Enclosure 16 to
LTR-RAC-20-94
Date: December 18, 2020

Enclosure 16

Response to Request for Additional Information

Soil & Material Engineers, Inc., 1982, Ground-Water Hydrology of the Westinghouse Electric Corporation Plant, Richland County, South Carolina: Report No. H-8119, March 1, 1982

SOIL & MATERIAL ENGINEERS INC. ENGINEERING-TESTING-INSPECTION

1302 Elmore Street, Columbia, South Carolina 29203 Phone (803) 252-5101

March 1, 1982

Davis & Floyd Engineers
1319 Reynolds Street
P.O. Box 428
Greenwood, S.C. 29646

Attention: Mr. Carl Burrell

Subject: Submission of Final Report, "Ground-Water Hydrology of the Westinghouse Electric Corporation Plant, Richland County, South Carolina" S&ME Report No. H-8119

Gentlemen:

As authorized, Soil & Material Engineers, Inc. has completed the ground-water hydrology study for the above referenced project. This report summarizes the results of our investigation and our conclusions regarding the hydrologic properties of strata beneath and in the immediate vicinity of the subject site. The report also contains our evaluations of the previous on-site investigations, and a summary of regional geologic and hydrogeologic investigations made in southern Richland County.

Soil & Material Engineers, Inc. appreciates the opportunity to have worked with Davis & Floyd Engineers and Westinghouse Electric Corporation. Should you or your client have any questions concerning the results of the study or this report, do not hesitate in contacting us.

Yours very truly,

SOIL & MATERIAL ENGINEERS, INC.

B.C. Spigner, RPG
Senior Hydrogeologist
Hydrology Division

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Senior Engineer
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GROUND-WATER HYDROLOGY
of the
WESTINGHOUSE ELECTRIC CORPORATION PLANT
RICHLAND COUNTY, SOUTH CAROLINA

SOIL & MATERIAL ENGINEERS, INC.

Hydrology Division
3025 McNaughton Drive
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S&ME Rept. No. H-8119

March 1, 1982

GROUND-WATER HYDROLOGY OF THE WESTINGHOUSE ELECTRIC CORPORATION PLANT RICHLAND COUNTY, SOUTH CAROLINA

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1.0 SUMMARY

The WEC site is underlain by four hydrogeologic units; from land surface, these are: the Terrace Unit (Unit I), the Upper Black Mingo Unit (Unit II), an artesian sand aquifer (Unit III) within the Black Mingo Formation, and the Tuscaloosa Formation (Unit IV).

The hydrogeology of the Terrace Unit in the area between the main plant and Sunset Lake was adequately documented during a study by Davis & Floyd Engineers and Law Engineering Testing Company (Davis & Floyd, 1980); LETCo, (1980a, 1980b). The information compiled by Davis & Floyd and LETCo, and the additional information compiled during this study indicates that ground water within the Terrace Unit occurs under water-table conditions and that the lateral flow of ground water within this unit is toward the south-southwest. Interpretations of ground-water movement in this unit, made from water-level measurements in November 1981, supports the original conclusions of Davis & Floyd and LETCo. This lateral flow is strongly influenced by topography, locations of recharge and discharge areas, and horizontal stratification of beds within this unit. Therefore, the movement of contaminants in the Terrace Unit will be predominantly by lateral flow in the direction of ground-water movement. A small spring, a man-made pond, and Sunset Lake are natural discharge areas for the Terrace Unit, and their lower topographic elevation exerts the dominant influence on the hydraulic gradient on the water table. Therefore, these natural discharge areas would likely limit the lateral movement of contaminants past Sunset Lake.

The Black Mingo Formation underlies the Terrace Unit, and two hydrogeologic units have been defined within this formation: the upper unit (Unit II) is a confining bed, and the lower unit (Unit III) is an artesian sand aquifer. Hydrogeologic Unit II is composed predominantly of clay and shale. The lithology, thickness, and estimated extremely low vertical hydraulic conductivity (K') of this unit in the area south of the main plant indicates that this unit should be an effective confining bed. It should greatly reduce the probability of vertical migration of contaminants through this unit. Even if vertical hydraulic conductivities were several orders of magnitude greater than estimates provided in this report, much greater vertical hydraulic gradients than now exist would be needed to cause downward vertical leakage of contaminants into underlying aquifers.

2.0 INTRODUCTION

2.1 BACKGROUND AND PURPOSE OF STUDY

The Westinghouse Electric Corporation (WEC) Plant is located in southern Richland County, South Carolina (Fig. 2-1). The plant site is located in the upper Coastal Plain, with some of the site property lying within the flood plain of Mill Creek, a tributary of the Congaree River. The main manufacturing building is constructed on ancient terrace deposits at an elevation of approximately 140 ft above MSL (mean sea level).

Various wastewater treatment facilities and operations are located immediately southwest of the main building and were described in a report by Davis & Floyd, Inc. (1980). Thus, it is not necessary to review these in detail here. These facilities, site topography, monitor well locations and other features are shown in Fig. 2-2 (Appendix), a map from the Davis & Floyd (1980) report.

Immediately southwest of these wastewater treatment facilities, a small man-made pond and Sunset Lake lie on the flood plain of Mill Creek at elevations of approximately 115-125 ft MSL. A small spring discharges into the northern edge of the small pond. According to the report by Davis & Floyd, a hydrogeologic investigation was initiated in 1980 when elevated concentrations of fluoride and ammonia nitrogen were detected in the pond and the spring.

As part of the Davis & Floyd investigation, 28 shallow monitoring wells were installed in 1980 by Law Engineering & Testing Company (LETCo). Two reports by LETCo contain descriptions of the well installation, shallow stratigraphy and hydrogeology of a portion of the WEC site (LETCo, 1980a,1980b). Water sampling and hydrogeologic analyses by Davis & Floyd indicated that the shallow Terrace aquifer southwest of the main plant building was contaminated and that ground water in the Terrace aquifer flowed in a south-southwesterly direction toward the pond and Sunset Lake. Subsequent to the investigation by Davis & Floyd, Inc., WEC and regulatory officials questioned the need for additional monitoring wells and whether it is likely that deeper aquifers beneath or adjacent to the site could become contaminated.

In September, 1981, Soil & Material Engineers (S&ME) Inc. was contracted by Davis & Floyd, Inc. to review previous studies and make recommendations as to whether additional hydrogeologic investigations were warranted. At a meeting with

FROM: AUGUSTA, GA.
USGS TOPOGRAPHIC MAP
1: 250,000

SOIL & MATERIAL ENGINEERS INC.
ENGINEERING-TESTING-INSPECTION
COLUMBIA, SOUTH CAROLINA

FIGURE 2-1. MAP OF CENTRAL S.C. SHOWING LOCATION OF THE WEC SITE.

the Davis & Floyd Project Manager and WEC officials on September 22, 1981, the following objectives were outlined:

1. Review available hydrogeologic reports for the site and available basic data that have been collected, and determine if the existing monitoring network is adequate to monitor the potential movement of contaminants through the shallow aquifer system.

2. Determine, from existing data, if there is a potential for contaminating deeper fresh-water aquifers beneath the site.

In our original proposed scope of work dated October 2, 1981 we outlined the following six tasks or work elements:

1. Meet with WEC officials and the Davis & Floyd Project Manager to review available data, plant facilities, and monitor well locations.

2. Reveiw existing hydrogeological reports of the site.

3. Review available well records in the files of State agencies and review other geologic data that may be available.

4. Obtain geophysical logs of several existing wells at and in the vicinity of the WEC site to explore the deeper strata penetrated by existing wells.

5. Attend a meeting with WEC and Davis & Floyd officials to present the preliminary findings of our initial data review, and geophysical logging.

6. Prepare a report of the additional data collected and review of the existing (Davis & Floyd, 1981) hydrogeological report.

Our preliminary findings and conclusions were presented to the Davis & Floyd Project Manager and WEC officials at a meeting on December 11, 1981. At that meeting it was agreed to perform the following consulting services:

1. Obtain split-spoon samples from the bottom of Wells W-2 and W-3 to determine the lithology and mineralogy of strata in the bottom of these wells.

2. Construct a four-inch diameter monitor well southwest of Well W-15 that would tap the Black Mingo Aquifer System at an approximate depth of 70-80 ft below land surface.

3. Construct a two-inch diameter well located in close proximity to the four-inch diameter well.

These services were to be performed in order to (1) estimate the hydraulic characteristics of upper strata within the Black Mingo Aquifer System; (2) provide a 4-inch diameter monitoring well tapping the uppermost aquifer within the Black Mingo Aouifer System; and (3) provide a shallow monitor well tapping the Terrace Unit which could be used to monitor piezometric head and water quality.

2.2 SCOPE

2.2.1 Scope of This Study and Report

Considerable hydrogeologic and geochemical data were collected on the shallow strata at the WEC site during the Davis & Floyd (1980) study. However, this information was limited to depths of about 30 ft below land surface. Hydrogeologic data were not available on strata below the shallow geologic unit. Two deeper environmental monitor wells were completed at the site in 1963 and 1969 (W-1) and two additional environmental monitor wells (Wells W-2,W-3) were installed in 1977. It was recommended that geophysical logs (gamma-ray and capiler) should provide useful hydrogeologic data on these four monitor wells that could be correlated with off-site data from previous studies made in southern Richland County.

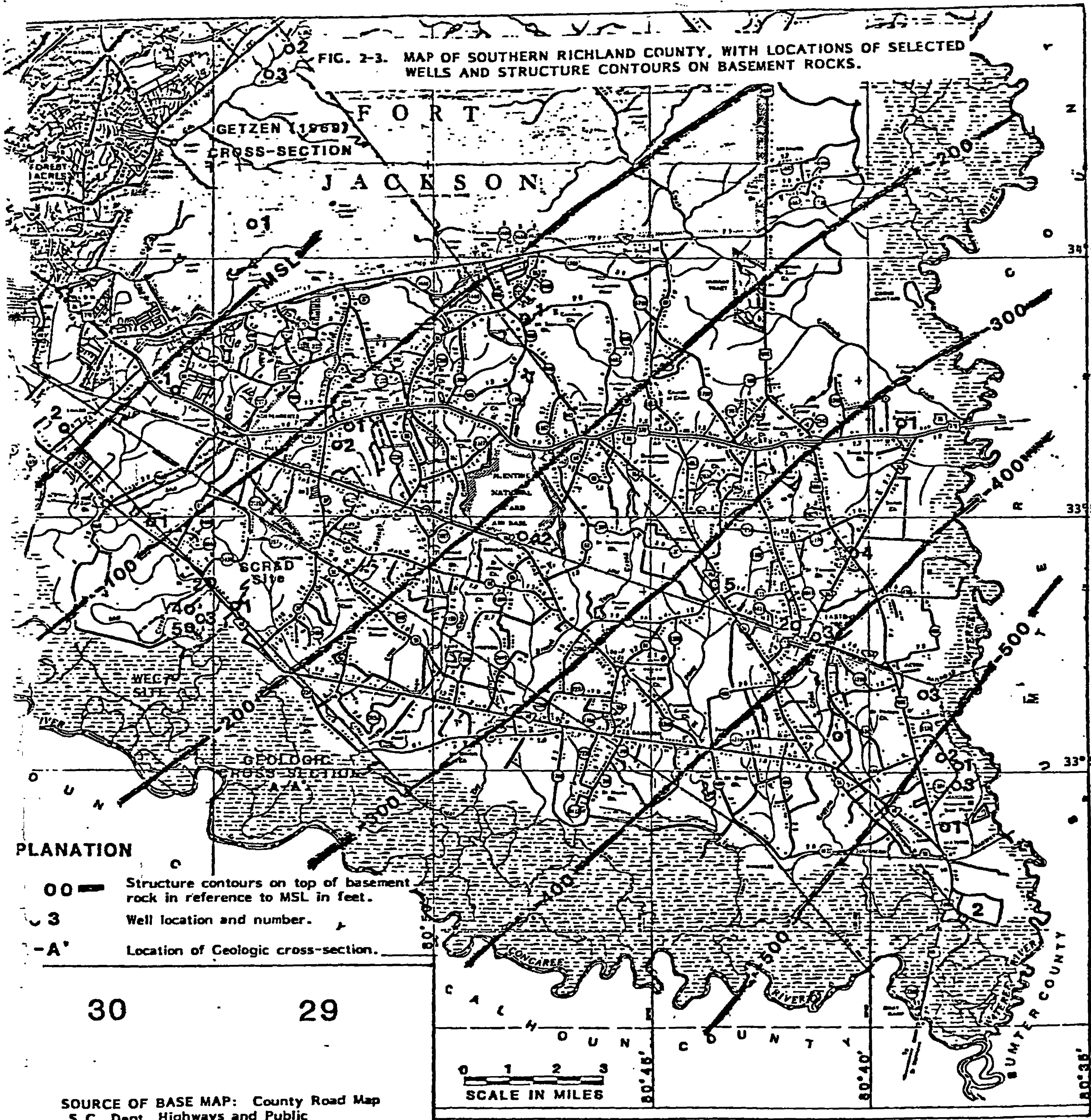
After review of these geophysical data collected by S&ME, and other reports on or adjacent to the site, several test wells were recommended to properly assess the hydrogeologic properties of strata below the shallow geologic unit. Because of the availability of considerable hydrogeologic data on shallow strata and geophysical data on the deeper wells at the site, it was agreed to limit hydrogeologic testing of deeper strata to one test hole at a location believed to be the most strategic location. An adjacent shallow well was to provide pertinent hydraulic data on shallow strata.

Hydrogeologic data from private and other water wells in the vicinity of the WEC property were obtained from well record files of state or federal agencies, well-drilling contractors, or other consultants (Sec. 2.2.3). Site maps, topographic elevations and elevations of previously constructed monitor wells at the site were available from the previous studies. Water-level measurements made by WEC personnel or others and stratigraphic boring logs of previously installed monitor wells were also made available.

2.2.2 Area of Investigation

The scope of this project required two study areas: (1) the WEC plant site, in particular, the southern part of the property; and (2) an adjacent, or regional, study area. The plant site study area is the area defined by previous on-site studies (Fig. 2-2, Appendix). The regional study area (Fig. 2-3) was defined by the hydrogeologic data that could be obtained from published reports, data in state agency files, and our preliminary review of these reports and data.

FIG. 2-3. MAP OF SOUTHERN RICHLAND COUNTY, WITH LOCATIONS OF SELECTED WELLS AND STRUCTURE CONTOURS ON BASEMENT ROCKS.



SOURCE OF BASE MAP: County Road Map S.C. Dept. Highways and Public Transportation 1:125,000

2.2.3 Investigation Methods

Report and Data Review

Report and data review involved the review and analysis of both on-site and off-site data. The most comprehensive on-site report was the Davis & Floyd (1980) report, which included two reports prepared by LETCo (1980a,1980b). Our approach in reviewing these reports was to utilize the basic data and derive independent conclusions regarding the hydrogeology of shallow strata on the site. Basic data from these reports were utilized to construct hydrogeologic cross-sections in order to interpret the shallow subsurface stratigraphy of the site. Since completion of the Davis & Floyd Report, WEC personnel have periodically measured water levels and collected samples for water-quality analyis by Davis & Floyd. These data were made available for our review and interpretation.

Our review of off-site reports is summarized in Sec. 2.3. Basically, there are few published hydrogeologic reports available for southern Richland County. Therefore, hydrogeologic data in the files of several state agencies and one federal agency were reviewed and analyzed for any information that would aid in interpreting the hydrogeology of strata at the WEC site. These data consisted of well records in the files of the SCWRC (S.C. Water Resources Commission), the SCDHEC (S.C. Dept. Health and Environmental Control), the SCGS (S.C. Geological Survey), and the USGS (U.S. Geological Survey-Water Resources Division).

These well records, normally supplied by well drillers, and consultants, consist of well-construction data, driller's logs, information on yield of the well, and location. Sometimes geologic cuttings (ditch samples) are collected and geophysical logs are made on certain wells. Our review indicated that information on water wells in southern Richland County and in the vicinity of the WEC site, in particular, is very general. Since much of the data in state and federal files has not been field checked or verified for accuracy, these data provide only a rough indication of ground-water conditions in the regional study area.

In our review of these well records, we utilized the records, geophyical logs, driller's logs and other records which appeared to be the most complete.

Some of the wells utilized in our regional hydrogeologic evaluation are shown on Fig. 2-3. Many of the well locations could not be verified with an accuracy of ± 0.5 mile; therefore, these locations should be regarded as approximate. For this report and for future reference, the well location grid utilized by S&ME is shown on Fig. 2-3. This grid, based on 5-minute latitude-longitude rectangles, is utilized for numbering wells by both the SCWRC and SCDHEC. Some of these wells and various geologic cross-sections published by others are discussed in Sec. 3.0.

Geophysical Logging

In order to derive some stratigraphic information on the deeper environmental wells installed at the site, caliper logs and natural gamma-ray logs were run by S&ME's geophysical logging department.

The caliper log is obtained with an electronic caliper probe which measures borehole diameter as it moves upward through the borehole. In a cased hole, the caliper log is useful in accurately measuring the depth of casing, in determining casing integrity (casing breaks if they exist), and in locating the positions of well screens and probable screen ruptures. Because well-construction data were not available on the deeper monitor wells at the site, we ran the caliper logs to determine the depth and integrity of casing and well screens. It was not necessary to obtain caliper logs of the 28 shallow monitor wells (W-6 through W-33) because well-construction data were available for these wells.

The natural gamma-ray log (frequently referred to as gamma log) is a log obtained with an electronic gamma probe (or sonde). This log is one of the most useful logs for obtaining subsurface information from water wells and stratigraphic test holes. Basically, the gamma probe measures the natural gamma radioactivity emitted by strata in the borehole. The gamma probe, which contains no radioactive source, electronically "counts" or measures the intensity of gamma rays emitted by strata. Because the gamma probe is unaffected by well casing, a gamma log can be obtained from a cased well.

In sedimentary rocks, such as the sands and clays that underlie the WEC site, clays contain and emit a higher gamma count than sands. Therefore, clays which are generally confining beds, can be differentiated from sands which are generally aquifers. The specific response (log signature) of a stratum, bed, or lithologic unit in a given area must be established. Therefore, good stratigraphic logs in representative wells at a given locality are absolutely necessary to establish the gamma response, or signature. The accuracy of stratigraphic correlations of strata from well to well by gamma-log interpretion is strongly weakened if wells are spaced too far apart. A "reasonable well spacing" for a given area must be established. This reasonable spacing must be established on a thorough knowledge of the subsurface geology.

Gamma logs were obtained from five wells (W-1,W-2,W-3,W-25, and W-27) and one abandoned water well adjacent to the site. In several wells, two gamma logs were obtained, with different time counts, to establish the best log signature. Our interpretations and subsurface correlations with these logs are discussed in Sec. 4.0. These interpretations were utilized to construct a hydrogeologic cross-section of the site, and in determining the proper depth to install a deep stratigraphic test hole (ST34).

Drilling and Stratigraphic Sampling

As mentioned earlier, considerable geologic information on shallow strata (to a depth of about 30 ft below land surface) was available in the area south of the main plant building. However, the geology of deeper strata was largely unknown. Our preliminary gamma-log correlations of the deeper strata (approximately 30-60 ft below land surface) in Wells W-1, W-2, and W-3 indicated the probable existence of clay confining beds below the Terrace unit, but information on their specific thickness, and physical and hydrogeologic character was limited. Therefore, stratigraphic (split-spoon) samples were obtained from the bottom of the deeper environmental monitor wells (W-2,W-3), and a stratigraphic test hole (ST34) was drilled to obtain samples of the Terrace unit and deeper strata.

Caliper logs of Wells W-1 and W-3 indicated that screens had not been placed in these wells, and that strata below the casing in Well W-2 had collapsed and had apparently filled the casing (indicating sand). Thus, Wells W-2 and W-3, at least, did not contain bottom plugs, and split-spoon samples were obtained to determine the stratigraphy in the bottom of these wells.

Stratigraphic Test ST34 and Well W-34

Our preliminary data review and geophysical logging indicated the probable existence of clay confining beds of the Black Mingo Formation underlying the Okefenokee Formation at the WEC site. The SCDHEC (1981) also inferred that a confining bed existed below the Okefenokee Formation in the vicinity of the WEC site.

Stratigraphic samples from ST34 were obtained by standard split-spoon sampling and mud-rotary drilling. Samples were obtained at 5-ft intervals and wash samples were observed between split-spoon intervals and described in the field by a hydrogeologist. A detailed geologist field log was maintained during the drilling. Split-spoon samples were placed in glass sample jars and transported to the laboratory for detailed lithologic description by a hydrogeologist. The hole was terminated at a depth of 85 ft in the Black Mingo Formation. No aquifer was present within the Black Mingo Formation at the site; and this test hole was plugged with cement grout.

Well W-34 was extended by mud-rotary drilling to a depth of 24 ft. A two-inch diameter PVC continuous slot screen was installed at a depth of 18 ft-23 ft below land surface. Clean quartz gravel was installed in the annular space between the screen and borehole wall to a depth of 16 ft-24 ft. A bentonite seal, 2-ft thick, was installed above the gravel at a depth of 14 ft to 16 ft. The annular space above the bentonite seal was then filled with neat cement grout to land surface. The well was developed with fresh tap water from a portable water tank.

2.3 PREVIOUS STUDIES

2.3.1 On-Site Studies

One of the major objectives of this study involved a comprehensive review and analysis of the Davis & Floyd (1980) and LETCo (1980a; 1980b) studies and reports. In addition published geologic or hydrogeologic studies made in areas adjacent or in the vicinity of the site were to be reviewed and evaluated for applicable data. A partial listing of the reports reviewed for this study are included in Sec. 6.0. A number of other general or regional-type reports were reviewed for applicable data. The most important, however, are listed in Sec. 6.0. Many of these references are quoted in later sections of this report. Thus, a detailed review and analysis of the specific contents of these reports are not reviewed in detail here.

The 1980 Davis & Floyd and LETCo reports provide a fairly comprehensive assessment of the hydrogeology of the Terrace Aquifer System in the area between the main plant and Sunset Lake. Most of the 28 monitor wells installed as a part of their study were located in this area. The general hydrogeology of the Terrace Unit beneath other portions of the site was evaluated with other borings. The basic data, hydrogeologic cross-sections of the shallow strata, ground-water movement and quality data provides the most comprehensive information of the hydrogeology of these shallow strata within 10-15 miles of the site.

2.3.2 Regional Studies

A number of regional or general-type reports contain information on the geology and hydrogeology of areas that include southern Richland County. Many of these reports contain little basic data that can be used with a reasonable degree of accuracy in interpreting the specific hydrogeology of strata beneath or adjacent to the WEC site. The most pertinent of the references consulted, are summarized below. Getzen (1969) studied the subsurface and near-surface geology of the area between Wateree and Fort Jackson, with emphasis on the stratigraphy of the Tuscaloosa Formation. He also provided pertinent information on the water-bearing properties of Tuscaloosa aquifers. Padgett (1980) studied the near-surface and subsurface stratigraphy of the Black Mingo Formation in the Wateree-Eastover area. Although this report was not specifically made to evaluate the hydrogeologic properties of the Black Mingo, his lithologic descriptions and geologic cross-sections provide pertinent data that can be used for hydrogeologic analysis.

Several published reports are available that describe the regional hydrogeology of southern Richland County or adjacent areas. The ground-water resources of the Wateree areas were described in a hydrogeologic report by Park (1980), published by the SCWRC. When combined with geophysical and drillers' logs obtained from wells in the study area, Park's hydrogeologic descriptions provide pertinent data for analysis.

A report on the S.C. Recycling & Disposal (SCR&D) site, located adjacent to the WEC site, was prepared by hydrogeologists with the Ground-Water Protection Division of the SCDHEC (1981). This report described the hydrogeology of the unconfined shallow aquifers beneath the site. A shallow-well monitoring network of 11 wells was constructed to monitor the movement of ground water and to evaluate the extent of ground-water contamination. The three deepest auger borings drilled by the SCDHEC provide the most pertinent stratigraphic information. The specific hydrogeology of geologic formations beneath the shallow sediments was not addressed in the SCDHEC study. The deepest SCDHEC well (Well Q29-f1) was drilled into the top of Black Mingo Formation clays at 45-47 ft below land surface.

When the data from all of these reports are combined and interpreted, they provide an adequate description of the hydrogeology of the sedimentary strata in southern Richland County. The on-site reports are obviously the most pertinent and comprehensive. The reports by the SCDHEC (1980), Getzen (1969), Padgett (1980), and Park (1980) were the most useful of the regional reports.

3.0 REGIONAL GEOLOGY AND HYDROLOGY

The occurrence, movement, and availability of ground water in any area are intimately related to the stratigraphy and structure of underlying geologic formations. Similarly, the near-surface geology largely controls the physiography of an area. The relationship of the geology, physiography and climate of an area ultimately controls the recharge of ground water to geologic formations beneath that area.

The term "regional" can be used to refer to any scale--from a few square miles to many hundreds of square miles. In this report, "regional" refers to the area shown in Fig. 2-3, southeastern Richland County. This area lies within the following USGS 7.5 minute topographic guadrangles: Fort Jackson South, Saylors Lake, Congaree, Gadsden, Eastover, and Wateree. The purpose of this section is to briefly summarize those "regional" relationships that are important in understanding the occurrence and movement of ground water beneath and adjacent to the WEC site. In Sec. 4.0 the site-specific hydrogeology is presented in greater detail.

3.1 PHYSIOGRAPHY--STRATIGRAPHY--CLIMATE

3.1.1 Physiography and Climate

Southeastern Richland County lies within the upper Coastal Plain subprovince of the Atlantic Coastal Plain. The topography of this area varies from very flat terrain with poor drainage near the Congaree River to well dissected, mature terrane in the Ft. Jackson South quadrangle.

The physiography of the upper Coastal Plain is controlled by the unconsolidated sands and clays of the Coastal Plain which are easily weathered in comparison to the hard, consolidated crystalline rocks north of Columbia, S. C. Columbia is located on the Fall Line which separates the Piedmont physiographic province to the northwest from the Coastal Plain province to the southeast.

The climate of southeastern Richland County has a pronounced effect on the availability of water available as recharge to the underlying geologic formations. Precipitation, which is mainly in the form of rain is fairly well distributed throughout the year. The average annual rainfall is about 50 inches, with spring and early summer being the wettest seasons. Droughts, which may be severe to agricultural production, are normally described as mild and sometimes occur in late summer and early fall. Some farmers in southeastern Richland County and in adjacent counties have turned to irrigation to avoid crop failures during these droughts. Although ponds and streams are used where sufficient, many crops are being increasingly irrigated by ground water.

The topography of the area surrounding the WEC plant is flat with only slight local relief. Several ancient marine "terraces" occur in the vicinity of the plant. These terraces have been mapped over large areas by their topographic elevations, which may vary only a few tens of feet over large areas. The WEC plant is located on the Okefenokee terrace, which has a range in elevation of about 130 ft MSL to 150 MSL near Columbia (Colquhoun, 1965). Southeast of the plant site, the Wicomico terrace has an elevation of 100 to 120 ft MSL. The Sunderland terrace occurs northwest of the WEC site, with elevations ranging from 170 to 190 ft MSL.

3.1.2 Geologic Setting--Stratigraphy and Structure

Sedimentary rocks (sediments), primarily sands and clays, underlie the upper Coastal Plain in Richland County. Outcrops are rare, and only a few feet or tens of feet of these sediments are exposed in a given area. Therefore, most of the knowledge on the geology of these sediments must come from interpretation of subsurface information obtained from stratigraphic test wells or water wells. Some of the water wells used in our regional geologic and hydrogeologic analysis are shown in Fig. 2-3, and the available data on these wells are summarized in Appendix Table 3-1.

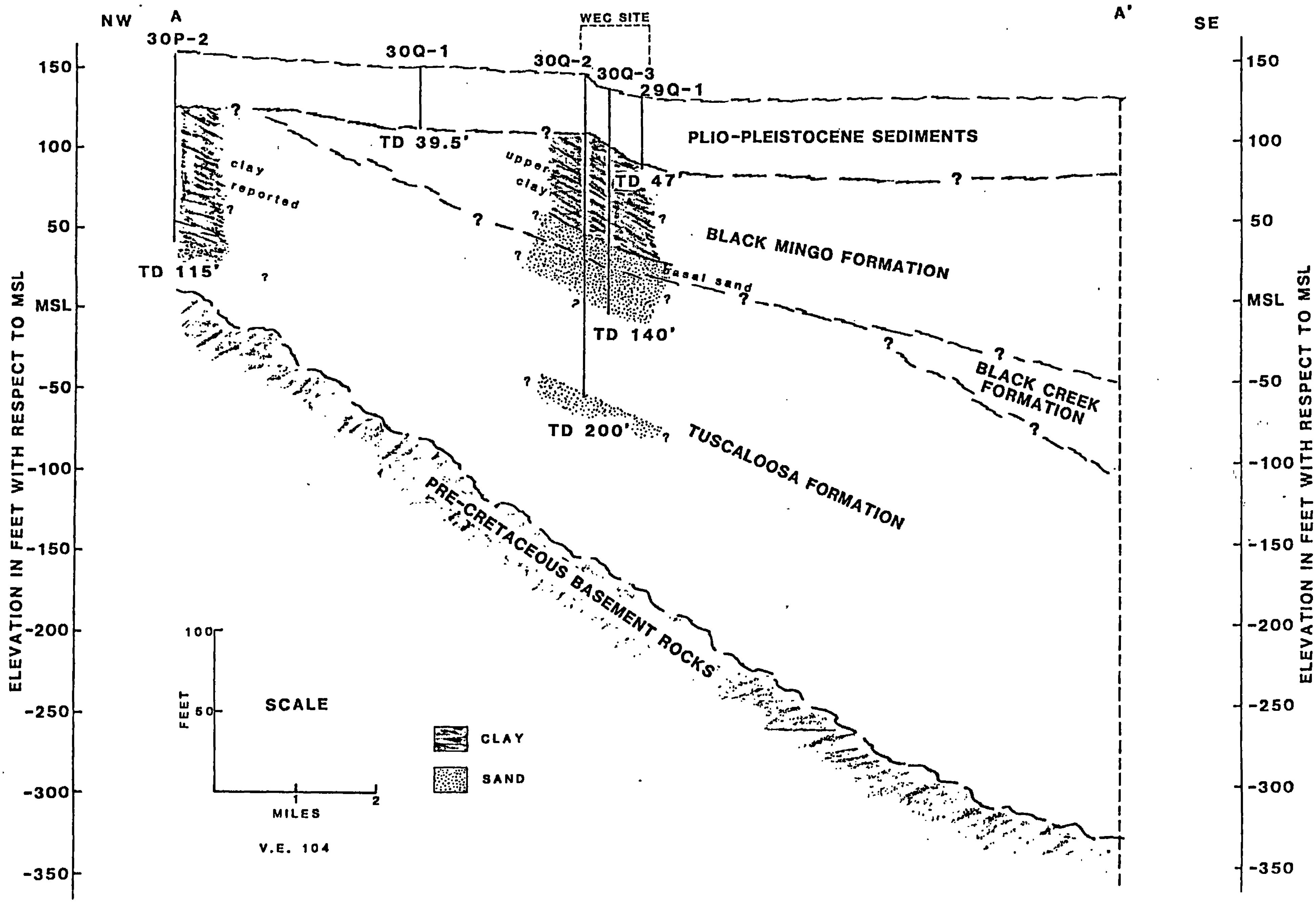
These sediments in Richland County thicken from a few tens of feet at Columbia at the Fall Line to approximately 700 ft near the Wateree River in southernmost Richland County. These sedimentary rocks, ranging from Late Cretaceous to Recent in age, overlie pre-Cretaceous crystalline "bedrock" or "basement". The upper surface of the basement dips toward the southeast at a rate of about 20-40 ft/mi (Fig. 2-3). The overlying sedimentary formations also dip toward the southeast and thicken in the direction of dip. Because of this southeastward dip, wells penetrate a certain geologic unit (bed or stratum) at progressively greater depths toward the southeast.

Several water wells in southeastern Richland County (Fig. 2-3) have penetrated the entire thickness of sedimentary rocks, terminating at or near the top of basement. Well 27Q-5 penetrated the top of basement at a depth of 540 ft: Further southeast, Wells 26Q-3 (658 ft) and 26R-1 (680 ft) were terminated at the top of crystalline bedrock. Many water wells located 10-15 mi northwest of the WEC site near Columbia and in the western part of Ft. Jackson have penetrated crystalline bedrock. Unfortunately, within several miles of the WEC site, we have not found any records of water wells that have been drilled to bedrock: thus, the geologic structure map (Fig. 2-3) must be regarded as a generalized representation of the dip of the bedrock surface.

The generalized geologic cross-section of southeastern Richland County (Fig. 3-1) shows our interpretation of the subsurface stratigraphy. This cross-section is perpendicular to the geologic structure contours in Fig. 2-3; thus, the cross-section should approximately represent the true dip of the geologic formations. A similar geologic cross-section was prepared by Getzen (1969), based on information obtained from Wells 28P-1, 27Q-5, and 26R-2; and more recently, Padgett (1980) constructed a geologic cross-section from information obtained from Wells 26Q-3, and 26R-1. Park (1980) used Well 26Q-2 in his hydrogeologic cross-section of Sumter County. Although there are some differences in the geologic interpretations of these investigators, the subsurface geology of southeasternmost Richland County near the Wateree River has been fairly well established.

Because the sedimentary rocks thicken to more than 600 ft toward the southeast, it should be expected that some strata (or lithologic units) present in southeasternmost Richland County will not be present at the WEC site. At the WEC site, the crystalline bedrock occurs at an elevation of about -100 to -150 ft MSL (ft below mean sea level). Therefore, with topographic elevations of 110-140 ft MSL, the sedimentary rocks at the WEC site should be about 240 ft to 290 ft thick, depending on land-surface elevation at a particular point (Fig. 3-1).

FIGURE 3-1. GENERALIZED GEOLOGIC CROSS-SECTION A-A', of SOUTHERN RICHLAND COUNTY.



3.1.3 Summary of Geologic Formations

The correlation of subsurface geologic formations (stratigraphic correlation) from well to well in a given area depends on the accuracy of information available and distance between wells. Although exposures of geologic formations are rare and the number of deep water wells in southern Richland County penetrating below Coastal Plain sedimentary rocks are widely spaced, the subsurface geology of these formations are fairly well known on a regional basis.

As stated previously in this report, several published reports or M. S. theses describe the subsurface geology of southern Richland County or adjacent counties. Getzen (1969) described the stratigraphy of the Upper Cretaceous Tuscaloosa Formation in southeastern Richland County. Smith (1979) and Padgett (1980) studied the stratigraphy of Tertiary age sediments in Lexington and Richland Counties. The near-surface geology of the upper Tertiary and Pleistocene terrace sediments was described by Colquhoun (1965). The following descriptions of geologic formations are based, in part, on these and other published references, supplemented with water-well information from various well-record files.

Basement Rocks

The geology of basement rocks in southern Richland County is poorly known because few wells have been drilled into these rocks. Compared to overlying formations, these rocks are essentially considered as "impermeable" or relatively impermeable. Therefore, these rocks are relatively unimportant to the overall geology and water-bearing properties of overlying sediments.

Tuscaloosa Formation

The Tuscaloosa Formation overlies bedrock and is the oldest sedimentary formation in southern Richland County. The Tuscaloosa was deposited on the eroded surface of bedrock during Late Cretaceous time. Although the lithology of the Tuscaloosa varies considerably in local areas, it has certain characteristics which are recognizable over large geographic areas.

In southern Richland County the Tuscaloosa Formation has been penetrated or tapped by many water wells; some of these wells are plotted on Fig. 2-3.

In general, the Tuscaloosa is a somewhat complex assortment of lithologies. It contains vari-colored (generally "light-colored") fine-to coarse-grained quartzose, feldspathic (containing feldspar) sands; and light-colored (grey, red, brown, purple, yellow) clays containing variable amounts of silt or sand. Fine-to-medium-grained gravel, and mica and lignitic wood framents are common constituents in this formation.

The Tuscaloosa Formation thins from about 300-350 ft in southeastern Richland County to less than 100 ft near Columbia (Fig. 3-1). Getzen (1969) subdivided the Tuscaloosa into 10 lithologic units (beds) in southeastern Richland County, which he designated by the letters "a" through "j". The upper part of what Getzen termed Tuscaloosa has been shown by several more recent studies (Smith, 1969; Padgett, 1980) to be the Black Mingo Formation.

In the middle and lower Coastal Plain and near the Wateree River in Richland County, the Black Creek Formation probably overlies the Tuscaloosa Formation. However, at and in the immediate vicinity of the WEC site, the Black Creek Formation is believed to be absent, and the Black Mingo Formation overlies the Tuscaloosa Formation (SCDHEC, 1981).

Black Mingo Formation

The Black Mingo Formation is the oldest Tertiary age geologic formation in southern Richland County. The subsurface geology (stratigraphy) of this unit has been studied by a number of investigators, especially in the last five years. Padgett (1980) studied the near surface and subsurface stratigraphy of this formation in southern Richland County and adjacent areas and reviewed previous reports that describe the geology of this formation.

Padgett (1980) showed that the Black Mingo Formation in Godspeed Farm Well No. 1 (Well 26R-1, Fig. 2-3) is approximately 100 ft thick and consists of (1) an upper deltaic unit and (2) a lower transgressive marine clay with a basal sand. He showed that the Black Mingo Formation thickened toward the southeast and is approximately 200 ft thick at Pinewood in Sumter County. Toward the northwest, in the Congaree River Valley, the upper part of the Black Mingo Formation has been removed by erosion. Therefore, in the immediate vicinity of the WEC site, the thickness of the Black Mingo Formation has been estimated to be only about 75 ft (SCDHEC, 1981).

As illustrated in Fig. 3-1, if the 75 ft thick estimate for the Black Mingo is correct and if it thins toward the northwest, it eventually pinches out between the WEC site and Well 30P-2. The base of the Black Mingo Formation in Fig. 3-1 was drawn with a southeastward dip of 10-15 ft/mi, a rate consistent with published values. However, many geologists have recognized the fact that the contact between the Black Mingo and underlying Tuscaloosa is problematic (Siple, 1959; Colquhoun, et al, 1969). This is because the lithologic similarity of the Black Mingo and underlying Cretaceous age formations (either Black Creek or Tuscaloosa) make the contact difficult to define in the subsurface, particularly with cuttings from rotary-drilled wells. Therefore, in the absence of specific subsurface information from wells in the vicinity of the WEC site, the thickness and stratigraphic relationships of the Black Mingo can not be accurately defined. The most complete stratigraphic data on the Black Mingo are from interpretation and correlation with gamma logs on WEC monitoring wells (W-1,W-2, and W-3) and from split-spoon samples in test well ST34. The upper part of the Black Mingo Formation at the WEC site is a dark - to medium-gray carbonaceous (lignitic) clay and shale which is as much as 60 ft thick (Wells W-3,ST34).

As shown by Padgett (1980) the Black Mingo Formation in southern Richland County is a complex and variable assortment of lithologies (rock types) deposited in marginal marine to deltaic environments. In these depositional environments, fine-grained sediments such as clays and silts dominate, with lenses (beds) of coarser-grained sand being locally present. Although the Black Mingo contains a wide range of grain sizes, it is typically known for the clays and shales which are dominant. These clays are typically dark-grey to brown, micaceous, highly plastic, and carbonaceous. They have been traced laterally for many miles from water-well records and outcrop data. Beds of light to medium-grey opaline claystone, with a smooth conchoidal fracture are common in the upper part of this formation. In Sumter County and adjacent areas, these beds were named the Tavern Creek bed by Padgett (1980).

Pliocene- Pleistocene Formations

In southern Richland County, sand and clay beds are exposed in scattered drainage ditches and road cuts. These sediments are generally on the order of 20 ft to 40 ft thick and are often referred to as Plio-Pleistocene sediments in reference to their late Tertiary (Pliocene) to Pleistocene ages. During late Tertiary to Pleistocene time, a series of marine terraces were formed, which have been named by geologists. In the immediate vicinity of the WEC site, the Okefenokee terrace has an elevation of 130 ft to 150 ft MSL. Some geologists have assigned formal geologic names to the sediments underlying these terraces. Thus, the Okefenokee Formation underlies the Okefenokee terrace.

These Plio-Pleistocene sediments contain various admixtures of silts, clays, and sands in beds which thicken or thin appreciably within short distances. The lithology of one bed (sand, for example) commonly grades laterally or vertically into another lithology(sandy clay, for example). Thus, even within a site-specific area of only a few hundreds of square feet, it is not unusual to find that the subsurface geology of these sediments is often difficult to correlate from one well to another.

3.2 REGIONAL HYDROLOGY

One of the objectives of this study was to evaluate the potential movement of ground water from the shallow geologic formation into deeper geologic formations beneath the WEC site. In accomplishing this objective, one of the work tasks was to review and evaluate existing subsurface information at the site and to correlate this information to subsurface information on geologic formations adjacent to or in the vicinity of the site. Because the subsurface geology of southern Richland County has not been mapped in detail by either geologists or hydrogeologists, some confusion exists, especially between geologists and hydrogeologists, concerning the nomenclature applied to various geologic "formations" in this area. Therefore, a brief explanation is necessary on the nomenclature applied to various hydrogeologic units in this report.

3.2.1 Ground-Water Occurrence

The occurrence, movement, and availability of ground water in southern Richland County are related to the stratigraphy (type of sediments) and structure (primarily the attitude) of underlying strata. A geologic formation, as formally defined by a geologist, is a recognizable stratum or several strata of similar lithologic character that is mappable or "traceable" within a certain geographic area. Some geologic formations, such as the Tuscaloosa Formation, contain a number of lithologic units such as clays, sands, clayey sand and gravel beds.

A hydrogeologic unit is a stratum, or several strata, that have similar water-bearing (hydrologic) properties. An aquifer is a hydrogeologic unit that transmits ground water or yields appreciable quantities of ground water to wells. Aquifers in southern Richland County are generally sands, clayey sands, or gravelly sands and these occur within all of the geologic formations in the area. One aquifer may be composed of relatively "clean" or well sorted medium to coarse sand and may yield appreciable quantities of ground water to wells. The same aquifer may contain appreciable quantities of clay or silt in another area, and would not be as permeable; and consequently would not yield as much ground water.

A confining bed is a hydrogeologic unit that is less permeable and does not readily transmit ground water or yield appreciable quantities of ground water to wells. Some confining beds are relatively impermeable, and others may be sufficiently permeable to allow some movement of ground water through them; but they would not yield appreciable quantities of ground water to water wells or even monitor wells. In southern Richland County, confining beds occur within all of the major geologic formations and are generally composed of relatively pure clay, silty clays, or clayey silts. Some clay beds within the Black Mingo Formation are especially known for their relatively impermeable nature.

In most of the study area (Fig.2-3) the subsurface boundaries of either the major geologic formations or major hydrogeologic units have not been precisely mapped by geologists or hydrogeologists except on a generalized basis. The vertical boundaries of a geologic formation may not actually coincide with the boundaries of a hydrogeologic unit. For example, at some places in the study area a sand occurs in the base of the Black Mingo Formation that is similar to a sand bed in the upper part of the underlying Tuscaloosa Formation. Therefore, these sands, although in two different geologic formations, would be considered as one hydrogeologic unit--an aquifer.

Confined and Unconfined Aquifers

Ground water in southern Richland County occurs under both artesian (confined) and water-table (unconfined) conditions. Artesian aquifers are aquifers that are confined, or contained, by confining beds. The water level in a well tapping an artesian aquifer will rise above the top of the aquifer; this water level represents a point on the piezometric surface, an imaginary "pressure" surface connecting points to which water will rise in tightly cased wells completed in the same aquifer. The water level in a well tapping a water-table aquifer defines the water table, the imaginary surface at which pressure is atmospheric. Water levels in wells penetrating a water-table aquifer may rise to a level at, above, or below the water table, depending on the well depth and whether the well is in a recharge or discharge area (Lohman, 1972).

In southern Richland County (Fig. 2-3) artesian aquifers occur within the Tuscaloosa and Black Mingo Formations. Ground water in the near-surface geologic formations gnerally occurs under water-table conditions. The artesian aquifers are recharged from two sources (1) rain falling in the outcrop areas located at higher elevations, and (2) vertical leakage through relatively permeable confining beds. The recharge areas for artesian aquifers within the Tuscaloosa Formation are located north of the WEC site in the Columbia-Ft. Jackson area. Because these areas are located at altitudes higher than those in southeastern Richland County, considerable artesian pressure is built up as ground water moves down the hydraulic gradient. The Black Mingo Formation does not contain such an extensive outcrop area. Therefore, recharge to artesian Black Mingo aquifers must occur from downward vertical leakage from shallow water-table aquifers or from upward vertical leakage from artesian Tuscaloosa Formation aquifers.

Recharge of water-table aquifers in southern Richland County occurs primarily from rainfall and infiltration in the immediate area, and the water table generally reflects subtle differences in topography. Topographically high areas are generally recharge areas, and lower areas are discharge areas.

3.2.2 Major Aquifer Systems and Ground-Water Use

Information compiled during this study indicates that three major aquifer systems occur in southern Richland County: (1) the Tuscaloosa Aquifer System, (2) the Black Mingo Aquifer System and (3) a surficial, or unconfined aquifer system. The Tuscaloosa Aquifer System, for practical purposes, is considered equivalent to the Tuscaloosa Formation, and the Black Mingo Aquifer System is considered equivalent to the Black Mingo Formation. Various shallow geologic formations are included within the unconfined aquifer system and this series of sands and clays have not been named on a regional basis.

Tuscaloosa Aquifer System

This series of sands and clays make up one of the most important artesian aquifer systems in the upper Coastal Plain. Clays occur within the Tuscaloosa and separate this aquifer system into a number of aquifers. This aquifer system underlies all of southern Richland County and artesian aquifers within this system supply ground water to many wells in this area. There are a number of beds within the Tuscaloosa aquifer system that are composed of medium-to coarse-grained sand and fine-to-medium gravel. These sand beds, which are as much as 20 ft to 40 ft thick, are prolific artesian aquifers.

The piezometric surface of this multiple-aquifer system, which may consist of several piezometric surfaces, has not been mapped in southern Richland County. Consequently, the direction of ground-water movement within this artesian aquifer system can only be inferred. Presumably, rainfall infiltrates the ourcrop areas at high elevations (+300 - +400 ft MSL) near Columbia and moves down the hydraulic gradient toward the south and southeast. About 15-20 mi down the dip in southern Richland County, major river valleys would be natural discharge areas for ground water moving through this aquifer system. Thus, the WEC site is presumably located in a ground-water discharge area of the Tuscaloosa.

As shown in Fig. 3-1, several wells at and in the vicinity of the WEC site tap artesian sand aquifers within the Tuscaloosa (Wells 30P-2,30Q-2,30Q-3). Well 30P-2, an abandoned test well at Atlas Road School, was reportedly terminated in "clay" at 115 ft. However, well 30Q-2 reportedly tapped a "porous sand" at 200 ft, which is interpreted to be a Tuscaloosa artesian aquifer.

Some wells in the Hopkins area (Grid 29Q, Fig. 2-3) and many small-diameter domestic wells northeast of the WEC site (Grid 29P) tap artesian sand aquifers within the Tuscaloosa Aquifer System. Most of these wells supply private homes (domestic wells) and small businesses, industries, trailer parks, and schools. Our review of well records indicates that there are no large-capacity Tuscaloosa wells located within about five miles of the WEC site. To the southeast, where Tuscaloosa aquifers thicken and are more permeable, several large-capacity irrigation wells (26R-1, 27Q-1) tap this aquifer system.

Black Mingo Aquifer System

Specific hydrogeologic units within the Black Mingo Formation have not yet been mapped in this area (Camille Ransom, S.C. Water Resources Commission, personal communic., 1981) Therefore, the Black Mingo "Formation" rather than "aquifer system ", is most often used by hydrogeologists in describing the hydrologic properties of this unit. A review of available water-well records at the SCWRC and USGS indicates that many water wells in the area between Hopkins and Eastover (Fig. 2-3) probably tap sand aquifers within the Black Mingo Formation. However, drillers' and geophysical logs and other specific well-construction data are rather fragmented. Some of the available well records for the study area are summarized in Appendix Table 3-1, and the wells are plotted on Fig. 2-3.

Several public-supply wells at Eastover (27Q-2,27Q-3) and two wells at the EcEntire NG Air Base (28Q-1,28Q-2) tap Black Mingo aquifers at depths of less than 200 ft. Specific pumping-test data on Black Mingo wells in the study area are not available, but some reported specific capacities of wells are in the range of less than 4 gpm/ft to about 10 gpm/ft. Local well drillers report that there is a considerable variation in hydrologic properties of aquifers within this aquifer system (Mr. P. McNeil, Heater Well Co., personal communic., 1981). This erratic hydrologic behavior is, in part, related to the depositional environment of Black Mingo strata. Sands commonly thin or grade laterally into sandy silts or even silty clays within relatively short distances. Thus, it is not unusual for relatively poor yielding wells to be located in fairly close proximity to higher yielding wells.

In the immediate vicinity of the WEC site (Fig. 3-1) wells deeper than about 125 ft would penetrate the Tuscaloosa Formation. Well 30Q-3 (WEC Well W-1), reportedly drilled to a depth of 140 ft probably encountered Tuscaloosa sediments. Currently, the open-hole section of this well (71-76 ft) is within the Black Mingo Formation. Well 30Q-2 reportedly penetrated "black mud and water" from land surface to 20 ft; impermeable clays from 20-200 ft; and a porous sand at 200 ft. While these reported data are admittedly poor, they do fit the stratigraphic sequence as illustrated in Fig. 3-1.

Ground water in Black Mingo aquifers occurs under artesian conditions where these aquifers are confined between clays. Near outcrop areas, ground water in shallow Black Mingo aquifers may occur under "semi-confined" or water-table conditions. Therefore, Black Mingo aquifers in southeastern Richland County receive recharge both from outcrop areas and from vertical leakage.

Many private and a number of public-supply wells have been drilled in the Hopkins area (Grid 29Q, Fig. 2-3) which tap or that have been drilled through the Black Mingo. In this area, we have not found readily available well records, geophysical and drillers' logs that could aid in tracing the subsurface distribution of aquifers and confining beds within the Black Mingo Formation.

The following conclusions concerning the Black Mingo Aquifer System in southeastern Richland County are based on the regional analysis of available data and on-site studies (discussed in Sec. 4.0).

1. In the immediate vicinity of the WEC site (within about five miles) ground water in lower Black Mingo aquifers occurs under artesian conditions because of clay confining beds in the upper part of this aquifer system (Fig. 3-1).

2. Strata within the Black Mingo are not known to outcrop within five miles of the WEC site. Thus, Black Mingo aquifers have "relatively" limited access to direct rehcarge.

3. Artesian Black Mingo aquifers in the vicinity of the WEC site should have relatively low artesian pressure, or head.

4. These Black Mingo aquifers should have "relatively poor" hydraulic properties relative to the more prolific artesian aquifers in the upper Coastal Plain, such as those in the Tuscaloosa Aquifer System.

5. Because artesian Tuscaloosa aquifers are recharged at higher elevations near Columbia, they should have higher artesian pressures than Black Mingo aquifers; thus,

6. Lower Black Mingo aquifers would be expected to receive considerable recharge by vertical upward leakage from higher head Tuscaloosa aquifers.

7. Extremely large ground-water withdrawals from Black Mingo aquifers in the vicinity of the WEC site are unlikely if a potential ground water user needed "large" quantities of ground water; that is, quantities

in excess of several to as much as 10 mgd (million gallons per day); if this quantity of ground water were needed, ground-water users would likely drill wells into more prolific Tuscaloosa aquifers. A properly designed and constructed Black Mingo well field with a number of large-diameter wells might supply as much as several million gallons per day of ground water. However, because Black Mingo aquifers in the vicinity of the site are relatively thin, less than about 20 ft thick, it is unlikely that a large-capacity well field could be supplied by Black Mingo aquifers.

8. Published data are not available that accurately defines the contact or stratigraphic relationship between the Black Mingo and Tuscaloosa Formations. The separation of the Black Mingo and Tuscaloosa Formations near the site (Fig.3-1) is based on reported data and should be considered as a generalized representation. In terms of downward vertical ground-water movement and potential contaminant movement at the WEC site, an accurate definition of this is not considered to be of critical importance for the purposes of this study.

Unconfined Aquifer System

The Plio-Pleistocene sediments in southern Richland County contain shallow sand aquifers, which are often not confined by overlying clays. Thus, ground water in these shallow aquifers generally occurs under unconfined (water-table) conditions. Actually the hydrogeology of these shallow aquifers is poorly known in southern Richland County, except in some site-specific localities. Most of the data on this aquifer system have been collected during site-specific studies, such as the study of the SCR&D site made by the SCDHEC (1981), and the comprehensive hydrogeologic study of thee WEC site made by Davis & Floyd (1980) and LETCo (1980a; 1980b).

Records are available on approximately 25-50 shallow wells in the regional study area at the SCWRC and USGS. These records indicate that the unconfined aquifer system supplies ground water to many small-diameter (2-inch, 4-inch) domestic wells in southern Richland County. These wells are typically 25-50 ft deep, and are equipped with shallow jet pumps that yield several gallons of water per minute, a yield sufficient to supply the drinking-water needs of an average family. These well records indicate that some of the shallow wells in the general vicinity of the WEC site often contain objectional amounts of iron.

4.0 HYDROGEOLOGY OF THE SITE

4.1 GROUND-WATER OCCURRENCE AND HYDROGEOLOGIC UNITS

4.1.1 General Overview

Three major aquifer systems underlie the WEC site: the Terrace Aquifer System, the Black Mingo Aquifer System, and the Tuscaloosa Aquifer System. These three major aquifer systems can be further differentiated into four local hydrogeologic units at the WEC site (Fig.4-1) with data currently available, as follows:

Unit I, the uppermost unit, is referred to as the Terrace Unit. This unit is regarded as a single hydrogeologic unit, even though the lithology and hydrologic properties vary considerably .

Unit II, the upper part of the Black Mingo Formation (or Aquifer System) consists primarily of clay and shale beds that function as a confining unit which restricts downward vertical ground-water flow.

Unit III, an artesian aquifer within the Black Mingo Aquifer System, consists of sand, and is tapped by several environmental monitor wells at the site.

Unit IV, the Tuscaloosa Formation (Aquifer System), has been penetrated by one monitor well at the site.

Crystalline "basement" rocks underlie the Tuscaloosa Formation at the site, and could be considered at a fifth hydrogeologic unit, but the hydrogeologic properties of these rocks are considered as relatively unimportant to the hydrogeology of overlying sediments.

Within the main area of interest for this study, the immediate area of the WEC plant and south to Sunset Lake, a knowledge of the hydrogeologic properties of crystalline basement rocks and overlying units IV and III are not as important as the hydrogeologic properties of the Terrace Unit (Unit I) and the upper part of the Black Mingo Formation (Unit II). Therefore, the hydrogeology of Units I and II are described in greater detail in this report.

4.1.2 Terrace Aquifer System (Unit I)

Available Data, Occurrence and Distribution

Considerable information is available on the thickness, lithology, and lateral distribution of Unit I at and in the immediate vicinity of the site. As part of the Davis & Floyd (1980) study, LETCo (1980a; 1980b) installed 28 monitor wells that tap this unit, and they constructed geologic cross-sections of the site from the boring logs. Most of these monitor wells are located in the area between the main plant building and Sunset Lake (Fig.2-2, Appendix), providing good stratigraphic coverage of the Terrace Unit in this part of the WEC property. The remaining wells were installed at various locations surrounding the main plant, primarily to provide additional stratigraphic information on the shallow strata.

Interpretations of these boring logs indicate that the Terrace Unit likely underlies the entire WEC property and areas adjacent to the property. Additional stratigraphic information on Unit I is provided by the geophysical logs of monitor wells W-1, W-2, and W-3, stratigraphic samples from test hole TH34, and monitor Well W-34.

Hydrogeologic cross-sections of the Terrace Unit (Figs. 4-2, 4-3) were constructed from boring logs prepared by LETCo (1980a, 1980b), boring log from test hole TH34, geophysical data, and observation of the upper 15-20 ft of the terrace sediments exposed in the escarpment north of the pond. The locations of these cross-sections are shown in Fig.2-2 (Appendix). The position of the base of this aquifer system (Figs.4-2, 4-4) is based on interpretation of gamma logs obtained from the deeper monitor wells and the geologist log of test hole TH34. As shown in Figs. 4-1 and 4-4, there is a pronounced gamma log signature at the contact between the sandy basal Terrace Unit and the top of the underlying Black Mingo Formation (Unit II). Therefore, the contact between Units I and II can be determined fairly accurately from gamma-log interpretation.

As shown in Fig.4-1, the basal surface of the Terrace Unit slopes gently in a south-southwest direction toward the Congaree River. The Terrace Unit is equivalent to the Okefenokee Formation which is a poorly sorted mixture of sands, clays, silts and gravel.

Thickness and Lithology

The Terrace Hydrogeologic Unit is considered to extend from land surface to the top of the underlying Black Mingo Formation (Aquifer System) (Fig. 4-1). Therefore, the thickness of this unit varies with topography across the WEC property. The thickness varies from about 20 ft at Well W-2 to about 40 ft beneath the storage area south of the main plant, and is about 25 ft thick beneath the area surrounding the pond and Sunset Lake.

As shown in Figs. 4-2, 4-3, and 4-4, the Terrace Unit is composed of a rather complex assortment of clays, silts, clayey silty sands or sandy silts, and sandy gravelly silts. The correlation of individual strata (lithologic units) in Figs. 4-2 and 4-3 is difficult, even between wells located only 150 ft apart. In general, strata within this unit become coarser with depth, and the basal part of this unit below the water table consists of gravelly, sandy silts which are locally clayey.

Water-Bearing Properties

Interpretation of the considerable number of wells tapping or drilled through the Terrace Unit indicates that there are no continuous clays between the water table and land surface (Figs. 4-2, 4-3). Therefore, ground water within the Terrace Unit occurs under water-table (unconfined) conditions. In general, the water table within the Terrace Unit is a subdued replica of the topography and is at atmospheric pressure. Thus, the recharge to and discharge from aquifers within this unit, under natural hydraulic gradients, is controlled, in part, by the topography of the immediate area. The hydraulic gradient of the water table in Unit I is very low and depends on topography, location of recharge and discharge areas, type and amount and duration and intensity of precipitation (which is the source of recharge), and hydraulic properties of the aquifer. The small spring located on the north side of the pond is a point discharge area for ground water moving through this unit (Fig. 4-4). Presumably, other small seepage springs are present along the pond and along the north side of Sunset Lake which would serve as natural discharge areas for the Terrace Unit (Fig. 4-3).

Typically, the fluctuation of the water table in an unconfined aquifer is greater in recharge areas, and less in discharge areas; The range of the annual fluctuation of the water table in the Terrace Unit is estimated to be about 10 ft. Fluctuations may be slightly greater in the area of the main plant and less near the pond and Sunset Lake, which are natural discharge areas.

The water-bearing properties of the Terrace Unit have been determined on the basis of the installed monitor wells and hydraulic conductivity data on selected wells. These properties are summarized in the cross-sections of the site (Appendix). Interpretation of boring logs of monitor wells indicates that the gravelly, sandy, silt unit in the bottom of the Terrace Unit appears to be the most permeable. As shown in Fig.4-3, strata within the screens opposite this unit have fairly low hydraulic conductivities (0.02 ft/day to 0.34 ft/day) which are typical values for a poorly sorted silt. In some areas, this unit would be considered more of a confining bed than an aquifer.

The water-bearing properties of the Terrace Unit in the area between the plant and Sunset Lake can be summarized as follows:

1. The coarser-grained strata in the basal part of the Terrace Unit are probably the most permeable, and these basal strata, composed primarily of gravelly, poorly sorted, sandy silt or silty fine sands, should dominate the lateral flow of ground water within this unit.

2. Although the Terrace Unit is lithologically complex, it could be considered reasonably uniform in terms of its water-bearing properties in the area between the main plant and Sunset Lake.

3. Because of the relatively poor sorting of strata within this unit, the water-bearing properties are expected to vary considerably over an area of hundreds or thousands of square feet. Therefore, minor inconsistencies in measured water levels or water-quality analyses should be expected.

4. The small spring indicates that some preferential flow occurs within the Terrace Unit, and may indicate that lenses of coarser-grained strata probably exist, such as small ancient channel sands.

4.1.3 Black Mingo Aquifer System

Available Data, Occurrence and Distribution

The Black Mingo Formation is interpreted to underlie the entire WEC site, and the full thickness of this formation was penetrated in Well W-1, reportedly drilled to an original depth of 140 ft (Fig.4-1). Gray clay was reportedly penetrated from approximately 30 ft to 71 ft below ground surface, and packed sand from 71-140 ft. The caliper log indicates that the borehole in the interval 71-76 ft is open within the Black Mingo Formation (Fig.4-1). As much as 60 ft of the Black Mingo Formation was penetrated in Well W-3, and Well W-2 penetrated the upper 35 ft of this formation. Reported information is available on Well 30Q-6, a well drilled in the general vicinity of the main plant in 1963 to a depth of approximately 105 ft. Gray clay occurred below the Terrace Unit (approximately 30 ft) to 105 ft below ground surface: The clay was reportedly cased off to a depth of 105 ft and the well produced 107 gpm with a drawdown of 15 ft.

The most complete lithologic data on the Black Mingo Formation was obtained from test hole TH34. The lithologic log of this well (Appendix Table 4-3) indicates that the upper part of the Black Mingo Formation consists of 58 ft of light- to medium-gray to dark-gray clays and shale in the interval from 27-85 ft below land surface (Fig.4-1). The lithology and color of these clays and the shale are indicative of the marine to marginal marine environment in which the Black Mingo Formation in southern Richland County was deposited. The dark-gray shale with a conchoidal fracture in the interval from 49-57 ft is characteristic of the Black Mingo Formation.

A split-spoon sample of the Black Mingo obtained from 61-62.5 ft in Well W-2 consists of saturated, fine- to coarse-grained quartzose sand which is poorly sorted. This sand is interpreted to be within Unit III, an artesian aquifer within the Black Mingo Formation (see Fig.4-1). The split-spoon sample obtained from 78-79.5 ft in Well W-3 is composed of gray, plastic clay within Unit II.

In summary, the borehole data available on the Black Mingo Formation at the WEC site provide rather conclusive evidence that the Black Mingo Formation beneath the WEC site consists of two hydrogeologic units that differ markedly in their hydrologic properties. The hydrologic characteristics of these two units are summarized in the following sections. The hydraulic properties of these two units are summarized in Sec. 4.2 and the question of vertical leakage is considered in greater detail.

Hydrogeologic Unit II

The thickness of Unit II ranges from about 35 ft to as much as 60 ft in the central plant site area (Fig.4-1). In test hole W-34, Unit II consists of 58 ft of light- to medium-gray, carbonaceous , micaceous clays and dark-gray, carbonaceous brittle shale with a massive, conchoidal fracture. Except for some thin laminae, no horizontal stratification was noted in the samples; and except for some moisture in the upper 3 ft of this unit, the remainder of the unit to the 85-ft depth was dry. These data indicate that:

1. The clays and shale in Unit II in the immediate vicinity of Wells W-3 and test hole TH34 should function as an effective confining bed.
2. Hydrogeologic correlations of Unit II between test hole TH34 and W-3, and between Well W-3 to Well W-1, and from Well W-1 to W-2 are reasonable.
3. Correlations based on gamma-log interpretation must be qualified because of the relatively long distance between Well W-3 and W-1, and the fact that strata can thin or thicken appreciably from one well to another. Additionally, structural discontinuities of beds, such as faults, can occur between widely-spaced wells, and unless recognized, can cause errors in stratigraphic correlations. However, there is no evidence of unusual thickening or thinning of strata or of structural displacement between these wells (Fig.4-1), nor are there published references available that indicate that such structural discontinuities exist in this area. It should be noted, in fact, that there are several gamma-log "kicks" within Unit II that can be reasonably correlated between these wells.

Hydrogeologic Unit III

The hydrogeologic properties of Unit III can be inferred from descriptions of Well W-1, the reported data on Well 30Q-6, a stratigraphic sample from Well W-2, and from the regional analysis of well data in the vicinity of the WEC site. As shown in Fig.4-1, Well W-1 penetrated the full thickness of the Black Mingo Formation, and reportedly encountered packed sand in the interval from 71 ft to 140 ft. The gamma and caliper logs indicate that a sand occurs from 71-76 ft which is not caved into the borehole. This would support the packed sand description. As shown in Fig. 3-1, this sand is interpreted to be a basal sand of the Black Mingo Formation. This interpretation is consistent with that of Padgett (1980) who showed that the Black Mingo Formation in southeastern Richland County contained a basal sand, overlain by clays.

Well 30Q-6 reportedly produced 105 gpm with a drawdown of 15 ft, indicating that the well had a theoretical specific capacity of about 7 gpm/ft of drawdown. This specific capacity is within the range of other Q/s values of wells tapping Black Mingo artesian aquifers in southern Richland County. The fine- to coarse-grained sand obtained from the bottom of Well W-2 is interpreted to be from Unit III.

Water-level measurements in Wells W-1, W-2, and W-3 made on November 19, 1981 indicate that ground water in Unit III occurs under artesian conditions, and the water levels in these wells rise approximately 15 ft to 20 ft above the top of this unit. These measurements indicate that the piezometric surface of Unit III slopes from northeast (from Well W-2) to southwest (toward Well W-3).

These data and data obtained from off-site Black Mingo wells indicate that the basal sand of the Black Mingo Formation at and in the general vicinity of the WEC site is an artesian sand aquifer which is confined by the overlying clays in the Black Mingo Formation.

4.1.4 Tuscaloosa Aquifer System

The Tuscaloosa Formation is a major hydrogeologic unit in southern Richland County, and underlies the Black Mingo Formation at the WEC site. Only one well [Well W-1] at the site is known to have penetrated into the Tuscaloosa Formation. Therefore, information on the hydrogeologic properties of the Tuscaloosa has been obtained from off-site wells tapping this formation. The Tuscaloosa Formation is interpreted to be approximately 100-140 ft thick at the site. The top of the Tuscaloosa Formation would be penetrated at an elevation of approximately +30 to +40 ft MSL in the vicinity of the main plant and at approximately mean sea level near the southeastern property boundary.

Well W-1 reportedly penetrated sand from about 71-140 ft. As shown in Fig.3-1 (Well 30Q-3), this well is interpreted to have penetrated the upper part of the Tuscaloosa Formation. Well 30Q-2, north of the WEC site, reportedly penetrated a sand at a depth of 200 ft, which is interpreted to be an artesian aquifer within the Tuscaloosa Formation.

Although considerable information is available on Tuscaloosa wells in southeastern Richland County, few wells are known to have penetrated this formation within several miles of the site. Therefore, the specific water-bearing properties of this aquifer system at the WEC site can only be inferred from the regional data (see Sec.3.2.2). If the Tuscaloosa Formation is only 100-140 ft thick beneath the site, the prolific artesian aquifers within this formation in southeastern Richland County would not be expected to exist at the site. It is reasonable to inferr that at least several artesian sand aquifers occur within the Tuscaloosa Formation at the site. However, because of the hydrogeologic nature of the overlying Black Mingo Formation summarized in this report, the hydrogeologic properties of the Tuscaloosa Formation are considered to be of minor importance in the analysis of the hydrogeology of overlying units.

4.2 HYDRAULIC PROPERTIES

4.2.1 General Principles

The hydraulic properties of an aquifer which are important in predicting the hydraulic performance of an aquifer are hydraulic conductivity (K), transmissivity (T), storage coefficient (S), and specific yield (Sy). The radial, or horizontal, velocity of ground water moving through a granular aquifer is controlled by the porosity of the aquifer (n), the hydraulic gradient (dh/dl), and the hydraulic conductivity (K).

The hydraulic conductivity is actually the volume rate of flow of ground water through a unit cross-sectional area of an aquifer (measured at right-angles to the ground-water flow direction, at a certain viscosity). The K is expressed in units of length/time, commonly in cm/sec or ft/day. For many years, the K was commonly called "field permeability" and was expressed as gpd/ft^2.

The transmissivity (T) of an aquifer is simply the K times the saturated thickness (m) of the aquifer; it is the rate at which ground water is transmitted through a unit width of an aquifer at a unit hydraulic gradient. Units of T are generally expressed as ft^2/day or as gpd/ft in older hydraulics literature.

The storage coefficient (S) of an artesian (or confined) aquifer is basically equivalent to the specific yield (Sy) of a water-table (or unconfined) aquifer. These are dimensionless coefficients that express the storage properties or behavior of aquifers. The S is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The S of most confined aquifers ranges from about 10^{-5} to 10^{-3}, and the S (or Sy) of most unconfined aquifers ranges from 0.1 to 0.3.

The radial, or essentially the "horizontal", velocity of ground water moving through a porous aquifer can be calculated from K, n (porosity), and the hydraulic gradient. The average linear velocity, $\bar{v}$, can be calculated with a modification of the Darcy equation:

$$\bar{v} = \frac{K}{n} \frac{dh}{dl} \qquad \text{(Eq. 4-2)}$$

The vertical movement of ground water from one aquifer through a confining bed into another aquifer is controlled by the vertical hydraulic conductivity of the confining bed (K'), the thickness of the confining bed (b'), and the difference in hydraulic head of the two aquifers, or head differential (dh). The vertical movement of ground water through or from the release of storage in a confining bed is termed leakage, and an aquifer which gains or loses ground water by vertical leakage is termed a leaky aquifer.

4.2.2 Hydraulic Properties of the Terrace Unit

Available information on the hydraulic conductivity of the Terrace Unit is summarized in Table 4-1. These values express the lateral, or radial, hydraulic conductivity (K) of strata within the Terrace Unit. These five wells are located in a radial line south of the waste-storage facilities and are therefore located in the area of most importance. The K values range from 0.02 ft/day to 0.88 ft/day. These values are within the general range of K values for a silty sand or sandy silt. In terms of ground-water production and contaminant movement, these are generally low values.

Because of horizontal stratification of beds in the Terrace Unit, the vertical hydraulic conductivity (K') of strata within this unit should be expected to be much less than the values in Table 4-1. Therefore, the lateral flow rate of ground water moving through the Terrace Unit should logically be much greater than the vertical flow rate. This greater lateral flow would tend to cause greater lateral dispersion of contaminants.

Assuming a saturated aquifer thickness of approximately 25 ft, and an average K of 0.37 ft/day, the average transmissivity (T) of the Terrace Unit would be approximately 9 ft^2/day (or 67 gpd/ft). These are comparatively low T values, and indicate that strata within this unit would be considered a very poor aquifer in terms of ground-water production potential for this part of the upper Coastal Plain. However, it would not be unusual that locally the K of sands within this unit could be high enough to yield small to moderate quantities of ground water (approximately 5-20 gpm) to wells.

With lithologic logs of the monitor wells located south of the main plant, reasonable estimates of hydraulic conductivity can be made in additional monitor wells. Therefore, the permeability of strata within Unit I is fairly well documented with the data available from the Davis and Floyd (1980) and Letco (1980a; 1980b) reports.

TABLE 4-1. SUMMARY OF HYDRAULIC CONDUCTIVITY DATA ON THE TERRACE UNIT, WEC SITE, (data from LETCo, 1980a).

WELL NO.	LAND SURFACE ELEV. (Ft)	HYDRAULIC CONDUCTIVITY, K			SCREENED INTERVAL	
		cm/sec	gpd/ft2	ft/day	BELOW LS (Ft)	ELEVATION, (Ft, MSL)
W-7	134.1	1.2×10^{-4}	2.5	0.34	15.5 - 18.5	118.6 - 115.6
W-9	135.2	3.1×10^{-4}	6.5	0.88	15.5 - 18.5	119.7 - 116.7
W-10	138.3	8.1×10^{-5}	1.7	0.02	18.5 - 23.5	119.8 - 114.8
W-12	136.8	1.2×10^{-4}	2.5	0.34	25.5 - 28.5	111.3 - 108.3
W-14	134.5	1.1×10^{-4}	2.3	0.30	23.5 - 28.5	111.0 - 106.0

4.2.3 Hydraulic Properties of the Black Mingo Units

Quantitative hydraulic data on the monitor wells penetrating the Black Mingo Formation (Units II and III) are not available. However, interpretation of data collected from test hole TH34 and geophysical logging of Wells W-1, W-2, and W-3 provide a reasonably good qualitative indication of the hydraulic behavior of the upper Black Mingo Hydrogeologic Unit (Unit II), which is the unit of importance in regard to possible downward leakage of ground water.

At test hole TH34, Black Mingo strata in the interval 27 ft to 85 ft below land surface is composed primarily of light- to dark-gray clays, shale and claystone (Appendix Table 4-3). Except for some moisture in the upper 3 ft of this unit, these beds were dry when samples were obtained during the test drilling. The clays become plastic when wet in the laboratory. The shale bed from 49-57 ft is massive with a conchoidal fracture when samples are broken. Field and laboratory estimates of the radial K of these clay and shale beds range from less than 10^{-7}cm/sec to 10^{-10}cm/sec. Because of the massive structure of these beds, the vertical K is estimated to be in the 10^{-9} cm/sec to 10^{-11}cm/sec range. A one-ft thick bed of dry, fine, clayey silty sand and silt occurs from 64-65 ft. The K of this bed is estimated to be less than 10^{-5}cm/sec.

A split-spoon sample from the Black Mingo (Unit II) in Well W-3 at a depth of 78-79.5 ft below land surface is also composed of gray, plastic clay. The K and K' of this clay are estimated to be extremely low also (less than 10^{-7}cm/sec). These data indicate that Unit II is a very effective confining bed in the vicinity of TH34, W-34, and W-3. Additionally, gamma log correlation from Well W-3 to Wells W-1 and W-2 (Fig.4-1) incicates that at least the upper 30 ft of the Black Mingo Formation is composed of clay or silty clay. Even though the gamma log does not provide quantitative hydraulic data, reasonable interpretation indicates that the Unit II underlies the Terrace Unit (Unit I) in the area from the main plant building to Well W-3 and TH34 near Sunset Lake. The confining bed also extends north of Well W-1 to Well W-2 (Fig.4-1).

Specific hydraulic data are not available on the hydraulic properties of Unit III. However, based on the information reported for Well 30Q-6 and the split-spoon sample from Well W-2, this unit should have a relatively high K. That is, a well with a specific capacity of 7 gpm/ft indicates an artesian aquifer that would yield several hundred gallons per minute of ground water to a properly constructed water well located near the main plant building. However, artesian Black Mingo aquifers in the general vicinity of the site are relatively thin, contain poorly sorted sediments, and Black Mingo wells have erratic yields.

4.3 UTILIZATION AND MOVEMENT OF GROUND WATER

4.3.1 General Concepts and Ground-Water Pumpage

Ground-water movement through aquifers and relatively permeable confining beds is controlled by natural features such as locations of recharge and discharge areas, rainfall and rainfall departure, and other climatic events, such as rainfall duration and intensity, and stratigraphic relationships of adjacent strata, and the hydraulic properties of these strata. Ground-water fluctuations and ground-water flow directions and rates are also affected by man-induced factors, such as construction of drainage facilities and most notably by pumping of wells. In order to provide a reasonable evaluation of ground-water movement, it is necessary to consider all of these natural and man-induced factors, even though detailed evaluation of each factor is unnecessary.

Ground water within the boundaries of the WEC site is currently not utilized as a source of drinking water nor for industrial process use. Well W-5, a small-diameter well, with a reported depth of 22 ft, has reportedly been used in the past for washing machinery and similar purposes. Therefore, except for this well, there is no ground-water pumpage within the property boundaries of the WEC.

There is currently no pumpage of ground water on properties immediately adjacent to the WEC site. Much of the area south, southeast, southwest, and west of the site is undeveloped wetland which lies below the 100-year flood elevation of approximately 130 ft MSL. Several tracts of farmland south of Sunset Lake and west of the site are utilized during the farming season, but there is no ground-water pumpage in these areas. Relatively small quantities of ground water are withdrawn from wells in areas north, northeast, and east of Bluff Road (Co. Road 48). However, to our knowledge, there are no pumping wells located within an approximate radius of 2000 ft of the main plant building.

Artesian sand aquifers occur within the Black Mingo and Tuscaloosa Formations in areas surrounding the WEC site. The effects of pumping on an artesian aquifer can extend for hundreds or several thousands of feet, depending on the pumping rate and hydraulic properties of the aquifer. Whether a sufficient quantity of ground water could be pumped from artesian aquifers within the Black Mingo and Tuscaloosa Formations in areas adjacent to the site that would significantly influence the movement of ground water in these aquifers at the site is not currently known. However, pumpage from wells in the vicinity of the site would have to be much greater than the quantity currently pumped in order to significantly affect ground water flow directions and rate at the site.

These data indicate that (1) presently there is no significant ground-water pumpage from the Terrace Unit or from the Black Mingo and Tuscaloosa artesian aquifers that influences the flow of ground water in these units beneath the WEC site and (2) it is doubtful that a sufficient number of wells could be located sufficiently close to the site to affect ground-water flow in the area southwest of the main plant. Additionally, as discussed later in this report, it is doubtful that pumpage from artesian Black Mingo or Tuscaloosa aquifers could significantly affect the movement of ground water within the Terrace Unit.

4.3.2 Lateral Ground-Water Flow -- Terrace Unit

The lateral flow of ground water in the Terrace Unit was studied by Davis and Floyd (1980) and by LETCo (1980a, 1980b). A piezometric map of the area south and southwest of the waste treatment facilities was made by Davis & Floyd Engineers (1980, Fig. 1) from water-level measurements obtained in Phase I observation wells. A second piezometric map was made by LETCo from water-level readings of 28 observations wells on July 16, 1980 (LETCo, 1980b, Fig. 1) From these maps, Davis & Floyd and LETCo concluded that the lateral flow of ground water south of the main plant was toward the south-southwest into the pond and Sunset Lake, and they correctly inferred that the pond and Sunset Lake intersected the water table within the Terrace Unit. Our interpretation of flow, made from measurements made in November, 1981 (Fig. 4-4) supports the original conclusions of Davis & Floyd and LETCo.

A number of water-level measurements have been made in the monitor wells at the site by WEC personnel. A piezometric map of the Terrace Unit from water-level measurements made by WEC personnel on November 15, 1981 is shown in Fig.4-4, and other water-level measurements are summarized in Appendix Table 4-2.

These piezometric maps and other hydrogeologic data summarized in this report indicate that the principle controls on the lateral flow of ground water in Unit I are (1) locations of local recharge and discharge areas, (2) horizontal stratification of strata within Unit I, and (3) the presence of the upper Black Mingo confining bed (Unit II) which restricts downward flow of ground water. Therefore, our conclusions of lateral ground-water movement through Unit I are consistent with those of Davis & Floyd (1980) and LETCo (1980b) that:

1. Ground water in the Terrace Aquifer System flows in a south-southwesterly direction toward Sunset Lake.
2. The predominant movement will continue to be in this direction, under natural hydraulic gradients, which will be the predominant direction of longitudinal dispersion.
3. The spring, pond, and Sunset Lake are point or line-sources of ground-water discharge which will tend to act as hydraulic barriers to the movement of contaminants past Sunset Lake.

These conclusions are also consistent with those of hydrogeologists with the SCDHEC (1981). They showed that ground-water flow is controlled by topography and locations of local discharge areas. They also illustrated (1981, Figs. 13-17) that the ground-water flow direction in the surficial aquifer is influenced by differential recharge rates; and that flow directions vary depending on the time water-level measurements are made relative to local rainfall events. However, flow direction changes at the SCR&D site were relatively minor and would not significantly affect the directions and rates of ground-water movement in this shallow, water-table aquifer.

The hydraulic gradient (dh/dl) of the water table can be measured from the piezometric map (Fig. 4-4). This gradient is utilized in the modified Darcy equation (Eq. 4.2) to calculate the average linear velocity, $\bar{v}$, of ground water. If a reasonable porosity value (n) of 30 percent for Unit I is chosen, an average hydraulic gradient of 0.025 ft/ft is measured from Fig. 4-4, and let K= 0.4 ft/day, the $\bar{v}$ would be approximately 2.5×10^{-4} ft/day (= 0.1 ft/yr). If we let K = 10 ft/day, which is probably more representative of the more permeable strata within the Terrace Unit, the $\bar{v}$ would be approximately 0.9 ft/day (= 325 ft/yr, rounded). These values represent an extremely wide range for the average linear velocity of ground water moving through this unit, and it is reasonable to expect that average linear velocities would vary considerably.

Lithologic analysis of samples from test hole TH34, an analysis of boring logs prepared by LETCo (1980a, 1980b) and the geophysical logging indicates that the basal part of the Terrace Unit probably contains the most permeable strata. This basal unit, shown in the hydrogeologic cross-sections, is interpreted to be approximately 10 ft to 15 ft thick and is composed of sandy gravelly silt or fine sand containing variable amounts of gravel and clay. The K of this thin unit is estimated to be several orders of magnitude higher than Unit II strata and overlying strata within Unit I. Therefore, the comparatively higher K of this basal unit should be expected to dominate the direction and rate of ground-water movement through Unit I.

4.3.3 Vertical Ground-Water Flow -- Leakage

In order to calculate the amount of vertical leakage through or the release of storage in a relatively permeable confining bed, it is necessary to know the lithology, thickness, and vertical hydraulic conductivity (K') of the confining bed, and the hydraulic heads at the top and bottom of the confining bed. It is also necessary to determine the lateral continuity of the confining bed and the hydraulic characteristics of units overlying and underlying the confining bed. The most common methods for determining leakance of a confining bed (Jacob-Hantush or Modified Hantush) require a pumping well with properly positioned observation wells. Use of these methods is ideally suited to water-supply hydrogeology where (1) confining beds are relatively permeable, (2) where considerable leakage of ground water from storage within a confining bed is expected or known to occur, (3) long-term pumping from a well or wells in an artesian aquifer below the confining bed is possible, and (4) there is very little concern for introducing any possible contaminants into an artesian aquifer with the artificially-created head differentials. Conditions (1) through (3) are not expected of Unit II at the WEC site: Since condition (4) requires reasonable caution, these methods are generally not ideally suited to analyzing leakage of Unit II at the site. Therefore, the hydraulic character of Unit II was evaluated by (1) utilizing available K data from the Terrace Unit (Table 4-1), stratigraphic sampling of Wells W-2 and W-3, and by obtaining split-spoon samples for analysis from test hole TH34.

Originally, test hole TH34 was to be completed as a 4-inch diameter monitor well in the uppermost aquifer within the Black Mingo Formation (Unit III). Well W-34, a 2-inch diameter monitor well, was to be located immediately adjacent to

TH34, with the screen set opposite the basal strata within Unit I. However, detailed stratigraphic sampling of test hole TH34 (Appendix Table 4-3) indicated that Unit II is composed of 58 ft of relatively impermeable clays and shale. Thus, installation of a screen in this test hole was not necessary and the borehole was grouted and plugged. Well W-34 was completed in the basal strata within Unit I to provide an additional water-level and water-quality monitor well at a strategic location.

Estimates of radial and vertical hydraulic conductivity of Unit II and the geophysical logging indicates that this unit is an effective confining bed or aquiclude, in the area near the pond and Sunset Lake between Wells W-3 and test hole TH34. Interpretation of Fig. 4-1 indicates that along a subsurface profile from Well W-3 to Well W-1 it is reasonable to conclude that Unit II is laterally continuous between these wells; and from test hole TH34 to Well W-1. This conclusion is also supported by the reported description of gray clay from about 30 ft to 105 ft in Well 30Q-6 (the 1963 well) and from off-site data from SCDHEC Well Q29-f1 which penetrated several feet of clay at 45-47 ft below land surface (SCDHEC, 1981). The estimated K' values of 10^{-7}cm/sec, and conservative Unit II thickness of 20 ft in the area southwest of the main plant would require extremely high vertical hydraulic gradients to artificially induce the movement of ground water from Unit I through Unit II, even neglecting any ionic exchange between ground water from Unit I and any moisture in Unit II. As mentioned in Sec. 4.3.1, there are no producing Black Mingo water wells on the site or sufficiently close to the WEC site which could create such high artificially induced vertical hydraulic gradients.

5.0 SUMMARY OF CONCLUSIONS

5.1 HYDROGEOLOGIC UNITS AND GROUND-WATER MOVEMENT

This study indicates that three major aquifer systems underlie the WEC site that have been correlated in wells located off the site. The shallowest aquifer system is the Unconfined Aquifer System which is approximately 30 ft to 50 ft thick in the vicinity of the site. At the WEC site, this aquifer system has been designated as the Terrace Hydrogeologic Unit in this report and is equivalent to the Okefenokee Formation, composed of sediments of Pliocene to Pleistocene age.

The Black Mingo Formation (Aquifer System) underlies the Terrace Unit and has been shown to consist of two hydrogeologic units. The upper part of the Black Mingo Formation has been designated as Hydrogeologic Unit II and consists of relatively low permeability clays, shales, and claystone which act as a confining bed. A basal sand within the Black Mingo Formation has been designated as Unit III and is an artesian sand aquifer which is tapped by several monotor wells at the site.

The Tuscaloosa Formation lies between the overlying Black Mingo Formation and underlying crystalline basement rocks, and has been interpreted to be approximately 100 ft to 140 ft thick at the site. One monitor well has penetrated into the top of the Tuscaloosa Formation at the site, and information from off-site Tuscaloosa wells has been used to correlate Tuscaloosa strata from off-site wells to this well. The Tuscaloosa Formation has been designated as Hydrogeologic Unit IV in this report. The hydrogeologic properties of Unit IV have been summarized from a considerable number of Tuscaloosa wells in southeastern Richland County. At the WEC site, the hydrogeologic properties of aquifers and confining beds within this unit are considered to be less important than the properties of overlying geologic formations.

The hydrogeology of the Terrace Unit in the area between the main plant and Sunset Lake was discussed in some detail in a hydrogeologic investigation by Davis & Floyd Engineers. This investigation involved the construction of 28 monitor wells in Unit I, and the well construction and hydrogeology of the Terrace Unit was described in two reports prepared by LAW Engineering and Testing Company (LETCo). The number of monitor wells installed during the Davis & Floyd (1980) study and the hydrogeologic information obtained adequately presented the hydrogeology of the Terrace Unit. Therefore, additional monitor wells were considered unnecessary.

Geophysical logging of on-site monitor wells and the construction of one test hole at a strategic location have added considerable knowledge to the hydrogeology of the Black Mingo Formation as well as the Terrace Unit beneath other parts of the site. A pronounced "kick" or signature on gamma ray logs can be used to trace the contact between the Terrace Unit and underlying confining beds of Unit II.

The lateral flow of ground water in the Terrace Unit (Unit I) in the area between the main plant and Sunset Lake has been shown to occur in a south-southwest direction. Ground water flowing through this unit in this area of the site, discharges into a small spring, a pond, and Sunset Lake, and it is unlikely that contaminated ground water would move past Sunset Lake. There are no Terrace Unit water wells located in the area south of Sunset Lake.

Information collected during this study indicates that the upper part of the Black Mingo Formation (Unit II) is a relatively effective confining bed that would tend to reduce the possibility that ground water will move by downward vertical leakage into underlying aquifers. Estimates of vertical hydraulic conductivity (K') are in the range of 10^{-7} cm/sec to 10^{-11} cm/sec. Since there is no pumpage from the artesian Black Mingo aquifer (Unit III) at the site, any vertical leakage would have to be caused by natural hydraulic gradients. It is unlikely that the low natural hydraulic gradients between Units III and I could cause this leakage, even if vertical hydraulic conductivities were many times greater than those estimated from the available data.

5.2 GROUND-WATER MONITORING PROGRAM

A considerable number of monitor wells (30) are available for monitoring the direction and rate of ground-water movement and the potential movement of contaminants in the Terrace Unit. Most of these monitor wells are located south of the main plant in the main area of concern. A review of these monitor well locations and the vertical placement of well screens and water levels indicates that:

1. The number and areal distribution of monitor wells between the plant and Sunset Lake are adequate to define ground-water flow direction and the potential movement of contaminants in this area. The number and locations of monitor wells located in other parts of the site are limited. At

this time, however, the need for additional monitor wells in these areas has not been demonstrated with the data currently available. If water-level monitoring is continued on a systematic basis, the range of water-level fluctuations can continue to be defined, and piezometric maps can be used to interpret ground-water flow directions.

2. An analysis of well-screen positions with respect to Terrace Unit thickness and water table positions within this unit indicates that the screens in wells located between the main plant and Sunset Lake are adequately positioned.

Three environmental monitor wells at the site currently tap the Black Mingo Formation. Geophysical logging of these wells and information from one stratigraphic test hole near Sunset Lake indicate that these three wells can be used to monitor the piezometric surface of Unit III. Therefore, the need for additional Black Mingo monitor wells has not been indicated on the basis of information evaluated for this study.

6.0 SELECTED REFERENCES

Colquhoun, D.J., 1965 Terrace Sediment Complexes in Central South Carolina: Atlantic Coastal Plain Geological Association Field Conference 1965 Guidebook, 62 p.

Colquhoun, D.J., Heron, S.D., Jr., Johnson, H.S., Pooser, W.K., and Siple, G.E., 1969, Up-Dip Paleocene-Eocene Stratigraphy of South Carolina: S.C. State Development Board, Division of Geology, Geologic Notes, v.13, no. 1, p. 1-25.

Davis & Floyd, Inc., Consulting Engineers, 1980, Groundwater Investigations, Westinghouse Electric Corporation Nuclear Fuel Division, Columbia, South Carolina, Unpublished Consulting Report, Job Number 3067-1.

Getzen, R.T., 1969, Cretaceous Stratigraphy of the Upper Coastal Plain in Central South Carolina: M.S. Thesis, University of South Carolina, Columbia, South Carolina, 67 p.

Hantush, M.S., 1955, Nonsteady Radial Flow in an Infinite Leaky Aquifer: Am. Geophys., Union Trans., v. 36, no. 1, p. 95-100.

-----, 1960, Modification of the Theory of Leaky Aquifers: Jour. Geophys. Research, v. 65, no. 11, p. 3713-3725.

Johnson, Phillip W., 1978, Reconnaissance of the Ground Water Resources of Clarendon and Williamsburg Counties, South Carolina,: S.C. Water Resources Commission Report #13, Columbia, South Carolina, 72 p.

Law Engineering Testing Company (LETCo), 1980a, Report of Preliminary Geohydrologic Assessment Westinghouse Nuclear Fuel Facility, Columbia, South Carolina: Consulting Report No. CO-537, dated June 12, 1980, 9 p.

-----, 1980b, Phase II - Generalized Geohydrologic Exploration Westinghouse Nuclear Fuel Facility, Columbia, South Carolina, Consulting Report No. CO-537, dated August 1, 1980, 11 p.

Lohman, S.W., 1972, Ground-Water Hydraulics: U.S. Geol. Survey Prof. Paper 708, 70 p.

Padgett, Gary G., 1980, Lithostratigraphy of the Black Mingo Formation in Sumter, Calhoun, and Richland Counties, South Carolina: M.S. Thesis, University of South Carolina, 68 p.

Park, A. Drennan, 1980, Ground-Water Resources of Sumter and Florence Counties, South Carolina: South Carolina Water Resources Commission Report 133, 43 p.

Pooser, W.K., 1965, Biostratigraphy of the Cenozoic Ostracods from South Carolina: University of Kansas Paleontological Institute (38), Arthropoda, Art. 8, 80 p.

Siple, G.E., 1957, Ground Water in the South Carolina Coastal Plain: Jour. Am. Water Works Assoc., v.49, no. 3, p. 283-300.

-----, 1959, Guidebook for the South Carolina Coastal Plain Field Trip of the Carolina Geological Society, Nov. 16-17, 1957: S.C. State Dev. Bd., Div. of Geology Bull. 24, 27 p.

Smith, G.E., III, 1979, Lithostratigraphic Relationships of Coastal Plain Units in Lexington County and Adjacent Areas, South Carolina: M.S. Thesis, University of South Carolina, Columbia, 139 p.

SCDHEC, 1981, Investigation of Ground Water at South Carolina Recyling and Disposal Company Bluff Road Site, Richland County, South Carolina: Ground-Water Protection Division, S.C. Department of Health and Environmental Control, Columbia, South Carolina, Open-File Report, 42 p.

South Carolina Water Resources Commission, 1971, Water Use in South Carolina, 1970: Columbia, South Carolina, 114 p.

Taylor, V.A., 1949, Geology of the Columbia North Quadrangle: M.S. Thesis, University of South Carolina.

Van Nieuwenhuise, D.S., 1978, Ostracode Biostratigraphy and Stratigraphy of the Black Mingo Formation, South Carolina Coastal Plain: Ph. D. Dissertation, University of South Carolina, Columbia, South Carolina, 92 p.

APPENDICES

South Carolina

SOIL & MATERIAL ENGINEERS WELL SUMMARY

Richland — TABLE 3 1. SUMMARY OF WATER-WELL DATA, SOUTHEASTERN RICHLAND COUNTY, S.C. — S&ME JOB NO. H 8119

S&ME Well No	State Number	Latitude Longitude	Elevation (MSL)	Owner/Location	Well Use	Total Depth	Casing Dia.	Casing Depth	Pump Rate	Date Comp.	Logs	Chemical Analyses	Well Cons.	Remarks
26P-1		33 56 80 39		Wateree Gun Club Near Wateree R.	P.S.						Gamma		Unk.	
26Q 1	26Q-W1		165 Topo Estm.	Test Well Hercules Site	Ind. Test									Sydnor Hyrodynamics
26Q 2	26Q X1 RIC 58		165 Topo Estm.	Test Well Hercules Site	Ind. Test	670	4			11/73	Drillers Res. Gamma			Sydnor Hydrodynamics
26Q 3	26Q q1		170 Topo Estm.	Test Well [illegible] Ltd. Ind. Site	[illegible] Test	660					Res. 9/1/70			Layne Atlantic
26R 1	26R-d1			Godspeed Farms No. 1 (26R-d1)	Irr.	680					Res. Gamma		GP	Layne Atlantic See Padgett, 1981. Supplies Center Pivot Irrig. Sys.
26R-2			84 Topo Estm.	Test Hole on Bates Old River	Test	394					Geologic			Getzen (1969, DH S-1)
26R-3	26R-c1 RIC-63		145	Test Well Hercules Site	Ind Test	594	10	145	2000	6/74	Drillers Res. Gamma			Sydnor Hydrodynamics. 10" SCN: 103' from 417-542 Ft. (Park, 1980).
27Q-1				Godspeed Farms No. 2	Irr.						None		Unk.	Berrie Well Drilling Pumped 2000-2500 GPM for ± 3 Mos/Yr. Supplies Center Pivot Irrig. System.
27Q-2				Eastover CW No.2 at "New" Water Tank.	P.S.	120	6	102	120	1/76	Gamma 1/16/76		GP	Coleman Well Co. Samples to SCDHEC SCN=6" dia. 102-112. WW, .045 Slot
27Q-3	RIC-60			Eastover CW No. 3	P.S.	156				3/77	Drillers Gamma		Unk.	Heater Well Co. SCN: 77-87 Samples to SCDHEC Gamma Log by Heater Well

S&ME FORM H-03 (4/81)

South Carolina

Richland

SOIL & MATERIAL ENGINEERS WELL SUMMARY

TABLE 3 1. SUMMARY OF WATER-WELL DATA, SOUTHEASTERN RICHLAND COUNTY, S.C.

S&ME JOB NO. H-8119

S&ME Well No	State Number	Latitude Longitude	Elevation (MSL)	Owner/Location	Well Use	Total Depth	Casing Dia.	Casing Depth	Pump Rate	Date Comp.	Logs	Chemical Analyses	Well Cons.	Remarks
27Q 4	RIC-153		±360 Topo Estm.	R.S. Henderson	Dom.	201	4	89	10	9/59	Drillers		Unk.	West Columbia Well Drilling, 9/59.
27Q-5		33 53 15 80 43 15	210 Topo	Test Hole	Test	544					Geologic			Getzen (1969, DH S-51) TD IN Basement at 540 (-330 MSL).
28P-1		33 58 80 47	410	Water Well Near Mt. Elon Ch.	Dom.	205				1964			Unk.	See Getzen (1969) Upper Marine MBR Kte.
28Q-1		33 54 25 80 47 50		McEntire Air National Guard Base	P.S.	70						Comp 1/18/68		SCN Rept. 65-70 Ft.
28Q-2		33 54 10 80 47 35		McEntire Air National Guard Base	P.S.	127						Comp 1/18/67		SCN Rept. 119-127 Ft.
29P-1	RIC-77	33 57 80 56		Defender Indus. 9031 Garners Ferry Rd.	Ind.		6 PVC				Gamma 10/20/78 USGS		Unk.	
29P-2	RIC-143	33 57 80 56		Mr. McGregor Hopkins Hwy (Co. Rd. 37)	Dom.	301	8 STL	210			Drillers (good)		GP	Heater Well Co., 1956 Screen: 8" dia. 210-214; 270-274; 280-284; & 290-294.
29Q-1	Q29-f1 SCDHEC		135 Topo Estm.	Test Well SCDHEC Site SCR&D	Mon. Well	47	2 PVC	17		8/80	Geologist (DHEC)	Comp SCDHEC	Yes	SCDHEC (1981). 2" PVC SCN 17-22 Pen. Tight Clay at 45 Ft.
29Q 2	Q29-f2 SCDHEC		135 Topo Estm.	Test Well SCDHEC SCR&D Site	Mon. Well	34	2 PVC	9.5		8/80	Geologist (DHEC)	Comp SCDHEC	Yes	SCDHEC (1981) 2" PVC SCN 9.5-14.5.
29Q-3	Q29-f3 SCDHEC		135 Topo Estm.	Test Well SCDHEC SCR&D Site	Mon. Well	24	2 PVC	14		8/80	Geologist (DHEC)	Comp SCDHEC	Yes	SCDHEC (1981). 2" PVC SCN 14-19

S&ME FORM H-03 (4/81)

STATE South Carolina

SOIL & MATERIAL ENGINEERS WELL SUMMARY

COUNTY Richland TABLE 3-1. SUMMARY OF WATER-WELL DATA, SOUTHEASTERN RICHLAND COUNTY, S.C. S&ME JOB NO. H-8119

S&ME Well No.	State Number	Latitude Longitude	Elevation (MSL)	Owner/Location	Well Use	Total Depth	Casing Dia.	Casing Depth	Pump Rate	Date Comp.	Logs	Chemical Analyses	Well Cons.	Remarks
29Q-4			135 Topo Estm.	Campbell's Garage	ABN Dom	28	2 STL				Gamma S&ME	Comp SCDHEC	No	SCDHEC (1981)
29Ø-1		34 00 40 80 54 18		Twin Lakes Rec. Area, Ft. Jackson	P.S.	113	6	103			Drillers			Heater Well Co., 9/69: 6" SCN. 103-108.
29Ø-2	RIC-54	34 03 00 80 59 00		U.S. Army Ft. Jackson	P.S.	460	6				Geologic			Lithologic Log-USGS
29Ø-3	RIC-53	34 02 55 80 59 00		U.S. Army Ft. Jackson	P.S.	135	6 (?)				Geologic			Lithologic Log-USGS Sox Brothers Drlg.
30P-1		33 57 80 55		Domestic Well Near Intersec. Co. Rd 88 & Hwy 76	Dom.	136					Rept. Data			10' of Perm. Sand Underlying Clays Driller unknown.
30P-2		33 56 80 58	153 Topo. Estm.	Atlas Road SCH. Test Well	ABN	115 Rept.					Rept. Data			Driller rept. 25-115 ft only clays. Abandoned test hole.
30Q-1	RIC-61		150 Topo. Estm.	Larson Property Bluff Road.	Dom.	39.5					Gamma 5/17/77		Unk.	
30Q-2			145 Topo Estm.	Private Well	Dom. (?)	200 (?)	Unk.	Unk.	Unk.					Driller rept. 0-20 black mud & water; 20-200 ft "impermeable" clay; at 200 ft porous sand.
30Q-3			137 Site Map	Well W-1 Westinghouse Elect. Corp. (WEC)	OBS	140 Rept. 76	4 STL	62	Unk. no pump	1969 ±	Gamma Caliper to 67 ft S&ME	Comp WEC	PAR	Rept. Orig. TD=140 Ft No Screen. open-hole 71-76 Ft. Logged to 76 Ft by S&ME
30Q-4			±138 Estm. Site Topo	Well W-2 Westinghouse Elect. Corp.	OBS	70 Rept.	4 STL		Not Pump	1977	Gamma Caliper to 62 ft S&ME	Comp WEC	PAR	Coleman Well DRLG. Strat. sample 61-62 by S&ME.

S&ME FORM H-03 (4/81)

STATE South Carolina

SOIL & MATERIAL ENGINEERS WELL SUMMARY

COUNTY Richland

TALBE 3-1. SUMMARY OF WATER-WELL DATA, SOUTHEASTERN RICHLAND COUNTY, S.C.

S&ME JOB NO. H-8119

S&ME Well No.	State Number	Latitude Longitude	Elevation (MSL)	Owner/Location	Well Use	Total Depth	Casing Dia.	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analyses	Well Cons.	Remarks
30Q-5			117.9 Site Map	WEC Well W-3 Adjacent to pond near Sunset Lake	OBS	79.5	4 STL	48	Not Pump	1977	Gamma Caliper to 62 ft		PAR	Coleman Well Drilling Geophysical Logs by S&ME
30Q-6			Estm. 140 approx.	WEC Unnumbered abandoned well	ABN	Rept. 105 Estm. 115	4 or 6	Rept. 105	107 Rept.	1963	None Rept. Data	N.A.	Unk.	Exact TD unknown. Rept. 30-105 ft. Gray clay. Rept produced 107 gpm/15 ft drawdown from packed sand from 105 ft to unknown depth.
30Q-7			Estm 134.0 Site Map	WEC Well W-5 In Equipment storage area	IND	22		Unk.	Estm. ± 5 gpm	Pre 1960's		Partial WEC	Unk.	Driller unknown. Old domestic well; formerly supplied house. Now occassion use for general yard use. Shallow jet pump. In small pump house.
30Q-8			117.5	WEC Well W-4 10 ft NE Well W-3	OBS	12	4 PVC	Estm. 10	NA	1977	See geop. logs for W-3		PAR	Coleman Well Drilling
30Q-9			125.0 ± estm from ElevW-15	WEC Stratigraphic Test Hole (ST34). 10 ft south of WEC Well W-34.	ABN & Plug	85.0	None	–	None	Dec. 1981	Drillers Geologist Lithologic	NA	NA	Stratigraphic test hole, S&ME Rig CME-55 18 split-spoon samples from LS to TD Logged in field & lab by hydrogeologist. Term in Black Mingo Formation.
30Q-10			125.0 estm from ElevW-15	WEC Well W-34 Location 80 ft W. of Pond.	OBS	24.0	2 PVC	18	NA	Dec 1981	See logs for STH 34A		Yes Obs.	S&ME;Rig CME-55. 2-in SCN 18-23 in basal Terrace Unit, gravel pack, Ben. Seal 14-16; cement grout 0-14. Csg. 2.0 ft above LS.
			NOTE	WEC Wells W-6 through W-33 See Remarks										See Boring Logs in LETCo Rept. 1980b Geologist logs.

S&ME FORM H-03 (4/81)

TABLE 4-2. SUMMARY OF WATER-LEVEL DATA, WEC SITE

NOTE: These water-level data are contained in Davis & Floyd (1981).

WELL NO.	ELEV. M.P.	DATE MEASURED	WATER LEVEL		MEASURED BY	REMARKS
			BELOW M.P.	ELEV.		
Phase 1 Data						
		5/22/80			WEC Personnel	See LAW (1980a) (11 Wells) Wells 6,7,8,9,10,11,12,13,14, 15, & 16.
		5/30/80			LAW Engineering	See LAW (1980a) (7 Wells) Wells 7,8,9,10,11,12, & 13. (missing were wells 6,14,15,16,17).
		6/3/80 (Piezometric Map by Davis & Floyd, 1981, Fig.1)			LAW Engineering	See LAW (1980a). (12 Wells) Wells 6 through 17.
		6/3/80	Readings supplied by LAW Engr.			See Davis & Floyd (1981, Table III). Wells 6 through 17. (12 Wells)
Phase II Data						
		7/10/80			LAW Engineering	See LAW (1980b) (only 3 Wells) Wells 18,19, & 24.
		7/13/80			LAW Engineering	See LAW (1980b) (12 Wells) Wells 18,19,20,21,22,23,24,25,26, 28,29, & 30. (missing were wells 6 through 17, 27,31,32, & 33).
		7/16/80 (Piezometric Map, LAW, 1980b, Fig.1)			LAW Engineering	See LAW (1980b) (measured all 28 wells, wells 6 through 33).
		7/16/80	Readings supplied by LAW Engr.			See Davis & Floyd (1981, Table VI). Wells 18 through 33. (16 Wells)

TABLE 4-2. SUMMARY OF WATER-LEVEL DATA, WEC SITE

NOTE: These water-level data collected since completion of Davis & Floyd (1981) Report.

WELL NO.	ELEV. M.P.	DATE MEASURED	WATER LEVEL BELOW M.P.	WATER LEVEL ELEV.	MEASURED BY	REMARKS
		1/21/81	Measurements from TOC		WEC Personnel	Measurements made prior to bailing; measurements in ft & in. (24 Wells measured). Wells 7 through 21, Wells 23 through 28, Wells 31, 32 & 33. Did not measure Wells 6, 22, 29 & 30.
		1/23/81	(Special Water Analysis Report)			
		5/6/81	Measurements from TOC		WEC Personnel	Measurements made prior to bailing. (27 Wells measured) Measured Wells 6 through 33, except Well 22.
		5/12/81	(Special Water Analysis Report)			
		9/1/81			WEC Personnel	Measured depth and water level in Well W-5 (intake pipe was removed). Well is 21.7 ft deep No water-level measurement.
		11/15/81	Most measurements made from TOC; Some from L.S.		WEC Personnel	Measured all 28 wells. (Wells 6 through 33). See data on following page.

TABLE 4-2. SUMMARY OF WATER-LEVEL DATA, WEC SITE

WATER-LEVEL MEASUREMENTS NOVEMBER 15, 1981

NOTE: Water-level measurements in ft and inches. These were converted to decimal readings without rounding to nearest tenth: These should be rounded to nearest tenth.

WELL NO.	ELEV. M.P.	DATE MEASURED	WATER LEVEL BELOW M.P.	WATER LEVEL ELEV.	MEASURED BY	REMARKS
W-6	137.81	11/15/81	11.25	126.56	WEC Personnel	M.P. = L.S.
W-7	135.89	11/15/81	11.83	124.06	WEC Personnel	M.P. = TOC
W-8	134.34	11/15/81	13.5	120.84	WEC Personnel	M.P. = L.S.
W-9	137.0	11/15/81	11.75	125.25	WEC Personnel	M.P. = TOC
W-10	138.28	11/15/81	17.66	120.62	WEC Personnel	M.P. = L.S.
W-11	141.32	11/15/81	17.66	123.66	WEC Personnel	M.P. = TOC
W-12	138.70	11/15/81	14.75	123.95	WEC Personnel	M.P. = TOC
W-13	139.41	11/15/81	12.33	127.08	WEC Personnel	M.P. = TOC
W-14	136.50	11/15/81	13.92	122.58	WEC Personnel	M.P. = TOC
W-15	128.85	11/15/81	11.66	117.19	WEC Personnel	M.P. = TOC
W-16	129.48	11/15/81	7.16	122.32	WEC Personnel	M.P. = TOC
W-17	139.03	11/15/81	see remarks			M.P. = TOC(?) stated as 4.5" (= 0.38 ft) above L.S. Reading listed as 12'17"(?).
W-18	138.58	11/15/81	11.83	126.75	WEC Personnel	M.P. = L.S.
W-19	143.70	11/15/81	23.54	120.16	WEC Personnel	M.P. = TOC
W-20	116.11	11/15/81	8.0	108.11	WEC Personnel	M.P. = TOC
W-21	117.90	11/15/81	10.33	107.57	WEC Personnel	M.P. = TOC
W-22	137.96	11/15/81	12.0	125.96	WEC Personnel	M.P. = L.S.
W-23	140.66	11/15/81	16.5	124.16	WEC Personnel	M.P. = TOC
W-24	143.17	11/15/81	12.75	130.42	WEC Personnel	M.P. = TOC
W-25	117.26	11/15/81	9.5	107.76	WEC Personnel	M.P. = TOC
W-26	142.82	11/15/81	23.08	119.74	WEC Personnel	M.P. = TOC
W-27	123.16	11/15/81	9.0	114.16	WEC Personnel	M.P. = TOC
W-28	139.95	11/15/81	12.25	127.7	WEC Personnel	M.P. = TOC

TABLE 4-2. SUMMARY OF WATER-LEVEL DATA, WEC SITE

WELL NO.	ELEV. M.P.	DATE MEASURED	WATER LEVEL BELOW M.P.	WATER LEVEL ELEV.	MEASURED BY	REMARKS
W-29	139.98	11/15/81	13.58	126.4	WEC Personnel	M.P. = TOC
W-30	138.37	11/15/81	11.92	126.45	WEC Personnel	M.P. = L.S.
W-31	138.24	11/15/81	9.83	128.41	WEC Personnel	M.P. = L.S.
W-32	141.81	11/15/81	18.16	123.65	WEC Personnel	M.P. = TOC
W-33	140.78	11/15/81	15.0	125.78	WEC Personnel	M.P. = TOC

Table 4-3. Lithologic (Stratigraphic) Log of Westinghouse Test Hole No. TH34

SPLIT SPOON NO.	SAMPLE NO.	SAMPLE DEPTH INTERVAL (FEET)	BLOW COUNTS	DESCRIPTION
1	1	1.5 - 2.0	2-2-3	Sand, moderate yellowish brown (10 YR 5/4), fine-very coarse, clayey; with very fine quartz gravel, slightly micaceous, dry.
1	1	2.0 - 2.5		Sand, dark yellowish brown (10 YR 4/2), fine to coarse, clayey, with fine quartz gravel; and clay, dark brown (5 YR 2/2), lignitic, dry.
2	3	4.0 - 4.5	4-5-3	Clay, very sandy, light brown (5 YR 5/6), moist, silty, plastic.
2	4	4.5 - 5.0		Sand, moderate yellowish brown (5 YR 5/4), fine to very coarse, with quartz gravel; and clayey, poorly sorted sand, moist.
2	5	5.0 - 5.5		Sand, same as above, grading downward into clay, moderate brown (5 YR 4/4), slightly moist, slightly micaceous, plastic.
3	6	9.0 - 10.0 (composite)	1-2-1	Silt, pale yelloiwsh brown (10 YR 6/2), very micaceous, clayey, slightly plastic.
3	7	10.0 - 10.5		Silt, same as above.
4	8	14.0 - 15.5 (composite)	3-3-5	Clay, moderate brown (5 YR 4/4), micaceous, silty, moist.
5	9	18.0 - 18.5		Silty clay, moderate yellowish brown (10 YR 5/4) grading downward with sharp break into Sand, fine to medium, micaceous, quartzose, loose, moist, permeable.

continued
Table 4-3

SPLIT SPOON NO.	SAMPLE NO.	SAMPLE DEPTH INTERVAL (FEET)	BLOW COUNTS	DESCRIPTION
5	10	19.0 - 19.5		Sand, silty, slightly clayey, micaceous, very fine to fine, moist, permeable.
6	11	24.0 - 25.5 (composite)	4-5-4	Sand, coarse-very coarse micaceous, with fine gravel, quartzose, silty, not much clay. Moderate to high permeability.
7	12	29.0 - 30.5	3-3-5	Clay, medium gray (N5), very plastic, no bedding or laminae (massive), slightly moist. Very low permeability.
8	13	34.0 - 35.5 (composite)	3-5-6	Clay, dark gray (N3), dry, massive. Very low permeability.
9	14	39.0 - 40.5 (composite)	4-7-11	Clay, medium gray (N5), massive, dry. Plastic when wet in lab. Very low permeability.
10	15	44.0 - 45.5 (composite)	4-5-7	Clay, medium dark gray (N4), dry, micaceous, massive. Plastic when wet in lab. Very low permeability.
11	16	49.0 - 50.5 (composite)	20-37-48	Shale, medium dark gray (N4), hard, blocky with conchoidal fracture, dry, lustrous sheen. Very low permeability.
12	17	54.0 - 55.3 (composite)	23-45-50/4	Shale, same as above, except lighter color-medium gray (N5), Very low permeability.
13	18	59.0 - 59.5	35-50/3-	Clay, light gray (N7), slightly silty, micaceous, dry, plastic when wet. Very low permeability.
13	19	59.5 - 59.7		Clay, silty, light gray (N7) micaceous, plastic when wet. Very low permeability.

continued
Table 4-3

SPLIT SPOON NO.	SAMPLE NO.	SAMPLE DEPTH INTERVAL (FEET)	BLOW COUNTS	DESCRIPTION
14	20	64.0 - 64.5	12-25-32	Sand, very fine to fine, clayey, silty, dry. Overall high plasticity. Low permeability.
14	21	64.5 - 65.0		Silt, clayey, light gray (N7) micaceous, with sparse fine to medium sand grains, dry. Low permeability.
14	22	65.0 - 65.5		Clay, silty, medium gray (N5), micaceous, with some fine to medium sand grains; grading downward at 65.2 ft to: Clay, medium light gray (N6), massive, blocky. Very low permeability.
15	23	69.5 - 70.0	22-36-50/5	Clay, light gray (N7), massive, not micaceous, no silt or sand. Very low permeability.
15	24	70.0 - 70.4		Clay, same as above.
16	25	74.0 - 74.8	28-50/5	Clay, same as above.
17	26	79.0 - 79.5	14-23-31	Clay, same as above, slightly silty; low permeability.
17	27	79.5 - 81.0		Silt, same as above light gray. Low permeability.
18	28	84.0 - 84.8	31-50/4	Claystone, medium gray, massive, blocky, dry. Very low permeability.

Total Depth 85.0 ft

Summary

0 - 27 OKEFENOKEE FORMATION - PLEISTOCENE (TERRACE HYDROGEOLOGIC UNIT)

Alternating beds of poorly sorted, fine to coarse sands, silt, and clays with quartz gravels scattered throughout. Very fine to coarse quartzose sand from 18.5 - 27.0 ft most permeable. Screen was set at 18 - 23 ft in Well W-34.

continued
Table 4-3

27 - 85	BLACK MINGO FORMATION (HYDROGEOLOGIC UNIT II)	
	27-49	Beds of medium-gray to dark gray, massive, micaceous, CLAY. Plastic when wet. Very low permeability. Moist in upper few feet only; dry below.
	49-57	Medium to medium dark gray SHALE, dry, blocky with conchoidal fracture, massive, with lustrous sheen when broken.
	57-65.2	Light gray, micaceous CLAY and SILTY CLAY, with low permeability; with 1.0 ft bed of very fine to fine CLAYEY SILTY SAND and clayey, light-gray, micaceous SILT. Low permeability, plastic when wet, except for granular silt stratum (64.5 - 65.0 ft).
	65.2-76	Light to medium light gray, non-micaceous, massive CLAY, dry in borehole, plastic when wet in lab. Essentially no permeability.
	76-83	Light-gray, massive, non-micaceous CLAY and massive slightly SILTY CLAY, dry, low permeability. Plastic when wet in lab.
	83-85	Medium gray, massive, dry CLAYSTONE, blocky, Very low permeability.

NOTES

1. Color designation Standard: Geol. Soc. of America, Rock-Color Chart, 1975.
2. Permeability (hydraulic conductivity) descriptions are qualitative estimates from visual field observation of drill cuttings and laboratory classification of split-spoon samples.
3. Standard Blow Count is number of blows required to drive 1 3/8 in I.D., 2 - in O.D. Split Barrel Sampler 6 inches with 140 Pound Hammer Falling 30 inches.

Field and Lab Analyses by
B. C. Spigner
Senior Hydrogeologist

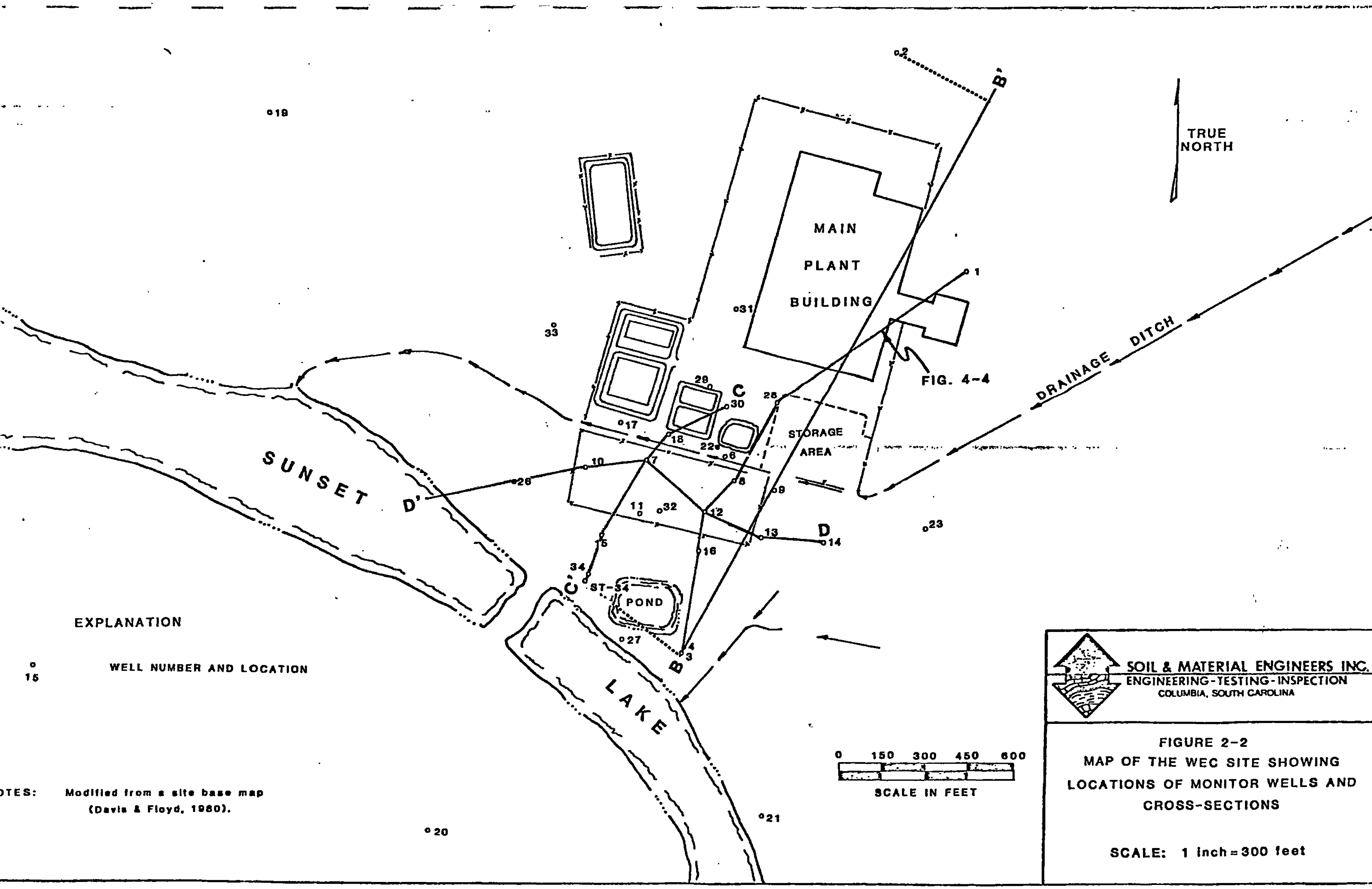


FIGURE 2-2
MAP OF THE WEC SITE SHOWING LOCATIONS OF MONITOR WELLS AND CROSS-SECTIONS

SCALE: 1 inch = 300 feet

FIGURE 4-1 GENERALIZED NORTH-SOUTH HYDROGEOLOGIC CROSS-SECTION B-B' OF THE WEC SITE

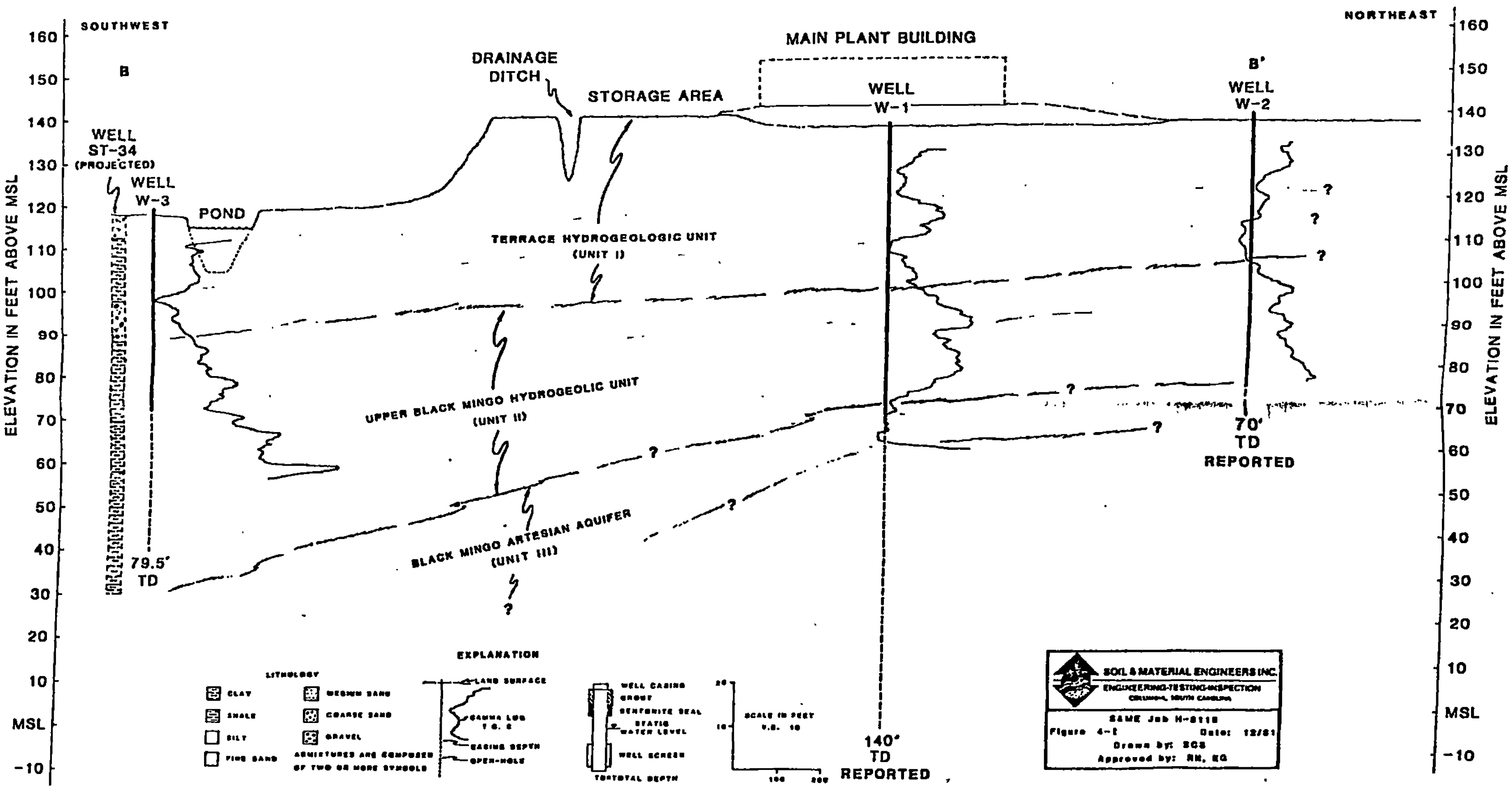


FIGURE 4-2 NORTH-SOUTH HYDROGEOLOGIC CROSS-SECTION C-C' OF THE TERRACE HYDROGEOLOGIC UNIT, WEC SITE BETWEEN PROCESS AREA AND SUNSET LAKE

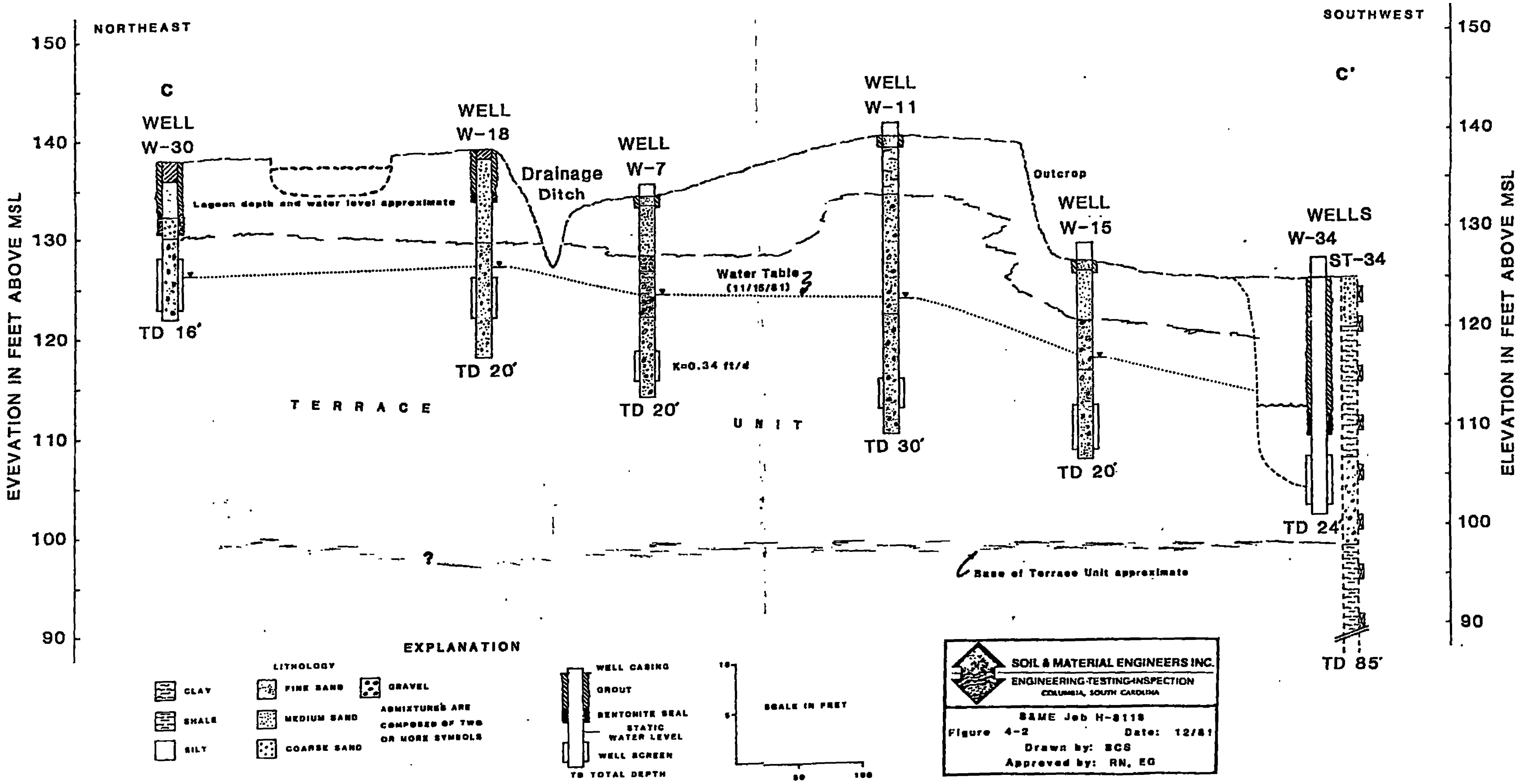


FIGURE 4-3 EAST-WEST HYDROGEOLOGIC CROSS-SECTION D-D' OF THE TERRACE HYDROGEOLOGIC UNIT SOUTH OF THE PROCESS AREA

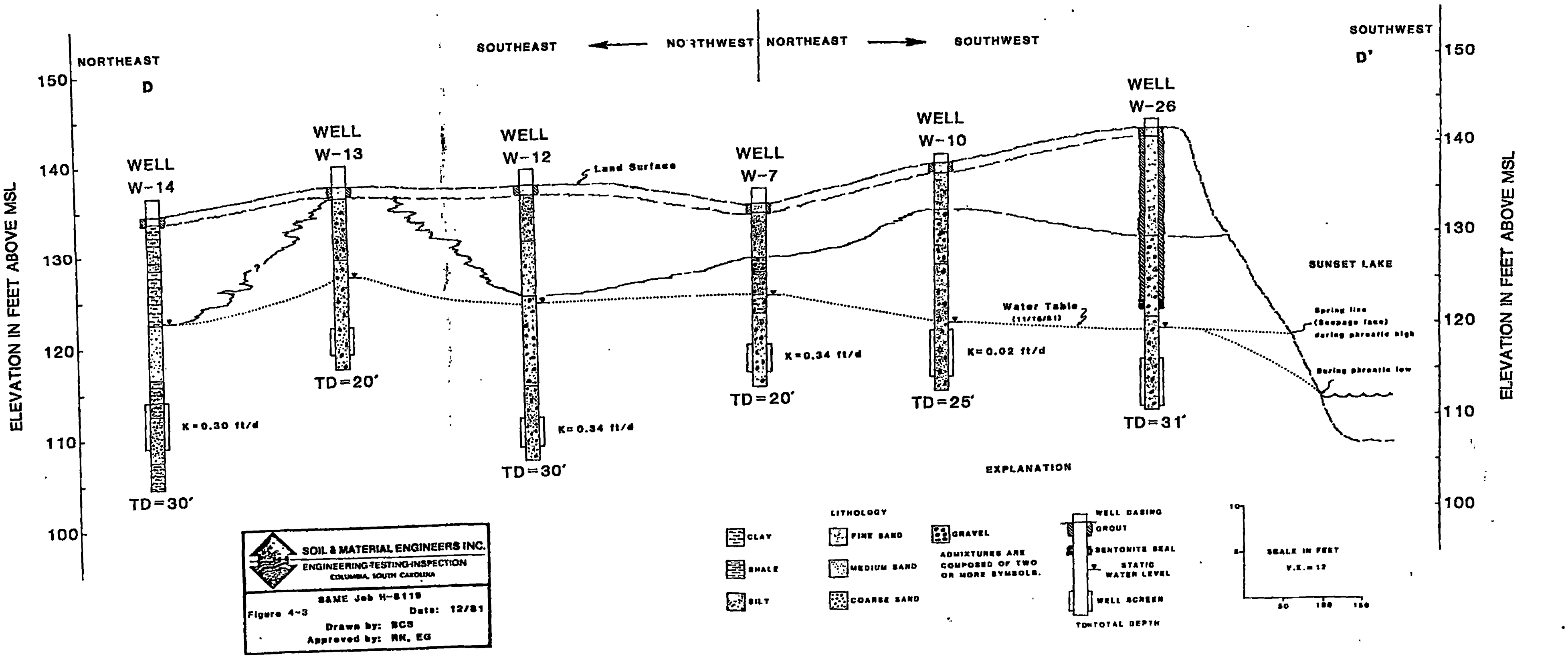
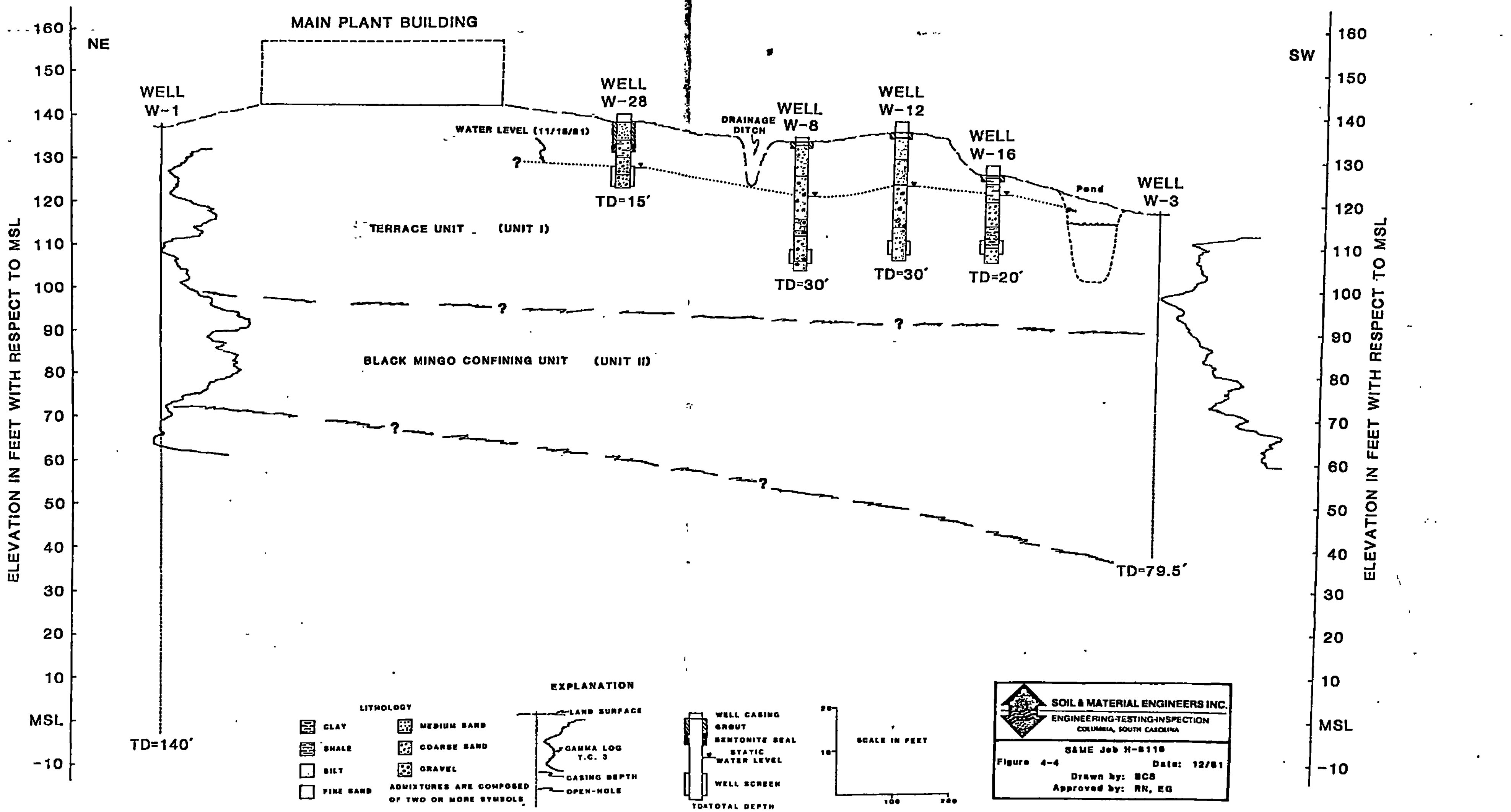
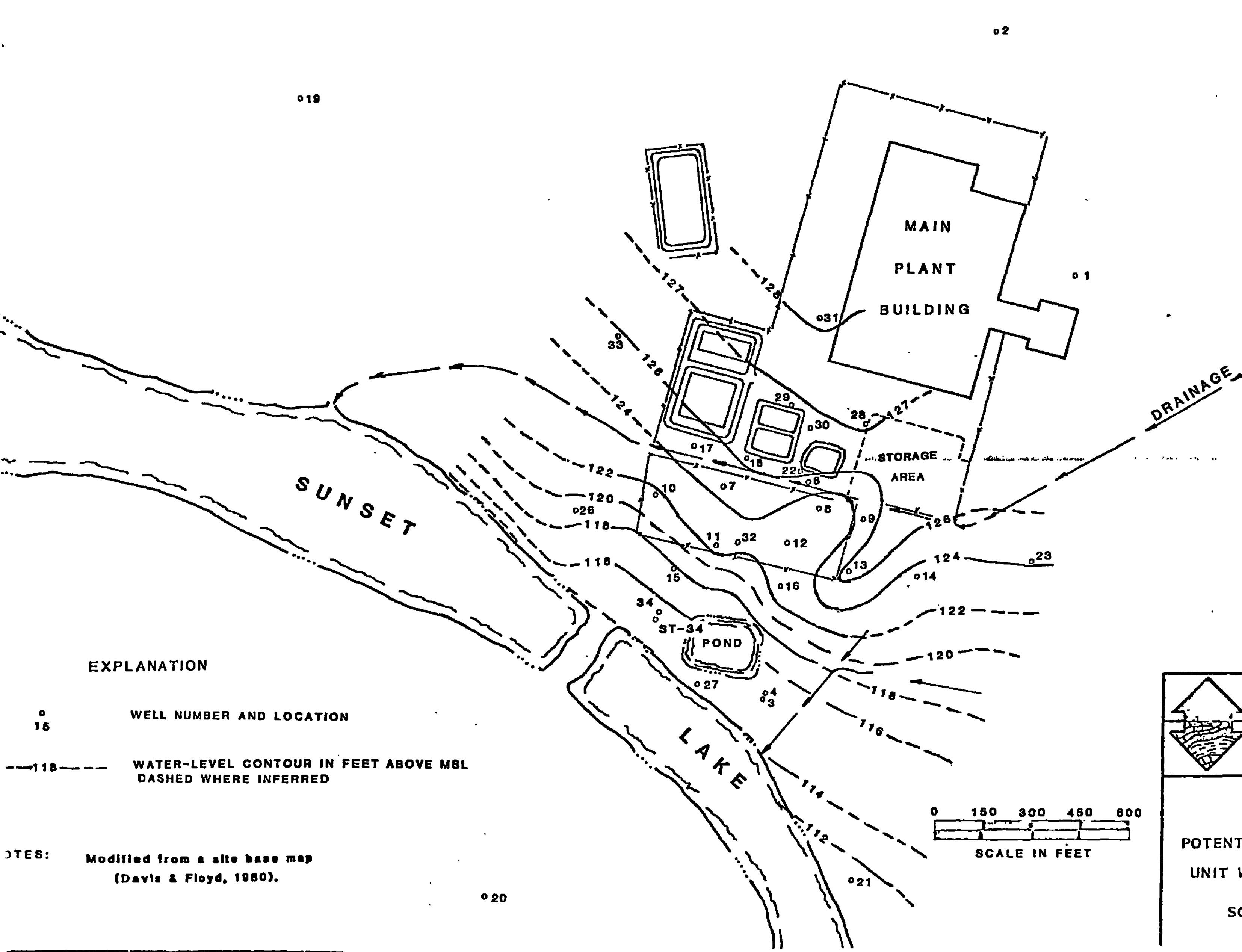


FIGURE 4-4 NORTH-SOUTH HYDROGEOLOGIC CROSS-SECTION OF THE TERRACE AND UPPER BLACK MINGO HYDROGEOLOGIC UNITS AT THE WEC SITE





WATER LEVEL MEASUREMENTS
NOVEMBER 15, 1981

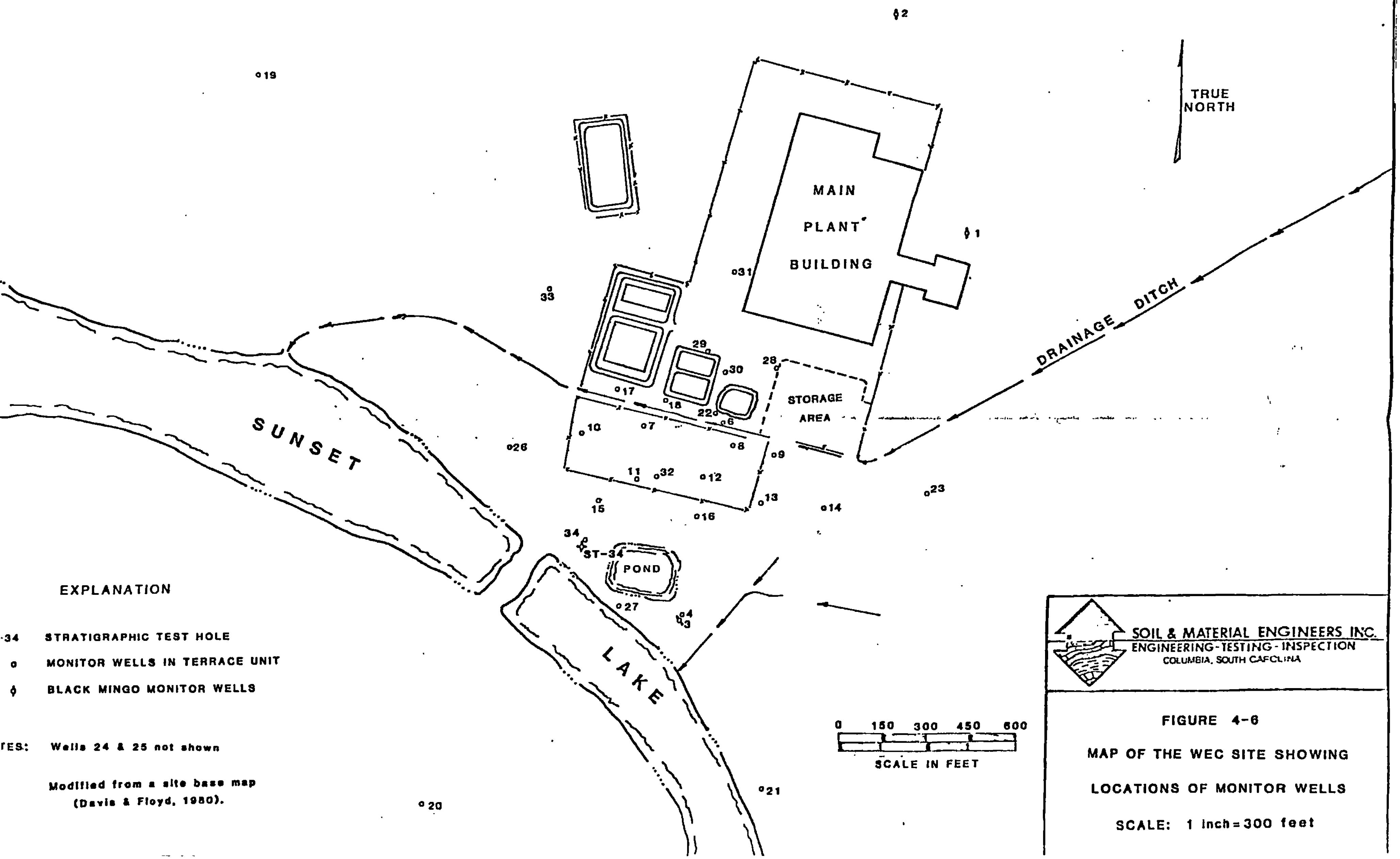
WELL NUMBER	ELEVATION (FEET)	WELL NUMBER	ELEVATION (FEET)
W-6	126.86	W-21	107.57
W-7	124.06	W 22	125.96
W-8	120.84	W-23	124.16
W-9	125.25	W-24	130.42
W-10	120.62	W-25	107.76
W-11	123.66	W-26	119.74
W-12	123.95	W-27	114.16
W-13	127.08	W-28	127.7
W-14	122.58	W-29	126.4
W-15	117.19	W-30	126.45
W-16	122.32	W-31	128.41
W-17		W-32	123.65
W-18	126.75	W-33	125.72
W-19	120.16		
W-20	108.11		

SOIL & MATERIAL ENGINEERS INC.
ENGINEERING-TESTING-INSPECTION
COLUMBIA, SOUTH CAROLINA

FIGURE 4-5

POTENTIOMETRIC MAP OF THE TERRACE UNIT WEC SITE, NOVEMBER 15, 1981.

SCALE: 1 INCH = 300 FEET



EXPLANATION

-34 STRATIGRAPHIC TEST HOLE

o MONITOR WELLS IN TERRACE UNIT

ϕ BLACK MINGO MONITOR WELLS

TES: Wells 24 & 25 not shown

Modified from a site base map (Davis & Floyd, 1980).

0 150 300 450 600

SCALE IN FEET

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FIGURE 4-6

MAP OF THE WEC SITE SHOWING LOCATIONS OF MONITOR WELLS

SCALE: 1 inch=300 feet