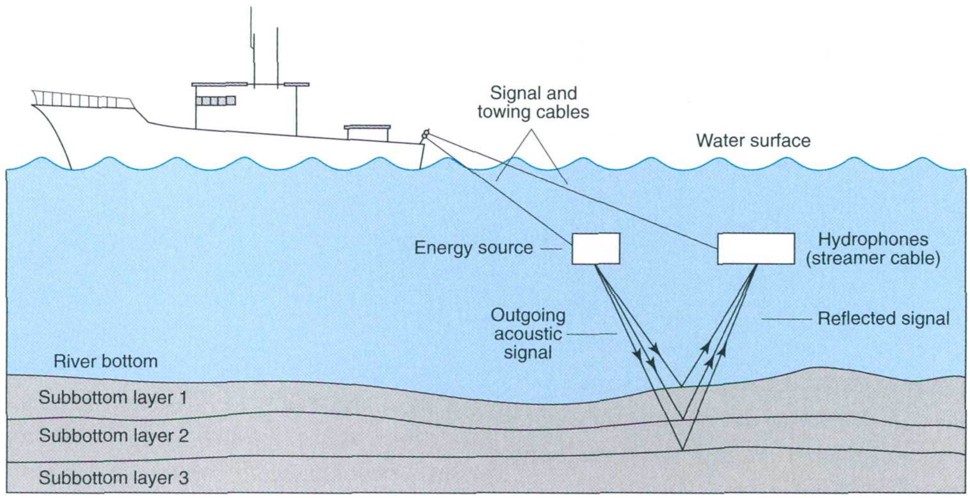

Figure 5. Ray paths from acoustic source to hydrophones for single-channel seismic profiling (Cardinell and others, 1990).

and processing. Quality assurance, quality control, and preliminary identification of possible subsurface features, such as buried channels, were accomplished by displaying a filtered portion of the seismic record on a printer. Field tests on July 7, 1998, indicated that the records with the best resolution for this particular study were obtained by using a power setting of 175 joules (J), a record length of 0.08 second (200-ft depth assuming acoustic velocity of 5,000 feet per second [ft/s]), and an analog filter setting between 300 and 1,500 Hertz. Lower power levels (105 J) resulted in insufficient penetration of the acoustic energy, whereas higher power levels (280 J) generally resulted in increased multiples in the seismic record as a result of the shallow water depth in the estuary (2 to 20 ft). More detailed discussions of the principles of seismic-reflection profiling can be obtained in Telford and others (1976), Sylwester (1983), and Cardinell and others (1990). Examples of uses of this method in the Southeast include Spechler (1994) and Tihansky and others (1996).

Development of Interval Velocities

One of the more difficult tasks in interpreting continuous seismic-reflection profiling data is obtaining accurate depth estimates to correlate with available borehole lithologic and geophysical data. Depth estimates can be obtained by using available borehole lithologic and geophysical data or by estimating the acoustic velocity of sound in the subsurface.

The seismic velocity of sound in sediments is needed to convert two-way travel times of reflections in the seismic record. Typically, a velocity of 5,000 ft/s is used for shallow-marine unconsolidated sediments when other acoustical velocity data are not available.

Miller and Xia (1996) computed an average velocity of 5,673 ft/s for the interval of 1 to 195 ft by using acoustic velocity data from three VSP surveys conducted in stratigraphic-test wells at the Air Station. Acoustic velocities were measured at 5-ft intervals in the sedimentary section during each VSP survey. The VSP data consisted of two profiles recorded in each hole to determine interval velocities in both the saturated and unsaturated zones. The VSP data and the techniques that were used to develop the 1995 average VSP velocity estimates are presented in Miller and Xia (1996) and Daniel and others (1996). These average velocity estimates were used to interpret the continuous seismic-reflection records for the 1994–95 study by Daniel and others (1996). Because the sediments beneath the Neuse River estuary are all saturated and may have a different average velocity than the land seismic-velocity data, a more accurate average velocity estimate for the continuous seismic-reflection work was needed.

The first step in this process was to develop a conceptual hydrogeologic model that assumed lateral continuity of underlying sediments of Tertiary age beneath the Air Station and the Neuse River estuary. The next step was to replace the uppermost 30-ft sediment interval of the averaged land-seismic acoustical velocity data (in unsaturated to saturated sediments) with water, assuming an interval velocity of 4,758 ft/s. Interval velocities were recalculated, and an average velocity curve was generated. The 30-ft interval was selected because of a combination of the variable water depth (2 to 20 ft) in the estuary and the average depth from land surface to the water table (about 14 ft). The resulting root-mean-square (RMS) velocity, obtained after averaging the data from the three VSP surveys and replacing the interval above the water table (0–30 ft) with an interval velocity of 4,758 ft/s, is shown in figure 6. An average velocity of 5,292 ft/s was calculated for the first 195 ft of the saturated marine sediment. The resulting depth estimates of reflectors in the estuary from this velocity analysis matched well with depths for key hydrogeologic units on land.

More detailed discussions of land seismic-reflection techniques and seismic-velocity analyses can be found in Dobrin (1976), Telford and others (1976), Miller and others (1986), Birkelo and others (1987), Jongerius and Helbig (1988), Goforth and Hayward (1992), Miller (1992), Miller and others (1994), and Miller and Xia (1996). References on vertical seismic-reflection profiling include Gal'perin (1974), Hardage (1983), and Balch and Lee (1984).

Geophysical Data Correlations

The 1998 continuous geophysical data, with the new interval velocity calculations, were compared with the 1994 continuous seismic-reflection profiling data of Daniel and others (1996) and with the results of the land seismic-reflection data of Miller and Xia (1996). Daniel and others (1996) identified two overlapping buried channel features in a portion of the Neuse River estuary at the north end of the Air Station. Three key 12-fold land seismic-reflection profile lines collected by Miller and Xia (1996) for Daniel and others (1996) (fig. 7) were line 1B (4,760 linear ft), line 2B (7,100 linear ft), and line 3B (4,800 linear ft). Data acquisition, processing parameters, and interpretations for these lines are discussed in detail in Miller and Xia (1996). Line 2B, located near the south boundary of the Air Station, revealed a complex sequence of cut-and-fill features along most of the line. Other less pronounced channel features were mapped on lines 1B and 3B, with both lines located north of the runways at the Air Station.

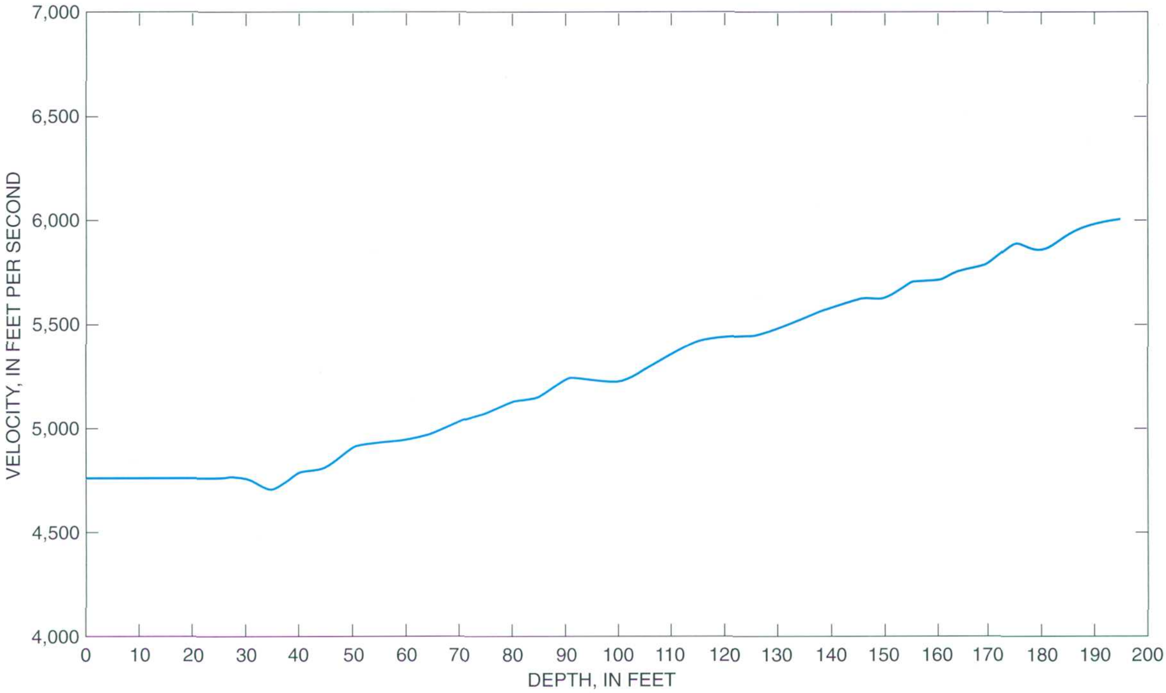

Figure 6. Modified root-mean-square velocity for 1995 Cherry Point vertical seismic-profiling velocity surveys.

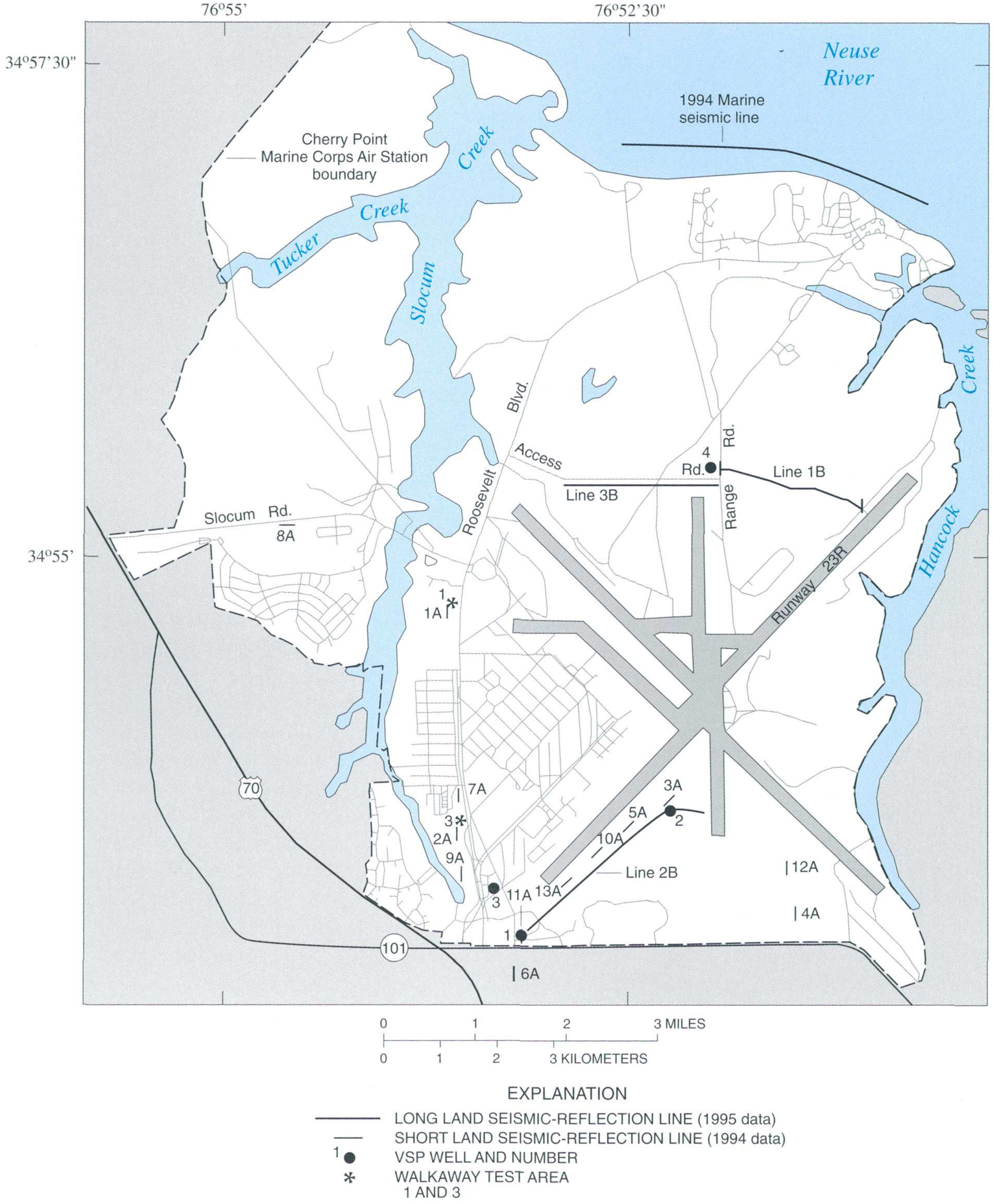

Figure 7. Locations of land seismic-reflection lines and vertical seismic-profiling (VSP) wells at the U.S. Marine Corps Air Station, Cherry Point, N.C., 1994–95 (modified from Miller and Xia, 1996).

Miller and Xia (1996) reported that the three common depth point (CDP) profiles (lines 1B, 2B, and 3B, fig. 7) were designed to detect and image the landward extension of several channel features interpreted in 1994 continuous seismic data, inferred from borehole data, and extrapolated between the two data sets. As stated in Miller and Xia (1996),

> The 12-fold CDP lines possess a horizontal resolution on the order of 16 ft to 49 ft and a practical vertical resolution of around 5.0 ft. This high resolution data set allowed detailed interpretations of Miocene scour and fill features. On all three profiles a strong reflection interpreted to be the Yorktown confining unit is relatively flat and continuous at about 39–49 ft depth. An apparent change in the seismic character, geometry, and depositional sequence of this shallow series of reflections is observed on the westernmost north lines and on the southern end of the south line. This change (acoustically similar on both lines) is most likely related to Quaternary erosion. *** it is not possible to ascertain if the Yorktown has been totally replaced with a younger clay unit or if the top of the Yorktown is partially eroded and then filled in with younger sediments. Nor is it possible to unequivocally determine how deep the younger channel might have been cut.

All 1995 land seismic-reflection data from Miller and Xia (1996) and Daniel and others (1996) were reviewed for this study. The basis for this review and re-interpretation of land seismic-reflection records was the mapping of newly identified buried channels beneath the Neuse River estuary. Re-interpretation of processed sections of land seismic-reflection line 1B for this study has resulted in the mapping of two possible additional low-relief buried channel features (fig. 8). Line 1B is located between Range Road and the north end of Runway 23R on the east-central part of the Air Station (fig. 7) and is located south of the two possible low-relief buried channel features originally mapped from the 1994 continuous seismic data. The easternmost of these channel features (mapped just below what is interpreted to be the Yorktown confining unit) cuts the underlying confining unit interpreted to be the Pungo River confining unit, between this feature and the western feature on line 1B. These two features could be separate channel features, two superimposed channels, or one channel. One stratigraphic test well (well 4) was placed west of line 1B; however, no stratigraphic test wells have been placed along this line to confirm the interpretation of the land seismic-reflection data in Miller and Xia (1996) or to determine the age of any confining material, if any confining units exist over these channel features.

RESULTS OF CHANNEL DELINEATION AND ALIGNMENT

The seismic data collected in July 1998 on the Neuse River directly offshore from the Cherry Point Marine Corps Air Station indicate the presence of other channel features in addition to those already identified in previous USGS reports. Several other possible channel features, both shallow (20–40 ft) and deep (40–80 ft), appear between Slocum Creek and Flanner Beach and between Hancock Creek and Cherry Point. An additional large, shallow channel-line feature was identified in the seismic data collected between Live Oak Point and Minnesott Beach on the north side of the estuary (fig. 4).

Penetration of the acoustic energy and the return of seismic reflections from nearshore areas were adversely affected in some areas by the hard clay bottom and gas entrapped in the sediment (organic sediment). Some of the seismic data lines had more than 90-percent usable data, whereas data collected in problem areas typically contained less than 25-percent usable data. Generally, the most usable seismic data were collected in parts of the estuary where hard clay bottoms or gassy sediments are not present.

The data-collection phase on the south side of the Neuse River was restricted within 0.5 mi of the shore because of the random placement of hundreds of crab cages and gill nets deployed by commercial fisherman. Data collection in the middle of the Neuse River was limited because of extensive hard-bottom areas that blocked the penetration of acoustical pulses.

The 1998 continuous seismic-reflection data reveal a complex sequence of both shallow and deep cut-and-fill features in seismic records collected between Flanner Beach (northwest of the Air Station) and Cherry Point (southeast of the Air Station). Two paleochannel alignment zones (fig. 9) have been identified from Flanner Beach to the eastern boundary of the Air Station. These two paleochannel zones each

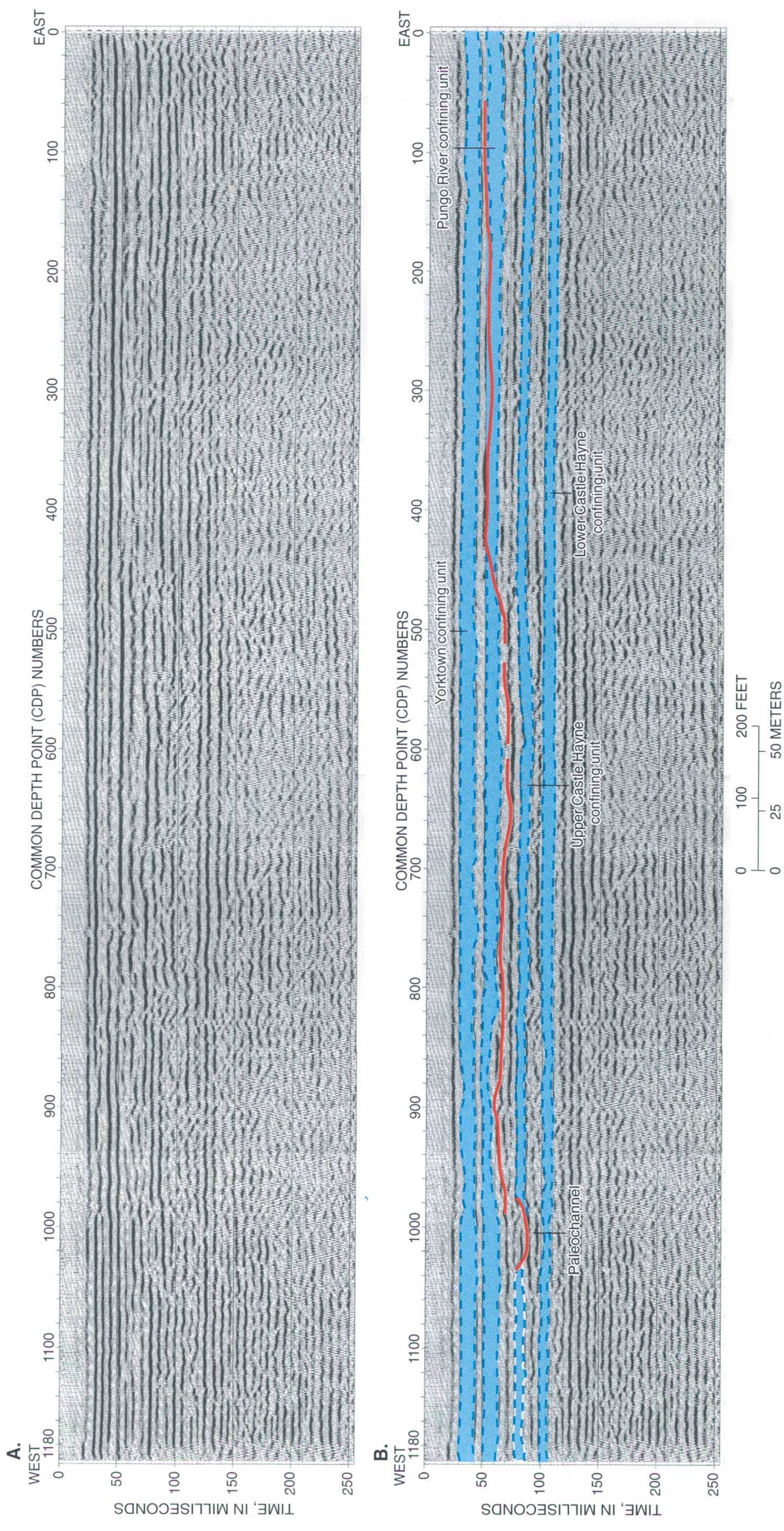

Figure 8. (A) Land seismic-reflection section 1B and (B) re-interpreted land seismic-reflection section 1B (modified from Miller and Xia, 1996).

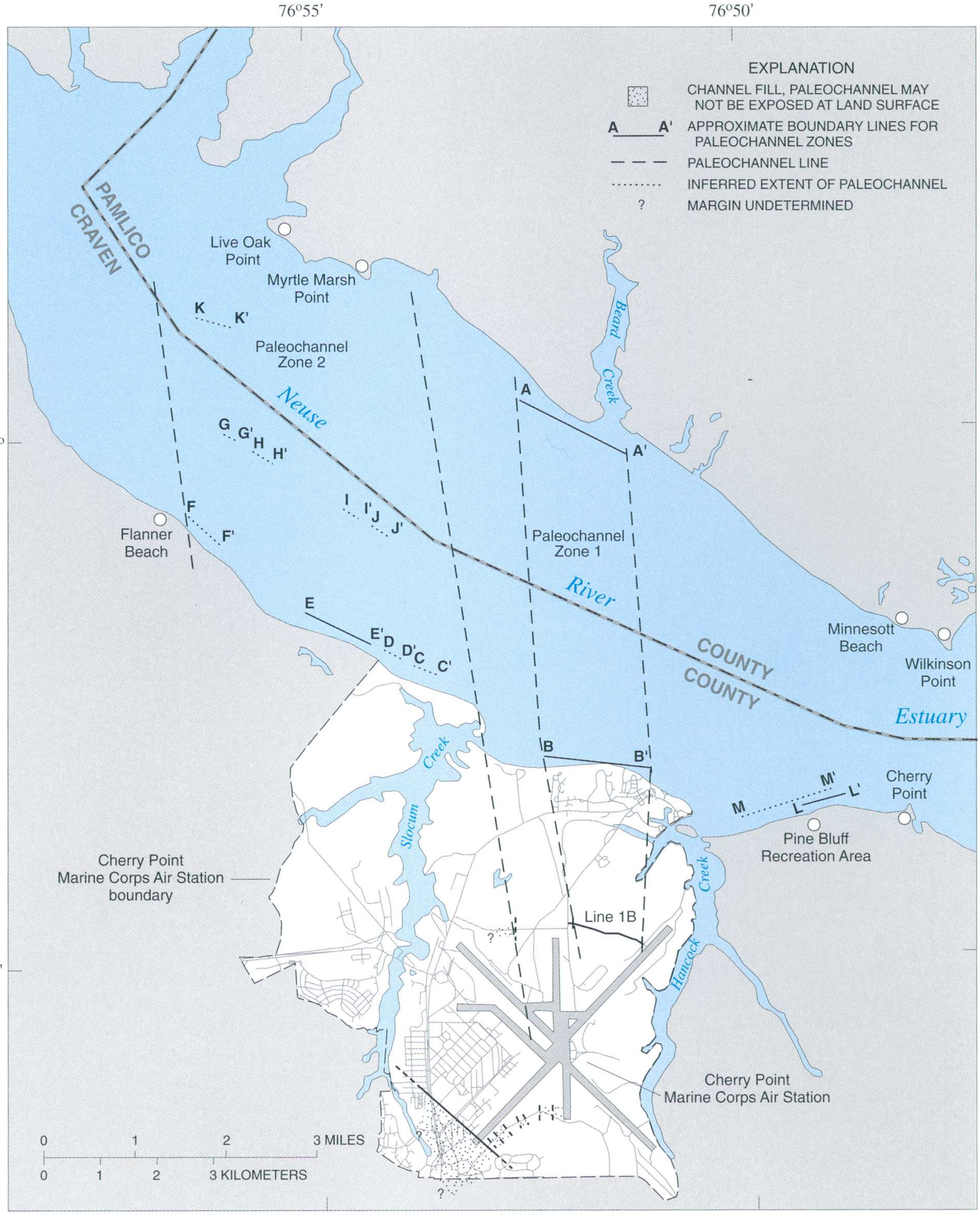

Figure 9. Locations of two possible paleochannel zones and the mapped paleochannels in the Cherry Point Marine Corps Air Station study area.

contain two or more paleochannel features that have been identified on one or more near-parallel seismic-reflection profiling lines. Several of these paleo-channels are shown in figures 10–19 (p. 21–29). Coordinates for the channel features shown in figures 10–19 are presented in table 1.

Most of the channel features are mapped along the stratigraphic boundary between the overlying, undifferentiated sediments of Quaternary age and the underlying, better-defined bedding planes of sediment interpreted to be of Tertiary age. Based on the seismic data collected in this study, the upper zone of discontinuous reflectors tends to thin to the northeast along both sides of the Neuse River. The underlying, more continuous reflectors tend to dip regionally to the southeast. A basal erosional scour feature can be traced between these two zones (figs. 10–19).

Several potential deeper channel features appear to exist within the older Tertiary sediment, but most of these features could not be identified with any degree of confidence and were not mapped for this report. Channels within the two paleochannel zones were mapped from a combination of 1998 paleochannel data, the 1995 land seismic data (Miller and Xia, 1996), 1994 continuous seismic-reflection data (Daniel and others, 1996), and from other lithologic and geophysical data.

The main and easternmost paleochannel zone (paleochannel zone 1, fig. 9) consists of two superimposed paleochannels (A–A' and B–B') that were mapped near the north and south shores of the Neuse River estuary opposite the Air Station by using continuous seismic-reflection profiling data (figs. 10, 11). These channels were correlated with two superimposed paleochannels that were mapped from continuous seismic-reflection profiling data collected along the south shore in 1994 (Daniel and others, 1996), and with land seismic-reflection line 1B collected in 1995. Results of this correlation are shown in figure 9.

Line A–A' (figs. 9, 10) indicates the presence of two cut-and-fill features located beneath the Neuse River near the north shore between Myrtle Marsh Point and Beard Creek. This feature is believed to be approximately 6,900 ft wide. However, the actual width of these two paleochannels may not be as much as 6,900 ft unless the seismic record is perpendicular to the direction of the two channels. The upper 40 to 50 ft of seismic record consists of discontinuous reflections and may represent undifferentiated Quaternary sands and clays. The reflectors within these two features are not well defined. The stronger reflector at the base probably represents the bottom of these two paleochannels, and this reflector overlies a zone of

Table 1. Locations, estimated widths, and estimated depths of mapped paleochannel features beneath the Neuse River estuary, N.C.

Paleo-channels (fig. 9)	Starting State-plane east coordinates	Starting State-plane north coordinates	Ending State-plane east coordinates	Ending State-plane north coordinates	Channel width (feet)	Estimated maximum depth (feet)
A–A'	2632945.00	463660.88	2639183.54	460541.61	6,900	55
B–B'	2640449.05	442481.94	2634309.96	443206.21	6,200	75
C–C'	2628063.85	447926.94	2626772.60	448416.73	1,300	60
D–D'	2626015.66	448817.46	2624991.57	449351.77	870	55
E–E'	2624279.15	449663.45	2620449.92	451489.01	2,100	42
F–F'	2615520.03	455412.50	2613632.81	457016.64	2,200	60
G–G'	2617427.33	460762.76	2618580.21	460033.85	1,000	50
H–H'	2619450.70	459494.57	2620329.69	458950.32	1,100	42
I–I'	2624195.28	456483.91	2625304.08	455850.43	1,000	60
J–J'	2642012.76	442102.82	2643312.50	440523.21	1,100	58
K–K'	2612027.54	465587.49	2612899.10	467422.35	1,500	42
L–L'	2651753.41	441065.01	2649239.26	440386.87	2,500	120
M–M'	2650905.45	441352.69	2645715.59	439748.55	5,100	120

more continuous (between 50 and 120 ft below sea level) reflectors that may represent older sediment of Tertiary age. The westernmost and older of the two paleochannels appears to cut deeper (50 to 55 ft below sea level) into the sediments of Tertiary age.

Line B–B' (figs. 9, 11) consists of the 1998 re-collection of seismic-reflection profiling data at the locations of two paleochannels originally reported in Daniel and others (1996). These two channel features are believed to be approximately 6,200 ft wide. The base of these two channel features is about 75 ft below sea level. The most significant differences between line B–B' and upgradient line A–A' are (1) the thickness of the sediments with discontinuous reflectors in line A–A' is less than in B–B', (2) the two paleochannels in line B–B' cut approximately 40 ft into the zone of continuous reflectors (older sediment), and (3) the buried channels shown in line B–B' are more distinguishable that those in line A–A' and appear to be covered with continuous reflectors. Similarities between the data sets on both sides of the Neuse River estuary are (1) the non-linear boundary between the discontinuous and continuous reflections in seismic records collected on both sides of the Neuse River estuary can be followed to the northwest and southeast, and (2) the uppermost zone of discontinuous reflectors thins to the northwest.

If the channels (A–A', B–B') that were mapped with the 1998 continuous seismic-reflection data occurred during the Pleistocene epoch, sediments within and overlying the buried channels mapped on lines A–A' and B–B' are most likely of Pleistocene age. This also could mean that any existing Yorktown and Pungo River confining units at the Air Station also may have been breached by this buried channel sequence. If this is the case, this paleochannel sequence could act as a conduit for ground-water flow or movement of contaminants from the surficial to the Yorktown, Pungo River, and Castle Hayne aquifers.

Nine other channels are located northwest of Slocum Creek (paleochannel zone 2, fig. 9; table 1) that were mapped with the seismic-reflection data. As with the channels mapped under the north shore of the Neuse River estuary, the sediments above these channels are mostly undifferentiated and may represent Quaternary sediments; whereas the seismic records, which contain more continuous reflectors, beneath the base of these channels may represent older sediments. These features are the most prominent on the seismic records collected in water depths generally less than 5 ft and are less defined on seismic records collected toward the northern shore. The estimated widths of these features range from approximately 870 ft (channel D–D') to 2,200 ft (channel F–F'). The bottom of these channels may represent the base of Quaternary erosion.

The northern boundary of a possible broad channel feature on the south shore of the Neuse River is located just north of Slocum Creek (figs. 9, 12). Three prominent features were observed on the seismic record (fig. 12). These three features include a ridge or bank that may represent the northern boundary of a broad channel with a cross-sectional area that may continue for at least 4 mi to the southeast to the end of the survey area (just northeast of Cherry Point). The northern end of this broad channel is approximately 15 ft below sea level and deepens to approximately 30 ft below sea level northwest of the mouth of Slocum Creek. Two other channel features (C–C', D–D') are mapped in figure 12. Channel C–C' (about 1,300 ft wide) is located within this broad channel and cuts an additional 40 to 50 ft into the underlying sediment. The base of this channel could be approximately 60 ft below the water surface of the Neuse River and may cut into the underlying Tertiary sediment. The second channel (D–D') is located about 0.25 mi north of paleochannel C–C'. This feature is approximately 870 ft wide. Paleochannel D–D' is not as deep (about 55 ft below sea level) as C–C' and may not cut into underlying sediments of Tertiary age.

The third broad channel (E–E') is approximately 0.5 mi northwest of the first two channels (figs. 9, 13), and the cross-sectional area of this feature may extend as much as 2,100 ft in a northwesterly direction. The base of this channel is estimated to be 42 ft below sea level near its northeastern boundary. The actual distance across this feature is unclear because it is not known whether the seismic record is perpendicular to the direction of the channel. The majority of sediment that fills these channels appears to be undifferentiated sediments of Quaternary age. As with most of the other channels, the base of these broad channels overlies more than 100 ft of sediment believed to be of Tertiary age.

A fourth channel (F–F') is located on seismic data approximately 3 mi northwest of Slocum Creek (figs. 9, 14). Of the nine channels mapped in paleochannel zone 2, this feature is one of the most complex, and it is difficult to delineate its boundaries. This feature is estimated to be approximately 2,200 ft across the cross-sectional area delineated on the seismic section. The base of this channel is approximately 60 ft below sea level. Another feature is a ridge or bank that may represent the northern boundary of a shallow broad channel, similar to channel E–E' (figs. 13, 14). However, the presence of gassy sediment and hard bottom areas to the southeast of this line segment prevents the mapping of the possible extent of this feature.

Two small channels (G–G', H–H') have been mapped with seismic-profiling data. The mapping of these two small channels was complicated by the presence of interbedded multiples in the seismic record. These two features are located approximately 1.5 mi northeast (offshore) of Flanner Beach (figs. 9, 15). Channel G–G' is estimated to be approximately 1,000 ft wide, and channel H–H' is estimated to be approximately 1,100 ft wide. The base of channel G–G' is approximately 50 ft below sea level, and that of channel H–H' is estimated to be about 42 ft below sea level. Both channels appear to cut into sediments of Tertiary age.

Two other channel features (I–I', J–J') have been mapped with seismic data approximately 1.5 mi southeast of channel H–H', midway between Flanner Beach and the mouth of Slocum Creek (figs. 9, 16). The mapping of these two channels was complicated by the presence of interbedded multiples in the seismic record. Both channels are located about 1.25 mi offshore. Channel I–I' is estimated to be 1,000 ft wide, and channel J–J' is estimated to be 1,100 ft wide. The base of channel I–I' is approximately 60 ft below sea level, whereas the base of channel J–J' is estimated to be about 58 ft below sea level. Both channel features cut into sediment of Tertiary age.

The last channel mapped in paleochannel zone 2 is channel K–K' (figs. 9, 17). Channel K–K' is located approximately 1.5 mi south of Live Oak Point. This feature was identified with seismic-profiling data and is estimated to be 1,500 ft wide and about 42 ft below sea level at its base. The sediment that overlies this feature is undifferentiated and is believed to be of Quaternary age. The base of this channel cuts into sediment of Tertiary age.

The last two channels identified (L–L', M–M') are located southeast of paleochannel zone 1 under the Neuse River near the Pine Bluff Recreational Area (figs. 9, 18, 19). Channel L–L' (fig. 18) was mapped entirely within sediment of Tertiary age and is estimated to be 2,500 ft wide, with a base about 120 ft below sea level. It is possible that this deeper channel may extend farther to the southwest toward the Air Station, but the poor quality of the nearshore continuous seismic-reflection profiling data prevent this from being determined. A shallow, unnamed channel is located above the southeastern part of channel L–L'. This shallow, broad channel occurs at the boundary between the overlying sediment of Quaternary age and that of older sediment of Tertiary age.

Channel M–M' (fig. 19) is located approximately 0.5 mi from shore and is estimated to be 5,100 ft wide, with a base about 120 ft below sea level. The seismic-profiling data indicate that this channel is complex and may consist of two or more overlapping channels. This feature is mapped entirely within sediments of Tertiary age and can be correlated with part of channel L–L'. Although this feature probably continues under the Neuse River to the north shore, it could not be correlated with certainty with the seismic-profiling data collected near the north shore of the Neuse River.

All 13 of the paleochannels identified in the continuous seismic-reflection profiling data in this report deepen from the northwest to the southeast. It is probable that the depths of some of the deeper paleochannels under the Neuse River continue under the Air Station and may be as much as 90 to 100 ft below sea level at the south end of the Air Station. If this is the case, then the Yorktown and Pungo River confining units may be breached by these paleochannels. If paleochannels filled with permeable sediment exist beneath the Air Station, these features could act as conduits for ground-water flow or movement of contaminants from the surficial to the Yorktown, Pungo River, or the Castle Hayne aquifers.

The results of this study have similar limitations to those of similar studies conducted by Cardinell and others (1990, 1993). Although much more information on paleochannel delineation and alignment within the Neuse River and at the Air Station was obtained from the 1998 continuous seismic-reflection profiling data, limitations on the use of these data exist. Accurate depth determinations of key hydrogeologic units on the seismic record depends on the accuracy of velocity data, lithologic data, paleoecological information, and other collaborating data, such as borehole geophysical well-log data. The accuracy of estimated channel widths is dependent upon the angle at which the continuous seismic-reflection profiling data are collected across the channel axis. It is not possible to identify lithology and facies changes from the reflection record alone, and seismic-reflection records will not supply information on hydraulic parameters, such as porosity and permeability, of key units. To determine hydrologic information and to confirm the interpretations made from the reflection records, physical data must be obtained from well borings and test wells.

SUMMARY AND CONCLUSIONS

The 1998 continuous seismic-reflection profiling survey on the Neuse River was useful in identifying previously unidentified channels beneath the Neuse River near the U.S. Marine Corps Air Station (MCAS) at Cherry Point, North Carolina. This continuous seismic-reflection profiling survey identified several paleochannels within the lower boundary of the overlying, undifferentiated sediment (believed to be of Quaternary age) with layered sediments believed to be of Tertiary age. The depth of the Quaternary/Tertiary boundary below the river bottom decreases to the northeast. The thickness of the undifferentiated sediments of Quaternary age that overly this boundary appears to increase generally to the southeast. Almost all of the channel features that were mapped from the seismic data and presented in this report were found along the lower part of this unit.

Depth to the reflectors on the continuous seismic-reflection profile records was estimated by modifying the average 1995 vertical seismic-profiling (VSP) interval velocity data obtained from stratigraphic test wells to account for the effects of water column on the Neuse River data. The resulting depth estimates matched well with the depths for key hydrogeologic units.

The results of the continuous seismic-reflection profiling survey data illustrate the complex lateral variability in the width of the channels. Complex reflection patterns underlie several of these shallower channels. These deeper reflection patterns may indicate deeper paleochannel features or may result from shallower channels.

Two potential paleochannel zones were identified by correlating the 1998 continuous seismic-reflection data and the 1995 land seismic data. These two paleochannel zones trend from the northwest to the southeast. Depths to most of these paleochannels range from less than 40 ft to more that 80 ft below sea level. The bottoms of several of the paleochannels may cut into the underlying confining units and aquifers of Tertiary age.

The easternmost channel consists of a large overlapping sequence, between 6,200 and 6,900 ft in width, that trends from the north shore of the Neuse River between Myrtle Marsh Point and Beard Creek across the Neuse River to the south shore of the Air Station and onto the Air Station east of Range Road. It is unclear if sediment overlying this channel sequence is of Quaternary or Tertiary age.

The second paleochannel zone includes several smaller channels located from northeast of the mouth of Slocum Creek to Flanner Beach, about 4 mi to the northwest of the Air Station. These paleochannels generally have little vertical relief, about 20 to 40 ft from bottom to top, and are similar in shape to those mapped on land seismic lines at the Air Station. The mapped channels on the continuous seismic sections are located at the erosional boundary between the overlying sediments of Quaternary age and the underlying sediment believed to be of Tertiary age.

The potential for movement of water from the surficial aquifer downward to the water-supply aquifer is greatest in areas where clay confining units are missing. This includes those parts of the Air Station where the Pungo River aquifer may be hydraulically connected to the upper Castle Hayne aquifer because of facies changes from clay to sand at the base of the Pungo River. Missing confining units could indicate the presence of a paleochannel. If paleochannels filled with permeable sediment exist beneath the Air Station, these features could act as conduits for ground-water flow or movement of contaminants from the surficial to the Yorktown, Pungo River, or Castle Hayne aquifers.

The results of this study need to be verified with more stratigraphic test wells located in the northeastern part of the Air Station east of Range Road and west of Slocum Creek on Slocum Road. VSP surveys and lithologic data would need to be collected at these stratigraphic test wells in order to correlate the seismic data and the shallow hydrogeology in this part of the Air Station. More land seismic-reflection data are needed on the northern half of the MCAS to further delineate paleochannel alignment and depth with channel features already mapped under the Neuse River and on the Air Station.

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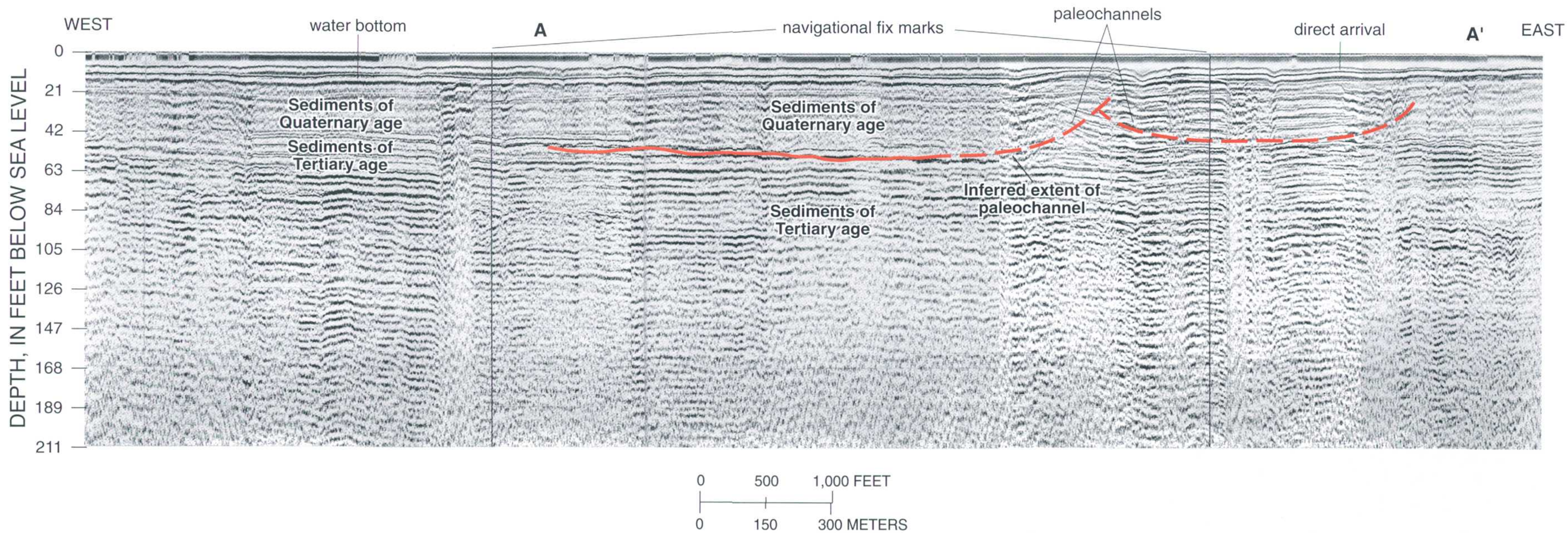

Figure 10. Continuous seismic-reflection profile (A–A') of two superimposed paleochannels beneath the Neuse River between Myrtle Marsh Point and Beard Creek on the north shore of the Neuse River, N.C.

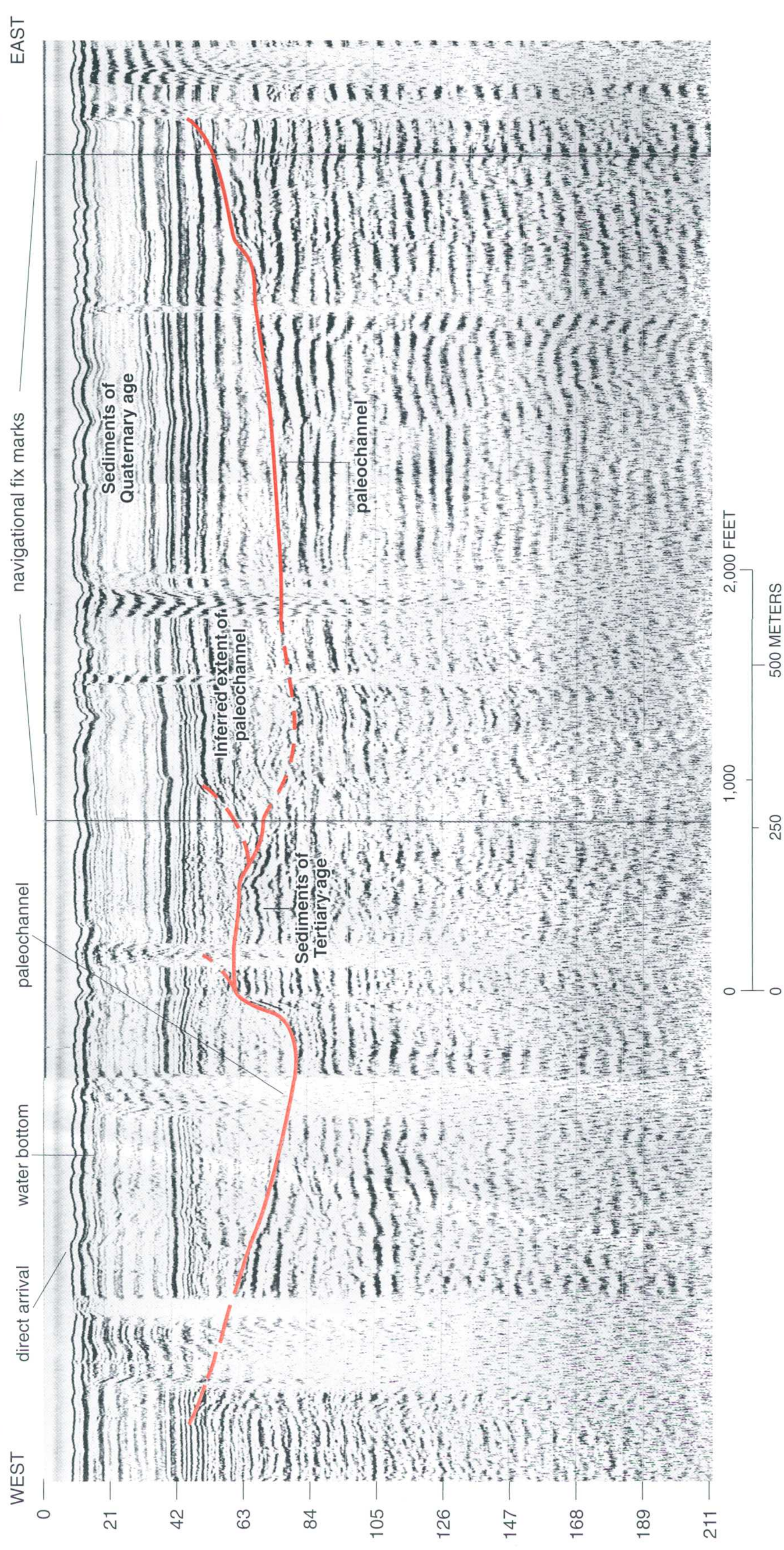

Figure 11. Continuous seismic-reflection profile (B–B') of two superimposed paleochannels beneath the Neuse River between Slocum Creek and Hancock Creek on the north boundary of the U.S. Marine Corps Air Station, Cherry Point, N.C.

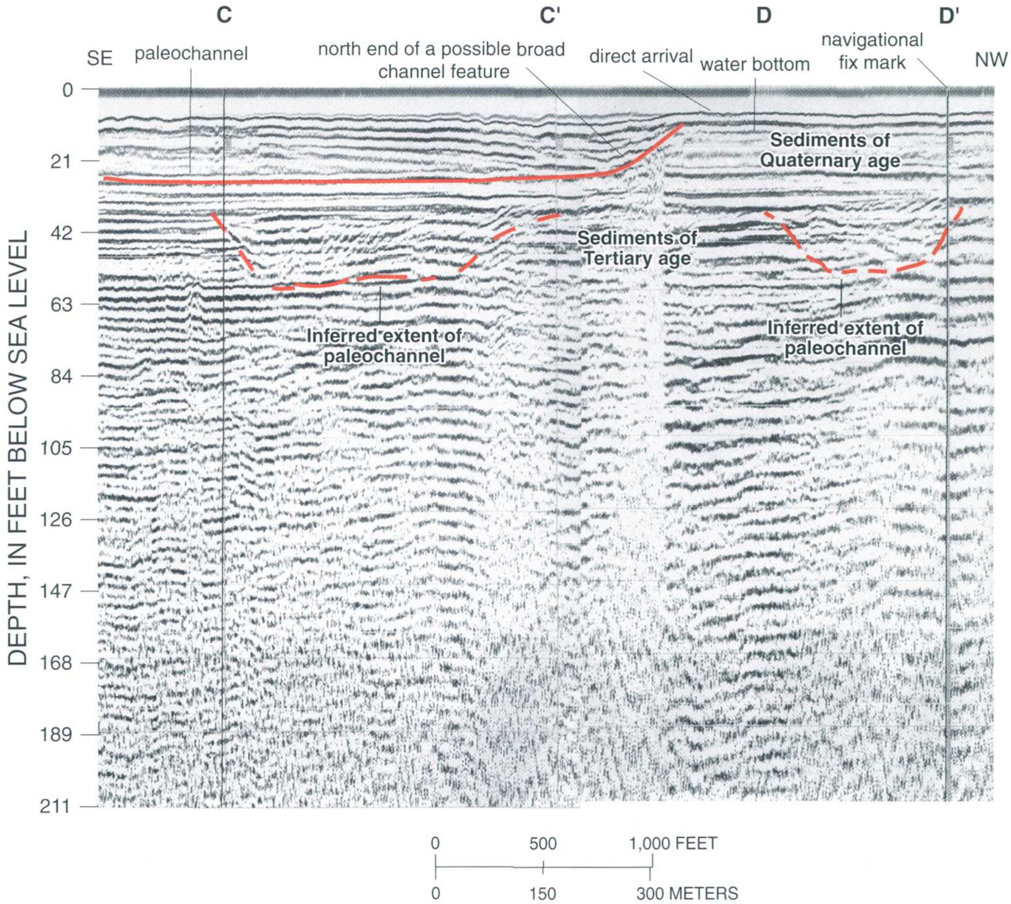

Figure 12. Continuous seismic-reflection profile (C–C' and D–D') of two small paleochannels and the northwestern boundary of a possible broad, shallow, channel feature beneath the Neuse River.

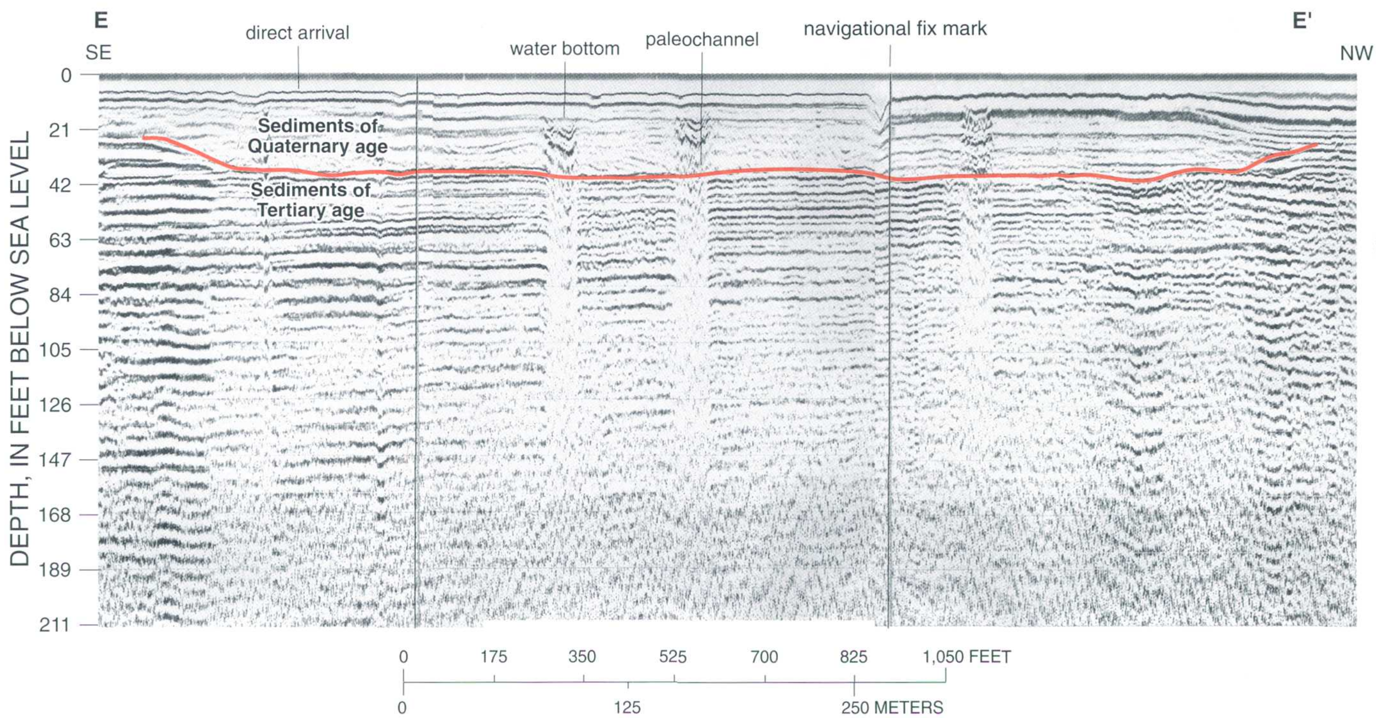

Figure 13. Continuous seismic-reflection profile (E–E') of a paleochannel beneath the Neuse River northeast of Slocum Creek.

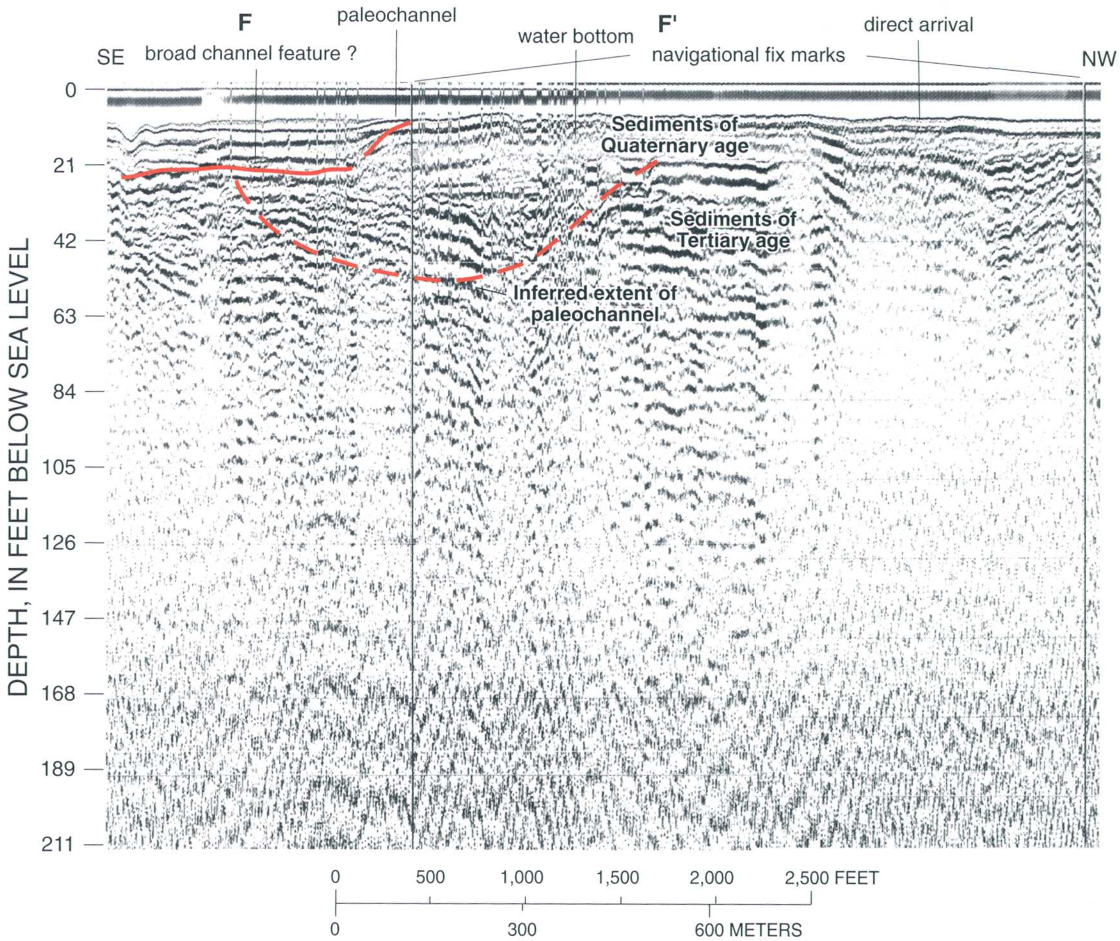

Figure 14. Continuous seismic-reflection profile (F–F') of buried channel feature beneath the Neuse River near Flanner Beach, N.C.

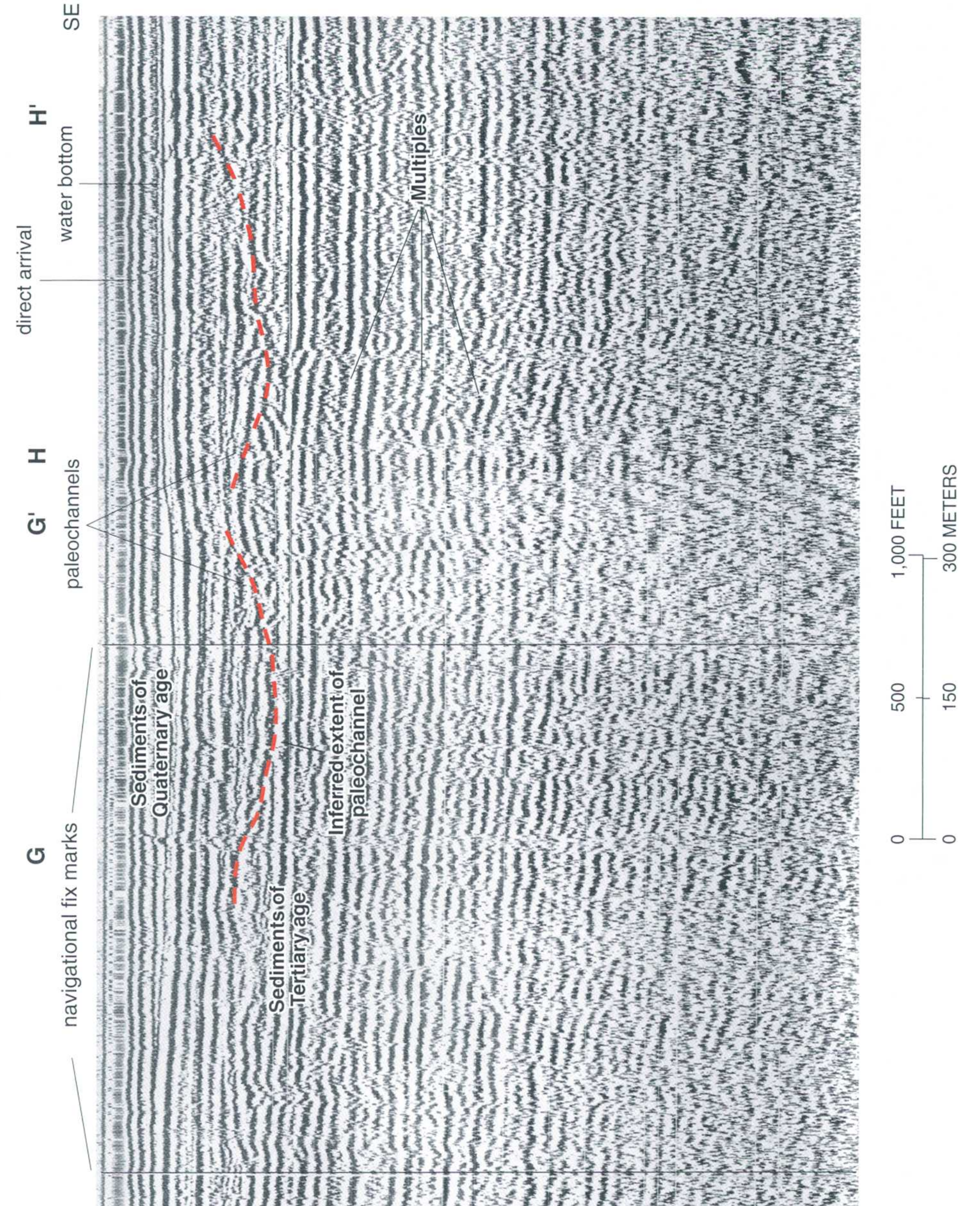

Figure 15. Continuous seismic-reflection profile (G–G' and H–H') of two small paleochannel features located approximately 1.25 miles offshore from Flanner Beach, N.C.

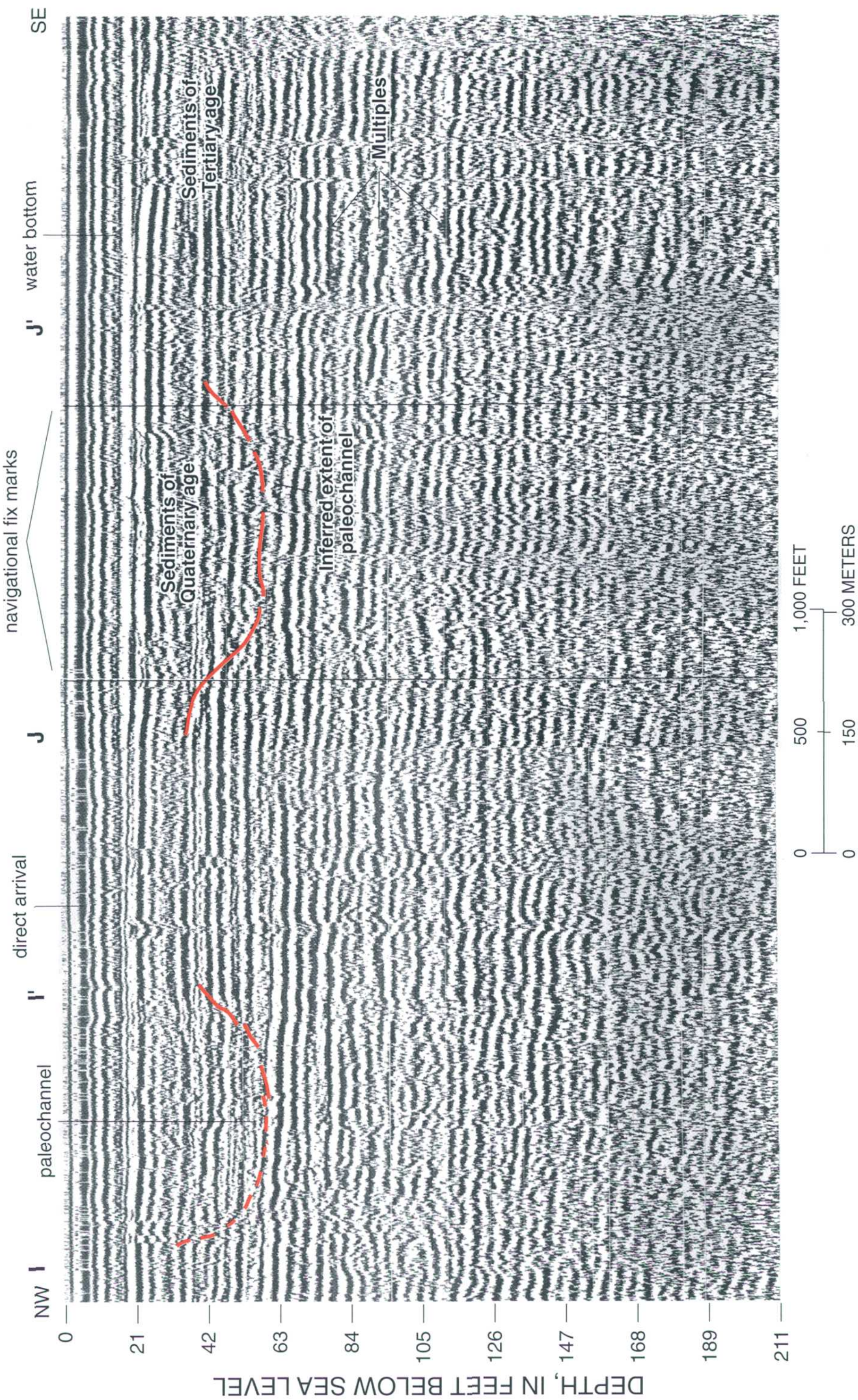

Figure 16. Continuous seismic-reflection profile (I–I' and J–J') of two small paleochannel features located approximately 1.25 miles offshore from Flanner Beach, N.C.

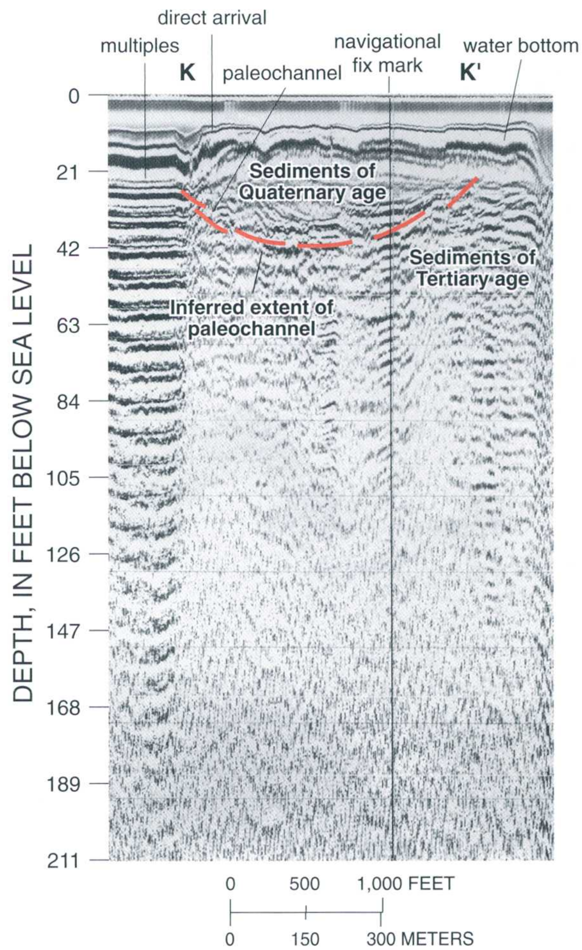

Figure 17. Continuous seismic-reflection profile (K–K') of one small paleochannel located beneath the Neuse River approximately 1.5 miles south of Live Oak Point, N.C.

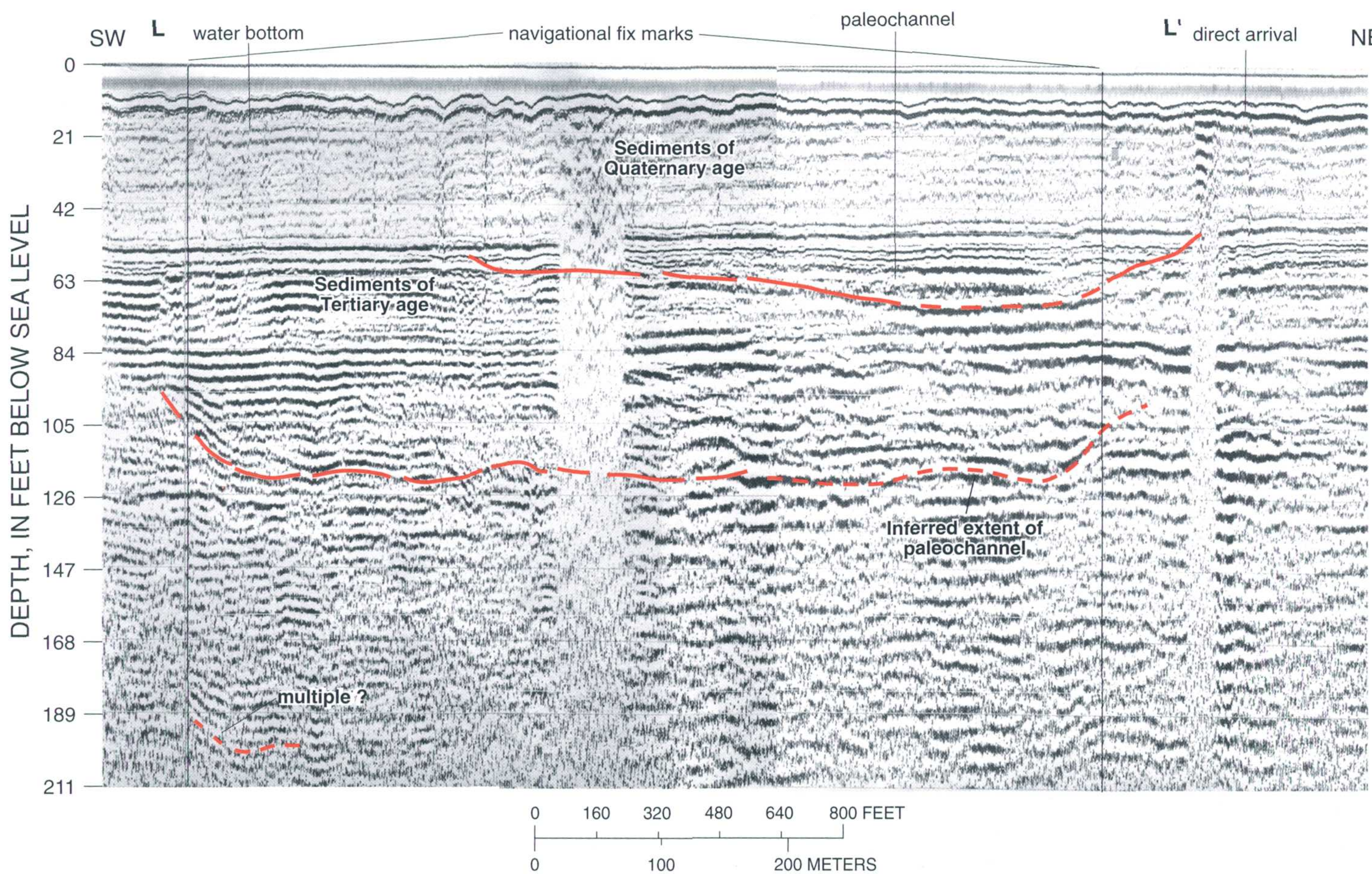

Figure 18. Continuous seismic-reflection profile (L–L') of a paleochannel feature near the Pine Bluff Recreational Area, N.C.

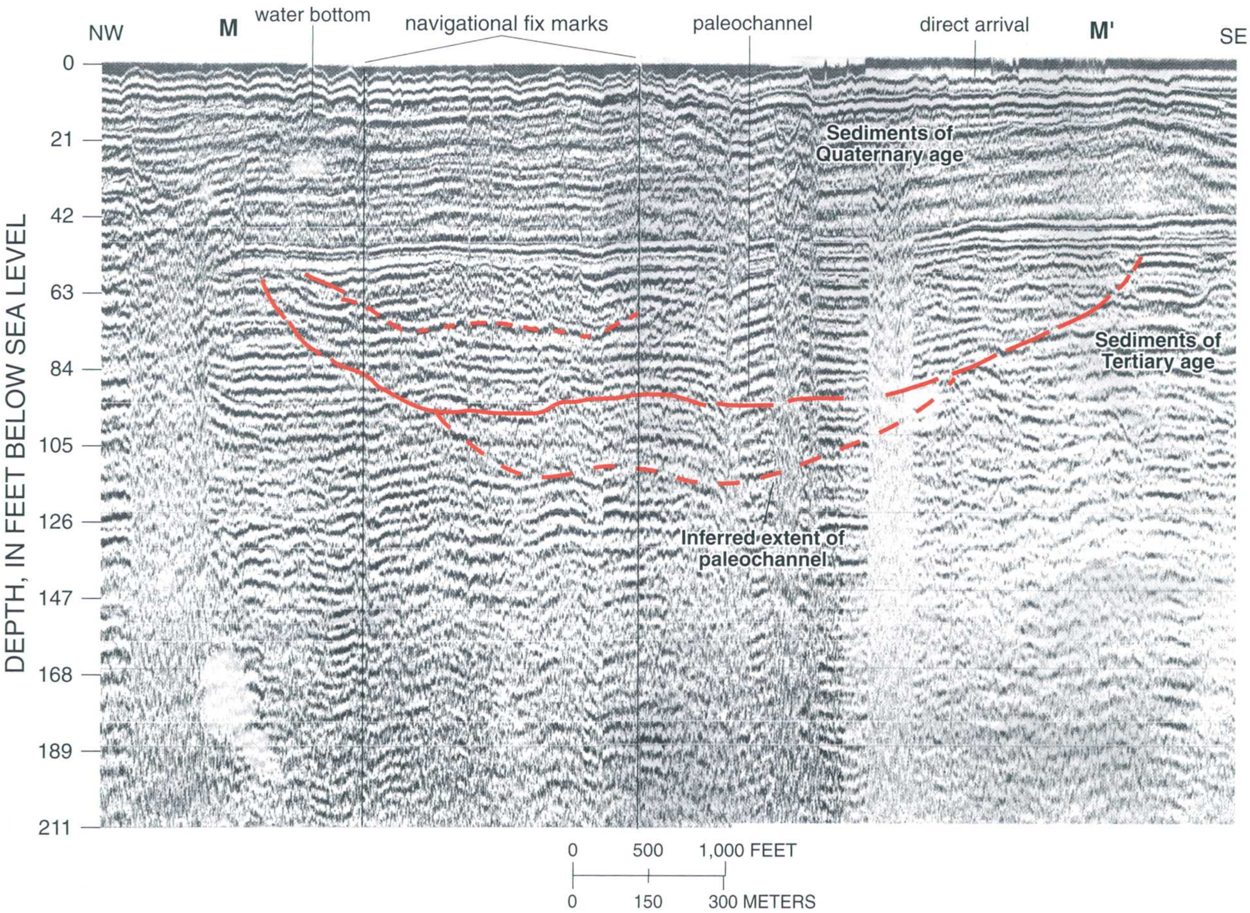

Figure 19. Continuous seismic-reflection profile (M–M') of a paleochannel feature offshore near the Pine Bluff Recreational Area, southeast of the Cherry Point Marine Corps Air Station, N.C.

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Cardinell

Application of Continuous Seismic-Reflection Techniques to Delineate Paleochannels Beneath the Neuse River at U.S. Marine Corps Air Station, Cherry Point, North Carolina

USGS WRIR 99-4099