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GEOLOGY OF SANTEE-COOPER PROJECT

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REPORT

TO THE SOUTH CAROLINA PUBLIC SERVICE AUTHORITY

on the

GEOLOGY OF THE SANTEE-COOPER PROJECT

By Stephen Taber

Geologist

June 20, 1939

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INTRODUCTION

The Santee-Cooper Hydroelectric and navigation project involves the diversion of most of the flow of the Santee River across a low divide into the drainage basin of the Cooper River. The Santee River has an average flow of 19,200 cubic feet per second, the largest of any North American river flowing into the Atlantic Ocean south of the St, Lawrence. The power plant, with a maximum head of about 75 feet, will be located less than 30 miles from the coast.

A long earth dam and dike, constructed across the Santee River where the elevation of the water is about 40 feet above mean sea level, will raise the water level to a maximum elevation of 75 feet and form the Santee Reservoir with an area of approximately 78,000 acres. A diversion canal will conduct the water across the divide at a point where the elevation is only 80 feet. Near Pinopolis a second dam will be built across Biggin Creek, a tributary of the Cooper River, at a point where the water is only 8 feet above sea level. This will form the Pinopolis Reservoir, with an area of about 59,000 acres.

Near the south end of the Santee dam a spillway will be built and at the Pinopolis dam a power house and locks are to be constructed. The channel below the Pinopolis dam will be deepened and the power plant will be constructed partly below mean sea level in order to take advantage of the increased head at times of low tide. Where the divides enclosing the Pinopolis reservoir are low, dikes are to be built, the longest and highest being on the east side of the basin near Bonneau.

In its inception the project is an old one, having developed gradually through a long period of time. In 1771 the Province of South Carolina employed Henry Mouzon, Jr. to make a map of the proposed Santee Canal to connect the Santee and Cooper rivers. In 1786 an act was passed by the legislature chartering "The Company for the Inland Navigation from Santee to Cooper River." Work was commenced in 1793 and the canal was completed in July 1800 at a cost of $750,000, Christian Senf being the Engineer.

The canal was 22 miles long, 35 feet wide at the surface of the water, with a minimum depth of 4 feet, and had ten locks all built of brick or stone.

The main difficulty in operating the canal was the lack of sufficient water where it crossed the divide between the two rivers, but it served as an important transportation route for over thirty years, until it was put out of business by the railroads. The rebuilding of the canal was suggested from time to time and in recent years the possibility of developing hydroelectric power has been connected with the navigation feature. In 1926, the Federal Power Commission granted the Columbia Railway and Navigation Company a license to develop the Santee-Cooper Project. In 1933 it was taken up as a public project, and in 1934 an act was passed by the state legislature creating the South Carolina Public Service Authority for the development of the project.

Since December 1934, the writer of this report has served as consulting geologist on the project, first for the Authority and later for the Harza Engineering Company. In the preparation of this report, which was authorized by the Authority in May 1939, use has been made of data obtained by Murray and Flood, Inc., and by the Harza Engineering Company. The writer is indebted to the engineers of both firms for their cooperation, and also to the engineers of the Authority and P.W.A. for criticisms and suggestions.

TOPOGRAPHY

The reservoir basins are in the central part of the South Carolina Coastal Plain (see Fig. 1), where relief is relatively low. Most of the area is shown on the topographic maps of the Manning, Eutawville, Chicora, Summerville, and Cordesville quadrangles, published by the United States Geological Survey, Broad, flat divides, that are commonly swampy, separate valleys with broad, swampy floors. The Coastal Plain slopes southeast toward the coast, but the slope is not uniform. The divide between the Santee and the Black rivers and also the divide between the Santee and the basins of the Cooper and Edisto rivers show somewhat steeper slopes from elevation 135 feet down to an elevation of 80 or 90 feet.

The Santee River flows easterly and southeasterly in a meandering course. The Cooper River and the lower part of the Edisto River with its tributary Four Hole Swamp, drain in a general southerly direction, and have shorter and more direct courses to the sea.

The southward flowing streams have extended their headwaters northward until the divide between them and the Santee is, in places, only two or three miles from the latter stream. This is a condition that frequently results in stream capture, and the Santee-Cooper Project is, perhaps, merely anticipating nature.

In most regions of relatively undisturbed, stratified rocks the large streams occupy deeper valleys than the small streams. The anamalous difference in elevation between the Santee and Biggin Creek, which makes the project possible, is a direct result of the

geological history of the region.

Solution topography, with numerous sink holes and several large limestone springs, is well developed in the area immediately south of the Santee River, especially in the vicinity of Eutawville. Sink holes are also numerous in the eastern part of the Pinopolis reservoir basin, and shallow depressions are scattered over much of the area. Several limestone springs supply water to Biggin Creek from the east. Where sink holes are abundant, subsurface drainage is good, swamps are absent, and small surface streams are scarce. In the area near Eutawville the few short streams that flow northward into the Santee, all have their sources in limestone springs.

The Santee River and nearly all of the small streams of the area flow through flood-plain swamps. The Santee swamp increases in width from about two miles near Parler, to three miles near Eutawville, and five miles at the dam site. Since the slopes descending to the swamp are relatively steep, especially in the upper part of the reservoir, little land outside of the swamp will be flooded, except in the lower part of the basin. Biggin Swamp is about a mile wide at the Pinopolis dam site.

Along the broad flat divide that separates the Cooper River basin from the Santee drainage, swamps are well distributed at elevations ranging from 75 feet to nearly 100 feet. The swampy area is most extensive on the west side of the Pinopolis reservoir basin in the area where the divides between the Cooper, Ashley, Edisto and Santee rivers come together. These swamps are due to poor subsurface drainage and to the fact that the small tributary streams have not had time to cut back and provide good surface drainage.

Several elliptical "bays" or swamps, found in the vicinity of the project, closely resemble the much discussed Carolina bays that are so well developed in the Myrtle Beach area. Toney Bay is a small elliptical swamp four miles south of Eutawville. Several bays are found near Bowman, twenty miles west of Eutawville, and another group of bays is located ten miles north of the Santee and eight miles southeast of Manning. No matter what their origin, these "bays" are so located as to have no effect on the project.

GENERAL GEOLOGY

Preliminary Statement

Three bed-rock formations, all Eocene in age, are found in the area of the project, but natural exposures of these formations are rare, for at most places they are buried under a thick blanket of Pleistocene deposits. The few exposures are limited to the vicinity of the larger streams and a few limestone springs and sink holes, places where the overburden has been removed by erosion. The distribution of the three

formations is shown on the accompanying geological map (Fig. 2), and their relative position on the geological sections (Figs. 3 and 4).

The black mingo is the oldest of the formations, the Santee limestone rests unconformably on top of it, and the Cooper marl lies conformably on the limestone. Many holes have been drilled to determine the position, thickness, and characteristics of the different formations.

Black Mingo Formation.

The Black Mingo formation is encountered directly under the Pleistocene blanket in the northeastern part of the area, but toward the southwest it passes under the Santee limestone. The contact between the two formations crosses the northeast corner of the Pinopolis reservoir basin and continues under the southern end of the Santee Dam site. The Black Mingo formation, resting unconformably on the Peedee formation of Cretaceous age, has a thickness of more than 125 feet on the south side of the Santee in the vicinity of Wilson Landing. It probably becomes thinner toward the south, but continues under the limestone beyond the Pinopolis dam site.

The Black Mingo formation consists chiefly of soft clay shales and sands, the shales being more abundant in the lower part of the formation, and the sands in the upper part, though in places they are interbedded in thin layers. The shales are dark gray to black in color when moist, changing to lighter gray on drying. The sands are commonly dark green from the presence of glauconite grains, but, in places, they are gray in color and composed almost exclusively of quartz. The formation is not exposed within the area of the project, but, in other localities where it outcrops at the surface, it is usually deeply stained by oxides of iron.

The shale has been well compacted by pressure, and will support heavy loads with little settlement so long as it is confined. When not confined it will support a load of several tons per square foot, but under heavier loads it would flow. If placed in water after drying, it slakes and swells to form a soft jelly-like clay. It is insoluble and highly impermeable.

Some of the sand is cemented with calcium carbonate to form a soft sandstone, and a few thin layers are extremely hard because of cementation with silica. The sandy phase is permeable and is one of the best aquifers in the area. It is insoluble and will support heavy loads without settlement.

Santee Limestone.

The Santee limestone immediately underlies the Pleistocene blanket throughout most of the area that will be flooded by the two reservoirs, and it rests on the eroded surface of the Black Mingo formation. The bed has a thickness of 93 feet near the Pinopolis dam site, where it has been protected from erosion by the overlying Cooper marl. It thickens gradually towards the southwest, and, because of erosion, thins out to a feather edge along its northern boundary.

The limestone varies in its appearance and characteristics in different parts of the bed. The upper part is granular and rather poorly cemented; and it is mostly greenish gray in color although, in places, it is creamy yellow. The lower portion of the bed is less granular, and it is commonly cellular from the solution of fossil shells, but it is well cemented. It is, on the average, lighter colored, ranging from light gray to creamy yellow and almost white. Hard and soft layers alternate, but, on the whole, the lower part of the bed is hardest. Surface exposures are mostly soft except where casehardening has occurred.

The rock is porous, a sample of the fresh granular rock obtained under the Cooper marl containing 24 per cent voids, but it is not very permeable except in areas where, because of exposure, solution channels have developed. In drilling for water immediately south of the area, wells are commonly carried through the Cooper marl and Santee limestone into underlying sands.

The limestone is relatively pure, in places containing less than 5 per cent of insoluble material. Glauconite, the principal impurity, is irregularly distributed through the bed, but is generally more abundant in the upper portion. It occurs mostly in the form of small grains, but is occasionally found in granular nodules an inch or more in diameter. In a few specimens considerable quartz sand was present, and a little pyrite was also observed. The limestone has been formed from the remains of Bryozoa, oysters, pectens and other organisms secreting calcium carbonate.

Because of its impurity the limestone is relatively soluble and solution channels tend to develop in it wherever there is opportunity for the circulation of water. It will support heavy loads without appreciable settlement. The well-cemented phases of the rock are relatively resistant to weathering and can be used for riprap and in the construction of buildings. The limestone is suitable for neutralizing acidity in soils, for making quick lime, and, when mixed with the overlying clays, it can be used in making Portland cement.

Cooper Marl.

Cooper marl covers the Santee limestone in the southern part of the Pinopolis reservoir basin. It thickens gradually toward the southwest and thins out toward the north. Under the flood plain of Biggin Creek, at the dam site, the marl is only a few feet thick and extends upstream for a mile or less, but under the valley slopes and divides it thickens and extends much farther north (see figs. 2 and 4).

The marl was deposited conformably on the limestone, and in places grades into it without any sharp line of demarkation. At other places the granular limestone grades into a calcareous quartz sand with glauconite grains, and this grades into the typical marl. In places near the outcrop, a little limestone has been dissolved from the top of the bed with a residual concentration of glauconite sand along the contact between the two formations.

The Cooper marl is dark greenish-gray in color when moist, becoming light gray on drying. It is variable in composition, but, on the average, contains 70 per cent or less of calcium carbonate, the residue consisting of clay, with more or less quartz and glauconite, and occasional small phosphatic nodules, A sample of fresh marl from a pit at the Pinopolis dam site contained 27.8 per cent water; and, when dried and placed in acid, yielded 53 per cent insoluble matter, chiefly clay. The calcium carbonate is present partly in the form of microscopic fossils, largely foraminifera, and partly as marly paste showing incipient recrystallization.

When wet the marl is tough, slightly plastic and highly impermeable. The tunnel conducting water from the Edisto River to Charleston was driven for over 20 miles through Cooper marl, and no lining has been found necessary. Because of its impermeability it is relatively insoluble, and solution channels, sink holes and similar features are not found in it. Marl from the Pinopolis dam site, when dried, and placed in water slakes slowly. When undisturbed and naturally saturated it will support moderately heavy loads, but it is not as strong as the underlying limestone, on which the power plant and locks will be founded.

Structure of Tertiary Strata.

The Eocene beds of the area dip toward the south with an average slope of about 6 feet per mile. Laminations due to bedding are absent or very poorly developed in both the Santee limestone and the Cooper marl. Widely spaced joints are present where these formations are exposed in the pits at the dam site, in the bed of Biggin Creek and in the sides of the old Santee

Canal, but all joints are tight and show no solution effects.

No evidence of the presence of faults has been found at the Pinopolis or the Santee dam sites or in their immediate vicinity. The distribution of intensities at the time of the Charleston earthquake of 1886 indicates that the disturbance was caused by a displacement along a fault extending in a northeast-southwest direction near Woodstock, twenty-three miles south of the Pinopolis dam site, and that the displacement could not have extended more than five miles northeast of Woodstock. If the fault continues northeastward it would be at least ten miles from the dam at the nearest point. The fault is in the crystalline basement rocks which are buried under Coastal Plain beds having a total thickness of about one-half mile, and there is no evidence that it extends upward into these beds.

Pleistocene Blanket.

The Pleistocene clays and sands, which blanket the Eocene formations over nearly the entire area, were laid down on a well-dissected coastal plain, burying the old topography. The old valleys have been largely re-excavated by their streams, but relatively little material has been removed from the broad flat divides where the Pleistocene sediments now have a maximum thickness of over 50 feet. An auger hole put down on the divide, a mile southwest of Eutawville, where the elevation is 119 feet, failed to reach the limestone at a depth of 51 feet; and several holes, located on other divides, penetrated over 45 feet of overburden. The average thickness of the Pleistocene deposits in the area is about 30 feet.

The character of the formation varies somewhat over the area, but, in general, it consists of a sandy layer at the bottom, which grades into sandy clay above, and this in turn grades into a fine sand or sandy loam at the surface.

The sand at the bottom is commonly rather coarse, and in places contains a few, small, water-worn quartz pebbles. It is quite permeable.

The middle two-thirds of the formation is a well-compacted mixture of sand and clay, unusually low in silt. The average for 140 auger holes near the Pinopolis dam site gave 50 per cent sand, 8 per cent silt, and 42 per cent clay, over an average thickness of 19 feet. The clays are generally mottled red or brown and gray. This part of the blanket is relatively impermeable.

The surface layer of sand and loam is commonly gray in color and ranges from a few inches up to 4 or 5 feet in thickness.

it is relatively permeable.

The formation is distinctly stratified, though most of the well-defined layers seem to be lenticular and not very persistent. Small lenses of clay and of sand are present, and on the east side of the Pinopolis reservoir basin a sharply defined clay bed was traced for about two miles. No cross bedding has been observed. The formation was probably deposited rapidly in shallow water. Some of the clays contain fossil diatoms, which indicate that the finer material may have been deposited in the brackish water of lagoons and estuaries. No unconformities have been observed within the formation.

The clay content of the blanket is sufficiently high at most places to render it relatively impermeable and make it an excellent natural lining for the reservoir basins. In only a few places is the blanket so sandy as to be very permeable, and fortunately these localities are mostly well within the basins. The blanket material can be used with proper selection for the construction of earth dams and dikes. Much of the clay is suitable for the manufacture of building brick and tile.

Estuary (?) Deposits.

The deposits found under the flood plains of the larger streams are different from the blanket deposit and are probably younger in age. The material under the Santee Swamp is mostly sand, except for a surface layer, 2 to 18 feet thick, which contains about 30 per cent clay and more silt than is normally present in the blanket deposit. These Santee Swamp deposits have a maximum thickness of about 50 feet. The deposits under Biggin Swamp are similar to those under the Santee Swamp except that they are only about 15 feet in maximum thickness and probably contain less clay. The age of Santee Swamp and Biggin Swamp deposits is probably Pleistocene, though the upper part of the deposits may in places be Recent, and fluvatile in origin.

GEOLOGICAL HISTORY

Deposition of Santee Limestone and Cooper Marl.

The surface on which the Santee limestone was laid down has been subjected to erosion, and therefore it was somewhat irregular, but the few drill holes that have passed through the limestone into the Black Mingo formation indicate that the surface is a gently tilted plain.

The materials forming the lower part of the Santee limestone were deposited in moderately deep water at some distance from the land, so that the shells were not badly broken up, and very little sediment of land origin was mixed with the calcareous

accumulations. Later, conditions changed so that much of the material was broken up by wave action and deposited as calcareous sand.

The change from the deposition of the Santee limestone to the deposition of the Cooper marl was brought about by conditions which permitted more soil to be washed in from the land, so that considerable clay and sand became mixed with the calcareous accumulations. The change did not involve the uplift and exposure of the Santee limestone to erosion, such as occurred after the Black Mingo formation was deposited; and, therefore, where the Santee limestone is now covered by the Cooper marl it has never been subjected to subaenial processes.

Erosion of the Eocene Formations.

Subsequent to the deposition of the Santee limestone and Cooper marl they were lifted above sea level and subjected to a long period of erosion. The Cooper marl was stripped off to expose the Santee limestone over most of the area that is to be flooded by the reservoirs, and, in the northern part of the area, some 75 or 80 feet of limestone was removed.

Broad valleys were cut across the Eocene formations and typical solution topography was developed on the Santee limestone. Much of this late Tertiary topography, which now lies buried under Pleistocene sediments, has been revealed by drilling operations.

In late Tertiary time the channel of the Santee River in the vicinity of Wilson Landing had been cut down to an elevation of about 5 feet below present sea level. (see Fig. 3) or about 30 feet below the present bed of the river. Biggin Creek had then cut its channel, in the vicinity of the dam site, to a depth of 3 feet above present sea level or 10 feet below the present bed of the Creek. Therefore, at this time, the relative elevation of the two streams was normal.

The buried topography is rougher than the present surface topography, and the divides narrower, but the differences in relief are not great.

The development of most of the solution effects in the limestone occurred while the limestone was exposed, and the distribution of the solution channels formed at that time is of importance in connection with possible leakage from the reservoirs. Since the limestone bed is nearly flat, and structural control therefore absent, the movement of ground water through the bed is from the divides toward the neighboring streams, in the general direction of the surface slopes. Thus, the large springs near the Santee River obtain their water supply from the sink-

hole area immediately south of them, and the general direction of subsurface drainage through solution channels is northward, in the opposite direction to the dip of the limestone. Similar springs in the area three miles east and southeast of Bonneau emerge from solution channels draining in a southwesterly direction toward Biggin Swamp. Therefore, the subsurface drainage is here obliquely across the dip of the limestone.

Since the buried divides developed on the limestone are approximately under the present topographic divides, it is unlikely that many solution channels are so located that they could conduct water from the reservoir basins into the stream systems that drain away from the basins.

Sea Level Changes of Pleistocene Time.

At the close of the Tertiary Period, world-wide crustal movements resulted in the submergence of the Coastal Plain. During the Pleistocene, the waxing and waning of ice caps resulted in alternate withdrawals and advances of the sea, and these fluctuations were superimposed on a general lowering of sea level. Periods of submergence were accompanied by accumulation of sediments, and periods of emergence by erosion, especially in valleys occupied by streams. Waves and currents washed much material into sink holes and down into the solution channels, so that the latter were partly, and probably largely, choked with sediments, chiefly sand. The valleys now drowned to form the estuaries of the Cooper and Ashley rivers were eroded during the periods of low sea level.

The surface layer of fine sand and sandy loam was probably formed by wave action as the sea was withdrawing, and by subsequent rain wash.

Development of Present Topography.

When the sea withdrew after the deposition of the Pleistocene sediments, the old topography was almost completely obliterated, but the major streams assumed their courses approximately over their old valleys and proceeded to re-excavate them. At the Pinopolis dam site, Biggin Creek has cut its present channel down into the Cooper marl about 2000 feet northeast of the old channel, which is only about 10 feet lower. (See Fig. 4.)

A meandering course assumed by the Santee River on top of the Pleistocene sediments was, in places, over the deeper portion of its old valley, where the limestone had been largely or entirely removed by erosion, but in other places it was over the upper slopes of the old valley, where the limestone remained at a relatively high elevation. In the southward bend near Wilson Landing, the river has cut down into the thin edge of the limestone bed, (see Fig. 3), the present channel being about two and one-half miles south of the old channel and approximately thirty feet higher. A half mile upstream, where it is now planned to locate the Santee spillway and dam (see Fig. 2), the

river, in its northward bend, is flowing on top of the thick deposit of sediments that fills the old valley. Farther downstream at Lenud's Ferry, hard limestone is reported to outcrop in the bluffs on both sides of the river.

The abnormally high elevation of the Santee River at the dam site, and its failure to clean out its old valley, are due to the resistance of the limestone on which the river has been superimposed at points farther downstream. The river is able to deepen its channel by erosion of the sediments filling its old valley only so fast as it deepens its channel in the more resistant limestone.

A small buried valley without surface expression has been located, by drilling, 2000 feet northeast of McBeth. The valley which is cut in limestone to a depth of 25 feet and drains in a southeasterly direction, has its head nearly a mile northwest of the present divide between Biggin Creek and Peafield Swamp.

Well-defined sink holes are now found in the area at points where the limestone either outcrops, is close to the surface, or is buried under permeable sands, and where good subdrainage is furnished by nearby valleys. Under these conditions the old sink holes have been enlarged by the solvent action of downward percolating water. The present surface depressions have developed, in part, through solution, and in part through the washing of blanket material down into the solution channels.

Drilling has located some buried sink holes that have no surface expression today, either because the solution channels leading from them are thoroughly blocked, or because the overlying blanket is so impermeable that downward percolation is inappreciable.

It is chiefly near large springs, where the emerging groumd water becomes concentrated, that the old solution channels have been cleared of the sediments that accumulated in them during the deposition of the blanket.

POSITION OF THE WATER-TABLE

The position of the water-table is one of the best indications of the permeability of the formations of an area. With few exceptions the water-table in the Santee-Cooper area is everywhere high. This is due chiefly to the prevailing high clay content of the Pleistocene blanket. The water-table is depressed in the vicinity of some sink holes, especially during periods of draught, thus clearly indicating downward drainage into solution channels. Fortunately most of these localities are well within the reservoir basins. Absence of a depressed water-table at other sink holes indicates no drainage through

the solution channels at the present time. At no place in the area was the water-table found to be below the surface of the limestone, except in the vicinity of springs. At most places along the major divides the water-table is high above the limestone. This means that drainage through the solution channels is retarded by the material that has been washed into them.

The problem of leakages is discussed further in connection with the geology of specific localities.

Flooding of the reservoirs will decrease the ground water gradient along flat shores and tend to raise the water-table in the immediate vicinity. This will be most noticeable in localities where the land is flat and the water-table already close to the surface. Some areas not now swampy may be made so unless precautions are taken. Most such trouble may be prevented by the construction of drainage ditches. The water-table will also tend to rise on the outside of dikes built on low divides. This may be prevented through the use of drainage ditches connected with streams that drain away from the reservoir.

PERCOLATION DOWN THE DIP OF STRATA

Leakage by artesian circulation down the dip of the beds should be small, and of no importance except, perhaps, locally at the Pinopolis dam, where some precautionary measures are advisable.

There is no evidence of solution channels in the limestone where it is covered by the impervious Cooper marl. Wells drilled immediately south of the area obtain very little water from the limestone. The artesian head will be increased locally, over the flooded area, but the average height of the water-table will be raised very little, since at many places it is now above the maximum flow line of the reservoirs. Percolation into the limestone will be slowed up by the Pleistocene blanket and percolation down the dip of the limestone should be very slow as the water cannot escape in appreciable quantities through the overlying marl at any point between the reservoirs and the coast.

EARTHQUAKE HAZARD

Since a destructive earthquake occurred in the vicinity of Charleston, S. C., August 31, 1886, it is advisable to consider the question of the possible recurrence of similar shocks and the probable effect of such shocks on dams and other structures that would be constructed as a part of the Santee-Cooper Project. No place is absolutely immune to earthquake shocks, but in some areas earthquakes are much less likely to occur than in others. Three criteria may be used in determining the seismicity of an area; statistics, relief, and structural geology.

During historic times only one destructive earthquake has originated in the Atlantic Coastal Plain, and only three have occurred in the eastern part of North America. De Ballore has shown that 94.6 per cent of the earthquakes of history have originated in two belts circling the earth. South Carolina is far from either of these belts. On the assumption that the risk is equal for all parts of the area lying east of the Appalachians, John R. Freeman states that one-half cent per $1,000.00 would cover the hazard to buildings. Dams have proved more resistant to damage by earthquakes than buildings.

It has been shown that earthquake frequency is roughly proportional to the relief of a region. The relief of the entire region east of the Appalachians is very low.

Earthquakes are most frequent in regions where differential movements of the earth's crust have been going on most rapidly during post-Tertiary time. In the South Carolina Coastal Plain such movements have been extremely slow, probably close to the minimum.

Since high dams of earth and of concrete, located close to the San Andreas fault on the San Francisco peninsula, were not damaged during the earthquake of 1906, it may be concluded that well-constructed dams in the South Carolina Coastal Plain would not be damaged by an earthquake equal in intensity to the shock of 1886.

GEOLOGY IN RELATION TO THE PROJECT.

Santee Reservoir.

The divides on both sides of the Santee reservoir basin are broad and well above maximum high water. No leakage can occur through them. Open solution channels in limestone are unquestionably present in the sink-hole area south of the river near Eutawville, but drainage through them will be into the reservoir, not out of it. For water to leak out, it would have to travel at least six miles through the divide to find an outlet at the elevation of maximum high water, about 75 feet. The water-table all along the divide is now higher than the reservoir level will be.

In the Eutawville area water will back up into sink holes, having a bottom elevation of less than 75 feet, and form ponds that will have to be included under the mosquito control. The formation of such ponds may be prevented by filling the holes with sand to an elevation just above high water level.

Near the lower end of the reservoir some of the land along the shore line is flat, and may become swampy unless additional drainage is provided.

Santee Dam and Spillway.

The Santee dam and spillway will be built across the Santee swamp, which has an average surface elevation of a little over 40 feet. Some leakage will occur through the sand that largely fills the old buried valley of the Santee, (see Figure 3), but the hydraulic head at this dam will be relatively low, and the surface blanket of clayey material will slow up percolation. This blanket should be carefully preserved above the dam during construction, and where it is thin or entirely absent, as in the channels of the Santee and Little rivers, it should be reinforced by artificial blanketing.

Vertical drains for relief of uplift pressure may be advisable below the dam in any areas where this service is not performed by borrow pits.

Since the limestone was removed by erosion in cutting the old Santee valley, solution channels are entirely absent under the main dam and the spillway. South of the spillway, where the dam becomes a relatively low dike, limestone is present, but in this area the Pleistocene blanket is thick, averaging about 25 feet, and has a high clay content. Although shallow depressions occur in the area, well-defined sink holes are absent, and the water-table is close to the surface.

Any water percolating under the dam will drain into the river, and a certain amount of water must be wasted in order to maintain the flow of the stream. A little leakage will do no harm, provided it is not concentrated at any point in sufficient volume to cause sand boils.

The energy of the water flowing over the spillway must be destroyed in order to prevent undercutting of the apron, but below this point erosion will be limited, as in the past, by the rate at which the stream can deepen its channel in the limestone on which it is flowing farther down-stream.

The sand in the old Santee Valley, and the underlying formations, should easily support the relatively light loads of the dam and spillway. Muck, such as is common in many swamps, is practically absent from the Santee Swamp.

Diversion Canal.

The divide crossed by the diversion canal is underlaid by the limestone, which is everywhere buried under the thick Pleistocene blanket. The average thickness of this blanket on each side of the divide is greater than is indicated in Fig. 3, for the line of section passes up Springwood Swamp on the northwest side of the divide and down Greenhill Branch and Biggin Creek on the opposite side. Much of the blanket has been removed by erosion along these drainage courses.

The data from drilling investigations indicate the presence of well-developed solution topography on the buried surface of the limestone under the present divide. Open cavities were encountered, but they are blocked so that water does not drain out through them appreciably faster than through the overlying blanket. The construction of the canal will not increase the pressure tending to cause circulation of water along solution channels under the divide, for the water-table on the divide is now about 5 feet higher than the water will be in the canal.

Any leakage from the canal would probably go into either the Santee reservoir or the Pinopolis reservoir. In order that water from the canal may leak out below the Santee reservoir, it would have to travel several miles under a flat divide where the water-table is now close to the surface.

Some of the limestone to be excavated is hard and well-cemented, but cellular from the solution of shells during the process of consolidation. The best of this limestone can be used for riprap. It would make a decorative and very appropriate building stone for use in the construction of permanent buildings in connection with the project.

The Pinopolis Dam, Powerhouse and Locks.

The geology of the Pinopolis dam site is shown on the accompanying map (Fig. 2) and longitudinal section (Fig. 4). Across Biggin Swamp the dam and reservoir will create the highest hydraulic gradient of any place on the project. There is no danger of water percolating through the thick Pleistocene blanket and Cooper marl underlying both ends of the dam; but, where the dam crosses Biggin Swamp, only a thin layer of the Cooper marl remains, and the overburden is also relatively thin and, in places, sandy.

Where the old buried channel of Biggin Creek crosses the dam site, about 2000 feet southwest of the present channel, the marl is only about 3 feet thick. The marl bed becomes thicker on passing downstream and also in going up the valley slopes on each side of the old channel; but upstream it gradually fades out, and, where it is thin, tree roots and erosion have probably formed holes in it.

In places a thin sandy layer separates the Santee limestone from the Cooper marl. Water, entering this layer at the outcrop and through holes in the marl, is under artesian pressure at the dam site and farther south, because it cannot escape through the overlying impervious marl. Since the water cannot readily escape, its movement is now extremely slow.

The flooding of the reservoir will put the water in the sandy layer under pressure equivalent to a head of about 75 feet, and, unless precautions are taken, this water may break through the marl immediately below the dam. Observation wells below the dam will indicate the development of uplift pressure during the filling of the reservoir, and additional vertical drains can be installed if necessary to relieve it. Although the leakage of water down the sandy layer would not be sufficient to endanger the dam, it would be advisable to cut off the flow as much as possible, for it will tend to increase because of solutions of limestone. More water will be brought in contact with limestone because of the increased flow, and this water will be a better solvent of limestone, since the water of the Santee has had little opportunity to dissolve calcium carbonate. Moreover, little sedimentation can be expected in the lower part of the Pinopolis reservoir.

The flow of water under the dam may be reduced by a cut off under the dam, by grouting, or by pumping a blanket of mud into the lower part of the reservoir as it fills.

The Cooper marl is impermeable, and therefore relatively insoluble, so that sink holes and solution channels are absent where it is the bed-rock formation. Moreover, solution channels are absent in the Santee limestone, where overlying marl has protected it, as in the vicinity of the dam site.

The limestone, immediately underlying the marl at the dam site, has a sandy texture and is poorly cemented. Most of it disintegrates rapidly on exposure to weathering, but, undisturbed, it will support heavy loads without appreciable settlement. It is good foundation material for the powerhouse and locks. The marl should be protected from drying in excavations made for foundations, for it tends to slack if it comes in contact with water after drying. It will support moderately heavy loads, but is not so strong as the limestone. The Pleistocene blanket in the vicinity of the dam site supplies excellent material for a rolled earth embankment.

West Side of the Pinopolis Reservoir Basin.

The divide forming the west side of the Pinopolis reservoir basin is broad, flat, and at many places swampy during rainy periods because of poor surface drainage. Even in areas that are not swampy, the water-table is mostly close to the surface and in only a few places is more than 10 feet in depth.

A low dike will be required along the southern half of the divide from the vicinity of Pinopolis to Cross School, as the ground surface averages about 69 feet in elevation and drops as low as 65 feet. The elevation of the northern half of the divide

ranges from 85 to 95 feet and averages about 90 feet.

Cooper marl, which underlies the southern part of the basin, extends northward along the divide to a point about one and one-half miles southeast of Chicora. The exact position of the boundary has not been determined. Santee limestone underlies the rest of the divide. The ground surface seems to be smoother over the marl than it is over the limestone. Shallow depressions are present in places but no well defined sink holes.

Along the dike line the Pleistocene blanket varies from 8 to 30 feet in thickness and averages about 16 feet. It consists of a sand-clay mixture, the upper half usually running somewhat higher in clay, but with a layer of fine sand or sandy loam at the surface.

Leakage under the West dike should be low as the hydraulic gradient will be low and the Pleistocene blanket, though thinner than in other areas, is relatively impermeable. Leakage is most likely to occur near Wassamassaw Swamp, which drains into the Ashley River, since the overburden is thinnest here and contains less clay than in most places. A shallow depression is present on the southwest side of the road. This section of the dike should be carefully watched when the reservoir is filled, and if trouble develops it can probably be stopped by local blanketing.

Along the northern half of the divide where no dike is needed, some land, not now swampy, will be made swampy; a condition that can be prevented, in part, with drainage ditches leading into the reservoir. The overburden is very thin in places and solution channels are present in the underlying limestone. A few years ago, Cross' pond in this area was completely drained through a channel in the limestone, but after plugging the hole with concrete the pond again held water. All of the solution channels in this area probably drain into the reservoir and they are not likely to give trouble.

East Side of Pinopolis Reservoir Basin.

The divide between Biggin Creek and the Santee which forms the north side of the Pinopolis reservoir basin, ranges from 74 to over 80 feet in elevation, and the divide forming the east side of the basin is almost as high for as far south as the Black Oak Church-Bonneau road. The overburden contains much clay and the water table is rarely more than 6 feet below the surface. Therefore the filling of the reservoir will bring little change in the elevation of the water table and leakage will be small along this section of the dike. Only a low dike will be required, and for a mile north of the Black Oak Church-Bonneau road no dike is necessary as the elevation of the divide is above 85 feet.

From the Black Oak Church-Bonneau road south to the vicinity of McBeth conditions are less favorable, and there is the possibility of excessive leakage unless precautions are taken. Conditions in this area are given in detail on the accompanying map (Plate I). The surface topography is shown by black contour lines, the topography developed on the Santee limestone is shown by green contours, and the position of the water-table is shown by red lines.

In the vicinity of the Black Oak Church-Bonneau road there is a large area, with elevation close to 60 feet, where the surface divide is poorly defined. On the southwest side of the road there is a large group of sink holes that extends well down into the reservoir basin. This sink-hole area is the gathering ground for the water that emerges at Woodboo Spring, about 11,000 feet southwest of the road.

A broad shallow valley in the buried limestone slopes southwest, and drilling shows that the sink holes in the limestone are commonly deeper than the depressions on the surface above them. The ground-water contours show that the subsurface drainage is southwest into the basin. The water-table is low, being 32 feet below the surface at one point near the line of the dike. Here the water level will be raised a maximum of 42 feet when the reservoir is filled. Also the water-table is depressed in the vicinity of some of the sink holes. These facts indicate that the Pleistocene blanket in this locality is relatively permeable. Although it contains some clay lenses, they are small and the overburden is more sandy than normal.

In drilling, small open cavities have been encountered in and on top of the limestone; and drainage through such solution channels is indicated by the depression of the water-table in the vicinity of sink holes, especially during times of drought. The presence of a few small surface depressions with vertical walls indicates recent caving to fill open spaces. It is possible that some of the open solution channels cross under the dike line.

In this area the Pleistocene blanket ranges from 27 to 40 feet in thickness and averages over 30 feet. During its deposition waves and currents washed much material into open spaces in the limestone; and, subsequent, downward percolating water has washed in additional material. The following facts indicate that the solution channels in the limestone are largely choked with sand and clay:

1. Some sink holes in the limestone have no corresponding depression in the Pleistocene blanket immediately over them.

2. The water table is not depressed in the vicinity of some sink holes.

3. The water table everywhere stands above the surface of the limestone, even where the latter comes close to the surface.

4. The flow from Woodboo Spring fluctuates very little with the rainfall.

5. Fluorescein, placed in the bottom of a shaft sunk to limestone in the large sink hole on the south side of the Black Oak Church-Bonneau road (at Test Hole No.23), never appeared at Woodboo Spring or any other spring in the area.

The limestone exposed in the bottom of the shaft was hard, but showed surface staining and evidence of extensive solution. The surface of the limestone was extremely irregular with a difference in elevation of 8 feet in a horizontal distance of 3 feet. The shaft was sunk with difficulty because of the quantity of water entering above the limestone. Five hundred grams of fluorescein sodium salt dissolved in water and placed in the bottom of the shaft was destroyed before the water emerged at any spring.

In this area I advise the blanketing of all deep, steep-sided sink holes within 4,000 feet of the dike line. I also suggest a thin clay blanket about 800 feet wide on the inside of the dike between Stations 370 - 00 and 394 - 00. Since there is a thick foundation of sandy soil on top of the limestone and since the hydraulic head will be relatively low, a very thin blanket should be sufficient. It could be pumped in after the reservoir has filled and after observations in outside wells and drainage ditches indicate that it is necessary.

Four hundred feet west of Test Hole D, and also in the vicinity of Test Hole G, perched water-tables have been observed. They are due to thin impermeable layers at the surface that are partly surrounded and underlaid by permeable sands having good subdrainage. Water moving down slope from the high-water-table to the northeast collects over the impermeable surface layers.

A rather sharply-defined limestone ridge, buried under the Pleistocene blanket, extends southeast from the sink hole area near the Black Oak Church-Bonneau Road. The overburden on top of the ridge is rather thin, being only 14.5 feet at Test Hole No. 19, but the water-table is within 11 to 13 feet of the surface, and it is improbable that solution channels extend under the ridge. Therefore leakage in this locality is not likely to be excessive, but observation wells and drainage ditches in the vicinity should be watched for objectionable leakage and blanketing applied if it becomes necessary.

Two thousand feet north of McBeth there is a saddle in the divide with a minimum elevation of 52 feet, the lowest point on any of the divides enclosing the reservoir basins. From the saddle a group of shallow depressions, ponds and sink holes extends easterly toward Fair Spring (see Plate I). This sink hole area is the collecting ground for the water that emerges

at the spring. The Pleistocene blanket over most of the sink hole area is permeable sand. About 1,600 feet west of the dike line, between Holes Nos. 6 and 9, a lenticular clay bed is encountered, which thickens toward the east and extends for a long distance along the dike. This clay bed will greatly reduce seepage under the dike where it crosses the saddle, and it should be carefully preserved during construction.

In the vicinity of Fair Spring the Pleistocene overburden has been largely removed by erosion, so that the limestone is exposed in places. The water, here concentrated from a large area, has partly cleared out the solution channels. When the reservoir is filled, the place where water can most readily enter solution channels in the limestone and reverse the flow will be at Fair Spring and along the drainage line immediately above it. I suggest the advisability of blanketing near the spring where the overburden has been largely removed, and later, when water is high enough in the reservoir to stop the flow from the spring, dump clay over the spring. The shallow ponds and depressions are not likely to cause trouble, but it would be advisable to blanket all deep, steep-side sink holes located between the spring and the saddle.

CONCLUSIONS

The Santee-Cooper Project is entirely feasible from a geological standpoint. Although there are problems they are such as can be handled by modern engineering methods.

The reservoir basins are largely underlaid by limestone that is full of solution channels, but few of these channels drain across the divides enclosing the basins, and the two dams will be located where solution channels are not a problem. The relatively impermeable Pleistocene deposits, that choke solution channels and blanket most of the area, are of the utmost importance in making the reservoir basins tight and the project feasible.

The long lines of dikes make it very difficult if not impracticable to entirely prevent objectionable leakage at every possible place in advance of filling of the reservoirs. Therefore a careful watch should be kept while the reservoirs are filling, and, if leaks develop, they should be promptly stopped by earth blankets, grouting or other means.

In order to better detect leaks, the flow of all of the small streams that drain away from the Pinopolis Reservoir and into the Cooper, Ashley, and Edisto rivers should be measured during periods of dry and wet weather before the reservoir is filled and while it is filling.

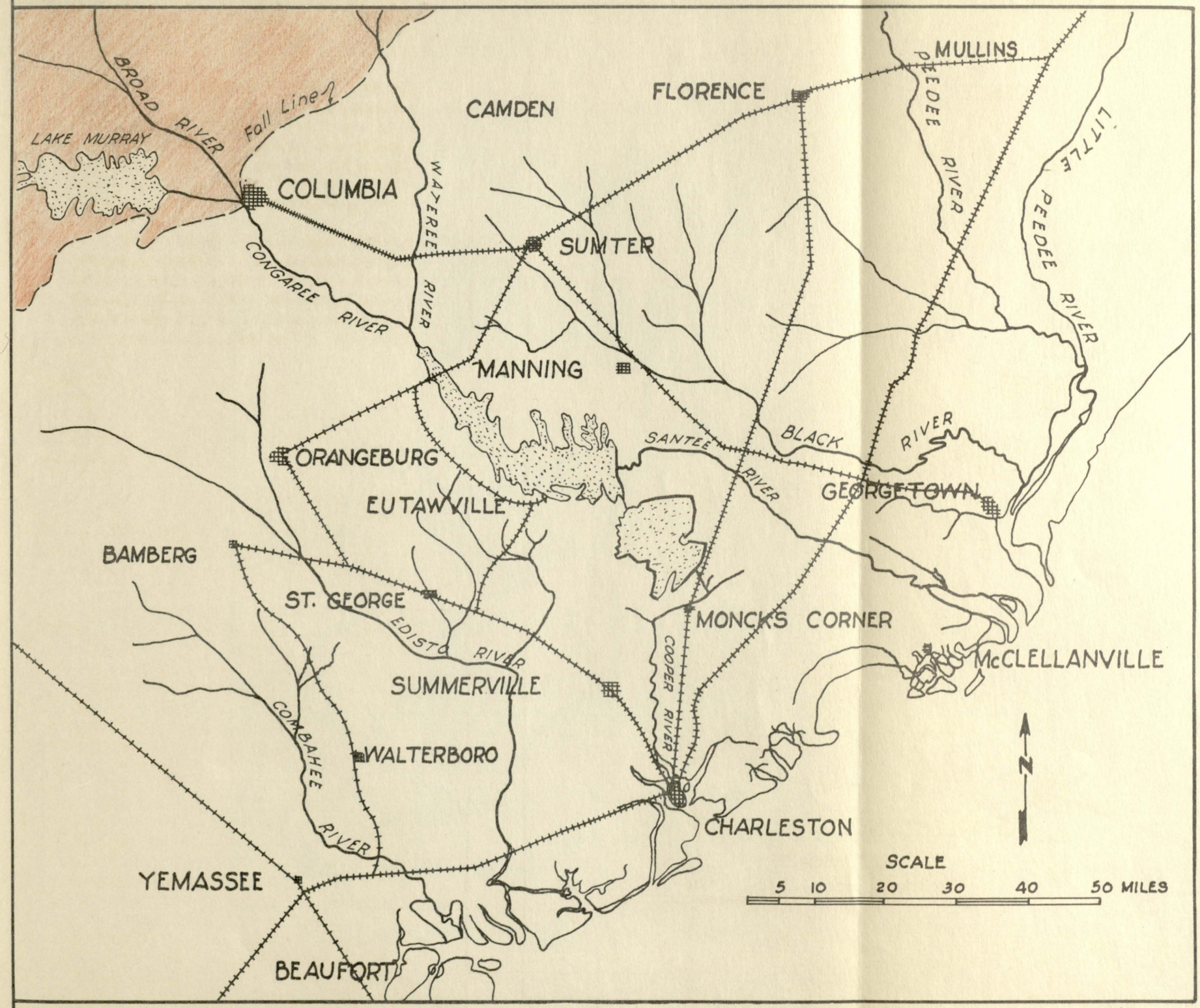
Fluctuations in the position of the water-table in bore holes, suitably located around the outside of the reservoir

should be carefully recorded during a period of a year or more preceding the filling of the reservoir and also while the reservoir is filling, and for a year or more thereafter. This will not only aid in the detection of leaks, but it will also furnish exact data on the effect of the reservoir on the water-table in the surrounding area, so that losses through damage suits can, as far as possible, be prevented.

The geology of the Santee-Cooper area is such that, if properly designed and constructed, the dams and dikes can be made as safe as similar structures elsewhere in the United States; and, if the necessary precautions are taken, the reservoirs can be made reasonably tight, so that leakage will not prevent the success of the project.

(Signed) Stephen Taber
Geologist

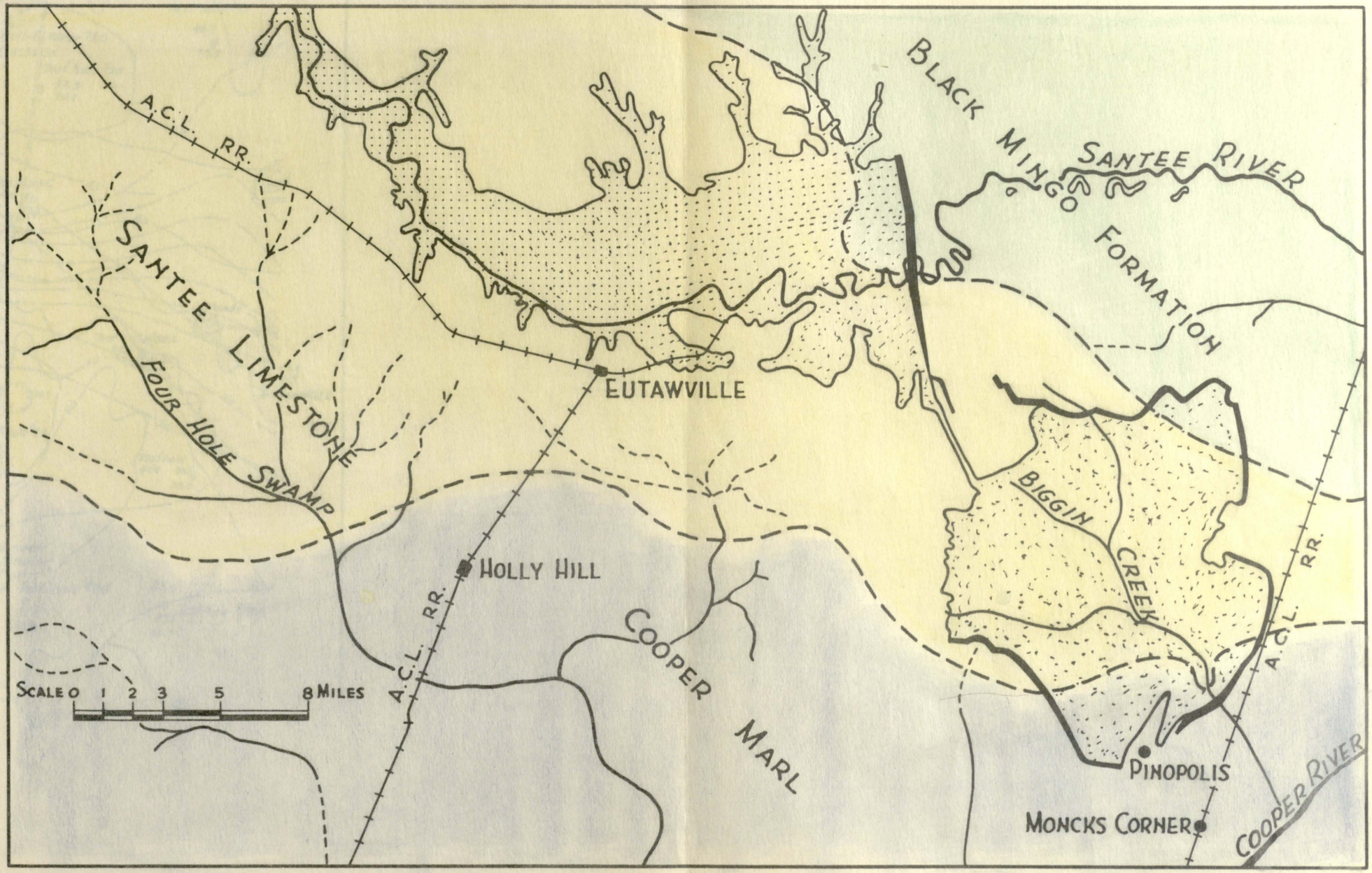
Stephen Taber - Fig. 1



MAP SHOWING LOCATION OF SANTEE-COOPER RESERVOIRS

Stephen Taber
Geologist

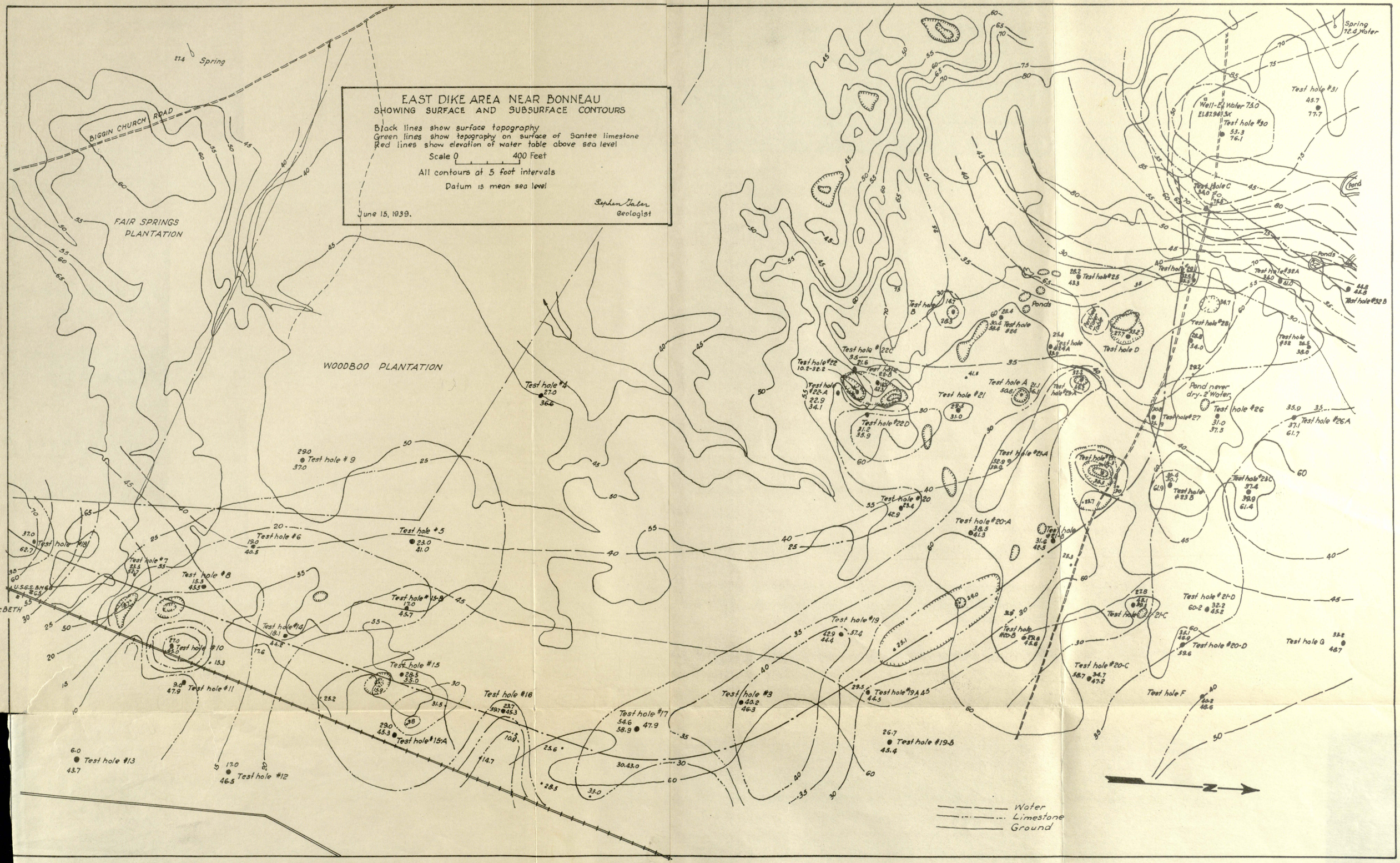
STEPHEN TABER FIG. 2

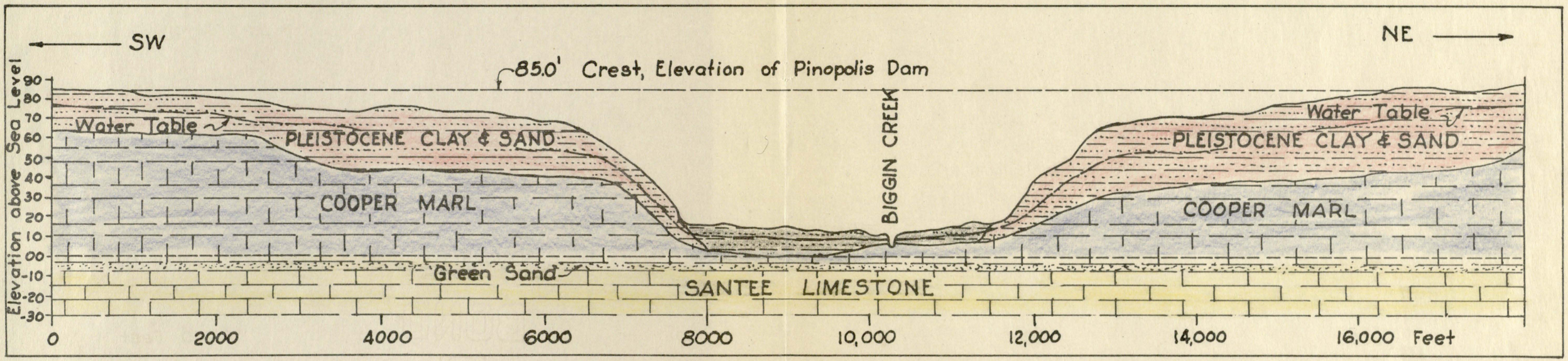


BLACK MINGO FORMATION SANTEE LIMESTONE COOPER MARL

GEOLOGICAL MAP OF SANTEE-COOPER AREA

Stephen Taber
Geologist


EAST DIKE AREA NEAR BONNEAU
SHOWING SURFACE AND SUBSURFACE CONTOURS
Black lines show surface topography
Green lines show topography on surface of Santee limestone
Red lines show elevation of water table above sea level
Scale 0 400 Feet
All contours at 5 foot intervals
Datum is mean sea level
June 15, 1939.
Stephen Taber
Geologist
BIGGIN CHURCH ROAD
FAIR SPRINGS PLANTATION
WOODBOO PLANTATION
McBETH
Spring
Water
Ponds
Pond never dry - 2' Water
Test hole A
Test hole B
Test hole C
Test hole D
Test hole F
Test hole G
Test hole #1
Test hole #5
Test hole #6
Test hole #7
Test hole #8
Test hole #9
Test hole #10
Test hole #11
Test hole #12
Test hole #13
Test hole #14
Test hole #15
Test hole #15-A
Test hole #15-B
Test hole #16
Test hole #17
Test hole #19
Test hole #19-A
Test hole #19-B
Test hole #20
Test hole #20-A
Test hole #20-B
Test hole #20-C
Test hole #20-D
Test hole #21
Test hole #21-A
Test hole #21-C
Test hole #21-D
Test hole #22
Test hole #22-A
Test hole #22C
Test hole #22D
Test hole #23
Test hole #23-A
Test hole #23B
Test hole #23C
Test hole #24
Test hole #24A
Test hole #25
Test hole #26
Test hole #26A
Test hole #27
Test hole #28
Test hole #28A
Test hole #28B
Test hole #30
Test hole #31
Test hole #32
Test hole #32A
Test hole #32B
Water
Limestone
Ground
N

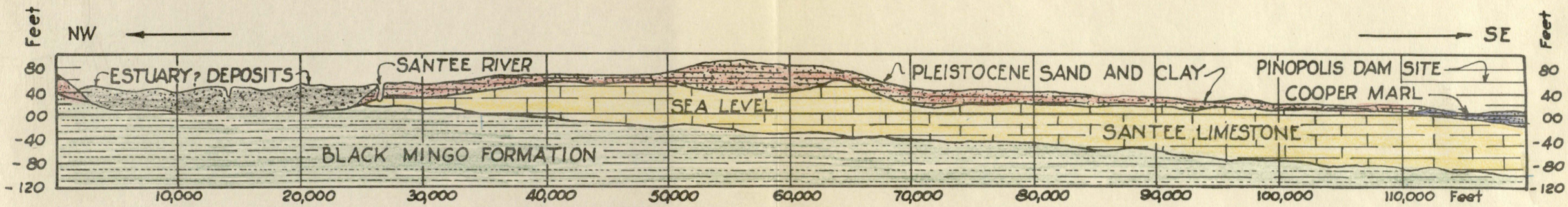


PROFILE AND GEOLOGIC SECTION ACROSS BIGGIN CREEK VALLEY AT PINOPOLIS DAM SITE

Stephen Taber
Geologist

Stephen Tabor Fig. 3

Santee dips 16' per mile



PROFILE AND GEOLOGICAL SECTION ACROSS THE SANTEE - COOPER AREA

Stephen Taber
Geologist