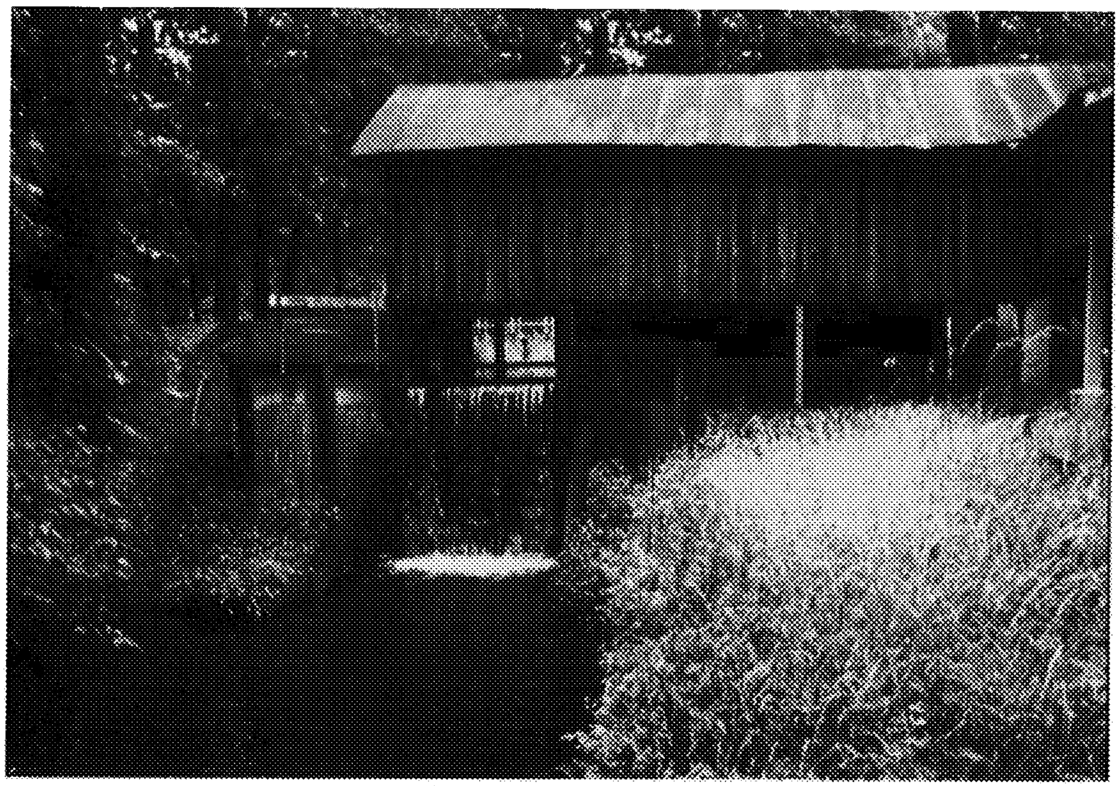
GEOLOGIC, HYDROLOGIC, AND WATER-QUALITY DATA FOR A MULTI-AQUIFER SYSTEM IN COASTAL PLAIN SEDIMENTS NEAR MILLERS POND, BURKE COUNTY, GEORGIA, 1992-93

by
John S. Clarke, William F. Falls, Lucy E. Edwards, Norman O. Frederiksen,
Laurel M. Bybell, Thomas G. Gibson, and Ronald J. Litwin
U.S. Geological Survey



Prepared in cooperation with the

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

U.S. DEPARTMENT OF ENERGY

INFORMATION CIRCULAR 96

Cover Photograph: *Miller's Mill, Burke County, Georgia*
[Photograph courtesy of John S. Clarke, U.S. Geological Survey]

GEOLOGIC, HYDROLOGIC, AND WATER-QUALITY DATA FOR A MULTI-AQUIFER SYSTEM IN COASTAL PLAIN SEDIMENTS NEAR MILLERS POND, BURKE COUNTY, GEORGIA, 1992-93

by

John S. Clarke, William F. Falls, Lucy E. Edwards, Norman O. Frederiksen, Laurel M. Bybell, Thomas G. Gibson, and Ronald J. Litwin

GEORGIA DEPARTMENT OF NATURAL RESOURCES
Joe E. Tanner, Commissioner

ENVIRONMENTAL PROTECTION DIVISION
Harold F. Reheis, Director

GEORGIA GEOLOGIC SURVEY
William H. McLemore, State Geologist

Prepared in cooperation with the

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

U.S. DEPARTMENT OF ENERGY

Atlanta, Georgia

1994

INFORMATION CIRCULAR 96

CONTENTS

ILLUSTRATIONS
[Plate is in pocket in back of report]

TABLES

CONVERSION FACTORS, ACRONYMS AND ABBREVIATIONS, AND VERTICAL DATUM

CONVERSION FACTORS

Multiply	by	to obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
	Flow	
gallon per minute (gal/min)	0.06309	liter per second
	Concentration	
part per million	1	milligrams per liter (mg/L)
	1,000	micrograms per liter (µg/L)
picocurie per liter	3.19	tritum unit
	Specific conductance	
micromho per centimeter at 25° Celsius (µmhos/cm at 25 °C)	1	microsiemens per centimeter at 25 ° Celsius (µS/cm at 25 °C)

Temperature

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

$$°C = 5/9\,(°F-32)$$

ACRONYMS AND ABBREVIATIONS

EPA	U.S. Environmental Protection Agency
EPD	Georgia Environmental Protection Division
DIC	Dissolved inorganic carbon
DNR	Georgia Department of Natural Resources
DOE	U.S. Department of Energy
SRS	Savannah River Site
TOC	Total organic carbon
USGS	U.S. Geological Survey

VERTICAL DATUM

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

GEOLOGIC, HYDROLOGIC, AND WATER-QUALITY DATA FOR A MULTI-AQUIFER SYSTEM IN COASTAL PLAIN SEDIMENTS NEAR MILLERS POND, BURKE COUNTY, GEORGIA, 1992-93

by

John S. Clarke[1/], William F. Falls[1/], Lucy E. Edwards[1/], Norman O. Frederiksen[1/], Laurel M. Bybell[1/], Thomas G. Gibson[1/], and Ronald J. Litwin[1/]

ABSTRACT

The Millers Pond test site, in northeastern Burke County, Georgia, was constructed during 1991-92 to better characterize the geologic, hydrologic, and water-quality characteristics of a multi-aquifer system in Coastal Plain sediments. These data are presented for 1992-93. The test site consists of a continuously cored 859 feet (ft) deep hole that penetrated the entire thickness of Coastal Plain sediments, and seven test wells developed at depths ranging from 80 to 735 ft. Lithologic and paleontologic examination of core indicated that there are at least 11 distinct lithologic units of Late Cretaceous through Eocene age at the site, having a total thickness of 852 ft. The test wells were screened in the Upper Three Runs aquifer, Dublin aquifer system, and Midville aquifer system. Upon completion and development of each well, a 72-hour aquifer test was conducted, water samples were collected and analyzed for chemical constituents, and continuous water-level recorders were installed.

Water-level fluctuations in wells completed in the confined aquifers at the Millers Pond test site were coincident and appear to mostly represent a mass-loading response to fluctuations of Savannah River stage, about 2 miles east of the site. Water-levels in the Upper Three Runs (water table) aquifer, however, showed little similarity to water levels in wells completed in the deeper confined aquifers, and are apparently influenced by precipitation, evapotranspiration, and possibly pumping.

Water from each of the seven zones screened at the Millers Pond test site is of good quality and low in dissolved solids. Concentrations of iron, however, exceed the U.S. Environmental Protection Agency's secondary drinking-water standards in all zones except the Upper Three Runs aquifer. Water from the Upper Three Runs (water table) aquifer contained 730 picoCuries per liter (pCi/L) of tritium. Tritium at concentrations slightly above the 1 pCi/L detection limit were measured in two wells screened in the upper part of Dublin aquifer system.

Although layers of clay and silt separate the screened intervals of wells completed in the Dublin and Midville aquifer systems, the uniform distribution of head, similarity of water-level fluctuations and water chemistry, and drawdown response during aquifer tests, indicate that parts of the two aquifer systems are hydraulically connected. Conversely, the uppermost part of the Dublin aquifer system seems to be hydraulically separated from adjacent water-bearing zones.

[1/]U.S. Geological Survey.

INTRODUCTION

The U.S. Department of Energy (DOE), Savannah River Site (SRS), has manufactured nuclear materials for the National defense since the early 1950's. A variety of hazardous materials, including radionuclides, volatile organic compounds, and heavy metals, are either disposed of or stored at several locations at the SRS. Contamination of ground water has been detected at several locations within the site (Westinghouse Savannah River Company, 1993, p. 12). Concern has been raised by State of Georgia officials over the possible migration of contaminated ground water through aquifers underlying the Savannah River (trans-river flow) into Georgia.

The U.S. Geological Survey (USGS), in cooperation with the DOE and Georgia Department of Natural Resources (DNR), is conducting a study to delineate the components of ground-water flow and water quality near the Savannah River. Stream-aquifer relations will be evaluated to determine the potential movement beneath or discharge into the Savannah River. The overall objectives of this study are to identify ground-water flow paths, quantitatively describe ground-water flow, and evaluate stream-aquifer relations between the Savannah River and underlying aquifers. The potential for trans-river flow will be evaluated under both current conditions and under selected hypothetical pumping scenarios.

The geologic, hydrologic, and water-quality characteristics of aquifers and confining units will be characterized to support the analysis. Accordingly, a test-drilling program was initiated and data collected and analyzed to determine the geologic, hydrologic, and water-quality characteristics of Coastal Plain sediments near the Savannah River (fig. 1). Clusters of test wells are being constructed in major aquifers at several locations along the Savannah River in Georgia (fig. 1).

Purpose and Scope

The purpose of this report is to present geologic, hydrologic, and water-quality data collected at the Millers Pond test site in northeastern Burke County, Ga. Data collected include the depth, thickness, geologic properties, paleontology (fossil content and identification), and water chemistry of the Coastal Plain aquifers at the site. These data, presented in graphs, tables, and diagrams, will provide correlations of stratigraphy and ground-water flow-system characteristics. Records of all data collected at the site are on file at the U.S. Geological Survey District Office, Atlanta, Ga.

The objectives of the test-drilling project were to (1) obtain core samples for geologic testing and paleontologic (fossil) examination; (2) obtain geophysical logs to aid in the description and definition of the lithology and physical characteristics of the sediments penetrated; (3) determine water quality from discrete water-bearing zones; (4) determine the pressure head at selected water-bearing intervals; and (5) determine hydraulic properties of water-bearing zones (not described in this report).

Description of Study Area

Sediments in the Atlantic Coastal Plain physiographic province consist of alternating layers of sand, silt, clay, and lesser amounts of limestone that dip southeastward forming several aquifers and confining units. Although data in South Carolina are plentiful, limited geologic, hydrologic, and water-quality data are available in Georgia to determine the characteristics of these aquifers and confining units adjacent to the Savannah River.

The Millers Pond test site is located in northeastern Burke County, about 16 miles (mi) south of Augusta, Ga., about 12 mi northeast of Waynesboro, Ga., and about 2 mi west of the Savannah River (fig. 1). The altitude of the site ranges from about 242 to 243 ft above sea level, as determined by use of a global positioning system.

Well-Numbering System

Each of the test wells at the Millers Pond test site were numbered according to the order of drilling; that is, test well 1 (TW-1) was the first well completed, TW-2 was the second, and so on. In addition to these project well numbers, wells in Georgia also are numbered according to a system based on the USGS index of topographic maps. Each 7 1/2-minute topographic quadrangle in the State has been given a number and letter designation beginning at the southwest corner of the State. Numbers increase eastward and letters advance alphabetically northward. Quadrangles in the northern part of the area are designated by double letters. The letters "I", "II", "O", and "OO" are omitted. Wells inventoried in each quadrangle are numbered consecutively beginning with 1. Thus, the 17th well numbered in the 30Z quadrangle is designated 30Z017.

Acknowledgments

The authors gratefully acknowledge the cooperation and assistance of Mr. M.A. Miller, who provided access to the Millers Pond property. David C. Prowell, geologist, USGS, provided valuable assistance and guidance regarding geologic interpretations at the site. Jerry Moore, Sally Benson, David Snipes, John Daggett, April James, and Sadie Price, Clemson University, conducted aquifer tests at the site, providing valuable information regarding aquifer interconnection. Robert Kalin, University of Georgia, provided assistance in the analysis of tritium in water samples.

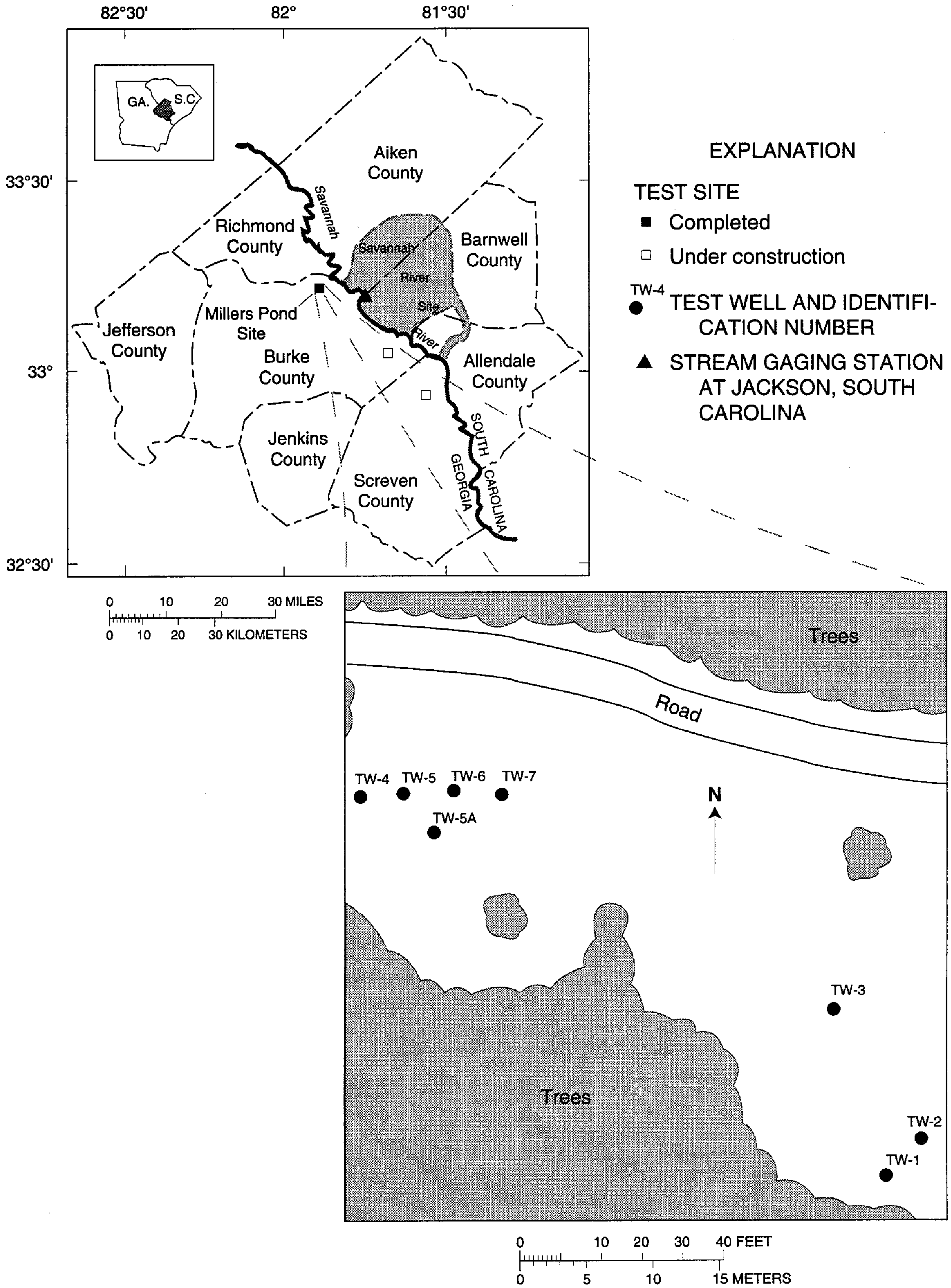


Figure 1. Location of Millers Pond test site, test wells drilled at the site, and other test sites.

WELL CONSTRUCTION AND CORING

During July 1991, a corehole penetrating Coastal Plain sediments and terminating in pre-Cretaceous basement rock was completed at the Millers Pond test site. Continuous, 2-in. diameter core samples were collected from a depth of 10 ft to a total depth of 859 ft using the wire-line coring method. The core samples were used to determine lithology, grain size, sand/clay ratio, and environment of deposition. The paleontology of selected core samples provided age control for the time of deposition. Borehole geophysical logs were not collected because of excessive caving problems and the corehole was abandoned. In December 1991, a second borehole was completed to a depth of 859 ft near the location of the abandoned corehole and borehole geophysical logs were collected.

To help characterize the vertical distribution of hydraulic head and water chemistry of Coastal Plain sediments at the Millers Pond test site, test wells were drilled and completed in seven water-bearing intervals at depths ranging from 80 to 735 ft. An attempt was made to position a screen at the top and base of each major aquifer system to determine the vertical head gradient and possible contrasts in hydraulic properties and water quality across the unit. Screened intervals for each well were positioned in layers having relatively higher sand content surrounded by clay beds of relatively lower permeability, as was determined by examination of core and geophysical logs. Screened intervals were made as large as possible (up to a maximum thickness of 40 ft) to allow adequate pumping rates during aquifer tests. Construction characteristics of the seven wells are shown on figures 2-8, and are summarized in table 1.

TW-1, completed in February 1992, was constructed from the second 859-ft boring using a 6-in. diameter steel casing and a telescoped 4-in. diameter steel casing and stainless-steel screen line (fig. 2). The 6-in. diameter steel casing was installed to a depth of 690 ft and pressure grouted in place. The 4-in. diameter casing and screen line then was telescoped from a depth of 684 ft using a lead K-packer. Initial plans were for installation of a sand filter pack; however, excessive caving of fine-grained sands from the interval 705-735 ft required that the well be completed without a filter pack. A 10-ft sediment sump of 4 in. casing with endcap was emplaced at 735-745 ft.

Problems associated with the construction of TW-1 forced a change in planned well construction. In subsequent wells (TW-2 through TW-7), a continuous 6-in. casing and screen line was used (figs. 3-8). In this procedure, the casing and screen line is placed in the borehole, and the filter pack, bentonite seal, and grout are emplaced in the annular space using a tremie pipe. TW-2, TW-3, and TW-7 were completed using a 6-in. diameter steel casing and stainless-steel screen line (figs. 3, 4, and 8). In the three shallowest wells (TW-4, TW-5a, and TW-6) 6-in. threaded and coupled polyvinyl chloride (PVC) casing and stainless-steel screen were used (figs. 5-7). PVC casing was used for the three shallowest wells because of its lower cost; whereas, steel casing was required in deeper wells because of its resistance to collapse. A 10-ft long sediment sump was emplaced beneath the screened interval in TW-2, TW-3, TW-4, TW-5a, and TW-6; a 5-ft long sediment sump was emplaced beneath the screened interval in TW-7.

TW-5 was installed in April 1992 using 6-in. PVC casing and stainless-steel screen. Subsequent well development showed that during construction, the screen line separated from the casing and left a gap open to the formation sand. After several attempts to stop sand infiltration into the well, it was abandoned and back-filled with cement grout. Another well (TW-5a) was completed adjacent to TW-5 during October 1992 using similar construction specifications as TW-5 (fig. 6).

Test wells 1, 2, 3, 4, 5a, 6, and 7 were developed using air surging and jetting techniques. Development of TW-3 also involved use of a polyphosphate deflocculant to aid in breaking down the drilling-mud cake on the borehole wall. Development in each of the seven wells continued until the return water was free of drilling mud and sand.

GEOLOGIC DATA

Coastal Plain sediments underlying Burke County range in age from Late Cretaceous to Holocene and consist of units of sand, silt, clay, and minor amounts of limestone. Lithologic and paleontologic evidence from the Millers Pond core suggests that at least 11 distinct lithologic units are present in the vicinity of the site, having a total thickness of 852 ft (plate 1). A generalized correlation of units of Late Cretaceous through Eocene age in the southeastern United States is shown in figure 9. These sediments unconformably overlie igneous and metamorphic rocks of Paleozoic age and consolidated red beds of early Mesozoic age (Chowns and Williams, 1983).

Lithology

Lithologic and geophysical characteristics of sediments at the Millers Pond test site are shown graphically on plate 1. A detailed description of the lithology, grain size and sorting, induration, texture, contact relations, and physical and biogenic sedimentary structure of core collected at the Millers Pond test site is shown in the Appendix. Textural classification of siliciclastic sediments, listed in the Appendix, was adapted from a standard grain-size scale (Wentworth, 1922) and includes: clay (less than 0.020 millimeters (mm)), silt (0.020 - 0.065 mm), sand (0.065 - 2.00 mm), granules (2.00 - 4.00 mm), and pebbles (4-64 mm). Sand-size

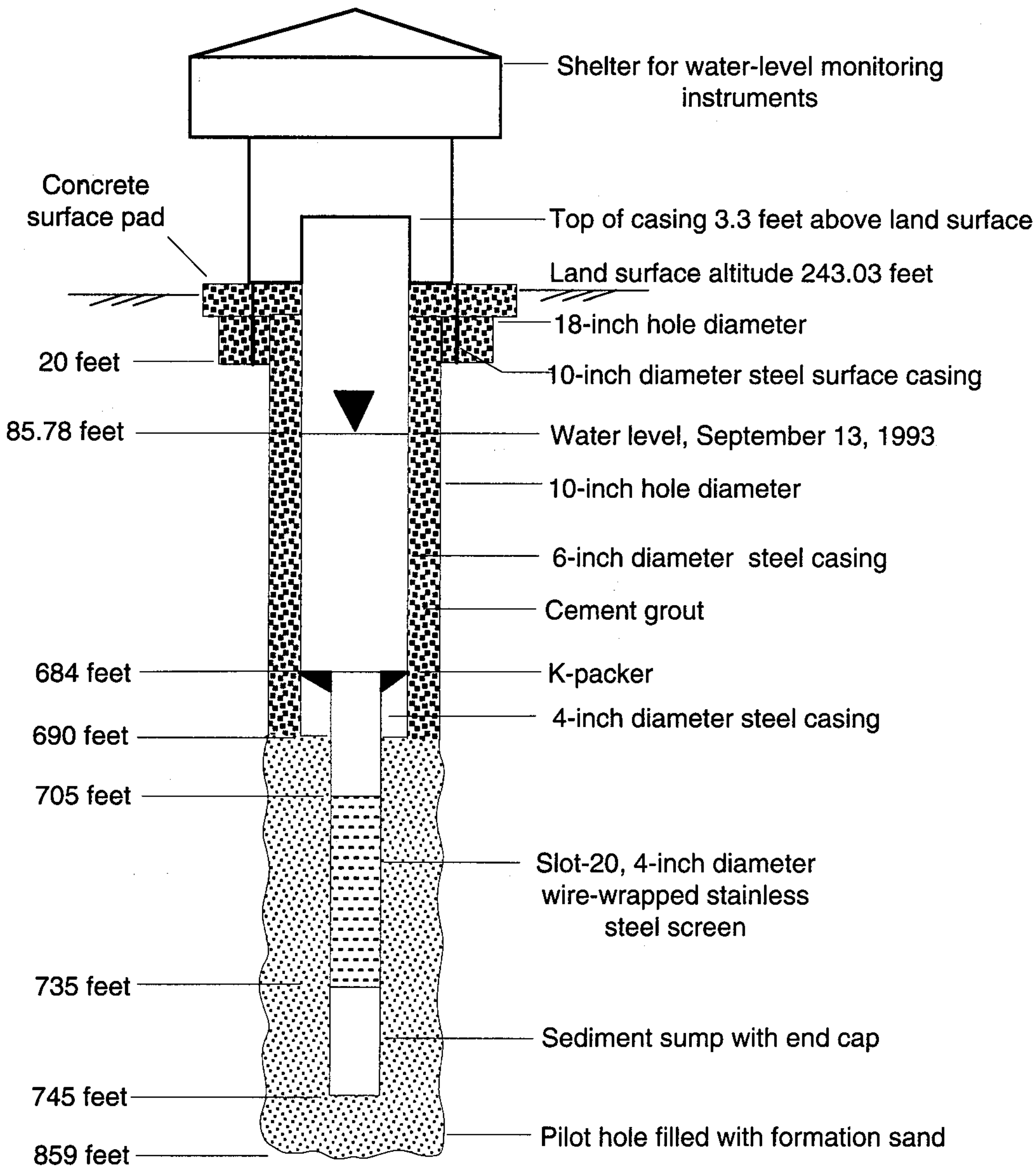


Figure 2. Schematic diagram of Millers Pond test well 1. Footages are depths below land surface.

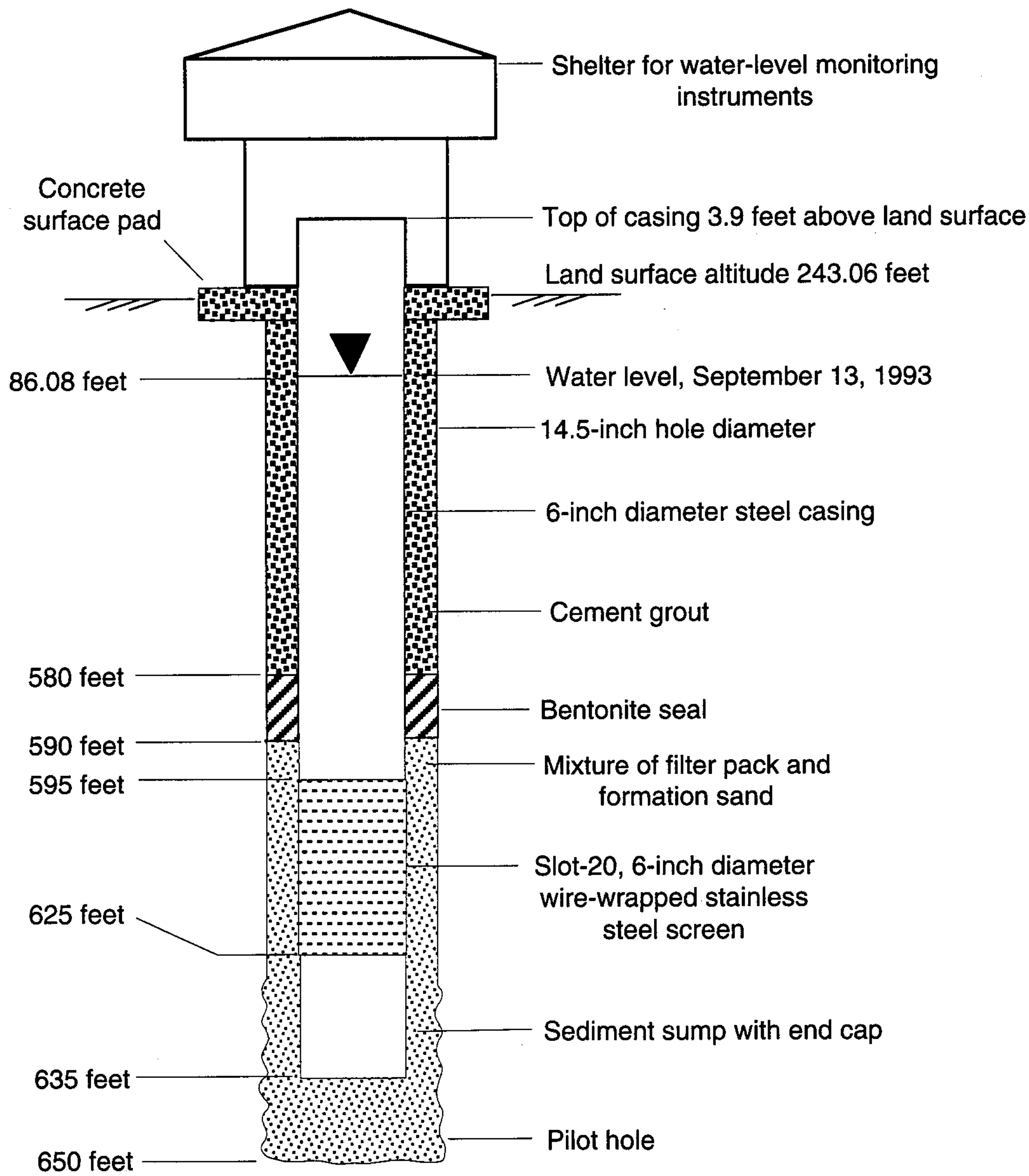


Figure 3. Schematic diagram of Millers Pond test well 2. Footages are depths below land surface.

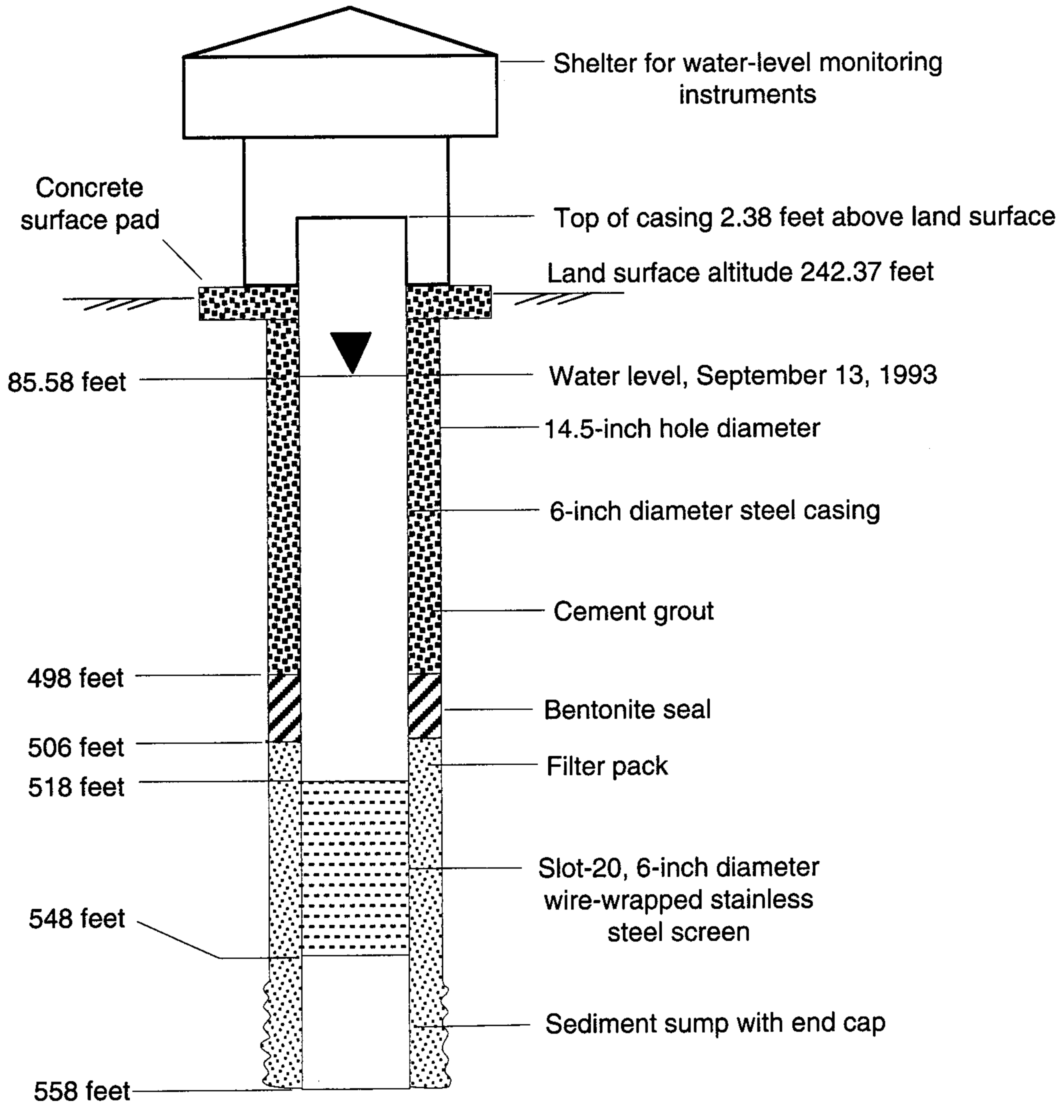


Figure 4. Schematic diagram of Millers Pond test well 3. Footages are depths below land surface.

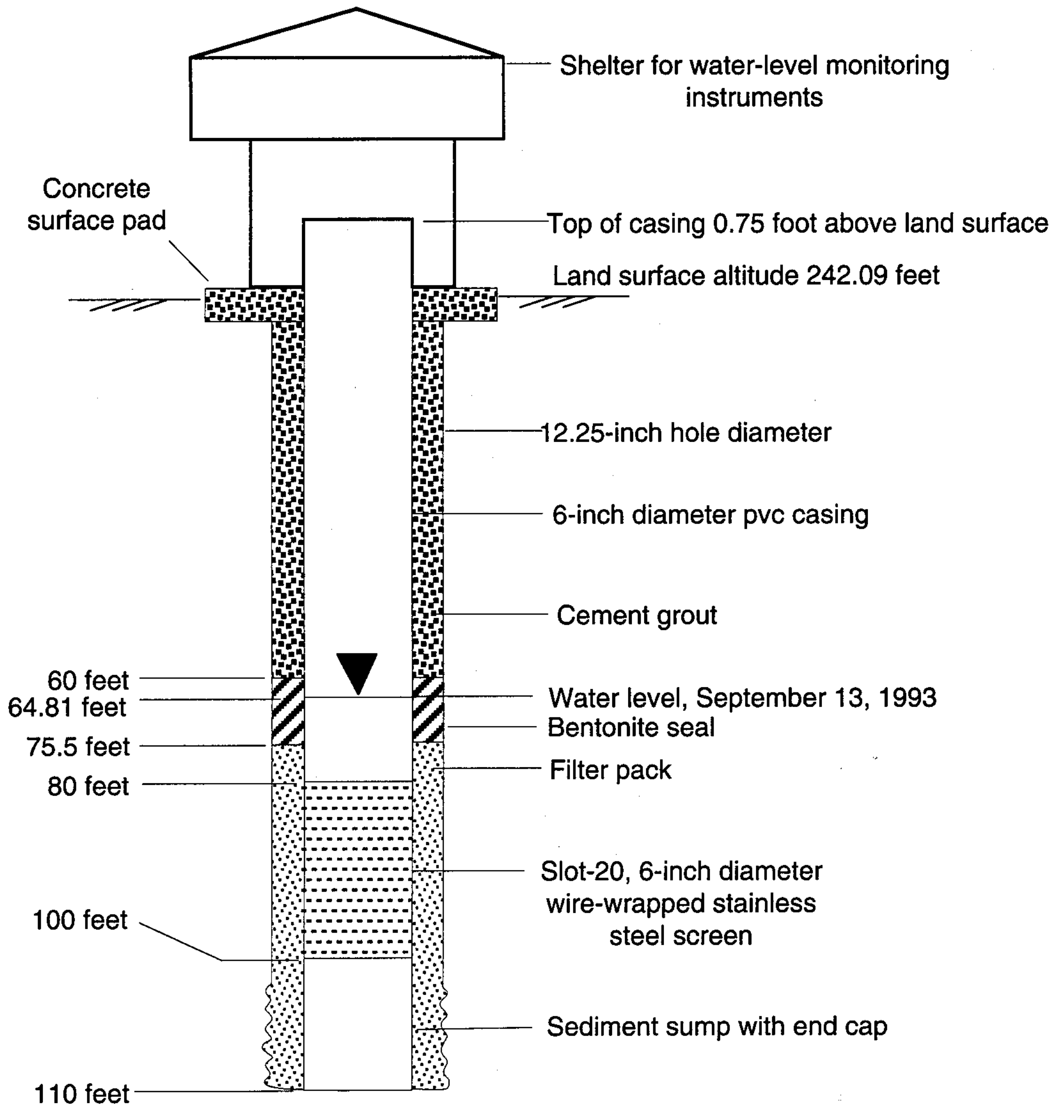


Figure 5. Schematic diagram of Millers Pond test well 4. Footages are depths below land surface.

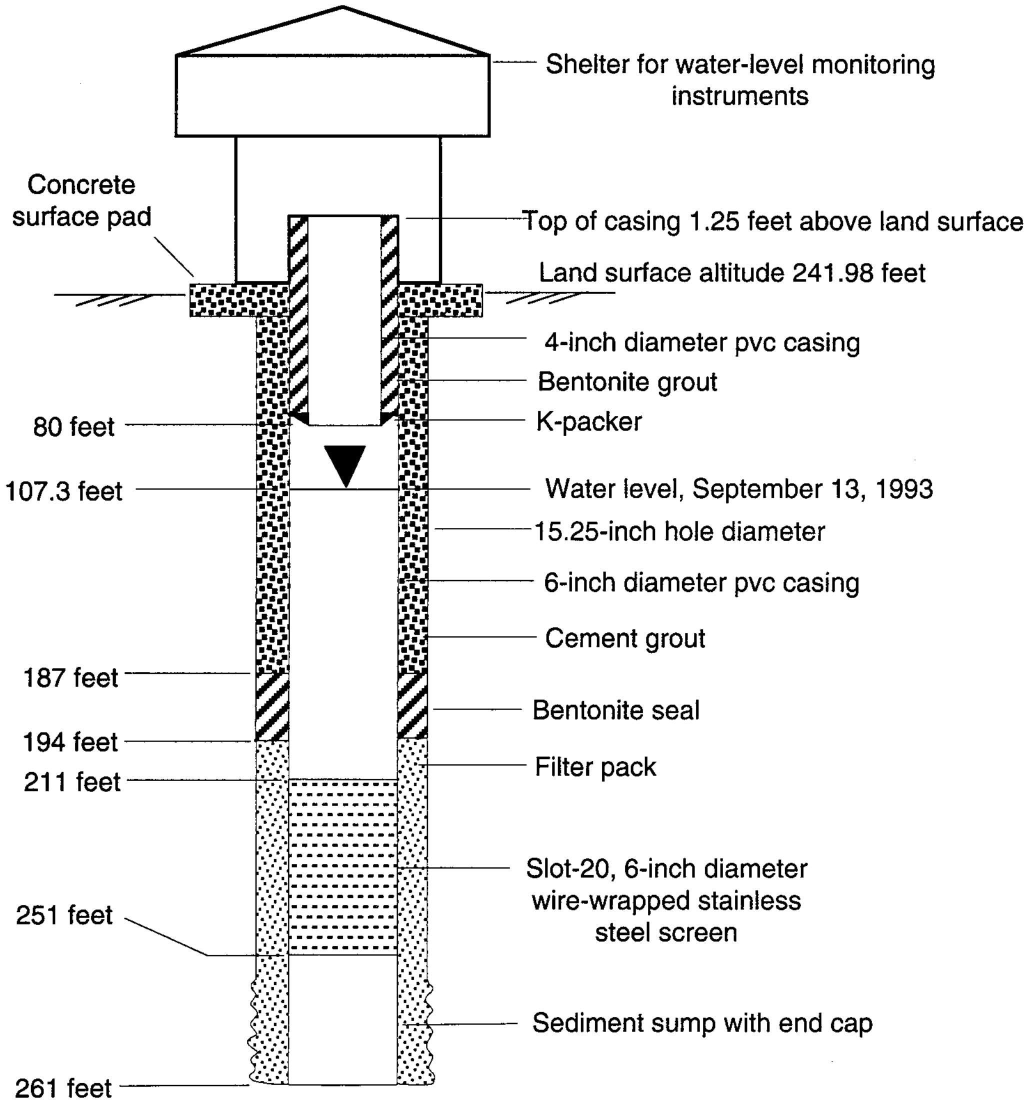


Figure 6. Schematic diagram of Millers Pond test well 5a. Footages are depths below land surface.

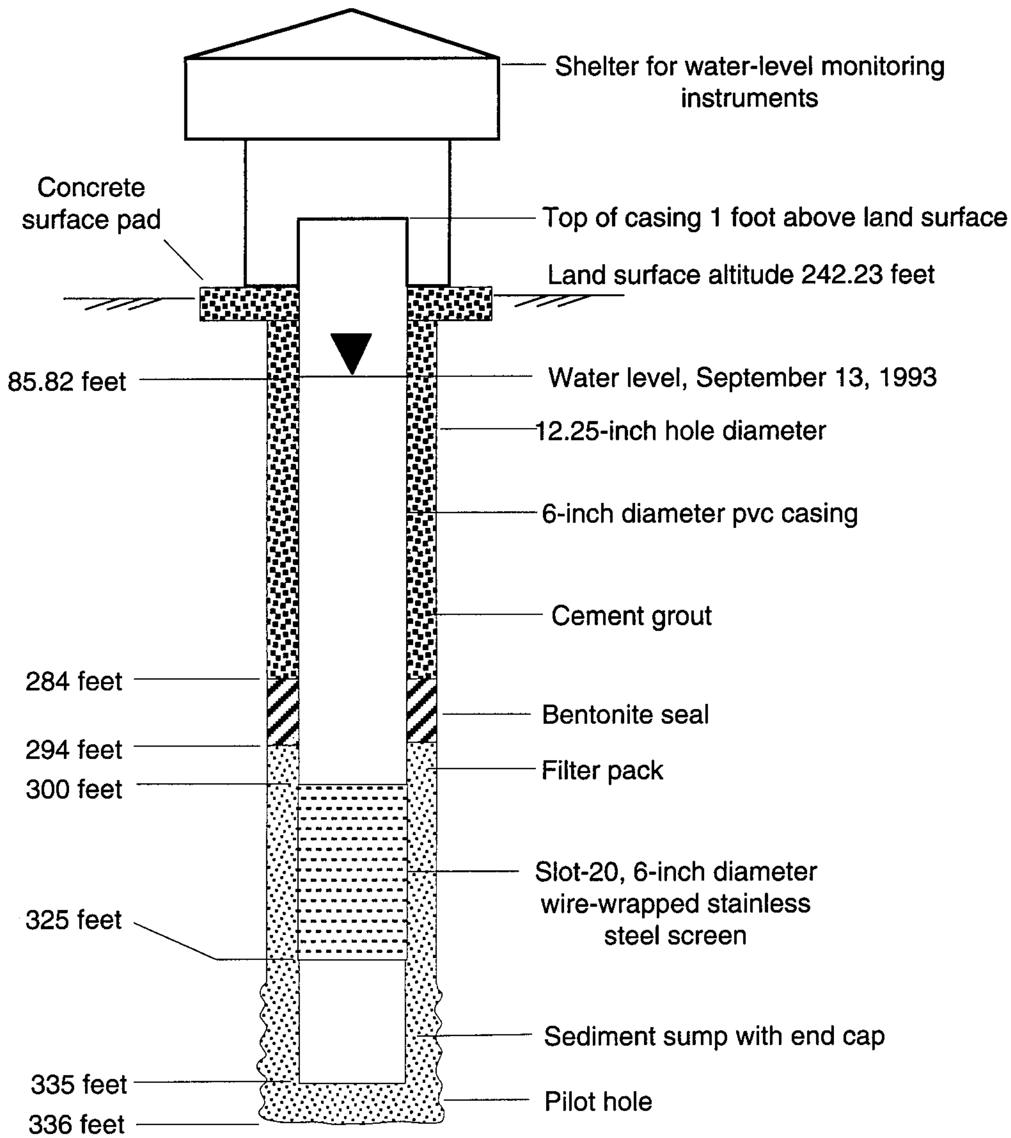


Figure 7. Schematic diagram of Millers Pond test well 6. Footages are depths below land surface.

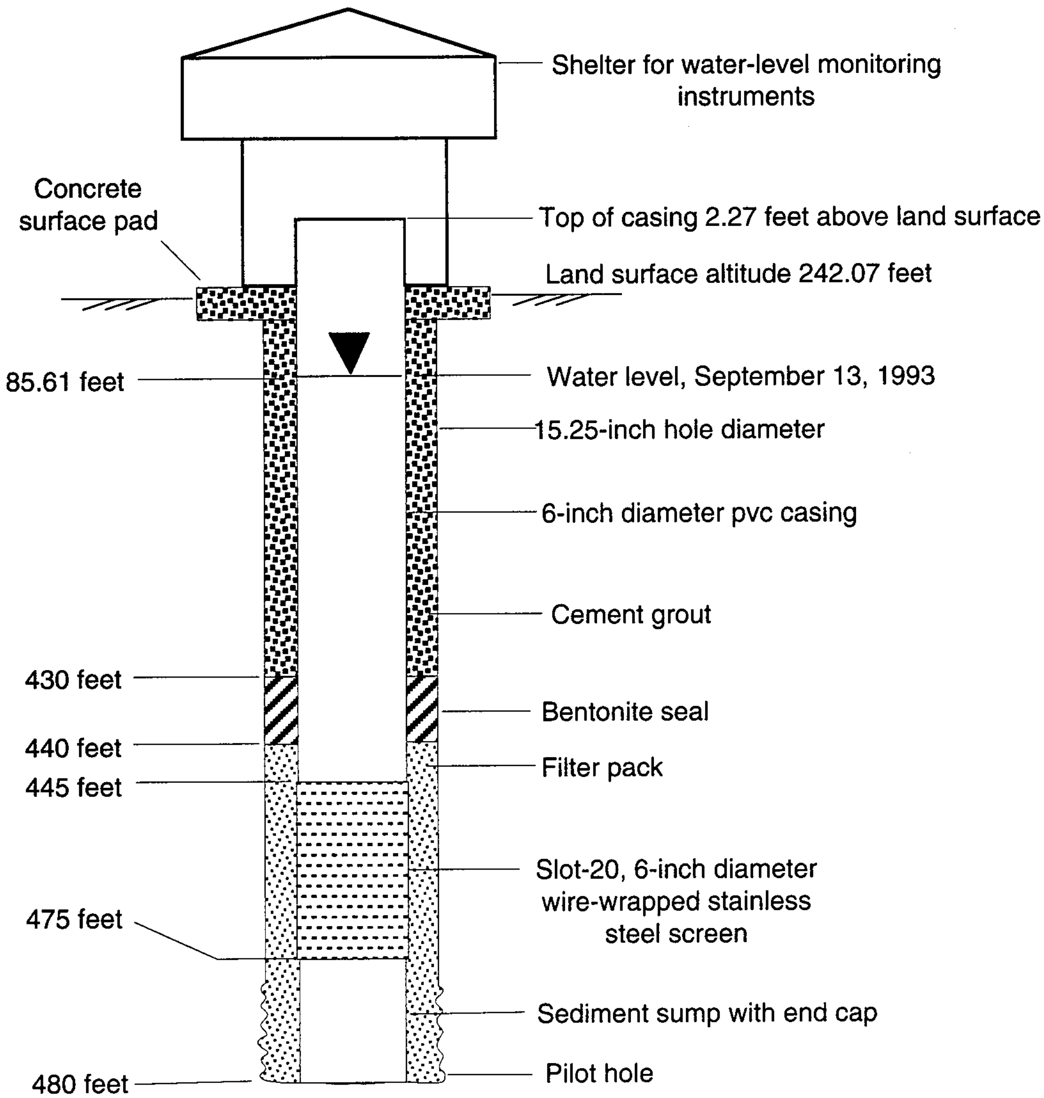
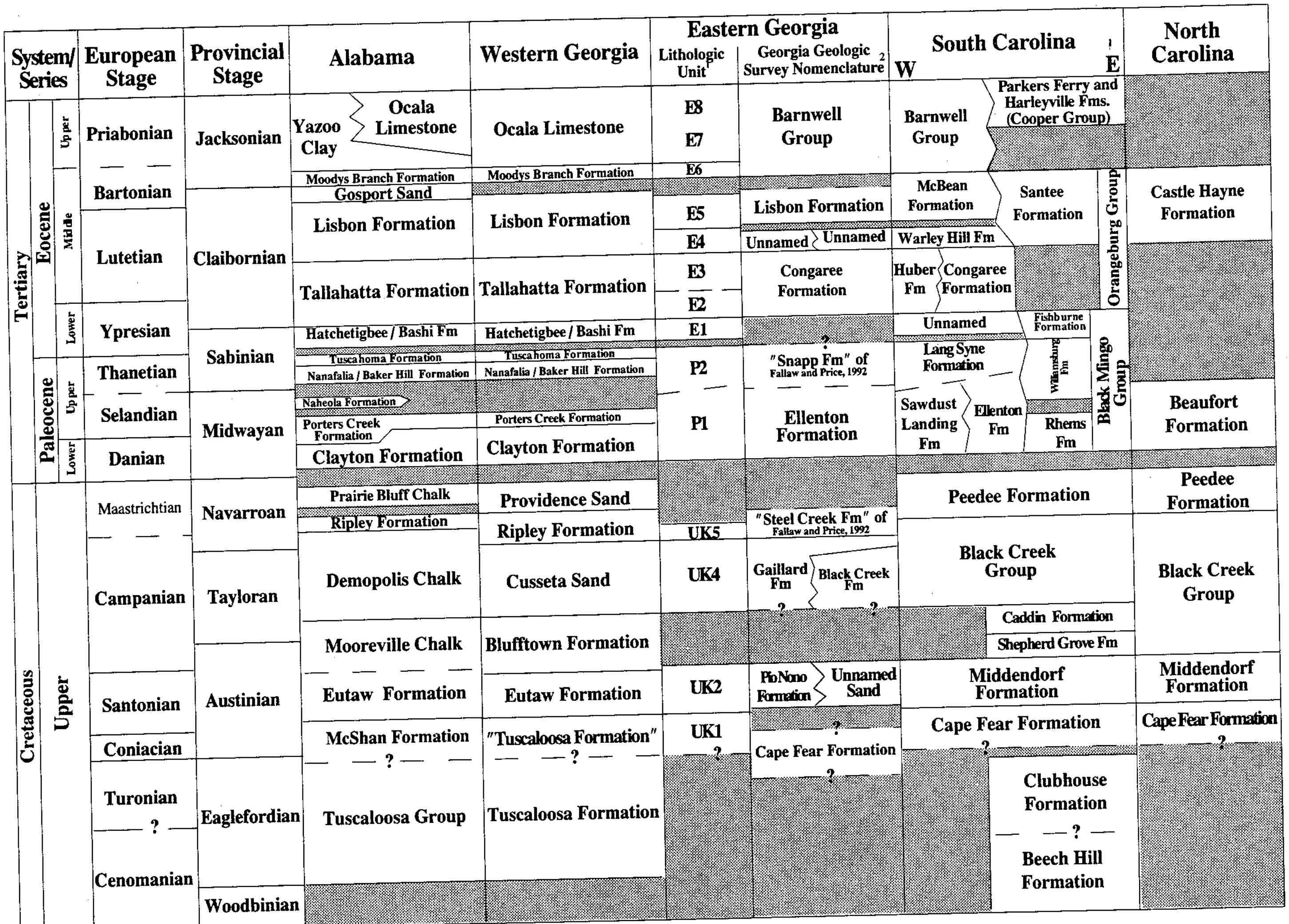


Figure 8. Schematic diagram of Millers Pond test well 7. Footages are depths below land surface.



1 Modified from Prowell and others, 1985

2 Paul F. Huddlestun, Georgia Geologic Survey, personnal commun., January 1994.

Figure 9. Generalized correlation of units of Late Cretaceous through Eocene age in the southeastern United States. Areas of shaded pattern indicate missing stratigraphic interval. Abbreviations used: Fm, formation.

grains are further subdivided into five classes: very fine (0.065 - 0.125 mm), fine (0.125 - 0.250 mm), medium (0.250 - 0.500 mm), coarse (0.500 - 1.000 mm), and very coarse (1.000 - 2.000 mm). Grain-size distribution and sorting of siliciclastic framework grains was based on visual classification of sand grains, granules, and pebbles. In this report, granules and pebbles are considered to be grain-size classes in estimates of sorting.

Categories of sorting were based on the number of grain-size classes observed in a sediment sample and are herein defined as: well sorted (one grain-size class), moderately sorted (two grain-size classes), poorly sorted (three or four grain-size classes), and very-poorly sorted (five or more grain-size classes). The size of heavy minerals, mica grains, clasts, lignite, and carbonate grains, and the abundance of matrix were not considered in sorting estimates.

Categories of induration for siliciclastic sediment depended on the amount of matrix and cement present. Samples from this core were categorized as: loose (grains are not bound by cement or clay matrix); clay-bound (framework grains are bound in a soft clay matrix); and friable (framework grains are bound in a hardened clay matrix and cement).

The textural classification of carbonates was based on the distribution and abundance of carbonate matrix and grains (Dunham, 1962). A mudstone contains less than 10 percent carbonate grains in a matrix-supported texture. A wackestone contains more than 10 percent carbonate grains in a matrix-supported texture. A packstone has a grain-supported texture having a carbonate matrix. A grainstone consists of carbonate grains without a matrix. Carbonates in core from the Millers Pond site are predominantly calcite and some aragonite. Carbonates are described as either loose, partially lithified, or lithified.

The Geological Society of America (GSA), Rock Color Chart (Geological Society of America, 1991), was used to identify the color of sediments. Color or colors for an interval are given as a written description using a GSA color code.

Micropaleontology

Paleontologic data provided geologic age, and paleontologic and lithologic data provided environment of deposition for several geologic units at the Millers Pond site. Twenty-five samples were examined for dinoflagellates, pollen, benthic foraminifers, and calcareous nannofossils, and 11 of the samples yielded age-diagnostic assemblages. The locations of samples are shown on plate 1 as small triangles adjacent to the lithologic column.

Palynomorphs from sample 1 (827-828 ft) include *Complexiopollis abditus*, *Complexiopollis* sp. D, *Complexiopollis* sp. E, *Complexiopollis* sp. I, *Momipites fragilis*, *Momipites* sp. I, *Praecursipollenites* sp. A, and *Santalacites minor*. Sample 2 (797-802 ft) contains *Complexiopollis exigua*, *Complexiopollis* sp. D, *Complexiopollis* sp. H, *Momipites* sp. H, and *Praecursipollenites* sp. A. Palynomorphs in these two samples suggest that this assemblage is correlative with the *Complexiopollis exigua-Santalacites* minor pollen zone (Zone V-A) of Christopher (1979) and Christopher and others (1979). Recently, this zone has been correlated with the Coniacian stage (Sohl and Owens, 1991). Previous correlations of this zone were more encompassing and included middle to late Turonian (Christopher, 1979a) and Santonian (Christopher, 1982b). Sohl and Owens (1991) correlate pollen zone V-A with the Cape Fear Formation in the Carolinas and the McShan Formation in western Alabama. The lack of both marine palynomorphs (dinocysts, acritarchs) and microforaminiferal linings suggests a nonmarine environment of deposition.

The pollen assemblage from sample 3 (517 ft) probably is correlative to pollen zone CA-4 of Wolfe (1976) and includes *Complexiopollis* sp. D, *Proteacidites* sp. (equivalent to PR-1 of Wolfe, 1976), and forms labeled CP3B-5, C3B-2, C3C-3, and NB-3 by Wolfe (1976). Zone CA-4 was correlated to the upper part of the lower Campanian and to part of the Tar Heel Formation of the Black Creek Group by Sohl and Owens (1991). The absence of marine dinocysts and microforaminiferal linings in this sample suggests a nonmarine environment of deposition.

Sample 4 (252-257 ft) contains diagnostic pollen species *Porocolpopollenites ollivierae* and dinocyst species *Carpatella cornuta* and *Spinidinium pulcherum*. The combination of these taxa place the age of this sample in the late part of the early Paleocene or the early part of the late Paleocene (Frederiksen, 1991; Williams and others, 1993). Sample 5 (237-242 ft) was only examined for dinocysts. It contains *Andalusiella* sp. aff. *A polymorpha*, Peridiniacean cyst sp. B, and Peridiniacean cyst sp. C of Edwards (1980). These species co-occur in the Porters Creek Formation in Alabama (Edwards, 1980), but the upper limits of their age ranges have not been documented. Both samples are correlative with unit P1 of Prowell and others (1985). The forms suggest a nearshore-marine environment of deposition.

Sample 6 (165 ft) contains both pollen and dinoflagellates. Pollen include *Caryapollenites prodromus* group or *Subtriporopollenites anulatus*, *Nudopollis terminalis*, *Tricolpites asper*, and *Betula infrequens*. The dinoflagellates include *Adnatosphaeridium* sp., *Cribroperidinium giuseppei*, *Diphyes colligerum*, *Operculodinium centrocarpum*, *Phthanoperidinium echinatum*, *Polysphaeridium zoharyi*, *Pentadinium favatum* (primitive forms), *Spiniferites* spp., *Turbiosphaera* cf. *T. galatea*, and *Wetzeliella* sp. The dinocysts suggest correlation with unit E3 of Prowell and others (1985) and are the biostratigraphic equivalent of the upper part of the Tallahatta Formation in Alabama (upper part of the lower Eocene and lower part of the middle Eocene) (Hazel and others, 1985). The forms suggest a nearshore-marine environment of deposition.

Sample 7 (155 ft) contains a diverse dinocyst assemblage including *Achilleodinium biformoides, Adnatosphaeridium?* sp., *Cordosphaeridium fibrospinosum, Lingulodinium machaerophorum, Nematosphaeropsis* sp., *Operculodinium centrocarpum, Pentadinium favatum, Pentadinium goniferum, Phthanoperidinium comatum, Polysphaeridium zoharyi, Spiniferites* spp., *Thalassiphora pelagica, Turbiosphaera magnifica,* and *Wetzeliella/Gochtodinium* sp. The overlap of *P. favatum* and *P. goniferum* indicates correlation with the lower part of unit E4 of Prowell and others (1985), and with one or more of the following units: the upper part of the Congaree Formation, the Warley Hill Formation, and the lower part of the Santee Formation (Lucas-Clark, 1992). However, the possibility of reworking cannot be excluded. The dominance by the *Wetzeliella* group suggests a nearshore-marine environment of deposition.

Carbonate-rich samples from 82-148 ft contained dinocysts, pollen, foraminifers, and calcareous nannoplankton of middle Eocene age. A diverse and abundant assemblage of dinocysts was observed in samples 8 (148 ft), 9 (124 ft), and 10 (120 ft) and includes: *Pentadinium goniferum, Pentadinium laticinctum laticinctum, Samlandia chlamydophora, Cordosphaeridium cantharellum,* and *Dapsillidinium pseudocolligerum.* The only age-diagnostic pollen types were encountered in sample 8: *Rouseia monilifera, Tetracolporopollenites lesquereuxianus,* and large forms of *Carya* (greater than 28 µm). Planktonic foraminifers were not present, but benthic foraminifers were identified in samples 8, 9, 10, and 11 (82 ft). Foraminiferal assemblages in these samples are dominated by specimens of *Hanzawaia, Cibicides,* or *Discorbis,* and they also may include abundant specimens of *Elphidium, Nonion,* and *Textularia.* Specimens of *Globocassidulina, Gyroidina,* and *Lenticulina* are also present. The species *Cibicides westi* was found in samples 10 and 11; this species is characteristic of middle Eocene strata, particularly those of the Lisbon and Gosport Formations and their equivalents. Samples 8 and 10 contain very sparse assemblages of calcareous nannofossils.

The microfossils identified in samples 8, 9, 10, and 11 indicate an age in the upper part of the middle Eocene (late Lutetian to Bartonian). Equivalent microfossil assemblages have been identified in the upper part of the Lisbon Formation and Gosport Formation of Alabama, the Lisbon Formation of Western Georgia, the McBean Formation of Eastern Georgia, and the McBean Formation and Santee Formation of South Carolina (Prowell and others, 1985). Lithologic characteristics and paleontologic evidence from this unit suggest deposition in a shallow (less than 100 ft in depth), open-marine environment. The foraminiferal assemblage indicates warm, well-oxygenated water.

HYDROLOGIC DATA

Water-bearing units at the Millers Pond site were related to previously named hydrogeologic units by comparing core and geophysical data collected at the site to interpreted borehole data from nearby sites reported by Miller (1986), Clarke and others (1985), Brooks and others (1985), and Aadland and others (1992). This comparison indicated that several lithostratigraphic equivalents to hydrogeologic units from the literature are present at the Millers Pond site. They are, in descending order: (1) loosely consolidated sand and calcareous sand of Eocene age that are updip equivalents to the largely carbonate Floridan aquifer system of Miller (1986); (2) the Dublin aquifer system (Clarke and others, 1985), comprised of sand of Paleocene and Late Cretaceous age; and (3) the Midville aquifer system (Clarke and others, 1985) comprised of sand of Late Cretaceous age. A generalized correlation of hydrogeologic units in the study area is shown in plate 1.

The Floridan aquifer system is comprised of the largely carbonate Upper and Lower Floridan aquifers (Miller, 1986) in downdip areas south of Millers Pond and the SRS. In updip areas, terrigenous sediments of Eocene age are hydraulically connected to the Upper and Lower Floridan aquifers. To account for this connection, Krause and Randolph (1989) included these updip equivalents in their simulation of ground-water flow in the Floridan aquifer system. Updip equivalents to the Upper Floridan aquifer have been referred to in the study area as the Jacksonian aquifer (Vincent, 1982) and the Upper Three Runs aquifer (Aadland and others, 1992). Updip equivalents to the Lower Floridan aquifer have been referred to as the Gordon aquifer system (Brooks and others, 1985) and the Gordon aquifer (Aadland and others, 1992). In this report, updip equivalents to the Upper Floridan aquifer are referred to as the Upper Three Runs aquifer. Updip equivalents to the Lower Floridan aquifer are referred to as the Gordon aquifer.

With the exception of the Gordon aquifer, one or more test wells were installed in selected intervals in each of the hydrogeologic units to determine their hydraulic properties, water levels, and water chemistry (table 1, plate 1). One well (TW-4) was completed in the Upper Three Runs aquifer, three wells (TW-5a, TW-6, and TW-7) were completed in the Dublin aquifer system, and three wells (TW-1, TW-2, and TW-3) were completed in the Midville aquifer system.

The uppermost part of the Dublin aquifer system, screened in TW-5a, is characterized by sand of Paleocene age that is separated from the lower parts of the aquifer system by clay of Paleocene and Late Cretaceous age. This upper part of the Dublin aquifer system as defined by Clarke and others (1985), was redefined by Aadland and others (1992) as part of the Meyers Branch confining system in the vicinity of the SRS. However, permeable sediments within the Meyers Branch are included in the uppermost part of the Dublin aquifer system in this report.

Following well completion and development, water-level recorders were installed in each well to continuously monitor water-level fluctuations and trends in water-bearing units. Water-level data were used to determine the vertical distribution of hydraulic head in the water-bearing units (table 1, plate 1) and the magnitude of water-level fluctuations.

Vertical distribution of hydraulic head gives an indication of the potential for vertical ground-water movement and interconnection between adjacent aquifers. Under unstressed conditions, upward gradients occur in discharge areas, downward gradients occur in recharge areas, and minimal vertical gradient exists in areas dominated by lateral flow. At the Millers Pond site, water levels measured on September 13, 1993, and corrected for altitude differences between wells, indicated that there was a slight upward head gradient of 0.84 ft between the deepest well (TW-1) screened in the interval 705-735 ft, and TW-6 screened in the interval 300-325 ft. The slight vertical head difference between the two screened intervals, completed in the Midville and Dublin aquifer systems, respectively, suggests (1) that the principal direction of ground-water flow is lateral in this interval, or (2) that the two aquifer systems are hydraulically interconnected, or (3) both. Such interconnection was reported in the vicinity of Millers Pond by Clarke and others (1985), and in the vicinity of the SRS by Aadland and others (1992), who referred to the interconnected aquifers as the Dublin-Midville aquifer system.

Water levels (corrected for altitude) in TW-5a, screened in the upper part of the Dublin aquifer system, indicate it is a potential hydrologic sink or low point of the aquifer systems at the Millers Pond test site. An upward head gradient of 20.73 ft was present between TW-6 and TW-5a (open interval, 211-251 ft); whereas between TW-5a and TW-4, screened in the Upper Three Runs aquifer (open interval, 80-100 ft), there was a downward head difference of 41.6 ft. The lower water levels in TW-5a may be the result of ground-water discharge from the water-bearing zone due either to regional pumping or incision of the upper part of the Dublin aquifer system by the Savannah River. Incision of sediments overlying the upper part of the Dublin aquifer system was reported in the Savannah River floodplain about 4 mi northeast of the Millers Pond test site by Leeth and Nagle (1994). This incision could allow the direct discharge of water from the aquifer system into the river, producing a cone of depression surrounding the river.

Relations among ground-water levels at the Millers Pond site; Savannah River stage; and precipitation for August-December 1992, at Augusta, Ga., are shown in figures 10 and 11. A hydrograph for TW-5a is not shown because the well was completed after this period.

In each well tapping the confined aquifers at the Millers Pond site (TW-1, TW-2, TW-3, TW-6, and TW-7), ground-water-level fluctuations were similar and seemed to respond mostly to fluctuations of river stage. During August-December, 1992, water levels in wells tapping the deeper confined aquifers (TW-1, TW-2, and TW-3 (fig. 10); and TW-6 and TW-7 (fig. 11) rose an average of about 1.4 ft, compared to a rise in river stage of about 13 ft, mostly during November and December 1992. In addition, two peaks of river stage were indicated by water-level peaks in the confined aquifers during October 1992.

To further evaluate the influence of river stage on ground-water levels in confined aquifers at the Millers Pond site, a statistical comparison using Spearman's rank correlation coefficient (SRCC) (Iman and Conover, 1983) was performed using ground-water-level data from TW-6 and stage data from the Savannah River at Jackson, S.C., gage. The SRCC measures the strength of the monotonic correlation between two variables. If the X variable and Y variable increase together, there is a positive correlation; if the X variable decreases as the Y variable increases, there is a negative correlation. The closer the SRCC is to either +1 (a positive correlation) or -1 (a negative correlation), the stronger the relation between the two variables. Evaluation of data from TW-6 and the Jackson gage during August-December 1992, showed a positive correlation (SRCC = 0.761, p-value <0.0001) between river stage and ground-water levels. Variations in water level not due to changes in river stage are likely the result of changes in ground-water pumping.

Possible explanations for the ground-water-level response to river stage at the Millers Pond site include direct influx of river water into an aquifer or a mass-loading pressure response. The depth of the aquifers and the distance (2 mi) from the Savannah River makes it unlikely that there is any direct influx of water from the river into the aquifers at Millers Pond. The most likely explanation for the ground-water-level response to stream stage is a mass-loading pressure response in the confined aquifers. Similar mass-loading responses to flooding and heavy rainfall in the vicinity of the SRS were reported by Siple (1967, p. 66); in the vicinity of the Millers Pond site by Benson and others (1993); and in east-central Georgia by Milby and others (1991).

Table 1. Well-construction and water-level data for test wells at the Millers Pond test site, Burke County, Georgia
[Water-bearing unit: M, Midville aquifer system; UT, Upper Three Runs aquifer; D, Dublin aquifer system; --, no data]

Well numbers (see figure 1)	Water-bearing unit	Altitude of land surface (feet)	Date of construction	Well depth (feet)	Casing		Screened interval		Water level		Remarks
					Depth (feet)	Diameter (inches)	Depth (feet)	Diameter (inches)	Below land surface (feet)	Date of measurement	
TW-1 (30Z017)	M	243.03	02/11/92	745	0-690 684-705 735-745	6 4 4	705-735	4	85.78	09/13/93	K-packer installed at 684 feet (see figure 2)
TW-2 (30Z021)	M	243.06	02/19/92	635	0-595 625-635	6 6	595-625	6	86.08	09/13/93	None
TW-3 (30Z023)	M	242.37	03/18/92	558	0-518 548-558	6 6	518-548	6	85.58	09/13/93	None
TW-4 (30Z022)	UT	242.09	03/19/92	110	0-80 100-110	6 6	80-100	6	64.81	09/13/93	None
TW-5 (30Z024)	D	241.98	04/09/92	260	0-210 250-260	6 6	210-250	6	--	--	Well abandoned
TW-5a (30Z028)	D	242.98	10/16/92	261	0-80 0-211 251-261	4 6 6	211-251	6	107.30	09/13/93	Replacement well for TW-5. Four-inch casing installed at 0-80 feet to seal off casing breach at 52-60 feet
TW-6 (30Z025)	D	242.23	07/02/92	336	0-300 325-335	6 6	300-325	6	85.82	09/13/93	None
TW-7 (30Z026)	D	242.07	08/--/92	480	0-445 475-480	6 6	445-475	6	85.61	09/13/93	None

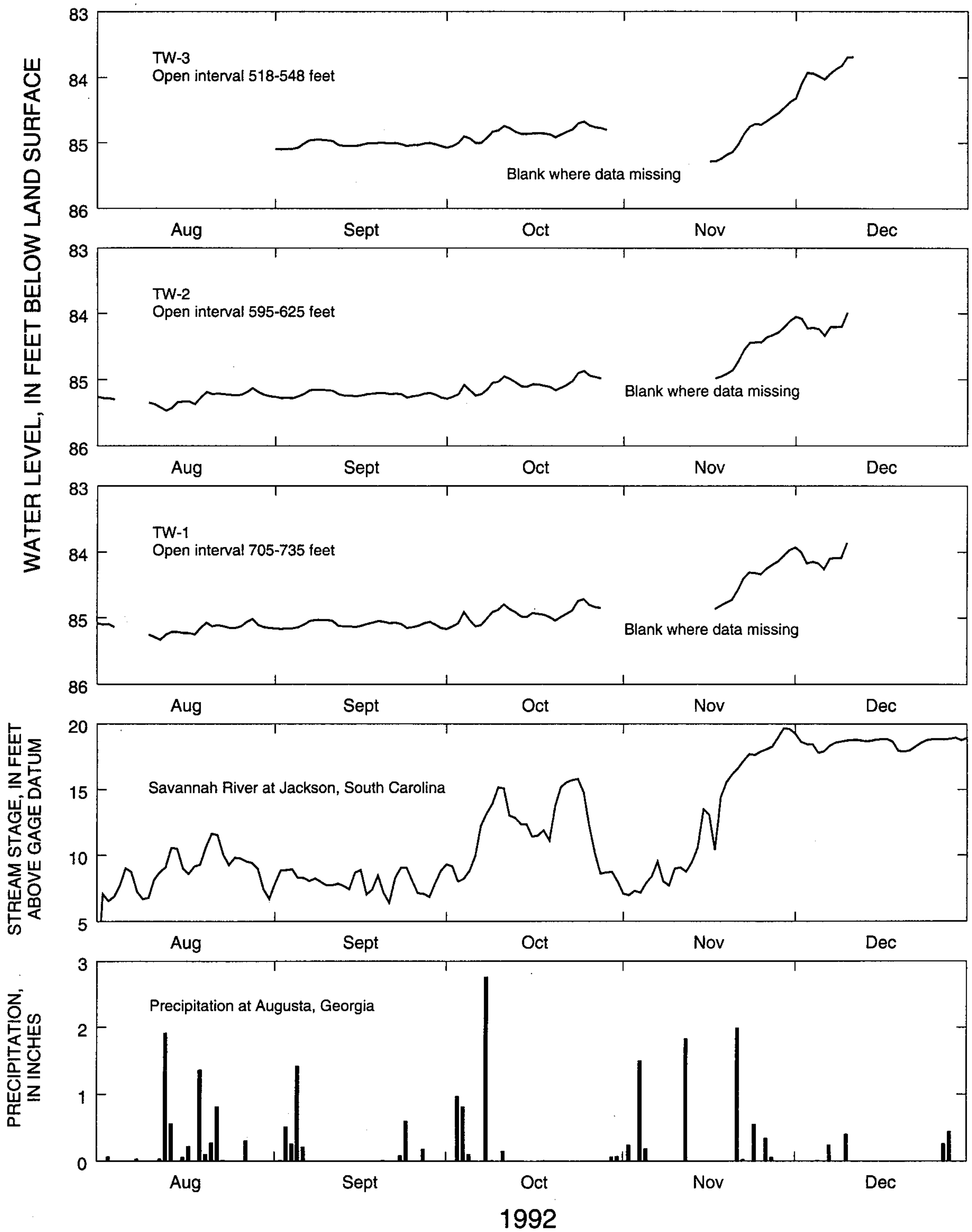


Figure 10. Daily mean ground-water levels in Millers Pond test wells 1, 2, and 3; daily mean stream stage at Savannah River at Jackson, South Carolina; and precipitation at Augusta, Georgia, August - December, 1992.

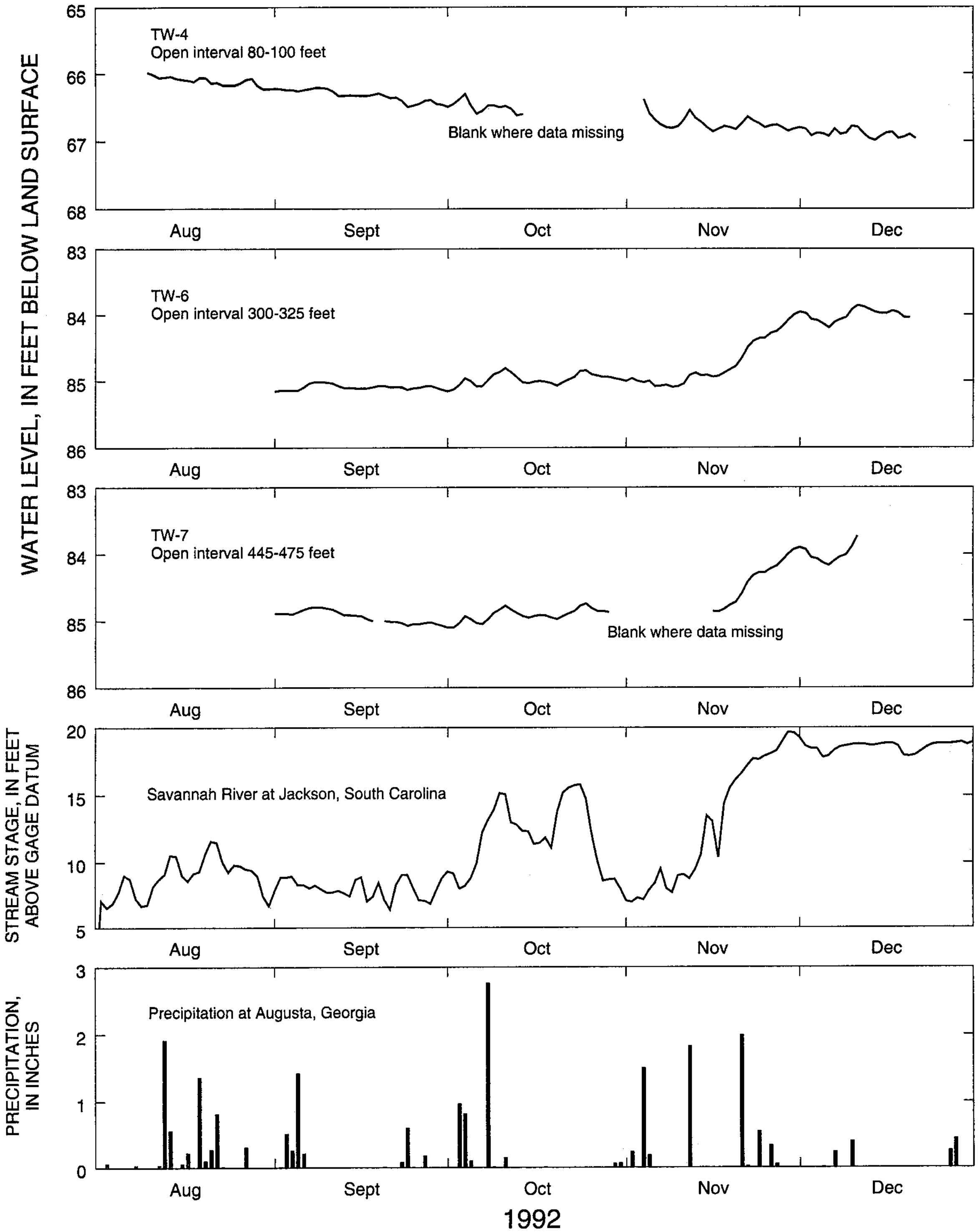


Figure 11. Daily mean ground-water levels in Millers Pond test wells 4, 6 , and 7; daily mean stream stage at Savannah River at Jackson, South Carolina; and precipitation at Augusta, Georgia, August - December, 1992.

The water-levels in TW-4, tapping the Upper Three Runs (water table) aquifer, showed little similarity to levels in the deeper confined aquifers. During August-December, 1992, the water levels in TW-4 declined about 1 ft, in contrast with rising water levels in the confined aquifers. Because of its shallow depth (80-100 ft), the water-level in TW-4 is influenced by changes in precipitation and evapotranspiration, but may also be influenced by ground-water pumping. Low rainfall and increased evapotranspiration and pumping during the summer and fall, may have resulted in water-level decline in the well.

WATER-QUALITY DATA

Water samples were collected from each test well following development and a subsequent pumping period of at least 24 hours to determine selected chemical and physical characteristics of the water-bearing zones. Samples were analyzed for dissolved concentrations of inorganic constituents, trace elements, tritium, and the presence of volatile and semi-volatile organic compounds (table 2). Alkalinity, dissolved oxygen, pH, specific conductance, and water temperature were measured at the wellhead prior to the collection of water samples.

Water sampled from each of the seven zones screened at the Millers Pond test site is low in dissolved solids and, with the exception of high concentrations of iron, is considered to be of good quality. Water from TW-1, TW-2, TW-3, TW-5a, TW-6, and TW-7 contained concentrations of iron that exceeded the U.S. Environmental Protection Agency (EPA) and Georgia Environmental Protection Division (EPD) secondary maximum contaminant level of 300 μg/L (U.S. Environmental Protection Agency, 1990a; Georgia Environmental Protection Division, 1993). In addition, water from TW-6 contained 93 μg/L of manganese, exceeding the EPA and EPD secondary maximum contaminant level of 50 μg/L (U.S. Environmental Protection Agency, 1990a; Georgia Environmental Protection Division, 1993).

Water from TW-4, screened in the Upper Three Runs (water table) aquifer, contained 730 picocuries per liter (pCi/L) of tritium, below the EPD primary maximum contaminant level of 20,000 pCi/L (Georgia Environmental Protection Division, 1993). The tritium concentration in TW-4 closely matched the concentration in stream baseflow near the site and probably is representative of that in the water-table aquifer (Summerour and others, 1994).

Tritium at slightly above the 1 pCi/L detection limit, were measured in TW-5a (2.23 pCi/L) and in TW-6 (3.19 pCi/L) screened in the Dublin aquifer system. Tritium above detectable levels was not detected in any of the other zones at the Millers Pond site. The most likely explanations for the low tritium levels in the confined Dublin aquifer system in TW-5a and TW-6 are (1) leakage of shallow ground water or precipitation having above-background concentrations of tritium along the annular space of the well, or (2) introduction of tritium into the aquifer through drilling fluids. Other possible explanations include (3) leakage of shallow ground water through overlying confining units and into the aquifer, or (4) lateral movement of ground water from recharge areas to the Millers Pond site. Of the second two possibilities, it is unlikely that downward leakage through confining units occurred in TW-6 because of the upward hydraulic gradient between it and TW-5a.

The vertical distribution of selected water-quality characteristics were plotted (fig. 12) to determine if any distinguishing chemical features exist in the different water-bearing zones at the Millers Pond site. In addition, a trilinear plot showing the percentage composition (in milliequivalents per liter) of major cations and anions in water was prepared to determine if any of the water-bearing zones were characterized by a unique water type (fig. 13).

Several patterns are evident on figure 12: (1) the specific conductance and the concentration of dissolved solids, hardness as $CaCO_3$, alkalinity as $CaCO_3$, silica, calcium, magnesium, and strontium, are greatest in the 211-251-ft interval (TW-5a), and decreases in concentration with increasing depth; (2) the pH of water decreases with depth, ranging from a high of 8.54 in the 80-100 ft interval (TW-4), to 5.96 in the 705-735 ft interval (TW-1); (3) with the exception of TW-1, the concentration of iron increases with depth, ranging from 18 micrograms per liter (μg/L) in the 80-100 ft interval to 2,600 μg/L in the 595-625 ft interval (TW-2); (4) anomalously high concentration of manganese (93 mg/L) is present in the 300-325 ft interval (TW-6); and (5) anomalously high concentration of zinc (610 μg/L) is present in the 445-475 ft interval (TW-7).

Although analyses from TW-5a indicate that water from the uppermost part of the Dublin aquifer system may be distinct from other units based on higher constituent concentrations, it is important to note that some of the higher concentrations may be a result of grout contamination introduced when nearby TW-5 was abandoned. Similarly, the anomalous concentration of zinc in TW-7, screened at the base of the Dublin aquifer system, probably is a result of collecting water samples from a galvanized discharge pipe.

With the exception of TW-1, each of the zones is characterized by a calcium-bicarbonate type water (fig. 13). Test well 1, however, is not dominated by any particular ion or ions. The difference in ionic composition between TW-2 and TW-3, screened in the middle and upper parts of the Midville aquifer system, respectively, and TW-1, screened at the base of the Midville, suggest that there is some hydraulic separation between the zones.

Table 2. Chemical and physical characteristics of ground-water samples collected from test wells at the Millers Pond test site, Burke County, Georgia
[Analyses by U.S. Geological Survey, except as noted; _units_: mg/L, milligrams per liter; mS/cm, microsiemens per centimeter; mg/L, micrograms per liter; pCi/L, picocuries per liter; _water-bearing unit_: M, Midville aquifer sytem; UT, Upper Three Runs aquifer; D, Dublin aquifer system; --, no data available; <, less than; E, estimated value]

Characteristic and unit	TW-1 (30Z017)	TW-2 (30Z021)	TW-3 (30Z023)	TW-4 (30Z022)	TW-5a (30Z028)	TW-6 (30Z025)	TW-7 30Z026)
Screened interval, in feet below land surface	705-735	595-625	518-548	80-100	211-251	300-325	445-475
Water-bearing unit	M	M	M	UT	D	D	D
Date sampled	12-14-92	11-04-92	01-08-93; 05-05-93[1/]	01-15-93	02-11-93	05-05-93	03-03-93; 05-05-93[1/]
Physical characteristics and inorganic constituents							
Hardness as calcium carbonate, mg/L	20.24E	40.43E	34.99E	48.98E	125.90E	74.21E	61.67E
Alkalinity, as calcium carbonate, mg/L	24.9	35.0	35.1	46.0	116.5	59.0	64.0
Oxygen, dissolved, mg/L	0.0	0.0	0.0	9.01	0.0	0.0	0.0
pH, standard units	5.96	6.11	6.33	8.54	7.78	6.55	6.49
Specific conductance, in µS/cm	110.0	111.0	102.0	101.1	256.0	163.0	147.0
Water temperature, degrees centigrade	21.0	22.4	21.5	16.8	20.7	21.0	20.8
Sum of constituents, mg/L	60.85	68.71	66.03	65.02	175.17	107.95	99.26
Inorganic carbon, dissolved, as carbon dioxide, mg/L	25.6	50.8	53.9	31.6	87.8	67.4	64.1
Nitrogen, ammonia dissolved, mg/L	<.01	.01	.01	.01	<.01	<.01	.01
Nitrogen, nitrite dissolved, mg/L	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Nitrogen, ammonia + organic dissolved, mg/L	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Nitrogen, nitrate and nitrite, dissolved, mg/L	<.02	<.02	.02	1.2	<.02	<.02	.06
Phosphorus, dissolved, mg/L	.03E	.13	.06	.02	.02	.03	.2
Orthophosphate phosphorus, dissolved, as phosphorus, mg/L	.04E	.05	.02	.02	<.02	.03	.02
Calcium, dissolved, mg/L	6.1	14.0	12.0	19.0	48.0	28.0	23.0
Magnesium, dissolved, mg/L	1.2	1.3	1.2	.36	1.4	1.0	1.0
Sodium, dissolved, mg/L	6.3	3.3	3.3	1.2	4.9	2.3	2.5
Potassium,dissolved, mg/L	2.4	1.6	1.5	.29	1.6	.88	1.7
Chloride, dissolved, mg/L	3.6	2.0	2.2	1.6	2.4	2.2	2.3
Sulfate, dissolved, mg/L	13.0	11.0	11.0	.4	10.0	10.0	9.8
Fluoride, dissolved, mg/L	0.2	0.2	0.2	<.1	<.1	0.2	0.1
Silica, dissolved, mg/L	11.0	11.0	11.0	9.0	36.0	26.0	18.0
Bromide, dissolved, mg/L	.17	.23	.1	.1	.25	<.1	<.1

Table 2. Chemical and physical characteristics of ground-water samples collected from test wells at the Millers Pond test site, Burke County, Georgia--Continued

Characteristic and unit	TW-1 (30Z017)	TW-2 (30Z021)	TW-3 (30Z023)	TW-4 (30Z022)	TW-5a (30Z028)	TW-6 (30Z025)	TW-7 30Z026)
				Trace elements			
Barium, dissolved, µg/L	19.0	30.0	28.0	17.0	10.0	30.0	24.0
Beryllium, dissolved, µg/L	3.0	<1.0	3.0	3.0	1.0	<1.0	<1.0
Cadmium, dissolved, µg/L	<5.0	<5.0	2.0	2.0	<1.0	<1.0	<1.0
Chromium, dissolved, µg/L	<10.0	<10.0	<5.0	<5.0	<5.0	5.0	<5.0
Cobalt, dissolved, µg/L	<10.0	<10.0	<3.0	<3.0	<3.0	<3.0	<3.0
Copper, dissolved, µg/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Iron, dissolved, µg/L	1,700.0	2600.0	2100.0	18.0	430.0	1500.0	1400.0
Lead, dissolved, µg/L	<50.0	<50.0	<10.0	<10.0	<10.0	<10.0	<10.0
Manganese, dissolved, µg/L	24.0	30.0	30.0	1.0	28.0	93.0	23.0
Molybdenum, dissolved, µg/L	14.0	<10.0	10.0	10.0	<10.0	<10.0	<10.0
Nickel, dissolved, µg/L	<10.0	11.0	<10.0	10.0	<10.0	10.0	<10.0
Silver, dissolved, µg/L	<5.0	<5.0	<1.0	1.0	1.0	<1.0	<1.0
Strontium, dissolved, µg/L	41.0	74.0	52.0	32.0	220.0	120.0	84.0
Vanadium, dissolved, µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc, dissolved, µ/g/L	140.0	180.0	94.0	10.0	54.0	130.0	610.0[2/]
Aluminum, dissolved, µg/L	<20.0	<20.0	<20.0	<20.0	20.0	<20.0	<20.0
Lithium, dissolved, µg/L	5.0	<5.0	<4.0	<4.0	6.0	10.0	<4.0
				Volatile organic compounds[3/]			
Dichlorobromomethane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Carbon tetrachloride, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichloroethane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Bromoform, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloroform, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Toluene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Benzene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chlorobenzene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloroethane, total, µg/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Ethylbenzene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Methyl bromide, total, µg/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Methyl chloride, total, µg/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0

Table 2. Chemical and physical characteristics of ground-water samples collected from test wells at the Millers Pond test site, Burke County, Georgia--Continued

Characteristic and unit	TW-1 (30Z017)	TW-2 (30Z021)	TW-3 (30Z023)	TW-4 (30Z022)	TW-5a (30Z028)	TW-6 (30Z025)	TW-7 30Z026)
Volatile organic compounds--Continued[3/]							
Methylene chloride, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	51.0
Tetrachloroethylene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Trichlorofluoromethane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1-Dichloroethane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1-Dichloroethylene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,1-Trichloroethane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,2-Trichloroethane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,1,2,2- Tetrachloroethane, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dichloropropane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Transdichloroethylene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Trans-1,3-Dichloropropene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Cis-1,3-Dichloropropene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Vinyl chloride, total, µg/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Trichloroethylene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Carbon disulfide, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Vinyl acetate, total, µg/L	<50.0	<50.0	<50.0	<50.0	<50.0	<50.0	<50.0
2-Hexanone, total, µg/L	<50.0	<50.0	<50.0	<50.0	<50.0	<50.0	<50.0
Styrene, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
1,2-Dibromoethane, total, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Xylene, µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Acetone, total, µg/L	<100.0	<100.0	<100.0	<100.0	<100.0	<100.0	<100.0
Methyl ethyl ketone, total, µg/L	<100.0	<100.0	<100.0	<100.0	<100.0	<100.0	<100.0
Tritium[4/]							
Tritium, pCi/L	<1.0	<1.0	<1.0	730.0[5/]	3.19[6/]	2.23[6/]	<1.0

1/Volatile organic compounds only.
2/High value may be the result of contact with galvanized discharge pipe.
3/Analyses by Georgia Department of Natural Resources, Environmental Protection Division.
4/Analyses by Alberta Environmental Centre, Vegreville, Alberta, Canada.
5/Accuracy of analysis (based on background readings) is ± 22.33 picoCuries per liter.
6/Accuracy of analysis (based on background readings) is ± 1.28 picoCuries per liter.

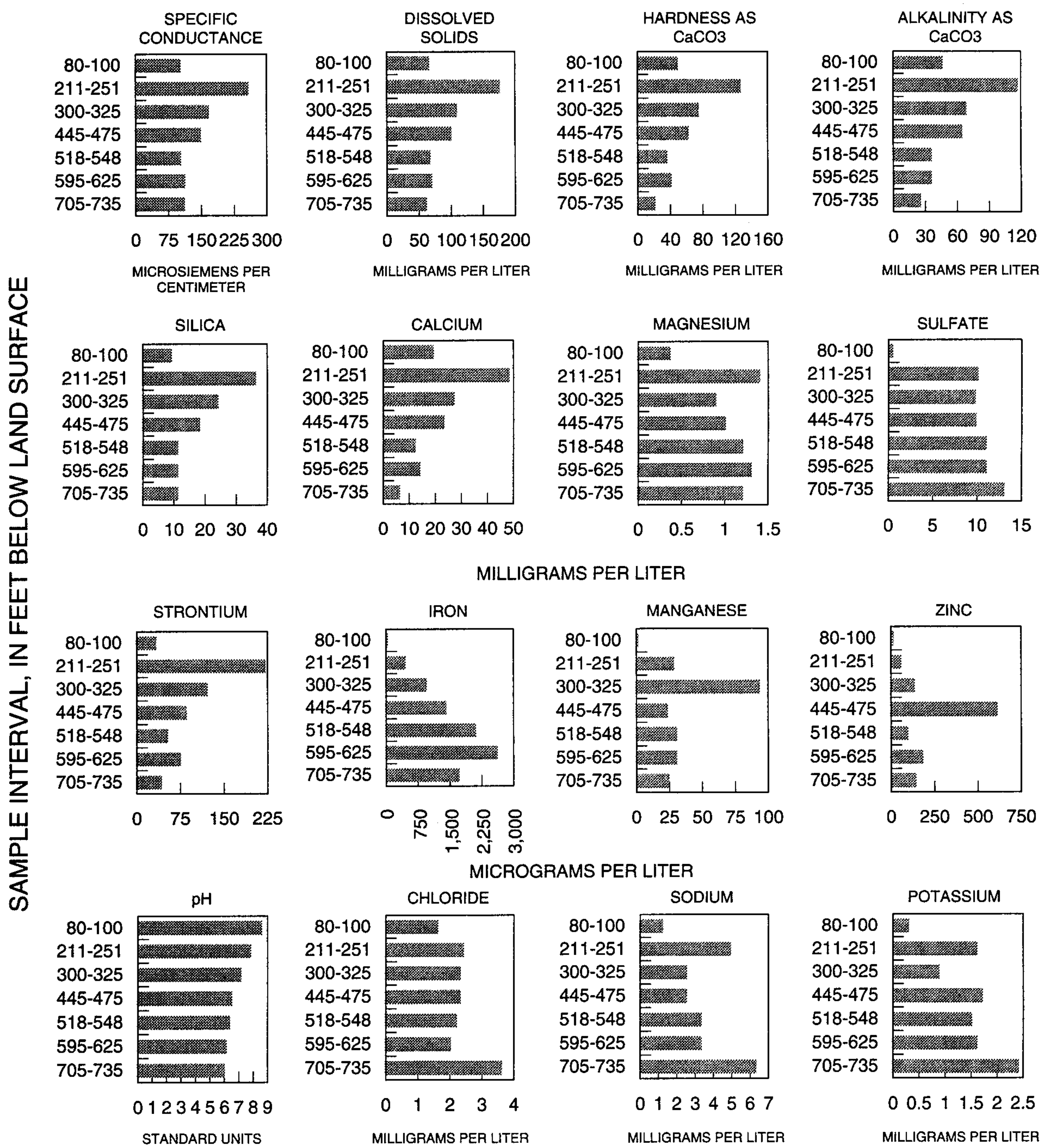
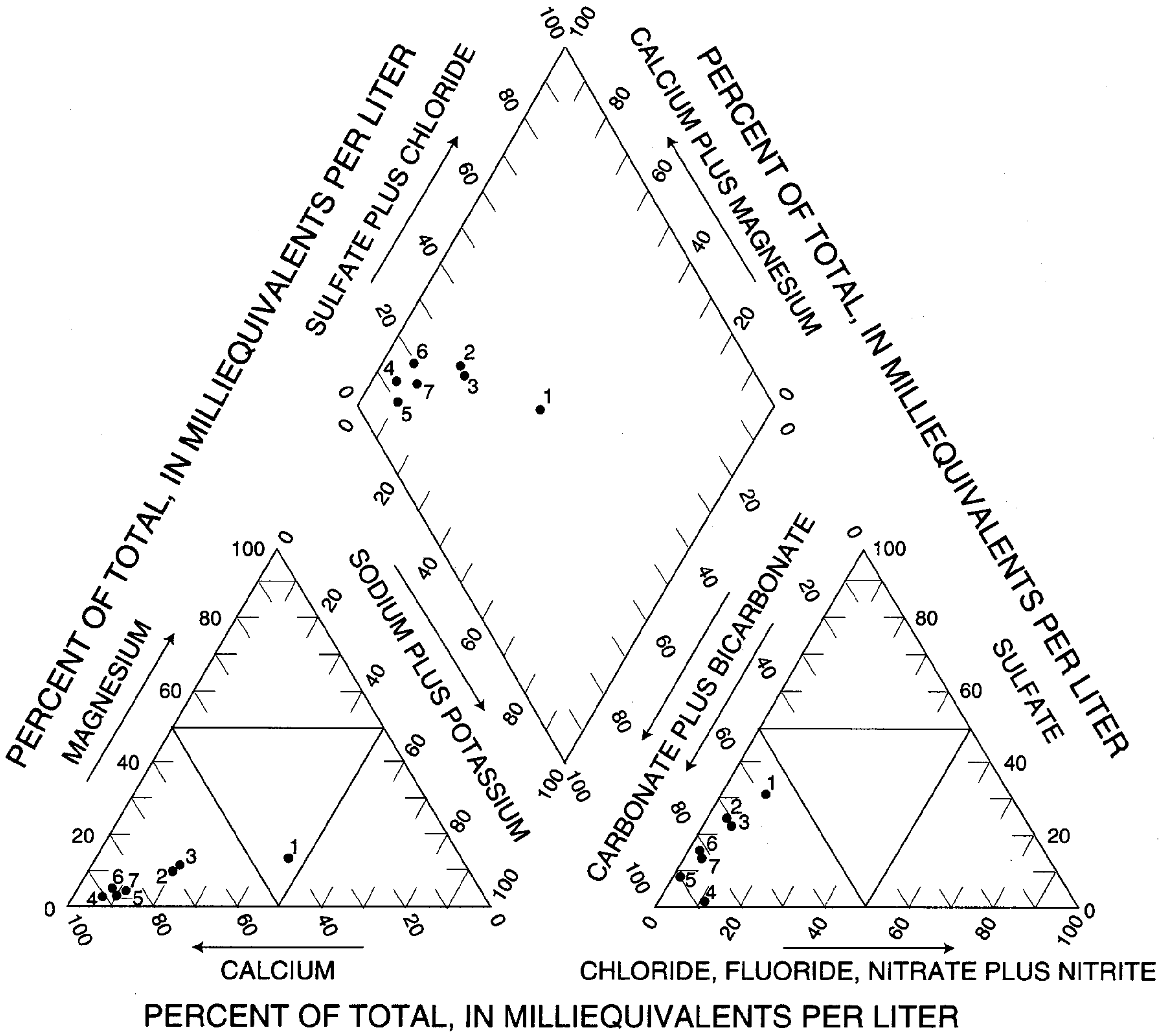


Figure 12. Distribution of selected chemical properties and constituent concentrations with depth at the Millers Pond site.



EXPLANATION

•[1] TEST WELL AND IDENTIFICATION NUMBER

Figure 13. Percentage composition of major ionic constituents in ground water at the Millers Pond site.

AQUIFER INTERCONNECTION

Ground-water-level and water-chemistry data were evaluated to assess the degree of aquifer interconnection at the Millers Pond site. In addition, aquifer tests were conducted at the site to give a qualitative indication of interaquifer leakage.

Evidence for interaquifer leakage was assessed during seven, 72-hr aquifer tests conducted during November 1992 to March 1993. For each test, the drawdown responses in three wells open to adjacent aquifers were measured while pumping one of the seven test wells (table 3). A measurable drawdown response was observed in adjacent zones during pumping of TW-1, TW-2, and TW-3, screened in the Midville aquifer system, and TW-6 and TW-7 screened in the Dublin aquifer system. No measureable drawdown was observed in adjacent zones during pumping of TW-4, screened in the Upper Three Runs aquifer, or TW-5a, screened in the upper part of the Dublin aquifer system.

Parts of the Dublin and Midville aquifer systems seem to be hydraulically connected at the Millers Pond site. Although low-permeability clay layers separate the water-bearing units screened in the two aquifer systems (TW-1, TW-2, TW-3, TW-6, and TW-7, plate 1), the uniform distribution of head (table 1, plate 1), similarity of water-level fluctuations (figs. 10, 11) and water chemistry (figs. 12 and 13), and drawdown response during aquifer tests (table 3) indicate that parts of the two aquifer systems are hydraulically connected. Depositional models of Cretaceous-age sediments that comprise the Dublin and Midville aquifer systems suggest that the clay and silt layers probably are of limited lateral extent, and thus, do not provide extensive confinement between layers.

The uppermost part of the Dublin aquifer system (TW-5a) is hydraulically separated from adjacent water-bearing zones. This hydraulic separation is indicated by (1) lack of drawdown response in adjacent water-bearing zones during aquifer tests, and (2) differences in hydraulic head, water-level fluctuations, and water chemistry between TW-5a and wells screened in the underlying Dublin and Midville aquifer systems (TW-1, TW-2, TW-3, TW-6, and TW-7). Layers of clay of Paleocene age separate the uppermost part of the Dublin aquifer system from adjacent water-bearing zones. These sediments apparently are more laterally extensive than clays in the underlying units and thus provide a greater degree of confinement than the underlying clay layers at the Millers Pond site.

Table 3. Drawdown response in pumped well and observation wells during 72-hour aquifer tests at the Millers Pond test site, Burke County, Georgia [Data from Jerry Moore, Clemson University, written commun., 1993; shaded values represent drawdown in pumped well; NM, zone not monitored during test]

Pumped well and test yield, in gallons per minute	Water-bearing unit and drawdown response in pumped well and observation wells (in feet)						
	Upper Three Runs	Dublin aquifer system			Midville aquifer system		
	TW-4	TW-5a	TW-6	TW-7	TW-3	TW-2	TW-1
TW-4 (8)	5.25	<0.0003	<0.0003	<0.0003	NM	NM	NM
TW-5a (41)	<0.0003	70.54	<0.0003	<0.0003	NM	NM	NM
TW-6 (12)	<0.0003	<0.0003	190.30	0.33	NM	NM	NM
TW-7 (19)	NM	NM	0.23	137.80	0.20	0.13	NM
TW-3 (165)	NM	NM	NM	0.88	209.98	0.66	<0.0003
TW-2 (65)	NM	NM	NM	0.13	0.23	88.59	0.13
TW-1 (178)	NM	NM	NM	0.06	0.10	0.56	147.64

SUMMARY AND CONCLUSIONS

This report contains geologic, hydrologic, and water-quality data of Coastal Plain sediments collected during 1991-93 at a test site in northern Burke County, Georgia. The test site consists of one 859-foot (ft) deep corehole and seven test wells screened at different depths. The corehole penetrated sediments of Late Cretaceous through Eocene age and incised pre-Cretaceous basement rock at a depth of 852 ft. Lithologic and paleontologic examination of core from the Millers Pond test site indicated that there are at least 11 lithologic units in the vicinity of the site.

Seven test wells were installed at depths ranging from 80 to 735 ft to determine the hydraulic properties, ground-water levels and water chemistry of Coastal Plain sediments. One well was completed in the Upper Three Runs (water table) aquifer, three wells were completed in the Dublin aquifer system and three wells were completed in the Midville aquifer system. Upon completion and development of each well, a 72-hour aquifer test was conducted, water samples were collected and analyzed for physical characteristics and chemical constituents, and continuous water-level recorders were installed.

Water-level data were collected to determine vertical head differences at the site. Water-level measurements during September 1993 indicate that a slight upward head gradient of 0.84 ft was present between the screened intervals of 705-735 ft and 300-325 ft, tapping the Midville and Dublin aquifer systems, respectively. This slight head difference indicates that the principal direction of ground-water flow is lateral in this interval or that the two aquifer systems are hydraulically interconnected, or both. Water levels in the 211-251 ft interval, screened in the upper part of the Dublin aquifer system, indicate it is a potential hydrologic sink or low point of the aquifer systems at the Millers Pond site. The lower water levels in TW-5a may be the result of ground-water discharge from the water-bearing zone due to regional pumping or incision of the upper part of the Dublin aquifer system by the Savannah River.

Water-level fluctuations at the Millers Pond test site during August-December 1992 were compared to records of river stage and precipitation to evaluate possible cause and effect relations. Water-level fluctuations in wells tapping the confined aquifers at the Millers Pond site were similar and generally correspond to fluctuations of river stage, and to a lesser degree, pumping. Alternatively, water-levels in the Upper Three Runs (water table) aquifer, showed little similarity to levels in wells tapping the deeper confined aquifers, and suggest that the water table is strongly influenced by precipitation, evapotranspiration, and pumpage.

Water from each of the seven zones screened at the Millers Pond site is of good quality and low in dissolved solids. Concentrations of iron, however, exceeded the U.S. Environmental Protection Agency and Georgia Environmental Protection Division secondary drinking-water standards in all zones except the Upper Three Runs aquifer.

Water from the Upper Three Runs (water table) aquifer contained 730 picoCuries per liter (pCi/L) of tritium. Tritium at concentrations slightly above the 1 pCi/L detection limit, were measured in two wells screened in the upper part of Dublin aquifer system and are probably the result of either (1) leakage of contaminated shallow ground water or precipitation along the annular space of the well or (2) introduction of tritium into the aquifer through drilling fluids. Other possible explanations include (3) leakage of shallow ground water through overlying confining units and into the aquifer or (4) lateral movement of ground water from recharge areas to the Millers Pond site.

To establish if any distinguishing chemical features of water-bearing zones exist at the Millers Pond test site, water types were determined and distribution of selected water-quality characteristics were plotted with depth. Water from the uppermost part of the Dublin aquifer system may be characterized by higher constituent concentrations; however, some of the higher concentrations may be a result of grout contamination from a nearby abandoned well. Most of the water-bearing zones are characterized by a calcium-bicarbonate type water; however, the base of the Midville aquifer system is characterized by a mixed water that is not dominated by any particular ion or ions.

Ground-water-level and water-chemistry data were evaluated together with preliminary results of 72-hour aquifer tests to assess the degree of aquifer interconnection at the Millers Pond site. Although layers of clay and silt separate the wells screened in the Dublin and Midville aquifer systems, the uniform distribution of head, similarity of water-level fluctuations and water chemistry, and drawdown response during aquifer tests indicate that parts of the two aquifer systems are hydraulically connected. Conversely, the uppermost part of the Dublin aquifer system seems to be hydraulically separated from adjacent water-bearing zones.

SELECTED REFERENCES

Aadland, R.K., Thayer, P.A., and Smits, A.D., 1992, Hydrostratigraphy of the Savannah River Site region, South Carolina and Georgia, *in* Price, Van, and Fallaw, Wallace, *ed.*, Geological Investigations of the central Savannah River area, South Carolina and Georgia: Carolina Geological Society fieldtrip guidebook, November 1992, Augusta, Ga., variously paged.

Aadland, R.K., and Bledsoe, H.W., 1990, Classification of hydrostratigraphic units at the Savannah River Site: Westinghouse Savannah River Company, Aiken, S.C., WSRC-RP-90-987, 15 p.

Aucott, W.R., Davis, M.E., and Speiran, G.K., 1987, Geologic framework of the Coastal Plain aquifers of South Carolina: U.S. Geological Survey Water-Resources Investigations Report 85-4271, 7 sheets.

Benson, S.M., Moore, Jerry, Daggett, John, and Snipes, D.S., 1993, The influence of barometric pressure fluctuations, earth tides, and rainfall loading on fluid pressures in Coastal Plain aquifers, Burke County, Georgia, *in* The Geological Society of America, abstracts with programs, March 1993: The Geological Society of America, v. 25, no. 4, p. 3.

Bledsoe, H.W., 1987, SRP baseline hydrogeologic investigation--Phase II: E.I. duPont de Nemours & Co., Savannah River Laboratory, Aiken, S.C., DPST-86-674, variously paged.

____1988, SRP baseline hydrogeologic investigation--Phase III: E.I. duPont de Nemours & Co., Aiken, S.C., DPST-88-627, variously paged.

Bledsoe, H.W., Aadland, R.K., and Sargent, K.A., 1990, SRS baseline hydrogeologic investigation-summary report: Westinghouse Savannah River Co., Aiken, S.C., Savannah River Site, WSRC-RP-90-1010, variously paged.

Brooks, Rebekah, Clarke, J.S., and Faye R.E., 1985, Hydrogeology of the Gordon aquifer system of east-central Georgia: Georgia Geologic Survey Information Circular 75, 41 p.

Chowns, T.M., and Williams, C.T., 1983, Pre-Cretaceous rocks beneath the Georgia Coastal Plain-Regional implications, *in* Gohn, G.S., *ed.*, Studies related to the Charleston, South Carolina earthquake of 1886--Tectonics and seismisisty: U.S. Geological Survey Professional Paper 1313-L, p. L1-L42.

Clarke, J.S., Brooks, Rebekah, and Faye, R.E., 1985, Hydrogeology of the Dublin and Midville aquifer systems of east central Georgia: Georgia Geologic Survey Information Circular 74, 62 p.

Christopher, R.A., 1979a, Normapolles and triporate pollen assemblages from the Raritan and Magothy Formation (Upper Cretaceous) of New Jersey: Palynolgy, v. 3, p. 73-121, pl. 1-9.

____1979b, The stratigraphic distribution of Normapolles and triporate pollen in zones IV, V, and VII of the Raritan and Magothy Formations (Upper Cretaceous) of New Jersey *(abs.)*: Palynology, v. 3, p. 281.

____1982a, The occurrence of the *Complexipollis-Atlantapollis* zone (palynomorphs) in the Eagle Ford Group (upper Cretaceous) of Texas: Journal of Paleontology, v. 56, no. 2, p. 525-541, pl. 1.

____1982b, Palynostratigraphy of the basal Cretaceous Units of the eastern Gulf and southern Atlantic Coastal Plains, *in* Proceedings of the Second Symposium on the Geology of the Southeastern Coastal Plain, March 1979, Arden, D.D., Beck, B.F., and Morrow, Eleanore, *eds.*, : Georgia Geologic Survey Information Circular 53, p. 10-23, pl. 1-3.

Christopher, R.A., Owens, J.P., and Sohl, N.F., 1979, Late Cretaceous palynomorphs from the Cape Fear Formation of North Carolina: Southeastern Geology, v. 20, no. 3, p. 145-159.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture, *in* W.E. Ham, *ed.*, Classification of carbonate rocks: American Association of Petroleum Geologists, Memoir 1, p. 108-121.

Edwards, L.E., 1980, Dinoflagellate biostratigraphy--a first look, *in* Reinhardt, Juergen, and Gibson, T.G., Upper Cretaceous and lower Tertiary geology of the Chattahoochee River Valley, western Georgia and eastern Alabama, Frey, R.W., *ed.*, Excursions in Southeastern Geology, Annual Meeting, 1980: The Geological Society of America, Field Trip Guidebook, v. 2, p. 424-427.

Falls, W.F., Prowell, D.C., Edwards, L.E., Frederiksen, N.O., Gibson, T.G., Bybell, L.M., and Gohn, G.S., 1993, Preliminary correlation of geologic units in three coreholes along the Savannah River in Burke and Screven Counties, Georgia [*abs.*], *in* The Geological Society of America, abstracts with programs: The Geological Society of America, v. 25, no. 4, p. 14.

Frederiksen, N.O., 1991, Midwayan (Paleocene) pollen correlations in the eastern United States: Micropaleontology, v. 37, no. 2, p. 101-123, pl. 1.

Frederiksen, N.O., and Christopher, R.A., 1978, Taxonomy and biostratigraphy of Late Cretaceous and Paleogene triatriate pollen from South Carolina; Palynology, v. 2, p. 113-145, pl. 1-3.

Geological Society of America, 1991, Rock color chart: The Geological Society of America, Boulder, Co., *7th* printing, *with revised text*, 1 color chart.

Georgia Environmental Protection Division, 1993, Rules for safe drinking water: Georgia Environmental Protection Division, Atlanta, Ga., chap. 391-3-5, p. 601-729.

SELECTED REFERENCES--Continued

Gohn, G.S., 1992, Revised nomenclature, definitions, and correlations for the Cretaceous formations in U.S. Geological Survey--Clubhouse Crossroads, Number 1, Dorchester County, South Carolina: U.S. Geological Survey Professional Paper 1518, 39 p.

Hazel, J.E., Bybell, L.M., Christopher, R.A., Frederiksen, N.O., May, F.E., McLean, D.M., Poore, R.Z., Smith, C.C., Sohl, N.F., Valentine, P.C., and Witmer, R.J., 1977, Biostratigraphy of the deep corehole (Clubhouse Crossroads corehole 1) near Charleston, S.C., *in* Rankin, D.W., *ed.*, Studies related to the Charleston, South Carolina earthquake of 1886--a preliminary report: U.S. Geological Survey Professional Paper 1028, p. 71-89.

Hazel, J.E., Edwards, L.E., and Bybell, L.M., 1985, Significant unconformities and the hiatuses represented by them in the Paleogene of the Atlantic and Gulf Coastal Province, *in* Interregional Unconformities and Hydrocarbon Accumulation, Schlee, J.S., *ed.*: American Association of Petroleum Geologists Memoir 36, p. 59-66.

Iman, R.L., and Conover, W.J., 1983, A modern approach to statistics: John Wiley and Sons, p. 325-345.

Krause, R.E., and Randolph, R.B., 1989, Hydrology of the Floridan aquifer system in southeast Georgia and adjacent parts of Florida and South Carolina: U.S. Geological Survey Professional Paper 1403-D, 65 p.

Leeth, D.C. and Nagle, D.D., 1994, Geomorphology and geologic characteristics of the Savannah River floodplain in the vicinity of the Savannah River Site, South Carolina and Georgia, *in* The Geological Society of America, abstracts with programs: The Geological Society of America, v. 26, no. 4, p. 24.

Logan, W.R., and Euler, G.M., 1989, Geology and ground-water resources of Allendale, Bamberg, and Barnwell Counties and part of Aiken County, South Carolina: South Carolina Water Resources Commission Report 155, 113 p.

Lucas-Clark, Joyce, 1992, Some characteristic fossil dinoflatgellate cysts of Eocene strata, Savannah River Site, South Carolina, *in* Geological investigations of the central Savannah River area, South Carolina and Georgia, Fallaw, Wallace, and Price, Van, *eds.*: Carolina Geological Field Trip Guidebook 1992, p. B-VII-1-B-VII-6.

Milby, B.J., Joiner, C.N., Cressler, A.M., and West, C.T., 1991, Ground-water conditions in Georgia, 1990: U.S. Geological Survey Open-File Report 91-486, 147 p.

Miller, J.A., 1986, Hydrogeologic framework of the Floridan aquifer system in Florida, and in parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1403-B, 91 p.

Prowell, D.C., Christopher, R.A., Edwards, L.E., Bybell, L.M., and Gill, H.E., 1985, Geologic section of the updip Coastal Plain from central Georgia and western South Carolina: U.S. Geological Survey Miscellaneous Field Studies Map MF-1737.

Siple, G.E., 1967, Geology and ground water of the Savannah River Plant and vicinity, South Carolina: U.S. Geological Survey Water-Supply Paper 1841, 113 p.

Sohl, N.F., and Owens, J.P., 1991, Cretaceous stratigraphy of the Carolina Coastal Plain, *in* Horton, J.W., Jr., and Zullo, V.A., *eds.*, The Geology of the Carolinas: Carolina Geological Society, 50th Anniversary Volume, University of Tennessee Press, Knoxville, Tenn., p. 191-220.

Summerour, J.H., Shapiro, E.A., Lineback, J.A., Huddlestun, P.F., and Hughes, A.C., 1994, An investigation of tritium in the Gordon and other aquifers in Burke County, Georgia--Final Report: Georgia Geologic Survey Information Circular 95 [*in press*].

U.S. Environmental Protection Agency, 1990a, Secondary maximum contaminant levels (section 143.3, part 143, National secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100-149, *revised* July 1, 1990, p. 674.

___1990b, Maximum contaminant levels (subpart B of part 141, National primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100-149, *revised* July 1, 1990, p. 559-563.

Vincent, H.R., 1982, Geohydrology of the Jacksonian aquifer in central and east-central Georgia: Georgia Geologic Survey Hydrologic Atlas 8, 3 sheets.

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, p. 377-392.

Westinghouse Savannah River Company, 1993, Savannah River site environmental report for 1992, summary phamphlet: Westinghouse Savannah River Company, Aiken, S.C., WSRC-TR-93-076, 34 p.

Williams, G.L., Stover, L.E., and Kidson, E.J., 1993, Morphology and stratigraphic ranges of selected Mesozoic-Cenozoid dinoflagellate taxa in the Northern Hemisphere: Geological Survey of Canada Paper 92-10, 137 p.

Wolfe, J.A., 1976, Stratigraphic distribution of some pollen types from the Campanian and lower Maestrichtian rocks (Upper Cretaceous) of the Middle Atlantic States: U.S. Geological Survey Professional Paper 977, p. 1-18.

APPENDIX

Lithologic description of Millers Pond core, Burke County, Georgia

[Unless otherwise reported, core recovery is 100 percent; ft, foot; mm, grain size, in millimeters]

Lithologic description	Depth below land surface, in feet
No recovery.	0-10
Sand, fine- to coarse-grained, moderately sorted, loose to clay-bound, clay matrix (5-15 percent), dark yellow orange (10YR6/6) with moderate red (5R4/6) to dark reddish brown (10R3/4) staining, gradational lower contact.	10-20
Sand, medium- to very coarse-grained, moderately to poorly sorted, loose, clay matrix (less than 5 percent), pale yellow orange (10YR6/6) to dark yellow orange (10YR6/6), lower contact not recovered, recovery 43 percent.	20-27
Sand, medium- to coarse-grained, moderately sorted, unidentified black heavy minerals (less than 1 percent), loose, clay matrix (5-10 percent), discontinuous clay laminae (5 percent), laminated at 38 ft, moderate brown (5YR3/4) to dark yellow orange (10YR6/6), lower contact not recovered, recovery 33 percent.	27-42
Sand, fine- to coarse-grained, granules (5-10 percent), pebbles (5 percent), poorly to very poorly sorted, loose, clay matrix (5-10 percent), moderate reddish brown (10R4/6), lower contact not recovered, recovery 30 percent.	42-47
Sand, fine-grained, well sorted, mica (1 percent), loose, clay matrix (5 percent), wavy laminated, dark yellow orange (10YR6/6), sharp lower contact.	47-48
Sand, medium- to coarse-grained, granules (5 percent), moderately to poorly sorted, loose, clay matrix (5-10 percent), moderate reddish brown (10R4/6), lower contact not recovered, recovery 38 percent.	48-52
Sand, medium- to coarse-grained, moderately sorted, lignite (1-2 percent, 1-3 mm), mica (1 percent), loose, clay matrix (less than 5 percent) pale yellowish orange (10YR8/6) to grayish orange (10YR7/4), lower contact not recovered, recovery 35 percent.	52-62
Sand, fine- to medium-grained, granules (5 percent), pebbles (1 percent), moderately to poorly sorted, lignite (1 percent), loose, clay matrix (5 percent), discontinuous clay laminae (5 percent), grayish yellow (5Y8/4), lower contact not recovered, recovery 80 percent.	62-67
Clay, well-laminated at 69 ft, dark yellowish orange (10YR6/6) to pale yellowish orange (10YR8/6), with lenses and laminae of fine-grained sand, lignite (1 percent, 1-2 mm), lower contact not recovered.	67-69
No recovery.	69-72
Sand, fine- to medium-grained, moderately sorted, lignite (5 percent,1-2 mm), clay-bound, clay matrix (10-20 percent), dark yellowish orange(10YR6/6) with pale greenish yellow (10Y8/2) clay clasts (10-20 percent), sharp lower contact.	72-73
Clay, lignite (1-2 percent, 1-2 mm), pale greenish yellow (10Y8/2),sharp lower contact.	73-73.5
Sand, fine- to medium-grained, moderately sorted, grading down to fine- to very coarse-grained, poorly sorted, clay-bound, clay matrix (10-20 percent), carbonate matrix (1-2 percent), dusky yellow (5Y8/4), sharp lower contact.	73.5-75
Carbonate, fine- to very coarse-grained quartz sand (20-25 percent), fragmented mollusk shells (10 percent), partially lithified, grayish yellow (5Y8/4), sharp lower contact.	75-76
Sand, medium-grained, well sorted, clay-bound, clay matrix (10-20 percent), dark yellowish orange (10YR6/6), lower contact not recovered, recovery 50 percent.	76-78
No recovery.	78-82
Carbonate, mudstone to grainstone, fine- to coarse-grained quartz sand (20-40 percent), macrofossils include pelecypods, large oysters, and urchins, pelecypods molds (2-10 percent), very pale orange (10YR8/2), sharp lower contact, recovery 95 percent.	82-100

APPENDIX--Continued

Lithologic description of Millers Pond core, Burke County, Georgia

Lithologic description	Depth below land surface, in feet
Sand, fine- to medium-grained, carbonate matrix (30 percent), carbonate grains (20 percent), moderately sorted, loose to partially lithified, grayish yellow (5Y8/4), lower contact not recovered, recovery 92 percent.	100-112
Carbonate, mudstone, fine-grained quartz sand (5-20 percent), partially lithified, yellowish gray (5Y7/2), sharp lower contact.	112-121
Carbonate, mudstone to wackestone, small pelecypods (5-20 percent), fine- to medium-grained quartz sand (10-20 percent), lignite (2-5 percent, 1-2 mm), glauconite (1-2 percent), clay matrix (5-10 percent), partially lithified, yellowish gray (5Y8/1) to light olive gray (5Y6/1), gradational lower contact.	121-131
Carbonate, mudstone to wackestone, with large pelecypod fragments (5 percent), small shark tooth, fine- to very coarse-grained quartz sand (20 percent), glauconite (5-10 percent), loose to partially lithified, yellowish gray (5Y8/1), sharp lower contact.	131-133
Sand, fine- to very coarse-grained, moderately to poorly sorted, carbonate matrix (20 percent), carbonate grains (25 percent), glauconite (2-5 percent), loose, yellowish gray (5Y8/1), sharp lower contact.	133-139
Carbonate, mudstone to wackestone, with spicules (2-5 percent), very fine- to fine-grained quartz sand (25-40 percent), glauconite (2-5 percent), lignite (1 percent, 1-10 mm), white (N9) clay clasts (1 percent) at 142.5 ft, burrow-mottled texture at 142-143 ft, loose to partially lithified, light olive gray (5Y6/1), sharp lower contact.	139-151
Carbonate, wackestone, large oysters and pelecypods (20 percent), very fine- to very coarse-grained quartz sand (20-30 percent), glauconite (2-5 percent), loose to partially lithified, light olive gray (5Y6/1), sharp lower contact.	151-154
Sand, very fine- to very coarse-grained, granules (5 percent), very poorly sorted, carbonate matrix (5 percent), pelecypods (10-20 percent), glauconite (2-5 percent), loose, light olive gray (5Y6/1), sharp lower contact.	154-155
Sand, very fine- to fine-grained, moderately to well sorted, lignite (1-2 percent, 1-2 mm), mica (less than 1 percent), loose, clay-lined burrows (5 percent), discontinuous laminae at 156 ft, light olive gray (5Y6/1), gradational lower contact.	155-162
Sand, fine- to coarse-grained, moderately to poorly sorted, loose, light brownish gray (5YR6/1), gradational lower contact.	162-164
Sand, fine- to very coarse-grained, poorly sorted, lignite (1 percent), black (N1) clay clasts (2-15 mm, 2-3 percent), loose, light brownish gray (5YR6/1), sharp lower contact.	164-165
Clay, massive, pyrite clusters (1-5 percent, 1-2 mm), medium light gray (N6) to yellowish gray (5Y8/1), sharp lower contact.	165-169
Clay, massive, very light gray (N8) to white (N9), patchy moderate red (5R4/6) to pale yellowish orange (10YR8/6) staining (20 percent), root-like pattern, gradational lower contact.	169-181
Clay, massive, very fine-grained sand (25-35 percent), very light gray (N8), lower contact not recovered	181-182
No recovery.	182-187
Clay, massive, very light gray (N8), patchy light red (5R6/6) to dark reddish brown (10R3/4) staining (35 percent), gradational lower contact.	187-202
Clay, silty (5-15 percent), mica (less than 1 percent), very light gray (N8) to yellowish gray (5Y8/1), sharp lower contact.	202-207
Sand, very fine- to fine-grained, well sorted, grades down to fine- to medium-grained, moderately sorted, mica (1-2 percent), lignite (1 percent, 1-15 mm), loose to clay-bound, clay matrix (5-15 percent), patchy pyrite (1-2 percent), yellowish gray (5Y7/2), lower contact not recovered, recovery 83 percent.	207-213
No recovery.	213-217

APPENDIX--Continued

Lithologic description of Millers Pond core, Burke County, Georgia

Lithologic description	Depth below land surface, in feet
Sand, fine- to very coarse-grained, quartz and smoky quartz granules (5-10 percent), lag of granules (10-20 percent) at 227 ft, poorly to very poorly sorted, mica (1-2 percent, 1-2 mm), loose to clay-bound, clay matrix (5-15 percent), white (N9) to very light gray (5Y6/1), sharp lower contact, recovery 30 percent.	217-227
Sand, fine- to medium-grained, moderately sorted, down to lag of fine- to very coarse-grained sand, granules (10 percent), pebbles (5 percent, 4-15 mm), loose to clay-bound, clay matrix (5-10 percent), very clayey (35 percent) at 228 ft, very light gray (N8), lower contact not recovered, recovery 60 percent.	227-232
Sand, fine- to medium-grained, moderately to well sorted, mica (1 percent), loose to clay-bound, clay matrix (5-15 percent), clay laminae (2-3 percent), pale yellow brown (10YR6/2) to olive gray (5Y4/1), lower contact not recovered, recovery 67 percent.	232-244
No recovery.	244-247
Clay, laminated, lignite (2-5 percent, 10 percent at 252 ft), laminae and beds of very fine-grained sand (10 percent), layer of coarse- to very coarse-grained sand with granules (10 percent) at 249 ft, mica (2-5 percent), olive gray (5Y4/1), lower contact not recovered.	247-250
No recovery.	250-252
Clay, laminated, mica (5 percent), lignite (5 percent, 1-2 mm), black (N1) to brownish black (5YR2/1), interlaminated and interbedded with very fine- to fine-grained sand, well sorted, loose, mica (5 percent), light olive gray (5Y6/1), gradational lower contact, recovery 80 percent.	252-257
Sand, fine- to medium-grained, well sorted, mica (2-5 percent), lignite (2-5 percent, 1-10 mm) at 263 ft, loose, clay matrix (less than 5 percent), yellowish gray (5Y8/1), black (N1) clay laminae (20-25 percent), sharp lower contact, recovery 30 percent.	257-263
Clay, massive, fine- to very coarse-grained sand (25-35 percent), very light gray (N8), gradational lower contact, recovery 50 percent.	263-269
Sand, fine- to very coarse-grained, granules (10-25 percent), pebbles (5-10 percent, 4-15 mm), very poorly sorted, smoky quartz (5 percent), clay bound, clay matrix (25-25 percent), very light gray (N8),sharp lower contact.	269-271
Clay, massive, fine- to very coarse-grained sand (25-35 percent), very light gray (N8), gradational lower contact.	271-273
Sand, fine- to medium-grained, moderately sorted, clay-bound, clay matrix (20 percent), mica (1-2 percent), very light gray (N8), gradational lower contact.	273-277
Sand, fine-to very coarse-grained, granules (10-25 percent), pebbles (5 percent, 4-8 mm), very poorly sorted, clay-bound, clay matrix (20 percent), smoky quartz (5 percent), very light gray (N8), sharp lower contact, recovery 70 percent.	277-284
Clay, massive, sand content increasing downward (5-35 percent), very fine- to fine-grained sand, very light gray (N8), minor grayish yellow (5Y8/4) staining (5-10 percent), gradational lower contact.	284-294
Sand, very fine- to fine-grained, well sorted, clay-bound, clay matrix (15-20 percent), pyrite clusters (1 percent, 1-2 mm), very light gray (N8), gradational lower contact.	294-296
Sand, fine- to very coarse-grained, granules (5-10 percent), pebbles (5 percent, 4-10 mm), poorly to very poorly sorted, smoky quartz (5 percent), mica (1-2 percent, 1-2 mm), white (N9) to very light gray (N8), lower contact not recovered, recovery 25 percent.	296-317
Sand, fine- to very coarse-grained, granules (5-10 percent), poorly to very poorly sorted, mica (1 percent), loose, clay matrix (less than 5 percent), bed of sandy clay at 332-333 ft, very light gray (N8), sharp lower contact, recovery 25 percent.	317-348
Clay, massive, fine- to coarse-grained sand (25 percent), light gray (N8), gradational lower contact.	348-349

APPENDIX--Continued

Lithologic description of Millers Pond core, Burke County, Georgia

Lithologic description	Depth below land surface, in feet
Sand, fine- to very coarse-grained, granules (5-15 percent), pebbles (5 percent, 4-12 mm) at 378 ft and at 395 ft, poorly to very poorly sorted, mica (1-2 percent), loose, clay matrix (5-10 percent), rounded clay clasts (5 percent, 5-15 mm) at 359 ft, white (N9) to very light gray (N8), lower contact not recovered, recovery 50 percent.	349-397
Clay, massive, fine- to medium-grained sand (5-15 percent), white (N9) to very light gray (N8), gradational lower contact, recovery 80 percent.	397-406
Sand, medium- to very coarse-grained, granules (5-20 percent), mica (2-3 percent, 1-2 mm), poorly to very poorly sorted, pebbles (5 percent) and clay clasts (1-2 percent, 5-20 mm) at 408 ft, 422 ft and 428 ft, loose, clay matrix (5-10 percent), clay laminae at 413 ft, 419 ft and 429 ft, white (N9) to very light gray (N8), sharp lower contact, recovery 65 percent.	406-429
Sand, medium- to very coarse-grained, moderately to poorly sorted, mica (1-2 percent), granules (5-10 percent) and pebbles (5 percent, 4-10 mm) from 442 to 447 ft, brown and black heavy minerals at 445 ft, loose, clay matrix (5-10 percent), white (N9) to yellowish gray (5Y8/1), sharp lower contact, recovery 60 percent.	429-447
Clay, lenses and laminae of very fine-grained sand (20 percent), mica (1-2 percent), sand content increasing downward, very light gray (N8), gradational lower contact.	447-449
Sand, fine- to very coarse-grained, poorly to very poorly sorted, granules (25 percent) and clay clasts (5 percent) at 460', granules (5-10 percent) at 474 ft and 479 ft, mica (1-2 percent), laminae of brown and black heavy mineral grains at 458 ft, loose, clay matrix (5-10 percent), white (N9) to very light gray (N8), sharp lower contact, recovery 65 percent.	449-480
Clay, massive, fine- to very coarse-grained sand (10-20 percent), very light gray (N8), lower contact not recovered.	480-482
Clay, massive, very fine- to fine-grained sand (5-30 percent) from 489 to 498 ft, mica (1-2 percent), very light gray (N8) with patchy moderate red (5R5/4) staining from 483 to 489' ft and patchy moderate yellow (5Y7/6) staining from 489 to 498 ft, gradational lower contact, recovery 80 percent.	482-498
Sand, very fine- to fine-grained, well sorted, clay-bound, clay matrix (10-15 percent), grading down to medium- to coarse-grained, moderately sorted, loose, clay matrix (less than 5 percent), mica (2-3 percent), clay laminae at 503 ft, light gray (N7), lower contact not recovered, recovery (50 percent).	498-511
Sand, medium- to very coarse-grained, granules (10-25 percent), very poorly sorted, clay clasts (less than 5 percent), mica (2 percent), smoky quartz (5 percent), loose, clay matrix (5-10 percent), light gray (N7), sharp lower contact.	511-513
Clay, questionable burrows at 517 ft, fine- to medium-grained sand (5-10 percent), lignite (1 percent, 1-2 mm), very light gray (N8), sharp lower contact, recovery 60 percent.	513-518
Sand, fine- to coarse-grained, moderately sorted, mica (1-2 percent), loose, clay matrix (5-10 percent), alternating with four intervals (522-523 ft, 531-532 ft, 536-537 ft, and 549-552 ft) of medium- to very coarse-grained sand with granules (5-15 percent), very poorly sorted, loose, clay matrix (less than 5 percent), pebbles (5 percent, 4-10 mm) at 536 ft and 550 ft, white (N9), lower contact not recovered, recovery 65 percent.	518-552
Clay, massive, fine- to coarse-grained sand (10-35 percent), very light gray (N8) with patchy moderate red (5R4/6) and moderate yellow (5Y7/6) staining, gradational lower contact.	552-558
Sand, fine- to coarse-grained grading down to fine- to very coarse-grained, moderately to poorly sorted, mica (1-2 percent), loose, clay matrix (5-10 percent), very light gray (N8) to white (N9), lower contact not recovered, recovery 50 percent.	558-577
Sand, fine- to very coarse-grained, granules (10-15 percent) and pebbles (5 percent, 4-10 mm) at 587', poorly to very poorly sorted, mica (1-2 percent), loose to clay-bound, clay matrix (5-10 percent, 25 percent at 577 ft), very light gray (N8) with dusky yellow (5Y6/4) staining (5 percent), lower contact not recovered, recovery 50 percent.	577-592

APPENDIX--Continued

Lithologic description of Millers Pond core, Burke County, Georgia

Lithologic description	Depth below land surface, in feet
Clay, massive, fine- to coarse-grained sand (10-20 percent), very light gray (N8) with patchy moderate red (5R5/4) and moderate yellow (5Y6/4) staining (10 percent), gradational lower contact, recovery 70 percent.	592-602
Sand, fine- to coarse-grained, poorly sorted, mica (1-2 percent), loose, clay matrix (5 percent), very light gray (N8), sharp lower contact, recovery 70 percent.	602-613
Sand, very fine- to medium-grained down to fine- to very coarse-grained, poorly to very poorly sorted, mica (1-2 percent), black heavy minerals (1 percent), loose to clay-bound, clay matrix (5-15 percent), yellow gray (5Y7/2) to light brown (5YR6/4), lower contact not recovered, recovery 30 percent.	613-630
Clay, massive, fine- to very coarse-grained (30-40 percent), mica (1-2 percent), very light gray (N8), gradational lower contact.	630-636
Sand, fine- to very coarse-grained, poorly sorted, mica (1-2 percent), clay-bound, clay matrix (25-35 percent), very light gray (N8), gradational lower contact.	636-639
Sand, fine- to very coarse-grained, poorly to very poorly sorted, granules (10-15 percent) and pebbles (5 percent) from 643 to 648 ft, black heavy minerals (1 percent), mica (1-2 percent), clay-bound, clay matrix (10-20 percent), white (N9) to very light gray (N8), sharp lower contact, recovery 60 percent.	639-648
Sand, fine- to medium grained, moderately sorted, mica (1-2 percent), loose, clay matrix (5-10 percent), clay laminae at 567 ft, very light gray (N8), lower contact not recovered, recovery 30 percent.	648-660
Sand, fine- to very coarse-grained, granules (10-20 percent), pebbles (5-10 percent, 4-12 mm), very poorly sorted, garnet (1-2 percent), black and amber heavy minerals (1-2 percent), smoky quartz (5-10 percent), loose, clay matrix (5-10 percent), very light gray (N8), sharp lower contact, recovery 35 percent.	660-663
Clay, massive, fine- to very coarse-grained sand (10 percent), very light gray (N8), sharp lower contact, recovery 40 percent.	663-668
Sand, fine- to medium-grained, moderately sorted, loose to clay-bound, clay matrix (5-15 percent), very light gray (N8), sharp lower contact.	668-669
Clay, massive, fine- to medium-grained sand (20-35 percent) below 677', mica (1-2 percent), very light gray (N8) with patchy dark reddish brown (10R3/4) and dusky yellow (5Y6/4) staining, lower contact not recovered.	669-678
Sand, fine- to very coarse-grained, with pebbles (5 percent, 4-10 mm), poorly to very poorly sorted, mica (1-2 percent), loose, clay matrix (5-10 percent), lower contact not recovered, recovery 18 percent.	678-692
Clay, massive, fine- to very coarse-grained sand (10-25 percent), very light gray (N8) with patchy moderate reddish orange (10R6/6) and dusky yellow (5Y6/4) staining, lower contact not recovered, recovery 65 percent.	692-699
Sand, fine- to medium-grained down to medium- to very coarse- grained, granules (5 percent), moderately to very poorly sorted, mica (1-2 percent), clay-bound, clay matrix (10-15 percent), very light gray (N8), sharp lower contact, recovery 32 percent.	699-713
Clay, massive, light gray (N7), lower contact not recovered.	713-714
No recovery.	714-717
Sand, very fine- to medium-grained, granules and pebbles of smoky quartz (5 percent), moderately sorted, lignite (5-15 percent, 1-20 mm), mica (2-3 percent), loose, clay matrix (5-10 percent), very light gray (N8), lower contact not recovered.	717-718
Sand, medium- to very coarse-grained, granules (10-25 percent), pebbles (5 percent, 10-20 mm), poorly to very poorly sorted, large piece of lignite and pyrite at 727 ft, mica (1-2 percent), clay clast at 728 ft, loose, clay matrix (5-10 percent), very light gray (N8), lower contact not recovered, recovery 25 percent.	718-737

APPENDIX--Continued

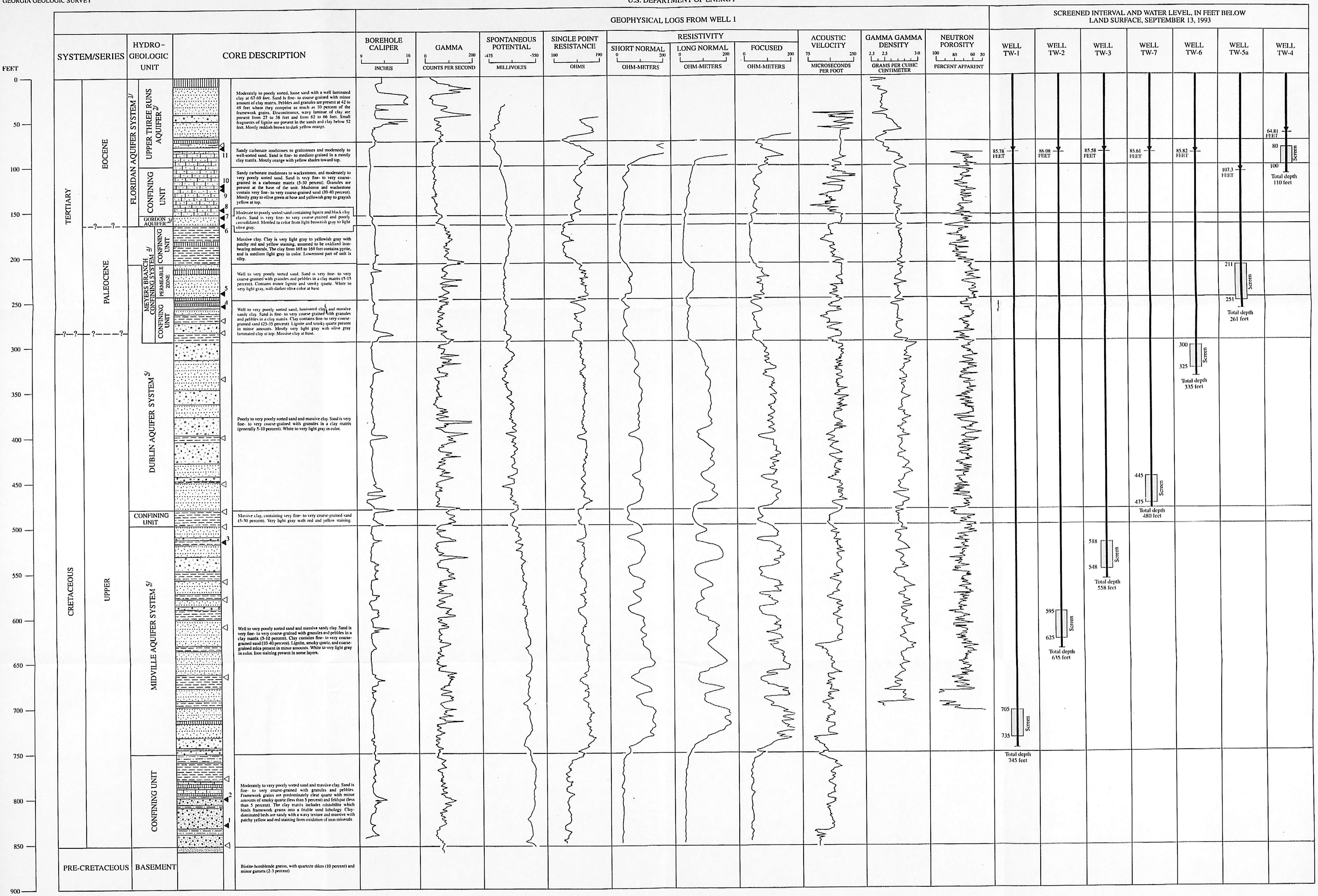
Lithologic description of Millers Pond core, Burke County, Georgia

Lithologic description	Depth below land surface, in feet
Sand, fine- to very coarse-grained, granules (5-10 percent), pebbles (5 percent), clay-bound, clay matrix (30-35 percent), very light gray (N8), sharp lower contact, recovery 85 percent.	737-744
Clay, massive, fine- to medium-grained sand (40 percent), very light gray (N8), lower contact not recovered.	744-746
Sand, fine- to very coarse-grained, granules (10-20 percent), pebbles (5-10 percent, 4-10 mm), clay clasts (2 percent), clay-bound, clay matrix (10-20 percent), very light gray (N8), sharp lower contact, recovery 80 percent.	746-751
Clay, massive, waxy, fine- to very coarse-grained sand (10-20 percent), very light gray (N8) with dusky yellow (5Y6/4) to moderate reddish orange (10R6/6) staining, sharp lower contact.	751-758
Sand, medium- to very coarse-grained, granules (10-20 percent), poorly to very poorly sorted, friable, clay matrix (20 percent), light red (5R6/6), sharp lower contact.	758-760
Clay, massive, waxy, grayish yellow green (5GY7/2) to light olive gray (5Y6/1) with patchy staining of dusky yellow (5Y6/4), moderate yellow (5Y7/6), and dark reddish brown (10R3/4), beds (0.5 ft) of fine- to very coarse-grained sand at 773.5 ft and 775 ft, sharp lower contact, recovery 58 percent.	760-780
Sand, fine- to coarse-grained, moderately to poorly sorted, feldspar (5 percent), friable, clay matrix (10-15 percent), light olive gray (5Y6/1), lower contact not recovered.	780-784
No recovery.	784-787
Sand, fine- to medium-grained, moderately sorted, mica (1-2 percent), friable, clay matrix (5-10 percent), light olive gray (5Y6/1), sharp lower contact.	787-789
Sand, very fine-grained, well sorted, loose, clay matrix (5 percent), light olive gray (5Y6/1), laminae (2-5 mm) of olive gray (5Y4/1) siltstone (10 percent), lower contact not recovered.	789-793
No recovery.	793-797
Siltstone, wavy laminated to mottled, lignite (less than 1 percent), mica (1-2 percent), friable, clay matrix (10-25 percent), light olive gray (5Y6/1) to olive gray (5Y4/1), sharp lower contact.	797-799
Sand, fine- to very coarse-grained, granules (10-25 percent), pebbles (10-30 percent, 4-30 mm) of quartz and feldspar, very poorly sorted, clay clasts (1-2 percent), mica (1-2 percent), black and dark red heavy minerals (2 percent) at 803 ft, friable, clay matrix (10-20 percent), pale olive (10Y6/2) to yellowish gray (5Y7/2), sharp lower contact.	799-807
Clay, massive, waxy, pale olive (10Y6/2) with moderately reddish brown (10R4/6) staining, bed of very fine- to fine-grained sand (808-809 ft), pale olive (10Y6/2), sharp lower contact.	807-810
Sand, very fine- to fine-grained, moderately to well sorted, down to fine- to very coarse-grained, granules (5-25 percent), pebbles (5-10 percent), very poorly sorted, mica (1-2 percent), feldspar (5-10 percent), friable to loose, clay matrix (5-15 percent), bed (0.3') of siltstone at 827 ft, light olive brown (5Y5/6) to moderately olive brown (5Y4/4) to pale olive (10Y6/2), sharp lower contact, recovery 77 percent.	810-834
Clay, massive, waxy, fine- to very coarse-grained sand (10-20 percent), pale olive (10Y6/2) to yellowish gray (5Y7/2), sharp lower contact.	834-840
Sand, fine- to very coarse-grained, granules (20 percent), pebbles (5-30 percent), very poorly sorted, friable, clay matrix (5-20 percent), bed (0.3 ft) of clay at 845 ft, pebble lag at 852 ft, large clast of saprolite at 848 ft, pale olive (10Y6/2) to dusky yellow (5Y6/4), sharp lower contact, recovery 58 percent.	840-852
Biotite-hornblende gneiss with quartzite dikes (10 percent), garnets (2-3 percent).	852-859

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

Prepared in cooperation with the
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
AND
U.S. DEPARTMENT OF ENERGY

INFORMATION CIRCULAR 96
PLATE 1



1/ Miller (1986).
2/ Aadland and others (1992). Also called Jacksonian aquifer (Vincent, 1982).
3/ Aadland and others (1992). Also called Gordon aquifer system (Brooks and others, 1985).
4/ Aadland and others (1992).
5/ Clarke and others (1985).

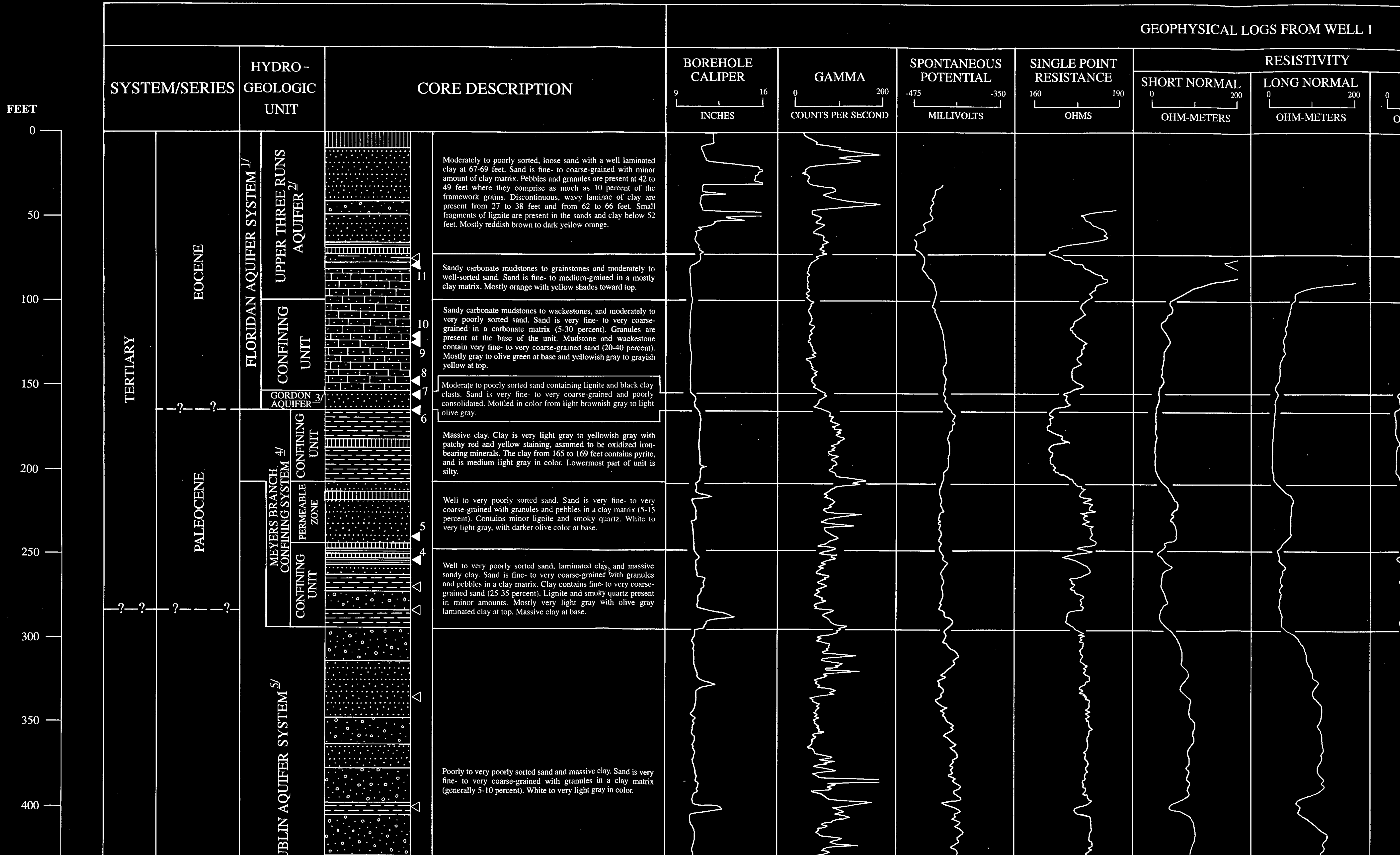
EXPLANATION

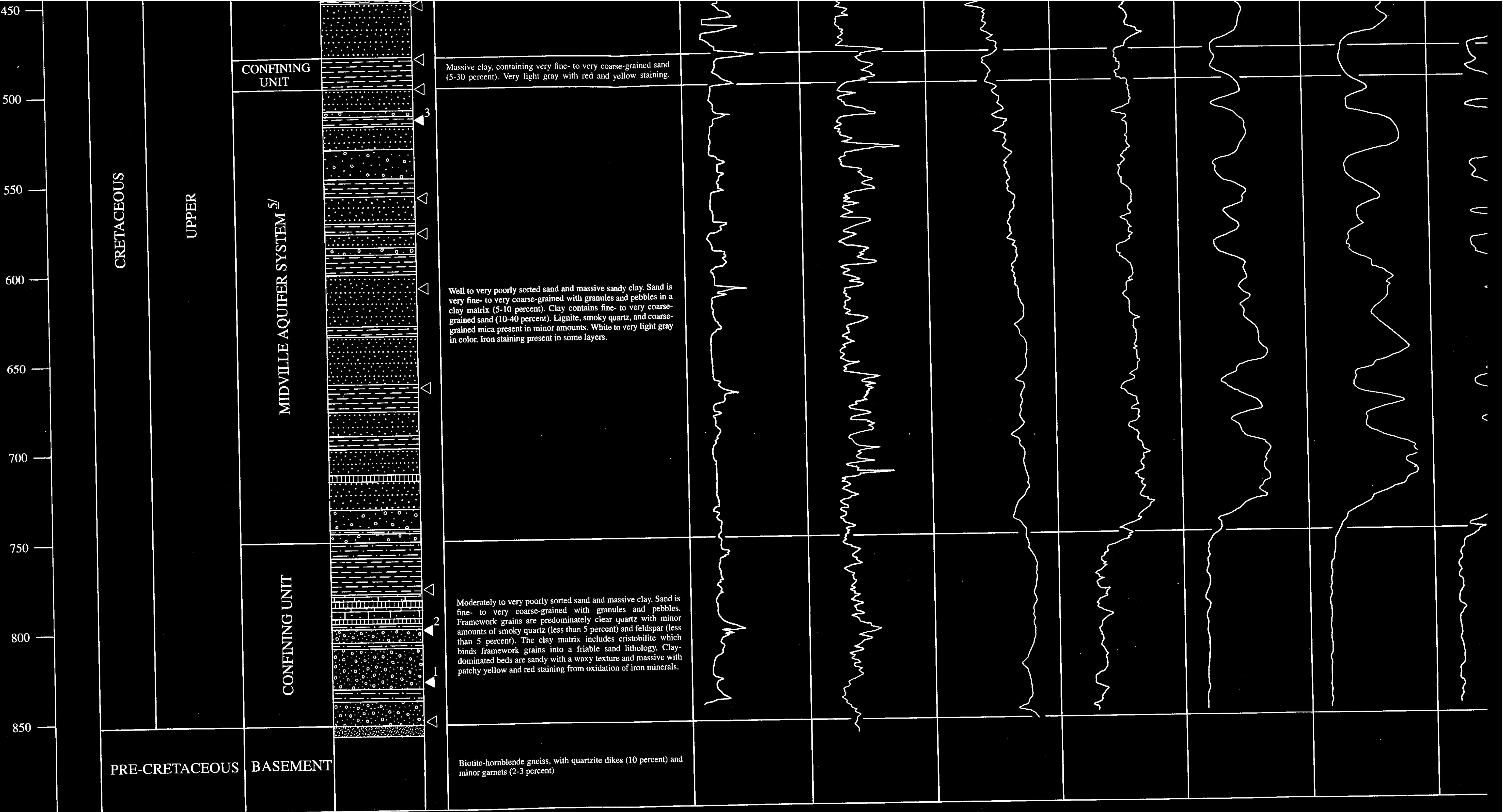
SAND WITH GRANULES OR PEBBLES
SAND WITH ABUNDANT GRANULES OR PEBBLES
SAND
SAND WITH ABUNDANT CLAY MATRIX
CLAY, MASSIVE
CLAY, MASSIVE, DENSE, WAXY, AND SANDY
CLAY, LAMINATED
CARBONATE, SANDY
BIOTITE-HORNBLENDE GNEISS
NO RECOVERY
▷ ▶2 PALEOLOGIC SAMPLE AND IDENTIFICATION NUMBER--Blank where sample barren of fossils. See text pages 13,14

CHART SHOWING GEOPHYSICAL LOGS, LITHIC LOG, AND CONSTRUCTION DIAGRAM OF WELLS AT MILLERS POND TEST SITE, BURKE COUNTY, GEORGIA

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

Prepared in cooperation with the
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
AND
U.S. DEPARTMENT OF ENERGY





1/ Miller (1986).
2/ Aadland and others (1992). Also called Jacksonian aquifer (Vincent, 1982).
3/ Aadland and others (1992). Also called Gordon aquifer system (Brooks and others, 1985).
4/ Aadland and others (1992).
5/ Clarke and others (1985).

EXPLANATION

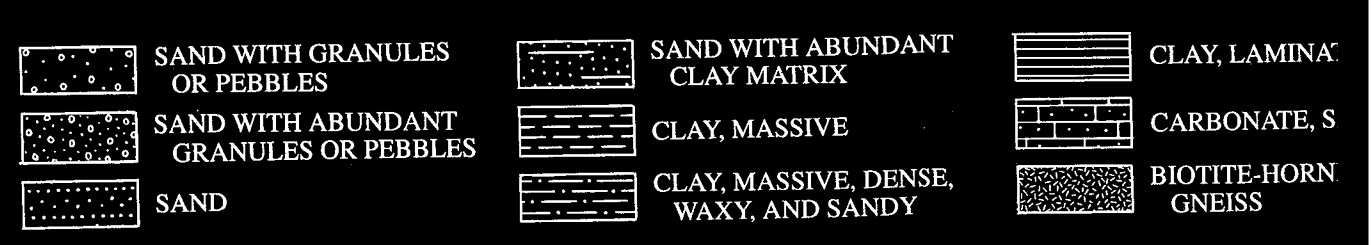
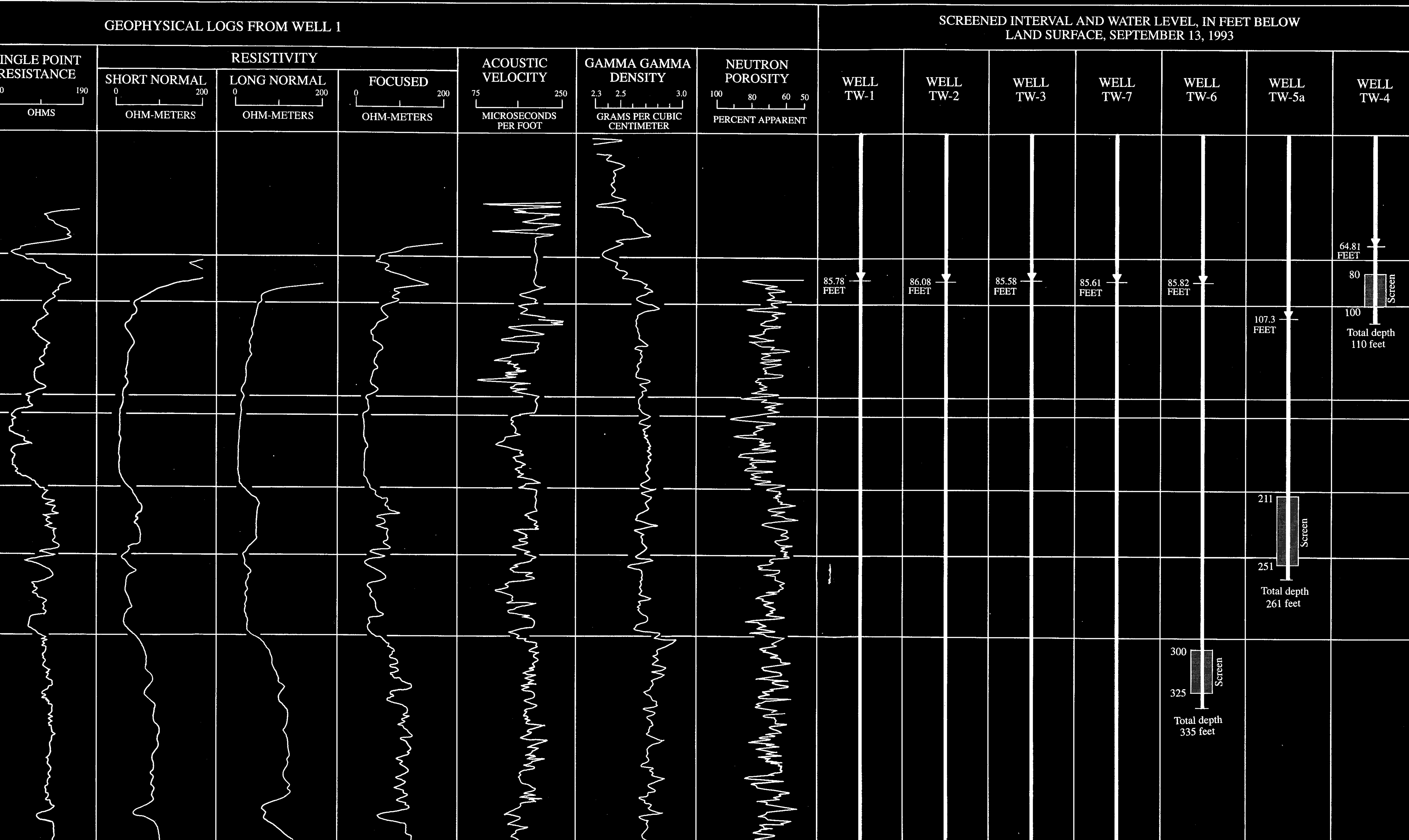
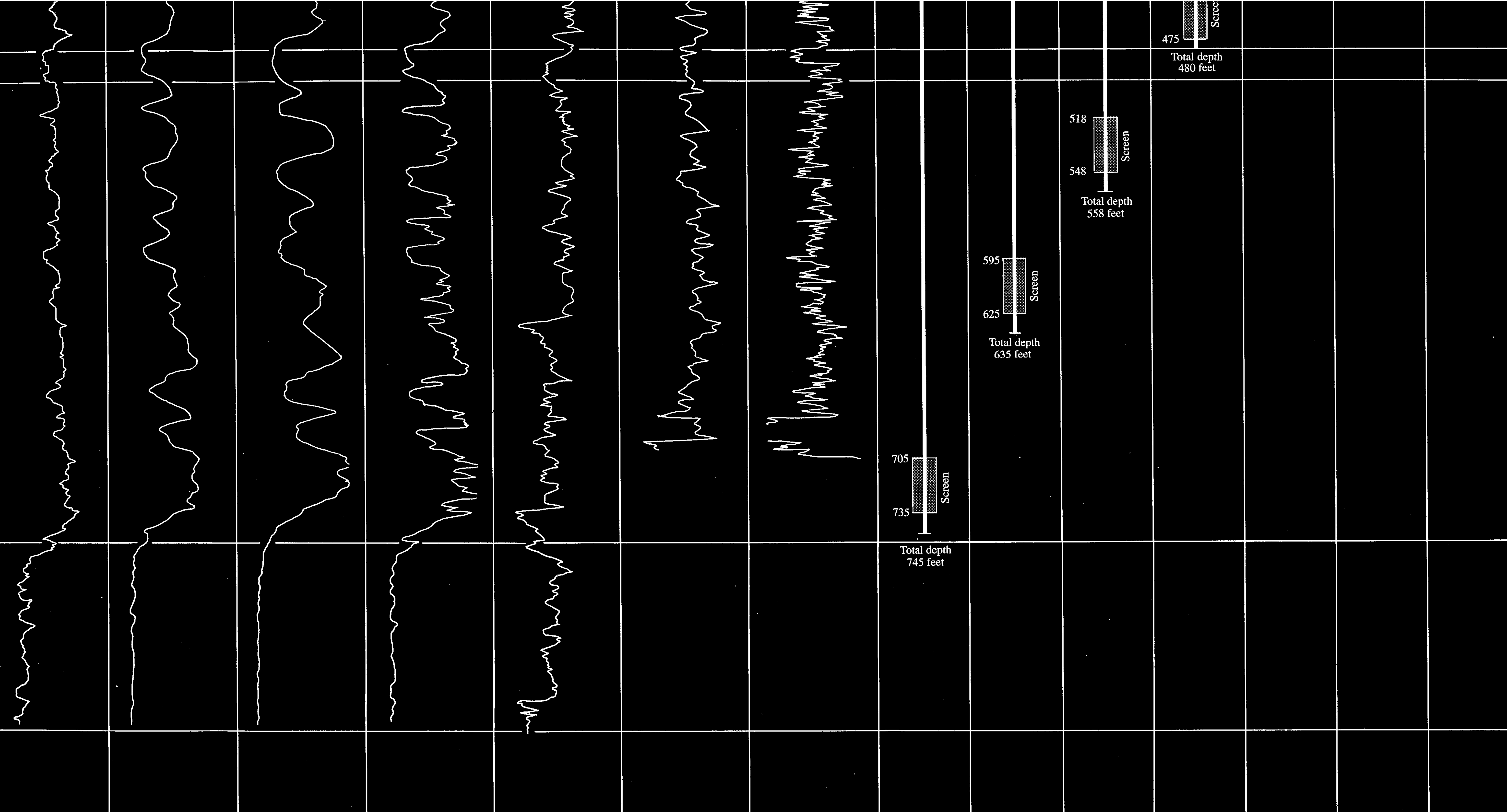


CHART SHOWING GEOPHYSICAL LOGS, LITHIC LOG, AND CONSTRUCTION DIAGRAM OF WELL

Prepared in cooperation with the
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
AND
U.S. DEPARTMENT OF ENERGY





EXPLANATION

SAND WITH ABUNDANT CLAY MATRIX

CLAY, MASSIVE

CLAY, MASSIVE, DENSE, WAXY, AND SANDY

CLAY, LAMINATED

CARBONATE, SANDY

BIOTITE-HORNBLENDE GNEISS

NO RECOVERY

▷ ▶2 PALEONTOLOGIC SAMPLE AND IDENTIFICATION NUMBER--Blank where sample barren of fossils. See text pages 13,14

AND CONSTRUCTION DIAGRAM OF WELLS AT MILLERS POND TEST SITE, BURKE COUNTY, GEORGIA

For convenience in selecting our reports from your bookshelves, they are color-keyed across the spine by subject as follows:

Red	Valley and Ridge mapping and structural geology
Dk. Purple	Piedmont and Blue Ridge mapping and structural geology
Maroon	Coastal Plain mapping and stratigraphy
Lt. Green	Paleontology
Lt. Blue	Coastal Zone studies
Dk. Green	Geochemical and geophysical studies
Dk. Blue	Hydrology
Olive	Economic geology
	Mining directory
Yellow	Environmental studies
	Engineering studies
Dk. Orange	Bibliographies and lists of publications
Brown	Petroleum and natural gas
Black	Field trip guidebooks
Dk. Brown	Collections of papers

Colors have been selected at random, and will be augmented as new subjects are published.