LOCK C

TENNESSEE - TOMBIGBEE WATERWAY
NEAR FULTON, MISSISSIPPI

FOUNDATION REPORT

U. S. Army Corps of Engineers
Mobile District

September 1992

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James H. Sanders

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The Lock C Foundation Report includes a written report document accompanied by a Folio of Drawings and Photographs describing the general geology and engineering characteristics of the site. Included in this report is a detailed summary of the foundation preparation procedures and construction operations for the Lock C structure which is located on the Tennessee-Tombigbee Waterway near Fulton, Mississippi.

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TENNESSEE-TOMBIGBEE WATERWAY

LOCK C

NEAR FULTON, MISSISSIPPI

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FOUNDATION REPORT

U.S. ARMY ENGINEER DISTRICT, MOBILE
CORPS OF ENGINEERS
MOBILE, ALABAMA

September 1988

CONTENTS

APPENDICES

SAMFC-AC

SUBJECT: Foundation Report, Lock C

District Engineer

Department of the Army

Mobile District, Corps of Engineers

Mobile, AL 36628

1. INTRODUCTION.

a. Location: Lock C is the seventh navigation structure on the Tennessee-Tombigbee Waterway above the confluence of the Tombigbee and Black Warrior Rivers. The Lock C site is about one mile southeast of Fulton, Mississippi, at navigation mile 389.0. The Lock C pool extends northward to Lock D at navigation mile 398.4. Since Lock C is a part of the canal section of the waterway, the pool is mainly confined between the right bank levee on the west, and high ground bordering the Tombigbee River floodplain on the east. The project location is shown on plates # 1, 2, and 3 of the accompanying folio of drawings and photographs.

b. Description of the Project: The principal structures of the Lock C project consist of a navigation lock located in a canal, a gated spillway adjacent to and to the right (west) of the lock, and earth dikes connecting the lock to the spillway, the lock to the levee on the left bank, and the spillway to the levee on the right bank.

The navigation lock has a chamber width of 110 feet and a length of

670 feet between the centerlines of the pintles. The lock provides a lift of 25 feet when the normal pool levels in Lock B and Lock C pools are at elevation 245 and 270, respectively. The top of the upper guide and guard walls are at elevation 277.0, the upper gate area lock walls are at elevation 280.0, the chamber area and lower gate area lock walls are at elevation 277.0, and the lower guide and guard walls are at elevation 252.0. The top of the upper and lower miter sills are at elevation 252.0 and 227.0, respectively, to provide a clear depth of 18 feet below the normal pool levels. The lock is filled and emptied by a series of intake ports located in the upper guide and guard walls, 12.5 foot square culverts in the lock walls, a system of filling and emptying side ports in the lock chamber walls, and a manifold discharge system that empties inside the lower approach to the lock. Flow in each of the two culverts is controlled by hydraulically operated reverse tainer valves.

The gated spillway consists of a broad crested concrete weir with the crest at elevation 258.0, and an apron at elevation 228.5. The overall length of the spillway, including the intermediate and end piers, is 220 feet. Flow over the crest is controlled by 4 tainer gates, each 45 feet long by 13 feet high, operated by individual electric hoists located on top of the 8-foot piers. A one-lane access bridge for service traffic is provided across the spillway for operation and maintenance. Concrete abutment walls are provided to form transitions from the gated spillway to the non-overflow dikes connecting the spillway to the lock on the left (east) and the levee on the right (west).

The left bank dike, with a top elevation of 280.0, connects the lock to the left bank levee, and is also used as an esplanade area. The left bank levee, also with a top elevation at 280.0, extends north and then northeast from the lock approximately 10,000 feet, and provides protection to the city of Fulton, Mississippi against flooding by Pool C. The pool side of the levee has 1 vertical on 10 horizontal slopes from natural ground to 3 feet above normal pool, and then 1 vertical on 5 horizontal slopes from 3 feet above normal pool to the 15 foot wide crest. The downstream, or landward, side of the levee has 1 vertical on 5 horizontal slopes from the crest to a 50 foot wide berm at elevation 266.0. From the elevation 266.0 berm down to natural ground the levee has slopes of 1 vertical on 3 horizontal. A combination impervious core and slurry trench is incorporated into the left bank dike to provide protection against seepage around the left side of the lock.

The right bank dike connects the lock to the spillway and the spillway to the right bank levee. The top width of this dike is a minimum 35 feet, and both upstream and downstream slopes are 1 vertical on 3 horizontal. The upstream slope and critical sections near the spillway are protected from erosion by riprap placed on bedding material over filter fabric. A combination impervious core and slurry trench protect against seepage both through and beneath the right bank dike.

The right bank levee is a continuation of the Canal Section levee which separates the canal from the Tombigbee River. The right bank levee construction limits for the Lock C project extend from approximately one mile downstream of the centerline of spillway to approximately one mile upstream of the centerline of spillway. The crest of the levee in the vicinity of Lock C is at elevation 280.0, and the crest width is 35 feet. The canal side slopes of the levee are 1 vertical on 5 horizontal from the crest to 3 feet above normal pool, and from 3 feet above normal pool to natural ground the slopes are 1 vertical on 10 horizontal. The riverside (west) levee slopes are 1 vertical on 5 horizontal.

c. Construction Authority: The Tennessee-Tombigbee Waterway Project, of which Lock C is a part, was authorized in the River and Harbor

Act approved by Congress on 24 July 1946 (Public Law 525, Seventy-Ninth Congress, 2nd Session) in accordance with recommendations contained in House Document 486, Seventy-Ninth Congress, 2nd Session.

d. Purpose of Report: This report is written in order to have on file a record of the conditions encountered and the procedures used in preparing the foundations for Lock C. It also contains a record of the character of the foundations on which concrete was placed.

e. Contractor and Contract Supervision: The contract for Lock C, No. DACW01-79-C-0018, dated 8 Nov 1978, was awarded to Blount International, Ltd., Mercury Division, of Montgomery, Alabama. Mr. Yerby Land served as project manager until being replaced by Mr. Tom Canfield in June 1979. Mr Canfield then served as project manager until completion of the project.

2. FOUNDATION EXPLORATION

a. Investigations Prior to Construction: The exploration drilling program at Lock C consisted of 92 borings. The Eutaw and Gordo Formations were cored in 37 holes with 6-inch x 7 3/4-inch double-tube, core barrels using diamond and carboloy-set bits. The maximum hole depth was 219 feet in hole C-403. Overall core recovery was approximately 88% for 2,780 lineal feet of drilling. Continuous splitspoon samples were taken in the overburden and sent to a field laboratory at Fulton, Mississippi for visual classification and moisture content determination. Atterberg limits and gradation test were run on representative samples. Jar samples of the six-inch cores were taken at five-foot intervals and their moisture contents were determined. Atterberg limits and gradation tests were also run on typical core samples. Shelby tube samples, Dennison tube samples, and core, preserved in wax and cheese cloth, were taken and sent to the

South Atlantic, Southwestern, and North Pacific Division Laboratories for extensive testing. An average of one out of every five feet of core was preserved by a coating of microcrystalline wax and cheese cloth. Color photographs were taken of all cores. Locations of all borings are shown on Plate 2-29 of Appendix II, Folio of Plates to Design Memorandum No. 17, Lock C - Lock, Spillway and Earthwork, dated January 1978. Further information may be obtained from Appendix III, Logs of Borings, and Appendix IV, Results of Laboratory Test Data, to the above mentioned Design Memorandum.

Two pump test were conducted at the Lock C site in order to determine the aquifer constants of the overburden and upper Gordo aquifers. No pump test was run on the lower Gordo aquifer because its physical characteristics were judged to be very similar to those of the lower Gordo aquifer at Lock B. The values obtained from the pump test on the lower aquifer at Lock B were, therefore, assumed to be valid for the lower Lock C aquifer. Thirteen piezometers were installed at the Lock C site in connection with the pumping test; five in the overburden, five in the upper Gordo aquifer, and three in the lower Gordo aquifer. The piezometer layouts and details of the pump wells are shown on Plates 2-16 and 2-17 of Appendix II, Folio of Plates to Design Memorandum No. 17, Lock C - Lock, Spillway and Earthwork, dated January 1978, while descriptions of the test and results obtained are contained on pages 2-7 and 2-8 of the referenced design memorandum.

b. Investigations During Construction: During the initial excavation of Gordo Formation material in the Lock C spillway area, a slickensided lignitic clay stratum was encountered, with a dip that indicated it would extend below design grade in the westernmost spillway monoliths. This clay stratum had been identified during the exploration and design stage of Lock C as a poor quality foundation material, mainly because of its low sliding shear strength. Since sliding resistance was critical to the spillway design, it was decided to drill additional core holes to further investigate this lignitic clay stratum and to determine its spatial relationship to the right side spillway monolith foundations.

Three core holes were drilled during construction, employing a Failing 314 drill rig and 6-inch x 7 and 3/4-inch double-tube core barrels, to better define the relation of the lignitic clays to the spillway foundation grade. The average depth of the holes was 9.9 feet and the core recovery was 100 percent. The cores were visually inspected and portions of the lignitic clay stratum, as well as portions of several other strata, were preserved in wax and cheese cloth and designated for direct shear test. Locations and logs of these borings are included in Appendix # 3 to this report.

The core holes, however, did not provide sufficient information to establish new foundation grades for the spillway monoliths due to the irregular dip of the lignitic strata. Therefore, a four-foot-wide inspection trench was excavated along the alignment of the spillway contact drains to a depth which encountered satisfactory foundation material. Elevations surveyed along the trench then were used to establish new foundation grades. The contact drains were installed prior to foundation preparation of the surrounding monolith foundations by excavating in the bottom of the inspection trench with a 1-1/2 foot wide Gradall bucket (see the photograph on plate # 37 of the accompanying folio of photographs and drawings).

3. GEOLOGY

a. Physiography: The Lock C project site is located in the Tombigbee and Tennessee River Hills physiographic province of the Gulf

Coastal Plain. Prominent topographic features of the area consist of the Tombigbee River flowing along the western edge of an approximately 1-1/2 mile wide flood plain, and adjacent low hills. Elevations range from a maximum of about 400 feet in the hills to about 250 feet in the flood plain. The concrete structures of the lock and spillway are located at the eastern margin of the flood plain in an area which, prior to start of construction, was both swampy and thickly wooded. The town of Fulton, Mississippi is about 1 mile northeast of the site and the Tombigbee River lies about 1 mile to the west.

b. General Stratigraphy and Structure: The Eutaw Formation, McShan Formation and Gordo Formation, all of Upper Cretaceous age, underlay the canal section of the Tennessee-Tombigbee Waterway. These deposits crop out, or are locally covered by relatively thin alluvial deposits, in a crescent-shaped belt about 30 miles wide, extending from northern Tennessee across Mississippi and Alabama into eastern Georgia. The regional strike varies from eastward in Central Alabama to northerly in northern Mississippi. The dip is about 20 to 30 feet per mile to the southwest and west. The regional structure is a simple monocline. No major faulting or conspicuous geologic anomalies have been mapped at the surface in the area of the Tennessee-Tombigbee Waterway.

The Eutaw Formation is the youngest of the Upper Cretaceous formations outcropping along the canal section of the Tennessee-Tombigbee Waterway. Stratigraphically, the Eutaw Formation has been separated into two subdivisions. The upper division has been named the Tombigbee Sand member, while the lower division is unnamed and is generally referred to as "the lower unnamed member", "typical Eutaw", or as "the main body of the Eutaw".

The Tombigbee Sand member is a massive bedded, glauconitic and micaceous, silty and clayey sand (SM to SC) with occasional layers of indurated sand and concretionary masses. Unweathered sand is usually gray to greenish gray, but upon weathering the iron constituents, chiefly glauconite and pyrite, oxidize to shades of yellow, brown, red, pink, and purple, eventually becoming deep red or brown. The Tombigbee Sand member differs from the lower unnamed member chiefly in having been deposited in slightly deeper, off-shore marine waters, thus producing a more massive type of bedding. The Tombigbee Sand is also more glauconitic and more calcareous.

The lower unnamed member of the Eutaw Formation consists of fine grained, glauconitic, micaceous sand (SP, SP-SM, and SM) with numerous thin clay laminae and several thicker silt (MH) and clay (CH) layers. The sands are dense, compact and characteristically cross-bedded. The clay strata are laminated, highly preconsolidated, and sometimes associated with lignite. The contact of the lower unnamed member of the Eutaw and the overlying Tombigbee Sand member is a gradational one and in the field it is difficult, or impossible, to draw a sharp line between them.

The McShan Formation disconformably underlies the Eutaw Formation along the canal section of the Tennessee-Tombigbee Waterway. The McShan Formation is of shallow-water marine origin, and it consists of thinly laminated to finely cross-bedded, varicolored, micaceous, fine sand and silts (SP, SP-SM, SM, and ML) and some thin laminae of gray clay (CL, CH). The sands and silts, for the most part, abound in muscovite mica. The sands also generally contain light colored glauconite grains, are finely cross-bedded or rippled, and have thin laminae of silt or clay along the bedding planes. Due to the similar physical character and engineering properties of the McShan deposits to those of the overlying Eutaw Formation, McShan materials have not been designated as such during previous investigations and construction for the Tennessee-Tombigbee

Waterway, but have been included with those of the lower unnamed member of the Eutaw Formation. The policy of including the materials of the McShan Formation with those of the overlying Eutaw Formation is continued in this report.

The Gordo Formation unconformably underlies deposits of the McShan Formation and represents the Tuscaloosa Group in outcrop along the canal section of the Tennessee-Tombigbee Waterway. The Gordo Formation can be divided into an upper member which reaches a maximum thickness of about 100 feet, and a lower member which reaches a maximum thickness of about 200 feet. The upper member is composed dominantly of indurated fat and lean clays (CL, CH) that are variably lignitic, and contain subordinate interbeds of silt (ML) and silty sand (SM). The color of the clay is dominantly gray, but varies from almost white to multi-colored red, yellow and gray. The lower member is composed dominantly of sand which generally becomes coarser with depth, grading near the bottom into a mixture of sand and chert gravel. Cobbles and boulders up to six inches in diameter are common in the basal part of the sand and gravel. The lower member of the Gordo is a major artesian aquifer which numerous wells in Mississippi tap for potable water.

The Coker Formation comprises the lower part of the Tuscaloosa Group, but it is overlapped in most of eastern Mississippi by strata of the Gordo Formation and is not encountered in the canal section of the waterway. Unconformably underlying the Coker Formation, or the Gordo Formation where overlapped, are sedimentary rocks of Paleozoic age.

c. Site Geology: The surfacial deposits at the Lock C project site consisted of an alluvial overburden with a uniform thickness of about 22 feet. As is typical of the Tombigbee River floodplain deposits, the Lock C overburden consisted of an upper impervious section overlying a lower pervious section (a fining upward sequence). The impervious section generally ranged from 10 to 12 feet thick and was comprised of fat clay (CH), lean clay (CL) and sandy clay (SC). The lower pervious section also generally ranged from 10 to 12 feet thick and was comprised of variably silty sand (SP, SP-SM, and SM), with only local and minor amounts of a basal gravel (GP) strata. Refer to the geologic sections on plates # 21, 22, and 23 of the accompanying folio of photographs and drawings for sections of the overburden deposits. Also see photographs # TENNO-110 and 111 on plate # 33 of the folio for photographs of typical overburden deposits at Lock C.

Underlying the overburden at the Lock C site were deposits of the Eutaw and Gordo Formations. Though the Eutaw Formation crops out in the hills bordering the Tombigbee River in the Lock C area, erosion by the river has removed all but isolated remnants of this formation at the project site. These isolated remnants generally consisted of a thin veneer of less than two feet maximum thickness, however, an exception to this general condition was a channel deposit which intersected the lock chamber area at nearly a right angle, and which measured approximately 250 feet wide by 20 feet deep. The Eutaw (McShan) materials with which this erosional feature was filled consisted of thin beds of silt, sand, and clay. Some of the clay beds were lignitic. Geologic sections showing this channel deposit are included on plates # 22 and 23 of the accompanying folio of photographs and drawings, while photograph # TENNO-228 on plate # 40 shows a close-up of some of the thin beds in this deposit.

Gordo Formation materials underlay the alluvial overburden deposits at the Lock C project, or, where present, the thin remnant Eutaw Formation deposits. The upper member of the Gordo Formation was a fairly uniform 85 feet thick at the site, while the lower member measured 107 feet thick in the only boring, C-430, which penetrated to the underlying Paleozoic rocks (refer to the geologic sections on plates # 21, 22, and 23 in the folio of drawings and photographs accompanying this report). At the project site the upper Gordo member consisted of two massive clay beds separated by a thick, silty sand bed. The uppermost of these clay beds averaged about 35 feet thick and was composed mostly of light gray to light tan, massive clay (CL, CH) containing several interbeds of lignitic clay (CH), sandy clay (SC) and clayey silt (ML). The lower clay bed of the upper Gordo member at the Lock C site was much like the upper clay bed, with the exception that much of the clay was red mottled, a feature commonly found in Gordo clays, and no lignitic clay interbeds were present. Since the upper clay bed of the upper Gordo member was the founding material for the Lock C structures, this bed is covered in more detail in section 3.f of this report.

The variably silty sand (SP, SP-SM, SM) bed which separated the massive clay beds of the upper Gordo member at the project site varied between 10 and 28 feet thick. This silty sand bed was micaceous, chalky, lignitic, and contained occasional thin interbeds and laminae of soft, fat clay (CH). Since this silty sand bed contained water under artesian pressure and occurred just beneath foundation grade, it is discussed further in sections 3.f and 4.b.1 of this report.

The lower member of the Gordo Formation at the Lock C project site consisted of an upper section approximately 90 feet thick which ranged from silty sand (SM) through poorly graded silty sand (SP-SM) and poorly graded silty gravel (GP-GM), to poorly graded gravel (GP). This portion of the lower member of the Gordo Formation is a major aquifer in northeastern Mississippi and is discussed further in sections 3.f and 4.b.1 of this report. In boring # C-430, a basal clay section of the lower member of the Gordo Formation was penetrated. This basal clay was about 20 feet thick and consisted of red and yellow mottled fat and lean clay (CH,CL), with occasional embedded gravel.

The structure of the Gordo Formation at the Lock C project site differed somewhat from that of the regional structure; a simple monocline dipping to the southwest or west at about 30 feet per mile. As the geologic sections on plates # 21, 22, and 23 of the accompanying folio of photographs and drawings show, a slight fold or flexure existed at the site in the upper massive clay member of the Gordo Formation. Using the lignitic clay beds as a reference, the axis of the slight fold was located just upstream of the upper pintle, and roughly paralleled the baseline of the spillway. The upstream limb of the fold dipped northerly at about 0.7 feet per 100 feet (37 feet per mile), the downstream limb dipped southerly at about 0.6 feet per 100 feet (30 feet per mile), and it plunged to the west at about 1 foot per 100 feet (53 feet per mile). As can be seen, the described feature is only a very minor flexure, however, it is possibly related to two other features which effected the lock and spillway foundations. The first of these two features consisted of a vertical joint which extended from just upstream of the lock right wall intake monolith foundation, to the spillway left abutment monolith foundations, and then diagonally across the gated spillway and stilling basin monolith foundation areas (refer to the foundation maps on plates # 26, 30 and 31, as well as photographs # TENNO 199, 200, and 310 on plate 46, TENNO 322 and 324 on plate 56, and TENNO 455 on plate 60 of the accompanying folio of photographs and drawings). This joint varied from about 1/2-inche to 1-inch wide and was filled with sand, which apparently had been piped up from the underlying upper Gordo aquifer. The second feature consisted of many irregular shaped columnar bodies of sand, generally about 1 foot in diameter, which were scattered throughout the otherwise massive clay foundations of the spillway monoliths (refer to the foundation maps on plates # 30 and 31 and also to photograph # TENNO 320 on plate 53, photographs # TENNO 345 and 346 on plate 55, to photograph # TENNO 325 on plate 56, and to photograph # TENNO 486 on plate 60 of the accompanying folio of photographs and drawings). These irregular columnar features also appear to have resulted from sand having been piped up from the Gordo aquifer underlying the clay foundation strata. It is possible that the vertical joint and the irregular sand columnar bodies resulted from artesian pressure in the upper Gordo aquifer rupturing the overlying clay after tensional stresses had been induced along the axis of the slight fold.

Though the vertical joint mapped at Lock C was by far the most extensive of any such feature encountered by the author on the Tennessee-Tombigbee Waterway, it is not believed to adversely effect the project, and it will not be discussed further in this report. The irregular shaped columnar sand bodies, however, were associated with some inferior foundation areas, and this will be discussed further in section 7.a of this report.

d. Bedrock Weathering: The massive Gordo clay (CH, CL) which was the founding strata for most of the concrete structures at the Lock C project was relatively unweathered, but exposed surfaces, unless protected, would suffer deterioration due to loss of moisture and accompanying shrinkage and "dry cracking". The lignitic clay beds which occurred within the massive clay strata were especially vulnerable to slaking, and this is one of the reasons that these beds were limited in their use as founding material. Besides deterioration due to exposure to air or moisture, all the Gordo materials were vulnerable to damage by equipment when wet.

The contract specifications for the Lock C project recognized the susceptibility of the Gordo materials to degradation from exposure to the elements and to equipment traffic, and established strict procedures to be followed in preparing the foundations for concrete structures, so as to minimize any deterioration of the foundations. As a result, weathered Gordo Formation materials were mainly limited to locations outside the monolith foundation areas where lignitic clays were exposed in excavation slopes. Most of this weathered material was removed during clean-up operations prior to placing backfill.

e. Leaching and/or Solution Activity: Neither the overburden, Eutaw Formation or Gordo Formation materials present at the Lock C site were of a type in which leaching and/or solution activity would be expected to occur. As expected, no signs of either activity was observed.

f. Ground Water: Three major sources of ground water existed at the Lock C project site, and each consisted of a confined artesian aquifer. The uppermost of these aquifers was composed of the lower, pervious portion of the alluvial floodplain deposits of the Tombigbee River. The piezometeric surface for this overburden aquifer at the Lock C site, as recorded during the six month interval (March through July 1979) which immediately preceded the start of construction dewatering and slurry trench installation, fluctuated only between elevation 253 and 254.5 - elevations which are essentially the same as those of the natural ground surface at the site. Since a slurry trench was selected to isolate the water of this aquifer from the excavation area, construction of the lock and spillway had no effect on the piezometeric surface of this aquifer outside of the immediate project area. Further information on this overburden aquifer is contained in Sections 3.b and 4.b.2 of this report.

The other two artesian aquifers present at the Lock C project site were located within the Gordo Formation. The uppermost of these aquifers occurred just below (10 to 20 feet) the lock and spillway foundation grades and is referred to in this and prior reports as the upper Gordo aquifer. The piezometeric surface for this upper Gordo aquifer at the Lock C site, as recorded during the six-month-interval (March through July 1979) which immediately preceded the start of construction dewatering, varied between elevation 262 and 266 - elevations which are 8 to 12 feet above natural ground at the site. Pumping of the dewatering wells during the construction period lowered the piezometeric surface of this aquifer in the construction area to about elevation 202 (a drawdown of about 62 feet). Drawdown curves plotted during operation of the dewatering system suggested that the upper Gordo aquifer is hydraulically connected to the lower Gordo aquifer somewhere east of the project site. These same drawdown curves also indicated that the upper aquifer has only a limited extent to the west of the project site.

The lowermost of the Gordo Formation aquifers at the Lock C project site, referred to in this and prior reports as the lower Gordo aquifer, was located approximately 67 feet below the lock and spillway foundation grades. The piezometeric surface for this lower Gordo aquifer at the Lock C site, as recorded during the six-month-interval (March through July 1979) which immediately preceded the start of construction dewatering, varied between elevation 270 and 273 - elevations which are 16 to 19 feet above natural ground at the site. Pumping from the dewatering wells during the construction period lowered the piezometeric surface for this aquifer in the construction area to about elevation 200 (a drawdown of about 73 feet).

The lower Gordo aquifer is a major source of potable water in northeast Mississippi. The radius of influence of the Lock C dewatering system on the lower Gordo aquifer was about 6 miles, a radius which included the entire area of the City of Fulton, Mississippi. Two of Fulton's municipal water wells, located approximately 5,200 and 9,200 feet from the Lock C project site, had their water levels lowered 24 feet and 17 feet, respectively, by the Lock C dewatering operation. This situation did not become critical, however, until the dewatering system at Lock D was put into operation. Though located further from the city, the Lock D dewatering system had a larger radius of influence on the lower Gordo aquifer (approximately 9 1/2 miles) and it lowered the water levels of the two Fulton water wells an additional 5 feet and 12 feet, respectively. Thus, the combined effect of Locks C and D dewatering systems on the two Fulton, Mississippi water wells was 29 feet at each well. This cumulative drawdown at the wells required the lowering of the intakes in these wells, and this lead to a further requirement for new pumps and motors capable of operating at the higher heads. The operation of the Lock D dewatering system also caused a drawdown of 7 1/2 feet at the lock C project site and, as a result, 2 of the Lock C dewatering wells were removed from operation so as to counteract this effect and also so as to reduce the effect of Lock C's dewatering system on the city of Fulton's water supply wells.

g. <u>Engineering Characteristics of the Foundation Materials</u>: An extensive laboratory testing program was carried out on both disturbed and undisturbed samples from the Lock C site so as to determine the engineering characteristics of the foundation materials. The tests conducted included water contents, Atterberg limits, and grain sizes for sample classifications, "Q" and "R" triaxial and "S" direct shear for evaluation of soil strength, and consolidation test for the determination of compressive characteristics. The results of all laboratory tests are contained on the Test Data Summary Sheets, Sheets 1 through 41 of Appendix IV to Design Memorandum # 17 - Lock C - Lock, Spillway and Earthwork.

Based on the results of the referenced testing program, design values were adopted for the construction of the Lock C project. The selected design values for the cohesive foundation materials (described in Section 3.c of this report) were $\phi = 22.0^0$ and C = 0.20 TSF, both parallel and across the bedding plane. These values were based on the ultimate shear strengths obtained from the results of consolidated, drained, direct shear test. The selected design values for the cohesionless foundation materials (described in Section 3.c of this report) were $\phi = 34.0^0$ and C = 0.0 TSF, both parallel and across the bedding plane, and were based on the maximum shear strengths obtained from the results of consolidated, drained, direct shear tests.

The bearing capacity for the lock was determined from Terzaghi's bearing capacity equation for continuous footings using weighted "ϕ" and "C" values derived from the shear strengths selected for design in the different types of foundation materials. The depth of potential shear was determined to be approximately 33 feet. The parallel and cross-bed values selected for design for each stratum through which the theoretical shear plane penetrated were multiplied by the ratio of the depth to the total shear zone depth so as to arrive at a final weighted value to use in the bearing capacity equation. The weighted "ϕ" and "C" values were 26.6^0 and 0.13 TSF, respectively. Using these procedures and values, the recommended bearing capacity for the lock of 5 TSF for both normal and temporary conditions was selected.

The bearing capacity for the spillway was also computed by Terzaghi's bearing capacity formula utilizing the same procedures as used for the lock. The depth of potential shear was determined to be approximately 58 feet, and the weighted value of "ϕ" and "C" were 27.6^0 and 0.11 TSF, respectively. Utilizing these values, a bearing capacity for the spillway of 5 TSF for both normal and temporary conditions was also selected.

4. <u>EXCAVATION PROCEDURES FOR COMPONENT PARTS</u>

a. <u>Excavation Grades</u>: All monoliths of the Lock C project were designed to be founded in the upper clay bed of the upper member of the Gordo Formation. Outlines of the structures are shown on the geological sections on plates # 21, 22, and 23 of the accompanying folio of drawings and photographs. As constructed, the design grade elevations were followed in all but three cases. In the first case, foundation grades for monoliths 9L, 10L, 11L, 12L, 14L, 19R, 20R, and 21R in the lock chamber area were lowered a maximum of four feet at the deepest point in order to remove silty and lignitic clay strata of a channel deposit which crossed the chamber area at approximately a right angle. In the second case, foundation grades for monoliths 1R through 8R in the upstream guide wall area were lowered 3 to 5 feet each in order to remove a lignitic clay strata and an associated underlying soft clay strata. In the last case, all the spillway foundation grades were lowered, from a minimum of 2 feet in monolith D9 to a maximum of 5.5 feet in monolith D1, also to remove a lignitic clay strata and an associated underlying soft clay strata.

b-1. Unwatering Provisions - Dewatering Wells: Two sources of water existing at the Lock C site which required control during the construction phase of the project were located within the Gordo formation. These sources consisted of a shallow artesian aquifer located about 10 feet below foundation grade, and a deeper artesian aquifer located about 65 feet below foundation grade (refer to the geologic sections on plates # 21, 22, and 23 of the accompanying folio of drawings and photographs).

The system designed to reduce the artesian pressure in these aquifers consisted of 20 deep wells arranged around the limits of the excavation for the lock and spillway structures, with an option for the installation of up to 8 supplementary wells. As built, only the 20 wells of the basic system were installed. Each of the 20 wells consisted of 10-inch inside diameter PVC screens and risers, set within a 20-inch-diameter hole. The entire upper aquifer thickness, and approximately 1/3 of the lower aquifer thickness, was screened by each well. The slot size of the screens was 0.05 inches, and the annular space between the screens and the edge of the 20-inch-diameter hole was filled with a tremied-in-place sand filter pack. The sand filter pack was placed so that it's top surface was within the massive clay strata overlying the upper aquifer, and a 2-foot-thick bentonite plug was then placed above the filter pack so as to isolate the screened portion of the wells from any water-bearing overburden material. The annular space above the bentonite plug was backfilled with ungraded sand. See plates # 4, 5, and 35 of the accompanying folio of drawings and photographs for the layout and details of the Lock C dewatering well system. Also, refer to appendix # 2 to this report for typical gradation curves of the sand filter pack used in the dewatering and relief wells.

Drilling for the Lock C dewatering wells was begun on July 17, 1979 by Southern Wellpoint Company, Inc., Blount International's dewatering subcontractor. The equipment employed for the drilling was a Failing Jed A, reverse circulation drill rig. Though it is generally recommended that the static water level be at a minimum depth of 10 feet when drilling with reverse circulation, when the drilling began at Lock C the piezometric level was 10 and 15 feet above ground level for the upper and lower Gordo aquifers, respectively. Revert was used to increase the weight of the drilling fluid during the installation of the first 5 wells, and no stability problems were encountered. Only the first few wells were drilled under the full artesian conditions, however, since pumping was begun as soon as possible after the installation of each well and, as a result, the artesian pressure in the Gordo aquifers was rapidly reduced. The reverse circulation method proved to be ideal for drilling the wells at the Lock C project. It easily removed the large gravel (up to 3-inch size) encountered in the lower Gordo aquifer, a task which can be a real problem when drilling large diameter holes by the mud rotary method.

Mechanical surging with a surge block was the development method chosen by the Contractor at Lock C. The typical effort expended on each well was 8 cycles of surging, with each cycle consisting of ten trips of the surge block. At the end of each cycle, the amount of fines which had been pulled into the well was measured by plunking, and then the fines were airlifted from the well. Development of each well was continued until a cycle of surging pulled no more than 0.2 feet of fines into the bottom of the well. This development strategy proved satisfactory for 16 of the 20 dewatering wells, however, the remaining 4 wells pumped excessive amounts of fines during acceptance testing and were, therefore, subjected to additional development. Upon retesting, these 4 wells also were found to be satisfactory.

Each of the Lock C dewatering wells was equipped with a submersible turbine pump which was manufactured by Jacuzzi Bros., Inc. and rated at 350 GPM at 114 feet total head. Powering each of these turbine pumps was a 15 horsepower motor manufactured by Century Electric Motor Company. Pumping of the dewatering wells began on 1 August 1979 from well #7, the first well of the system to be installed. Pumping from the remaining wells was started as they were installed, with all of the odd numbered wells being installed prior to the installation of any of the even numbered wells. By 11 October 1979, all of the odd numbered dewatering wells were pumping, with a combined discharge of about 1,100 GPM (110 GPM/well average). Pumping of the entire dewatering system was not attempted until 7 December 1979, and due to problems which will be discussed below, this attempt was only continued through 12 December 1979. During the attempt to pump the entire system of wells, the maximum pumping rate was 1,530 GPM (96 GPM/well average) with a total of 16 wells pumping. Due to excessive drawdown of the piezometeric surface beneath the lock and spillway structures, the pumping rate was then reduced to 1,220 GPM (68 GPM/well average), this time with 18 of the 20 wells pumping (the motor for well #7 had failed, and well #20 pumped so little water that it had been turned off).

As the wells of the Lock C dewatering system were brought into operation, it soon became apparent that the flow to the system would be much less than estimated during the design phase of the project (approximately 1,100 GPM instead of an estimated 4,600 GPM). This situation was not considered critical, and plans were made to offset the resulting reduced pumping rate simply by removing several of the dewatering wells from operation. Therefore, on 13 December 1979 the Contractor was directed to discontinue pumping from wells #3, 5, 8, 10, 13, 14, 16, and 20. At this stage other features of the Lock C dewatering system combined with the reduced flow to the system to cause many pump motor failures (13 motors failed by 15 February 1980). Submersible pump motors are designed to be cooled by the water which they help pump. The relative large size of the screens used in the Lock C dewatering wells (10-inch inside diameter) meant that in order to achieve the generally stated minimum required velocity of 0.5 feet/second of cooling water past the motor, approximately 90 GPM would have to be pumped by each well. The following are the factors which are believed to have resulted in insufficient cooling of the motors:

1) Though the system was pumping approximately the minimum amount required for cooling when only 12 wells were in operation, some wells pumped more than the minimum required while others pumped less than the minimum required.

2) Due to drawdown requirements, the pumps installed in the Lock C dewatering wells were specified to be placed 10 feet above the bottom of the wells. Since the motor is mounted below the pump intake, this requirement meant that only that portion of water entering the bottom ten feet of well screen in each well would flow past the motor. It is estimated that because of this effect, possibly as much as 50% of the water being pumped by each well was not available for cooling the motor.

3) During pumping of the Lock C dewatering system, iron oxide slime

rapidly encrusted the pump intakes and discharge piping. Though this problem was common to most, if not all, of the other projects on the Tenn-Tom Waterway, it was encountered to a severe degree at Lock C. It is possible that accumulations of this slime in the bottom of the dewatering wells contributed to the overheating and subsequent failure of the pump motors. A more confirmed, though indirect, effect on the system was caused by iron oxide slime which collected on the inside of the flowmeters installed in the discharge piping from each well (see the photographs on plate # 35 of the accompanying folio of photographs and drawings). This coating in many cases amounted almost to a plugging and it decreased the inside cross-sectional area of the flowmeters. Test conducted in 1981 determined that the iron slime fouling the flowmeters resulted in the discharge measurements being inflated by about 18 percent. The inflated discharge measurements effected the dewatering system during the early stage of operation when its existence was not suspected. During this early stage, the period when the pump motors were starting to fail, determinations of whether the amount of cooling water flowing past each pump motor was adequate or not was based on the inflated flowmeter readings, thus delaying the decision to replace the pumps and motors.

As a result of the above stated problems, the decision was made in early 1980 to replace the pumps and motors in the Lock C dewatering wells with smaller units (120 GPM at 125 feet total head Jacuzzi pumps and 5 horsepower Century motors). However, since all the conditions which adversely effected the original motors installed in the dewatering wells would also effect the smaller motors, the new units were required to be fitted with flow inducer sleeves. A flow inducer sleeve consists of a tube which is sealed above the pump intake and extends down over the motor below, thereby causing all of the water pumped by the well to first flow past the motor. During the period 5 May 1980 through 6 June 1980, the smaller units were installed in 13 of the 20 Lock C dewatering wells (pumping of the remaining 7 wells was permanently discontinued). The required flow inducer sleeves were constructed by the Contractor out of 8-inch diameter well-head-seals, installed over the discharge pipe above each pump, and 8-inch inside diameter PVC pipes which connected to the well-head-seals and extended down over the pump and motor combinations (see photographs of the smaller units with the flow inducer sleeves being installed on plate # 35 of the accompanying folio of drawings and photographs).

b-2. Unwatering Provisions - Slurry Trench: The overburden aquifer was also a main source of water at the Lock C project site requiring control during the construction phase. This aquifer was typically found below an impervious clay cap at a depth of 10 to 15 feet and it ranged from 10 to 13 feet in thickness. The method chosen to control this water-bearing zone consisted of a bentonite/soil backfilled slurry trench extending completely around the lock and spillway excavation area. Also included within the slurry trench was a portion of the downstream lock approach channel so that work in this area could also be done in the dry. The economics of installing a slurry trench instead of relying on a wellpoint system were justified since portions of the trench were designed to become functional parts of the completed project. These portions were connected to the lock and spillway structures by east and west slurry trench "tie-ins" and they act in combination with the "tie-ins" to lengthen the overburden seepage path between the upper and lower pools, thereby reducing the seepage gradient to a safe level (see plate # 34 in the accompanying folio of photographs and drawings for photographs of the slurry trench installation).

Construction of the slurry trench at Lock C was begun on 24 July

1979. Slurry Services International of Crossett, Arkansas was the sub-contractor in charge of the slurry trench installation. The trench was three-feet-wide and was keyed approximately one foot into the impervious Gordo Formation clays which underlay the overburden deposits. Average depth of the trench was 26.2 feet and the maximum depth was 29 feet. Only 22 working days were required for the excavation and backfilling of the trench. Since the trench was 6,024 feet in length, an average of 274 linear feet of trench was installed per working day.

The natural sodium bentonite required for manufacturing the slurry used in the Lock C slurry trench was delivered by rail to a spur located 9 miles south of Fulton, Mississippi, and from there to the project site by tanker truck. The bentonite was initially proportioned with water using a flash mixer discharging into a small, approximately four cubic yard tank. The resulting slurry was then circulated through a six-inch pump several times for additional mixing prior to being discharged into a hydration/storage pond. The slurry was maintained in a mixed condition within the storage pond by intermittent pumping through a 6-inch pump which was connected to a 4-inch-diameter flexible hose which was arranged so that it would move about inside the pond.

Excavation of the slurry trench was performed using a Koehring 1066 backhoe. The slurry level within the trench was always kept within one foot of the working surface of the trench by pumping from the storage/hydration pond through a 4-inch-diameter flexible hose. The bottom of the trench was keyed approximately one foot into impervious Gordo Formation clays, and was cleaned of any accumulated sediments by a small clam bucket operated by a Koehring 305 crane. Samples of the trench bottom were taken on 50 foot centers to assure that the correct key was being achieved. The samples were taken either by direct excavation with the backhoe bucket or by a thick-wall sampler which was attached to a tooth of the backhoe bucket.

The backfill for the trench consisted of the more pervious fraction of the trench excavation materials blended with approximately 10,000 cubic yards of pervious borrow obtained from sand and gravel quarries near Tremont, Mississippi. The pervious borrow was required in order to meet the specified backfill gradation limits of 10 to 25% passing the #200 sieve. The backfill material was mixed with slurry, clammed from the trench bottom during the cleaning process, by tracking and blading with a 1150B Case wide-tracked dozer. After mixing, the backfill was placed in the trench using the clam bucket until it daylighted above the slurry in the trench. The remaining backfill was then dozed into the trench at the top of the established backfill slope so that the backfill was displaced by slumping in the direction of the trench excavation.

c. Overburden Excavation: Overburden excavation for the Lock C contract was mainly accomplished during the period May 1979 through December 1979. Excavation was paid for under one bid item, "General Excavation", and since this method of payment was used, no separate overburden excavation quantities were kept. In the beginning, the equipment employed for the overburden excavation typically consisted of one 30-B Brucyris Erie dragline, one 61-B Brucyris Erie Dragline, three 627 Caterpillar scrapers, and five assorted Caterpillar dozers. Later, as clearing was completed and the site drainage was improved, the three 627 scrapers were replaced by four Caterpillar 637 scrapers; one or two Caterpillar 245 backhoes were used to load four D550/D350 dump trucks; the number of dozers were almost doubled to nine; and a Caterpillar 12-E motor grader was added to maintain the roads. Due to extreme wet conditions at Lock C, the 30-B dragline was used to clear much of the site while working on mats. Occasionally, when two 245 backhoes were on site, one loaded dump trucks while the second one top loaded scrapers.

d. Eutaw and Gordo Formation Excavation: Excavation of the Eutaw and Gordo Formation materials at the Lock C site was mainly accomplished during the period January 1980 through April 1980. Due to the absence of lithified strata in the Eutaw and Gordo materials, they were excavated essentially with the same equipment used to excavate the overlying overburden materials. Basically, the only difference was the draglines were not used in excavating the Eutaw and Gordo materials, nor were the four dump trucks.

e. Line Drilling or Pre-Splitting: Since no lithified strata were present in the Eutaw and Gordo Formation materials at the Lock C site, no line drilling or pre-splitting was required. Instead, the Contractor used angled cutting blades welded to the sides of dozer blades to trim the Gordo excavation to the required 1 on 1.5 side slopes.

f. Foundation Preparation: Due to the deterioration of the Gordo Formation foundation materials upon exposure to the atmosphere, and in accordance with the contract specifications, a strict excavation sequence was followed during foundation preparation for the concrete structures. This sequence consisted of excavating to a maximum depth of 24 inches above foundation grade until at least 30 days prior to scheduled concrete operations in each major segment, such as the chamber walls, guide walls, abutment walls, or spillway areas. Within the 30-day period preceding scheduled concrete placement, the Contractor was allowed to lower the excavation level to 12 inches above final grade. The remaining 12 inches of material was removed in conjunction with final foundation preparation for each individual monolith. A minimum 6-inch protective concrete slab was then placed on the final foundation grade.

Removal of the final 12 inches of cover during foundation preparation was performed on all foundations by using a track-mounted, Warner & Swasy

G-660 Gradall equipped with a 5-foot-wide ditch cleaning bucket. This bucket had a smooth cutting edge and worked relatively well in excavating the cohesive Gordo Formation materials.

As the excavation proceeded in each individual monolith area, any remaining loose materials was removed by blowing with compressed air augmented with minor hand shoveling. The foundation surfaces were immediately covered with quilted cotton curing mats as they were cleaned, and then the mats were lightly moistened with water so as to preserve the natural water content of the foundation material. Upon completion of an entire monolith area, the mats were temporarily removed to allow final foundation mapping, photographing, and approval. This entire excavation and clean-up process, and the placement of the minimum 6-inch protective concrete slab, was completed within 24 hours on all foundations except a few in which equipment failure caused delays. In these few exceptions the affected foundations were examined for reapproval, and any required corrective measures were taken prior to concrete placement.

g. Safety Precautions Against Slope Failures: There were no special precautions against slope failures taken at the Lock C project.

5. PILE DRIVING OR CONSTRUCTION OF OTHER SPECIAL FOUNDATIONS

No pile or other special foundations were incorporated as part of the permanent structures on this project.

6. FOUNDATION ANCHORS

A total of 142 post tensioned anchors were installed in the stilling basin for the Lock C gated spillway. The anchor locations and typical installation details are shown on plate 16 of the accompanying folio of drawings and photographs. The anchor locations are also shown on the stilling basin foundation maps, plates 30 and 31.

Each anchor installation consisted of a 1 1/4-inch diameter Dywidag threadbar tendon as manufactured by Dyckerhoff and Widmann, Inc., grouted within a vertical or angled hole. The vertical anchors were installed in the spillway training wall monoliths, and were each drilled to a depth of approximately 65 feet. The anchors installed in stilling basin proper monoliths were angled 30^0 upstream and were drilled to a depth of approximately 67 feet. The drilled holes for the anchors were 6-inch diameter, with the bottom 17 feet underreamed to a 12-inch diameter. A 23-foot length of polyethylene tubing was placed over an upper section of each bar so as to provide a free stressing length while also allowing for first stage grouting to within 3 feet of the base of the stilling basin concrete. The stressing procedure consisted of loading each anchor to a maximum of 150,000 pounds (jacking load) to obtain a 131,000 pound lift-off load. Load loss was then checked after a minimum of 24 hours and if the loss was within 5% the anchor was approved; however, if the loss was greater than 5% the initial lift-load was reapplied. Retesting for load loss was then performed after an additional 2-hour period had elapsed, and if the loss was then within 5% the anchor was approved; however, if the loss was again greater than 5% the Contracting Officer was to evaluate the test results and take corrective action.

The Contractor employed an Acker model MP Mark IV drill rig, and also a 35 ton crawler crane equipped with 75 linear feet of drill leads and a hydraulic top head drive, to drill the anchor holes. The crawler crane and drill leads were used to drill those anchors which the Acker drill rig could not gain access to because of the stilling basin baffels. A Servco drag type underreamer was used to ream the bottom 17 feet of each hole to a 12-inch diameter.

Prior to grouting, the depth of each anchor hole was checked with the grout hose. Grout was then pumped through the hose so as to fill each hole from the bottom. Excess grout was then removed from the top of each hole so that the grout columns would not be in contact with the concrete of the stilling basin monoliths, and the anchor bars were inserted into the grout filled holes. The grout plant used for the installation of the bars was a model CG-500, manufactured by Chem Grout, Inc. This plant consisted of two mixers of 4 1/2 cubic feet capacity each, and a positive displacement Moyno pump. The grout mix used consisted of 5 gallons of water and 1/2 pound of Interplant-N expansion aid per bag of cement.

A lightweight, electric-powered hydraulic jack was used in stressing the tendons. This jack was placed over a pull rod threaded over a portion of the tendon extending above the anchor nut. The jack contained a socket wrench and ratchet device which allowed the nut to be tightened as the load was applied and the tendon elongated. The magnitude of the prestress force applied was monitored by reading a pressure gage inserted in the hydraulic line. The gage pressure was converted to load by multiplying by the precalibrated ram head area of the jack. The precalibrated area was determined for the gage and jack combination, by the supplier, by using a load cell prior to shipping the equipment to the Lock C project.

Drilling for the installation of the stilling basin anchors at Lock C was begun on 20 Oct 81 and completed on 3 Mar 82. Stressing, testing, and acceptance of all the anchors was completed by 9 April 83, except for the two upstream left anchors in monolith S-15 which had failed. These two anchors were redrilled in early May 82, each about five feet left of its original location. Except for the offset in location, the westernmost of these two anchors was installed as designed. When drilling for the other replacement anchor, however, the riser of relief well RW-24 was encountered when a depth of 20 feet was reached by the angled hole. It was then decided to drill and install the second replacement anchor vertically. The abandoned angle hole which had encountered the relief well riser was filled with bentonite pellets and grouted. The two replacement anchors were tested and approved in June 1982.

7. CHARACTER OF FOUNDATIONS

a. Foundation Surfaces: The concrete structures of the Lock C Project were founded on strata of the upper member of the Gordo Formation. The lock walls and miter sills, and the spillway gated monoliths were all founded on a massive-bedded, fat to lean clay (CH to CL). The prepared foundation surfaces on this clay were generally very smooth, with only occasional minor, short tears in the clay caused by the action of the excavation equipment. These minor tears were generally removed with shovels as part of the foundation preparation. A more important exception to the general case was an area of disturbed soft clay encountered in the downstream, chamber side corner of lock monolith 12R. This soft clay surrounded the location of a water well used during the design phase of the project, and it's disturbed condition apparently resulted from collapse associated with removal of underlying sand during the pumping test for the design of the dewatering system. A second exception to the typical foundation condition of the major structures was the vertical sand features encountered in some of the spillway foundations. These sand features usually did not require special treatment; however, a more extensive zone of softer sand encountered in the downstream left corner of monolith D-6 was covered with filter fabric and filter material, and tied into the contact drainage system.

Many of the lock struts and stilling basin monoliths were also founded on the same fat to lean clay as described above, but there were also many of the these foundations which were founded on a lignitic fat

(CH) clay. The author had been transferred from the Lock C project prior to any foundation preparation on lignitic materials; however, this material is known to slake fairly rapidly when exposed.

b. Condition of the Foundations: The concrete monolith foundations at the Lock C project were generally in very good condition. The only exception to the very good condition were the cases cited in the preceding paragraph.

c. Water at Foundation Grade: There was no ground water encountered at foundation grade during foundation preparation for the Lock C project.

8. FOUNDATION TREATMENT.

a. Grouting Prior to Concrete Placement: The contract specifications contained no provisions for grouting prior to concrete placement. None were needed and none were performed.

b. Curtain Grouting: The contract specifications contained no provisions for curtain grouting. Instead, slurry trenches were installed for seepage control.

c. Control of Artesian Uplift Pressure: As previously discussed, there are two aquifers underlying the concrete structures at the in the Lock C site. These aquifers require relief of uplift pressure during the life of the project. Relief wells were incorporated into the project to reduce these pressures (see plates # 17, 18, 19, and 20 of the accompanying folio of photographs and drawings). Twenty-two relief wells are located within the lock area of the project, and six relief wells are located within the spillway area of the project.

The lock relief wells screen both the upper and lower Gordo aquifers, where as the spillway relief wells only screen the upper aquifer. The relief well screens are 6" ID PVC, and are set within 16" diameter holes. The annular space between the screens and the edge of the holes was filled with a tremied-in-place sand filter material. A settlement joint was installed in each relief well just below foundation grade. An 18-inch thick bentonite plug was installed in the annular space of the wells adjacent to the settlement joints.

Southern Wellpoint Company, Inc., was the subcontractor who installed the relief wells. A Failing reverse circulation Jed A drill rig, the same rig employed to install the dewatering wells, was used to install the relief wells. Water was used as the drill fluid and a mechanical surge block was used to develop the wells. As it did with the dewatering wells, the reverse circulation drill rig worked extremely well in installing the relief wells.

d. Uplift Pressure Cell System: Thirty-five uplift pressure cells and twelve pore pressure cells were installed in the lock and spillway structures for the purpose of checking design assumptions.

The uplift cells were of standard construction: 1 1/2-inch-diameter, slotted PVC well screen, with a 20-inch length of screen installed in a gravel-packed 6-inch-diameter hole drilled 4 feet into the foundation material, and a 9-inch length of screen installed in a 6"x 16"x 24" gravel-packed box placed at the concrete/foundation interface. A 1 1/2 inch-diameter steel pipe connected the screened portion of each uplift pressure cell to its reading station atop the concrete structure.

The pore pressure cells were of a construction similar to that of the uplift pressure cells except that there was only one slotted PVC well screen section, and it was 12 inches in length and installed within a 24"x 24"x 12" gravel-packed box located at the concrete/backfill interface. The pore pressure cells were connected to their reading stations in the same manner as were the uplift pressure cells.

e. Other Instrumentation: Thirty-five temporary and thirty-eight permanent piezometers were installed prior to and during the construction of the Lock C project. These piezometers were either 1 1/2-inch or 2-inches in diameter and were of the open wellpoint type. The tips were located either in the overburden, the upper Gordo aquifer, or the lower Gordo aquifer. Monitoring of the piezometers began prior to construction the dewatering wells.

Twelve heave points were installed prior to the start of excavation at the Lock C project. These points monitored heave of the founding material during excavation for the concrete structures. Shortly after the placement of concrete commenced, the monitoring of the foundation reaction to construction activities was switched to settlement points located in the concrete. Records of the monitoring of the heave and settlement points are on file in the Mobile District Office.

Bronze alignment insert were set on each side of the construction joints atop the lock and spillway monoliths for the determination of displacement and differential movement.

9. POSSIBLE FUTURE PROBLEMS.

There are no anticipated future problems at the Lock C project.

10. RECORD OF FOUNDATION APPROVAL.

The dates on which the excavation of the final foot of overlying Gordo Formation material was initiated for each monolith foundation area are listed below. Also listed are the dates on which the foundations were approved, and the dates on which the foundation slabs were placed. For many of the foundations placed after the transfer of the project geologist, however, only the dates for concrete placement were recorded, or no dates were recorded.

RECORD OF FOUNDATION PLACEMENTS

LOCK

Monolith Foundation	Date Excavation Started	Date Foundation Approved	Date Concrete Placed
1 L	30 Jun 1980	30 Jun 1980	30 Jun 1980
2 L	27 Jun 1980	27 Jun 1980	27 Jun 1980
3 L	27 Jun 1980	27 Jun 1980	27 Jun 1980
4 L	26 Jun 1980	26 Jun 1980	26 Jun 1980
5 L	26 Jun 1980	26 Jun 1980	26 Jun 1980
6 L	25 Jun 1980	25 Jun 1980	25 Jun 1980
7 L	25 Jun 1980	25 Jun 1980	25 Jun 1980
8 L	25 Jun 1980	25 Jun 1980	25 Jun 1980
9 L	24 Jun 1980	24 Jun 1980	24 Jun 1980
10 L	20 Jun 1980	20 Jun 1980	20 Jun 1980
11 L	18 Jun 1980	18 Jun 1980	18 Jun 1980
12 L	17 Jun 1980	17 Jun 1980	17 Jun 1980
13 L	16 Jun 1980	16 Jun 1980	16 Jun 1980
14 L	16 Jun 1980	16 Jun 1980	16 Jun 1980

Monolith Foundation	Date Excavation Started	Date Foundation Approved	Date Concrete Placed
15 L	16 Jun 1980	16 Jun 1980	16 Jun 1980
16 L	13 Jun 1980	13 Jun 1980	13 Jun 1980
17 L	13 Jun 1980	13 Jun 1980	13 Jun 1980
18 L	13 Jun 1980	13 Jun 1980	13 Jun 1980
19 L	12 Jun 1980	12 Jun 1980	12 Jun 1980
20 L	12 Jun 1980	12 Jun 1980	12 Jun 1980
21 L	11 Jun 1980	11 Jun 1980	11 Jun 1980
22 L	11 Jun 1980	11 Jun 1980	11 Jun 1980
23 L-U	1 Jul 1980	1 Jul 1980	1 Jul 1980
23 L-D	1 Jul 1980	1 Jul 1980	1 Jul 1980
24 L-U	1 Jul 1980	1 Jul 1980	1 Jul 1980
24 L-D	1 Jul 1980	1 Jul 1980	1 Jul 1980
25 L-U	1 Jul 1980	1 Jul 1980	1 Jul 1980
25 L-D	2 Jul 1980	2 Jul 1980	2 Jul 1980
26 L-U	25 Jul 1980	25 Jul 1980	25 Jul 1980
26 L-D	25 Jul 1980	25 Jul 1980	25 Jul 1980
27 L	2 Jul 1980	2 Jul 1980	2 Jul 1980
1 R	24 Jul 1980	24 Jul 1980	24 Jul 1980
2 R-U	28 Jul 1980	28 Jul 1980	28 Jul 1980
2 R-D	28 Jul 1980	28 Jul 1980	28 Jul 1980
3 R-U	29 Jul 1980	29 Jul 1980	30 Jul 1980
3 R-D	29 Jul 1980	29 Jul 1980	30 Jul 1980
4 R-U	29 Jul 1980	29 Jul 1980	30 Jul 1980
4 R-D	30 Jul 1980	30 Jul 1980	30 Jul 1980
5 R-U	1 Aug 1980	1 Aug 1980	1 Aug 1980
5 R-D	1 Aug 1980	1 Aug 1980	1 Aug 1980
6 R-U	1 Aug 1980	1 Aug 1980	1 Aug 1980
6 R-D	4 Aug 1980	4 Aug 1980	4 Aug 1980
7 R-U	4 Aug 1980	4 Aug 1980	4 Aug 1980
7 R-D	4 Aug 1980	4 Aug 1980	4 Aug 1980
8 R-U	5 Aug 1980	5 Aug 1980	5 Aug 1980
8 R-D	5 Aug 1980	5 Aug 1980	5 Aug 1980
9 R	10 Jun 1980	10 Jun 1980	10 Jun 1980
10 R	10 Jun 1980	10 Jun 1980	10 Jun 1980
11 R	9 Jun 1980	9 Jun 1980	9 Jun 1980

Monolith Foundation	Date Excavation Started	Date Foundation Approved	Date Concrete Placed
12 R	9 Jun 1980	9 Jun 1980	9 Jun 1980
13 R	6 Jun 1980	6 Jun 1980	6 Jun 1980
14 R	6 Jun 1980	6 Jun 1980	6 Jun 1980
15 R	4 Jun 1980	4 Jun 1980	4 Jun 1980
16 R	4 Jun 1980	4 Jun 1980	4 Jun 1980
17 R	4 Jun 1980	4 Jun 1980	4 Jun 1980
18 R	3 Jun 1980	3 Jun 1980	4 Jun 1980
19 R	3 Jun 1980	3 Jun 1980	3 Jun 1980
20 R	2 Jun 1980	2 Jun 1980	2 Jun 1980
21 R	29 May 1980	30 May 1980	30 May 1980
22 R	29 May 1980	29 May 1980	29 May 1980
23 R	29 May 1980	29 May 1980	29 May 1980
24 R	28 May 1980	28 May 1980	28 May 1980
25 R	28 May 1980	28 May 1980	28 May 1980
26 R	27 May 1980	27 May 1980	27 May 1980
27 R	26 May 1980	26 May 1980	26 May 1980
28 R	21 May 1980	23 May 1980	23 May 1980
29 R	21 May 1980	21 May 1980	21 May 1980
30 R	15 May 1980	15 May 1980	15 May 1980
31 R	19 Jun 1980	20 Jun 1980	20 Jun 1980
U/S Miter Sill-R	5 Jun 1980	5 Jun 1980	5 Jun 1980
U/S Miter Sill-L	27 Aug 1980	27 Aug 1980	27 Aug 1980
D/S Miter Sill-R	not recorded	not recorded	20 Oct 1981
D/S Miter Sill-L	not recorded	not recorded	20 Oct 1981
Stop Log Sill-R	not recorded	not recorded	5 Nov 1981
Stop Log Sill-L	not recorded	not recorded	8 Oct 1981
Strut # 1	not recorded	not recorded	29 Jul 1981
Strut # 2	not recorded	not recorded	29 Jul 1981
Strut # 3	not recorded	not recorded	28 Jul 1981
Strut # 4	not recorded	not recorded	28 Jul 1981

Monolith Foundation	Date Excavation Started	Date Foundation Approved	Date Concrete Placed
Strut # 5	not recorded	not recorded	14 Aug 1981
Strut # 6	not recorded	not recorded	17 Aug 1981
Strut # 7	not recorded	not recorded	19 Aug 1981
Strut # 8	not recorded	not recorded	19 Aug 1981
Strut # 9	not recorded	not recorded	20 Aug 1981
Strut # 10	not recorded	not recorded	24 Aug 1981
Strut # 11	not recorded	not recorded	18 Sep 1981
Strut # 12	not recorded	not recorded	21 Sep 1981
Strut # 13	not recorded	not recorded	23 Sep 1981
Strut # 14	not recorded	not recorded	24 Sep 1981
Strut # 15	not recorded	not recorded	24 Sep 1981
Strut # 16	not recorded	not recorded	29 Sep 1981
Strut # 17	not recorded	not recorded	29 Sep 1981
Strut # 18	not recorded	not recorded	30 Sep 1981
Strut # 19	not recorded	not recorded	30 Sep 1981
Strut # 20	not recorded	not recorded	1 Oct 1981
Strut # 21	not recorded	not recorded	6 Oct 1981
Strut # 22	not recorded	not recorded	6 Oct 1981
Strut # 23	not recorded	not recorded	7 Oct 1981
Strut # 24	not recorded	not recorded	7 Oct 1981
Strut # 25	not recorded	not recorded	12 Oct 1981
Strut # 26	not recorded	not recorded	12 Oct 1981
Strut # 27	not recorded	not recorded	12 Oct 1981
Strut # 28	not recorded	not recorded	13 Oct 1981
Strut # 29	not recorded	not recorded	13 Oct 1981
Strut # 30	not recorded	not recorded	14 Oct 1981
Strut # 31	not recorded	not recorded	2 Nov 1981
Strut # 32	not recorded	not recorded	2 Nov 1981

Monolith Foundation	Date Excavation Started	Date Foundation Approved	Date Concrete Placed
		SPILLWAY	
D-1	12 Aug 1980	12 Aug 1980	12 Aug 1980
D-2	26 Aug 1980	26 Aug 1980	26 Aug 1980
D-3	2 Sep 1980	2 Sep 1980	2 Sep 1980
D-4	5 Sep 1980	5 Sep 1980	5 Sep 1980
D-5	9 Sep 1980	9 Sep 1980	9 Sep 1980
D-6	3 Sep 1980	3 Sep 1980	3 Sep 1980
D-7	28 Aug 1980	29 Aug 1980	29 Aug 1980
D-8	25 Aug 1980	25 Aug 1980	25 Aug 1980
D-9	13 Aug 1980	13 Aug 1980	13 Aug 1980
W-1	not recorded	not recorded	2 Jul 1981
W-2	not recorded	not recorded	6 Jul 1981
W-3	not recorded	not recorded	10 Jul 1981
W-4	not recorded	not recorded	6 Jul 1981
W-5	not recorded	not recorded	24 Jul 1981
W-6	not recorded	not recorded	24 Jul 1981
W-7	not recorded	not recorded	24 Jul 1981
W-8	not recorded	not recorded	23 Jul 1981
S-1	not recorded	not recorded	16 Jul 1981
S-2	not recorded	not recorded	16 Jul 1981
S-3	not recorded	not recorded	17 Jul 1981
S-4	not recorded	not recorded	22 Jul 1981
S-5	not recorded	not recorded	23 Jul 1981
S-6	not recorded	not recorded	23 Jul 1981
S-7	not recorded	not recorded	24 Jul 1981
S-8	not recorded	not recorded	16 Jul 1981
S-9	not recorded	not recorded	16 Jul 1981
S-10	not recorded	not recorded	17 Jul 1981
S-11	not recorded	not recorded	22 Jul 1981

Monolith Foundation	Date Excavation Started	Date Foundation Approved	Date Concrete Placed
S-12	not recorded	not recorded	23 Jul 1981
S-13	not recorded	not recorded	23 Jul 1981
S-14	not recorded	not recorded	24 Jul 1981
S-15	not recorded	not recorded	21 Jul 1981
S-16	not recorded	not recorded	21 Jul 1981
S-17	not recorded	not recorded	21 Jul 1981
S-18	not recorded	not recorded	22 Jul 1981
S-19	not recorded	not recorded	22 Jul 1981
S-20	not recorded	not recorded	22 Jul 1981
S-21	not recorded	not recorded	23 Jul 1981

SUBMITTED BY: James H. Sanders

JAMES H. SANDERS, JR
PROJECT GEOLOGIST

APPENDIX # 1

SOURCES OF GEOTECHNICAL CONSTRUCTION MATERIALS

1) Riprap and coarse concrete aggregate

   Mississippi Stone Company
   Iuka Quarry

2) Fine concrete aggregate

   Miss-Ala Sand Company
   Near Tremont, MS

3) Filter material for dewatering wells and relief wells

   Northern Gravel Company & Arkola Sand and Gravel
   Muscatine, Iowa Fort Smith, Arkansas

4) No. 1 bedding material (under all riprap except #1 riprap)

   Mississippi Stone Company
   Iuka Quarry

5) No. 2 bedding material (under #1 riprap)

   Obtained from downstream channel excavation

6) Compacted #1 filter material (used in the spillway contact drains and the top 6" inches of fill under the lock floor)

   Bonds Pit
   Tremont, MS

7) Filter fabric

   Advance Construction Specialties Co.
   Memphis, TN

8) Cement

   United Cement Company
   PO Box 4525
   Jackson, MS

9) Flyash

   Monier Resources & Walter N. Handy Co
   Wilsonville, AL Springfield, MO

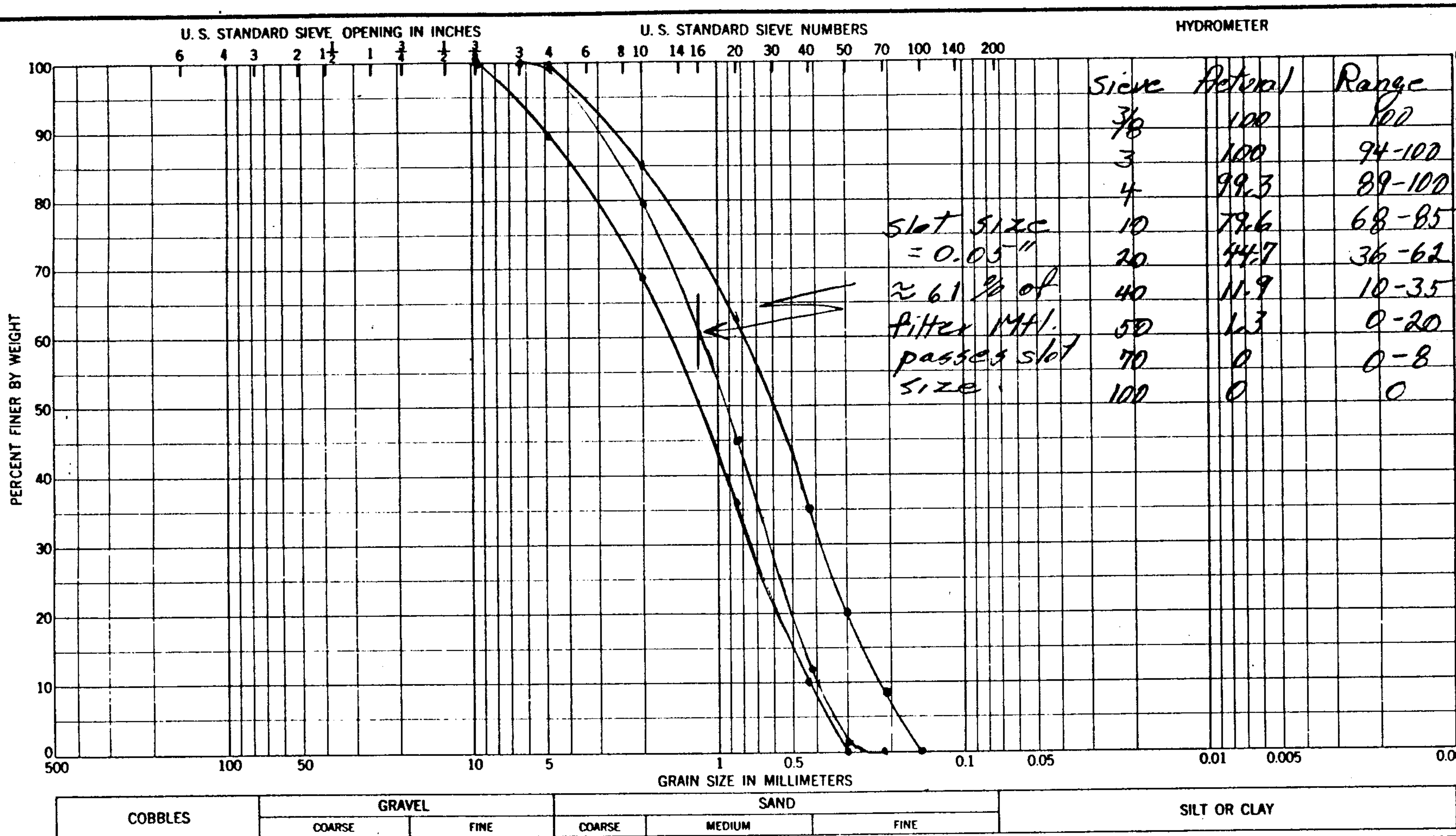
10) Concrete air entraining agent

   W. R. Grace

APPENDIX # 2

TYPICAL GRADATION CURVES FOR DEWATERING AND

RELIEF WELL FILTER MATERIAL

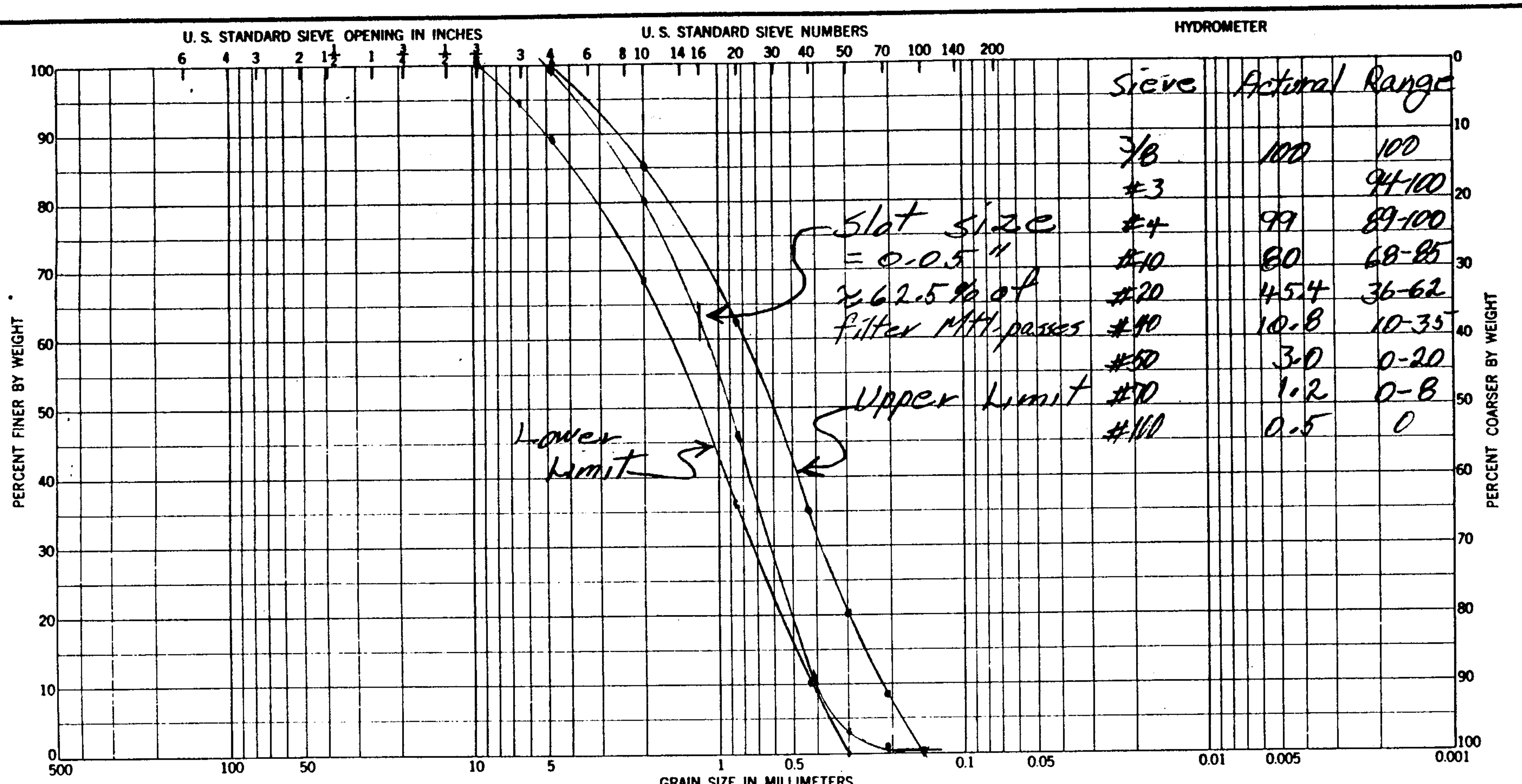


Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project Lock C
Dewatering Well # 9
Area Filter Mtl. Gradation
Boring No.
Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sieve	Actual	Range
3/8	100	100
#3		94-100
#4	99	89-100
#10	80	68-85
#20	45.4	36-62
#40	10.8	10-35
#50	3.0	0-20
#70	1.2	0-8
#100	0.5	0

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project: Lock C
Relief Well Filter MH

Area: 12/3/79

Boring No.

Date

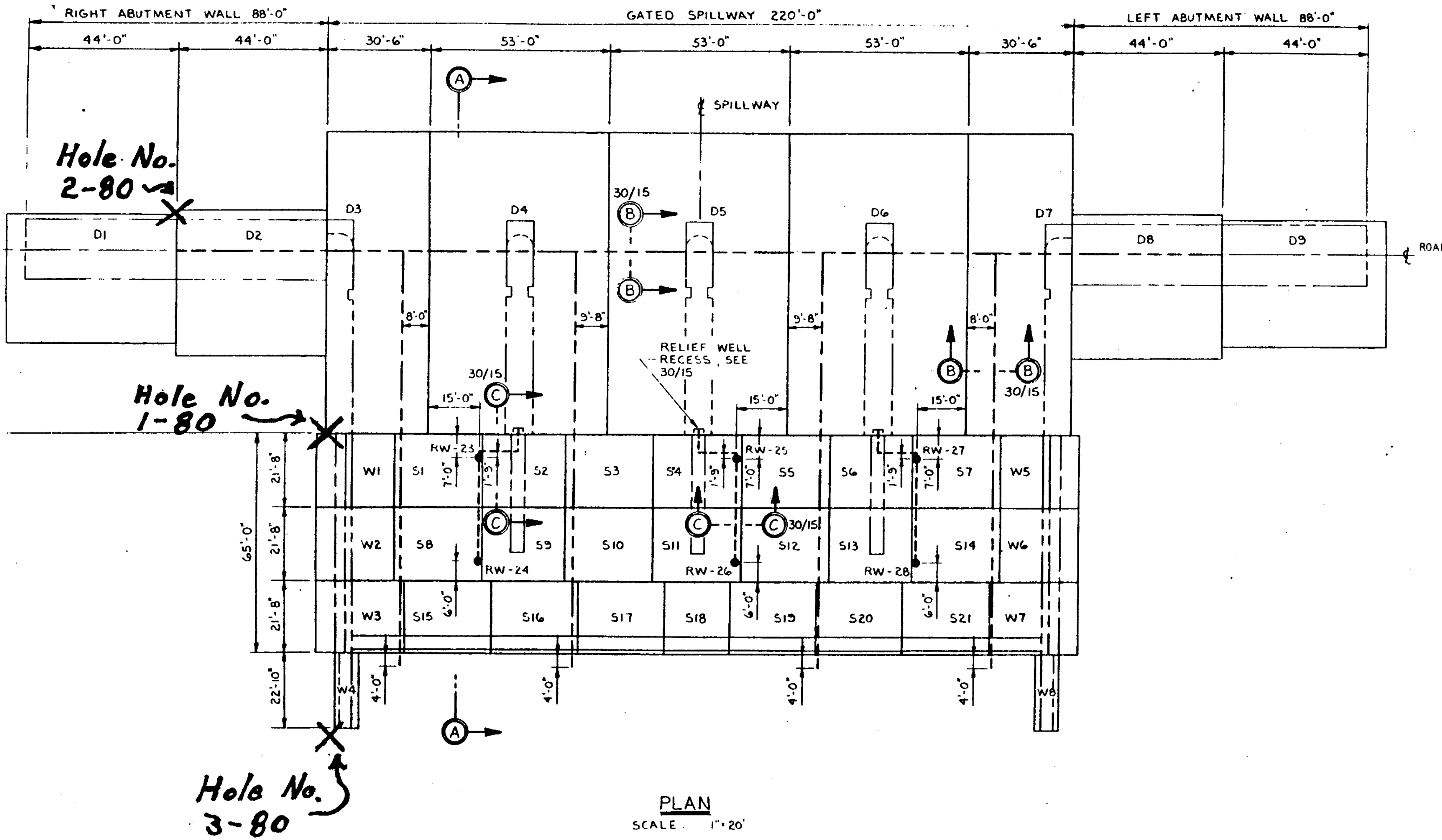
GRADATION CURVES

ENG FORM 1 MAY 63 2087

APPENDIX # 3

LOGS OF CORE BORINGS

DRILLED DURING CONSTRUCTION



PLAN
SCALE 1"=20'

James Sanders (corrected Copy) 1-8

BORING LOG	DIVISION South Atlantic	INSTALLATION Mobile District	SHEET 1 OF 1 SHEETS

1. PROJECT: Lock C Spillway Excavation	10. SIZE AND TYPE OF BIT: 6" x 7 3/4" Carboloy
2. LOCATION (Coordinates or Station):	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: Mobile District	12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 314
4. HOLE NO. (As shown on drawing title and file number): 1 - 80	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
5. NAME OF DRILLER: L. Lucas	14. TOTAL NUMBER CORE BOXES: 4
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER: Not observed
	16. DATE HOLE: STARTED 5-22-80; COMPLETED 5-23-80
	17. ELEVATION TOP OF HOLE: 225.8
7. THICKNESS OF OVERBURDEN: 0.0	18. TOTAL CORE RECOVERY FOR BORING: 100 %
8. DEPTH DRILLED INTO ROCK: 11.1	19. SIGNATURE OF INSPECTOR: J. C. Shaw
9. TOTAL DEPTH OF HOLE: 11.1	

W/C %	ELEVATION	DEPTH	SYM.	CLASSIFICATION OF MATERIALS (DESCRIPTION)	FIELD HARD-NESS	% CORE REC.	BOX OR SMPL NO.	REMARKS
	225.0	0.8	CH	Fat Clay Gray O3→ Tan	B-C			El. 225.0 - 222.6 Few zones grade to clayey silt, ML
			CL	Silty Lean Clay, sl. sandy w/ num. lig. incls. Brownish Gray O3→ Tan	C	100	1	
	222.6	3.2	CH	Lignitic Fat Clay, stiff w/ num. lignite incls. Dk. Gray to Black	C	100	2	El. 223.0, 222.8: Fat clay seams, .02'-.03' thick. "C" but sl. softer than the silty lean clay.
	220.2	5.6	CH	Fat Clay, stiff, becomes silty near base. Gray to Brownish Gray	C *	100		
	217.8	8.0	CL	Silty Lean Clay, stiff, massive w/ num. minute grains of siderite.	C	100	3	El. 222.6: Chalky Silt seam, .05'-.025', white, "C".
							4	
	214.7	11.1						Bottom of Hole

*d. 5.6 - 6.6' slightly softer, hardness "B-C". Suitable Fdtn. @ 6.6' El 219.2

WRAPS (depth)

1. 3.4 - 4.3
2. 4.3 - 5.2
3. 6.6 - 7.5
4. 10.1 - 11.1
5. 5.2 - 6.6

Tests - Direct Shear

(1) (little darker)

(5) (softest material)

(3) (Lower part - suitable fdtn.)

Remarks (continued):

El. 220.3: Jt, slk., 45°

El. 220.0 - 219.7: 3 Jts., approx. parallel, slk. dip 45°-55°. These jts dip in opposite direction from upper jt @ El. 220.3.

Hole grouted w/ 2 bags of cement.

2-80

BORING LOG	DIVISION South Atlantic	INSTALLATION Mobile District	SHEET 1 OF 1 SHEETS

1. PROJECT: Lock C Spillway Excavation
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: Mobile District
4. HOLE NO. (As shown on drawing title and file number): 2 - 80
5. NAME OF DRILLER: L. Lucas
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 0.0
8. DEPTH DRILLED INTO ROCK: 10.6
9. TOTAL DEPTH OF HOLE: 10.6
10. SIZE AND TYPE OF BIT: 6" x 7 3/4" Carboloy
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 314
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
14. TOTAL NUMBER CORE BOXES: 3
15. ELEVATION GROUND WATER: Not Observed
16. DATE HOLE: STARTED 5-23-80; COMPLETED 5-27-80
17. ELEVATION TOP OF HOLE: 225.8
18. TOTAL CORE RECOVERY FOR BORING: 100 %
19. SIGNATURE OF INSPECTOR: J. C. Shaw

W/C %	ELEVATION	DEPTH	SYM.	CLASSIFICATION OF MATERIALS (DESCRIPTION)	FIELD HARD-NESS	% CORE REC.	BOX OR SAMPLE NO.	REMARKS
	224.8	1.0	CH	Lignitic Fat Clay, slk'd., brittle w/ lig. incls. Black	C	100	1	
	221.7	4.1	CL	Silty Lean Clay, sl. sandy w/ num. lig. incls. Few zones grade to (ML) Brownish Gray $\xrightarrow{O_2}$ Tan	C-D / C			
	220.3	5.5	CH	Lignitic Fat Clay, stiff w/ num. lig. incls. Dk. Gray to Black	C	100		
	215.2	10.6	CH	Fat Clay, stiff, massive w/ occ. zones of minute siderite grains. Also, occ. specks of lignite. Lt. Gray $\xrightarrow{O_2}$ Tan	C	100	2, 3	El. 219.7 - 218.3: More slk'd jts. may appear as core dries. El. 217.5: Sealed jt., probably slk'd. Bottom of Hole

Note: Nothing softer underneath lignitic material. Suitable Fdtn. = El. 220.3

WRAPS (depth)

1. 0.0 - 0.8
2. 2.5 - 3.5
3. 4.3 - 5.6
4. 7.5 - 8.4
5. 5.6 - 6.0

Hole grouted w/ 2 bags

Test - Direct Shear
(3) Lignitic matl.
(4) Suitable Fdtn.
(5) sl. softer matl.

BORING LOG

BORING LOG	DIVISION South Atlantic	INSTALLATION Mobile District	SHEET 1 OF 1 SHEETS
1. PROJECT Lock C Spillway Excavation		10. SIZE AND TYPE OF BIT 6" x 7 3/4" Carbide	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Mobile District		12. MANUFACTURER'S DESIGNATION OF DRILL Failing 314	
4. HOLE NO. (As shown on drawing title and file number) 3-80		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None	
5. NAME OF DRILLER L. Lucas		14. TOTAL NUMBER CORE BOXES 2	
6. DIRECTION OF HOLE ✓ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER Not observed	
		16. DATE HOLE STARTED 5-27-80; COMPLETED 5-27-80	
7. THICKNESS OF OVERBURDEN 0.0		17. ELEVATION TOP OF HOLE 225.6	
8. DEPTH DRILLED INTO ROCK 7.9		18. TOTAL CORE RECOVERY FOR BORING 100 %	
9. TOTAL DEPTH OF HOLE 7.9		19. SIGNATURE OF INSPECTOR J. C. Shaw	

W/C %	ELEVATION	DEPTH	SYM.	CLASSIFICATION OF MATERIALS (DESCRIPTION)	FIELD HARDNESS	% CORE REC.	BOX OR SMPL NO.	REMARKS
			ML	Predominately Clayey Silt w/ num. lignite incls. Brownish Gray $\xrightarrow{O_2}$ Tan	C	100	1	
	223.0	2.6						
		3	CH	Lignitic Fat Clay, stiff w/ lignite incls. Dk. Gray to Black	C			
	221.1	4.5	CH	Fat Clay, stiff w/ occ. lignite incls. Lt. Gray $\xrightarrow{O_2}$ Tan	C	100	2	El. 219.2 - 219.0: "B-C". Slks may appear as core dries.
						100		
	217.7	7.9						Bottom of Hole
				WRAPS (depth)				El. 218.3 - 218.0: Num. siderite grains.
			1.	0.8 - 1.8				El. 218.0 - 217.7: Clay becomes silty (CL).
			2.	3.5 - 4.5				
								Hole grouted w/ 2 bags of cement