(4)

US Army Corps
of Engineers
Savannah District

HARTWELL LAKE PROJECT
Savannah River, Georgia And South Carolina

REHABILITATION OF CLEMSON UPPER DIVERSION DAM

CONTRACT NO. DACW21-83-C-0066

CONSTRUCTION FOUNDATION REPORT

VOLUME 1 OF 2

AUGUST 1989

U.S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

DEPARTMENT OF THE ARMY
SAVANNAH DISTRICT, CORPS OF ENGINEERS
P.O. Box 889
SAVANNAH, GEORGIA 31402-0889

REPLY TO
ATTENTION OF:
CESAS-EN-B

30 November 1989

MEMORANDUM FOR Commander, Cameron Station, Alexandria, VA 22314, ATTN: DTIC/DA-2

SUBJECT: Hartwell Lake Project, Savannah River, Georgia and South Carolina, Rehabilitation of Clemson Diversion Dam, Construction Foundation Report

1. Enclosed are twelve (12) copies of referenced report, submitted in accordance with ER 1110-1-1801.

2. If you have any questions, please feel free to call the Project Manager, Mr. D. L. Parrott, at 912-944-5713.

FOR THE COMMANDER:

J H Rogers

Encls (12 cys)

JOSEPH H. ROGERS, JR., P.E.
Acting Chief, Engineering Division

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18. SUPPLEMENTARY NOTES: The report was prepared from written narratives, drawings, and oral information given by Project Geologist Timothy A. Pope.
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
    - Prior Seepage problems
    - Site Geology
    - Design Considerations
    - Construction Proceedures
    - Cutoff Wall

    (See Reverse Side)
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Clemson Upper Diversion Dam had experienced downstream seepage problems since shortly after construction in 1961. Several repairs were attempted from 1963 until 1977. By 1981 it became apparent that some type of positive cutoff solution was needed. Many types of repair methods were considered before a cutoff wall was selected as the type of remedial method.

The report covers foundation investigations prior to wall construction and site geology. Construction procedures for the cutoff wall are described in detail. A downstream drainage system was also constructed and this is described

19. (Continued)

Panel Excavation
Panel Cleaning
Concrete Placement
Concrete Quality
Drainage System Downstream of Cutoff Wall
Investigations During Construction
Concrete Quality Control
Instrumentation
Site Restoration
Possible Future Problems

20.(Continued)

in the report. Many piezometers were relocated during construction and piezometric surfaces at the dam were mapped before and after cutoff wall construction. The report contains several maps and cross sections illustrating piezometric data. Site restoration and possible future problems are also described.

HARTWELL LAKE PROJECT

SAVANNAH RIVER, GEORGIA AND SOUTH CAROLINA

REHABILITATION OF CLEMSON UPPER DIVERSION DAM

CONTRACT NO. DACW21-83-C-0066

CONSTRUCTION FOUNDATION REPORT

In Two Volumes

VOLUME I - TEXT, PLATES, AND APPENDIX A

August 1989

U.S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

HARTWELL LAKE PROJECT

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SAVANNAH RIVER, GEORGIA AND SOUTH CAROLINA

REHABILITATION OF CLEMSON UPPER DIVERSION DAM

PERTINENT DATA

LOCATION OF CLEMSON DIVERSION DAM

The site is located adjacent to Clemson, South Carolina, Seneca River Channel, approximately 21 miles above its confluence with the Savannah River. It is 27 miles above Hartwell Dam, 96 miles above Strom Thurmond Dam, 116 miles above Augusta, Georgia, and 316 miles above the mouth of the Savannah River.

HARTWELL LAKE

Elevations - Feet Above MSL	
Spillway crest (Hartwell Dam)	630
Minimum design pool	625
Static full pool	660
Top of gates	665
Maximum design surcharge	674

DAM (CLEMSON UPPER DIVERSION DAM)

Rolled earth fill, homogeneous with inclined chimney drain and horizontal drainage blanket	
Maximum height, feet	75+/-
Length, feet	2,100+/-
Elevations, Feet Above MSL	
Roadway, top of dam (design)	679
Roadway, top of dam (existing)	680+
Crest width, feet	16
Design freeboard above maximum design surcharge	5

APPROXIMATE QUANTITIES

Earth fill, CY	1,700,000
Stone slope protection, CY	30,000
Drainage area above diversion dam, sq. mi.	9.4

HARTWELL LAKE PROJECT

SAVANNAH RIVER, GEORGIA AND SOUTH CAROLINA

REHABILITATION OF CLEMSON UPPER DIVERSION DAM

CONTRACT NO. DACW21-83-C-0066

PROJECT CHRONOLOGY

Contract Award	22 Jun 83
Notice to Proceed	2 Aug 83
Preconstruction Conference	2 Aug 83
Begin Site Work	September 83
Excavate Top 5 Feet of Dam	October 83
Begin Guidewall Construction	October 83
Begin Test Panels	10 Nov 83
Complete Test Panels	19 Dec 83
Begin Coring Test Panels	21 Dec 83
Complete Coring Test Panels	23 Jan 84
Begin Production Panels	30 Jan 84
Begin Coring Production Panels	18 Apr 84
Complete Guidewall Construction	April 84
Complete Production Panels	23 May 84
Begin Filling Old Seneca River Channel	30 May 84
Complete Coring Production Panels	11 Jul 84
Complete Rebuilding of Top 5 Feet of Dam	July 84
Complete Jacking of Drain Pipe under SC Highway 93	July 84
Complete Filling Old Seneca River Channel	11 Sep 84
Complete Site Restoration	October 84

HARTWELL LAKE PROJECT

SAVANNAH RIVER, GEORGIA AND SOUTH CAROLINA

REHABILITATION OF CLEMSON UPPER DIVERSION DAM

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CONSTRUCTION FOUNDATION REPORT

1. INTRODUCTION

1.1 Project Location: The Clemson Upper Diversion Dam is located in Pickens County, South Carolina, adjacent to the town of Clemson and the property of Clemson University. The dam spans the old Seneca River Valley approximately 21 miles above its confluence with the Savannah River, 28 miles above Hartwell Dam, and about 317 miles above the mouth of the Savannah River.

1.2 Project Description: The Upper Clemson Diversion Dam was constructed as part of the Hartwell Reservoir Project. Consisting mostly of random earth fill, the dam extends for a length of 2,100 feet. The dam is approximately 60 feet high (maximum elevation of 681 feet MSL) and has gravity berms both upstream and downstream. It has an inclined drain at el. 650 MSL which extends to a blanket drain at an elevation of 600 feet MSL. This dam, in conjunction with the Lower Diversion Dam and a pumping station, was constructed to prevent flooding of Clemson University land by the Hartwell Reservoir impoundment. The pumping station is operated by the Government to remove runoff and seepage from the protected area.

1.3 Authorization: The Upper Clemson Diversion Dam is a part of the Hartwell Lake Project, which was initially authorized by the flood control Act of May 17, 1950. The rehabilitation of the Upper Dam was authorized through the Discretionary Authority of the Chief of Engineers in 1980. This report was prepared in compliance with ER 1110-1-1801, "Construction Foundation Reports".

1.4 Purpose of Report: The purpose of this report is to provide a record of the design data and assumptions, specification requirements, construction equipment and procedures, and foundation conditions encountered during the rehabilitation of the dam. The performance of the concrete cutoff wall as shown by project instrumentation and the experience gained during its construction should assist in design of future comparable projects. This report satisfies the requirements of Appendix A to ER 1110-2-100 for the retention of a permanent collection of project engineering data.

1.5 Necessity for Rehabilitation: Since shortly after the empoundment of the Hartwell Reservoir in 1962, the toe of the Clemson Upper Dam has been plagued by the development of boils, seeps, and springs. Recommended remedial work has been accomplished over the years; however, the conditions for which the works were accomplished continued to occur, usually just beyond the limits of the completed remedial work. Emergency repairs were required to control boils which, if left unrepaired, had the potential for causing possible failure of the dam through piping and flooding of the protected areas. Even after the completion of the numerous repairs, potential for flooding as a result of uncontrollable seepage related problems still existed. The protected area contains farmlands, roads, service areas, parking lots, buildings, athletic facilities (including a football stadium), all belonging to Clemson University, and a Government owned pumping station. Flooding of this area would have resulted in considerable economic loss and a high potential for loss of life.

1.6 Rehabilitation of Dam: Numerous repair methods and combinations of methods were considered for the rehabilitation of the Upper Dam. A concrete cutoff wall using slurry wall panel construction techniques was the main method used for controlling the seepage at the site. The concrete cutoff wall extends from Station 1+00 to Station 22+50 (see Plates 2 and 3) and is 78.0 to 96.0 feet deep in the valley portion of the wall, with most of the panels being about 90 feet deep. The wall is 2 feet thick and 2150 feet long. The depth (average of three bites) of Panel 1, starting at Station 1+00, is 21.3 feet, and the average depth of Panel 80, ending at Station 22+50 is 68.2 feet. Most of the panels are about 90 feet deep and the deepest panel is 96.0 feet deep. The wall contains a total of 80 production panels and 10 test panels. The total excavated area was 160,157.30 SF and 13,583.50 CY of concrete were used in the construction of the cutoff wall (Soletanche and Rodio, 1984). The panels were constructed with specialized equipment under full head of Lake Hartwell by a prequalified contractor and expert in the field.

The other part of the rehabilitation project was the excavation and backfill of the old Seneca channel downstream of the dam. This channel had to be drained, excavated, and backfilled with a filter system next to the excavated foundation and a random fill cover above the filter. This was the only work which was accomplished on visible foundations. Also, a new storm drain pipe had to be jacked under S.C. Highway 93 to improve drainage from this area.

1.7 Prime Contractors and Subcontractors: Soletanche & Rodio, Inc. of McLean, Virginia was awarded the contract for their bid of $2,178,900.00. During the project, Soletanche merged with the Reinforced Earth Co. to form Recosol Inc. of McLean, Virginia. The Project Manager/QC System Manager was Michel Gavillet. The Job Superintendents were Mike Manuel and Fhodor Malijenovsky.

The main subcontractors were Soil and Material Engineers, Inc. of Spartanburg, South Carolina who did the concrete testing and Froehling & Robertson of Greenville, South Carolina who performed the concrete core drilling. The subcontractor for excavation and backfill downstream of the dam was Eastern Contractors of Columbia, South Carolina. The Project Manager was Tillman Williams and the Superintendent was Martin Covington. Other specific site work was performed by the subcontractors listed below.

Subcontractor	Work Performed
Concrete Specialties, Inc.	Guide Walls
Eastern Contractors, Inc.	Clearing and Grubbing
Eastern Contractors, Inc.	Reconstruction
Eastern Contractors, Inc.	Degrading
EZ Bore	Pipe Jacking, HWY 93
Hill Electric Co., Inc.	Misc. Electrical Work
J & R Fencing Co.	Fence
Kelletts Well Boring, Inc.	Test Excavation Equipment
Trade Rentals, Inc.	Clearing and Grubbing
Williams Electric	Misc. Electrical Work

Metromont Materials (Seneca Plant) of Spartanburg, South Carolina, supplied the concrete for the cutoff wall.

1.8 Key Resident and Design Staff: The following personnel were involved with the construction phase of the rehabilitation of the Clemson Upper Dam:

James E. Evans	Area Engineer
Charles A.(Tony) Herndon	Construction Representative
Tom List	Office Engineer
Timothy A. Pope	Project Engineer/Geologist
Dan W. Renfro	Area Engineer
Richard A. Rowe	Area Engineer
Stanley A. Simpson	Engineer Trainee
Charles W. Slover	Construction Representative
Dennis M. Thomas	Construction Representative

The following were the project design personnel:

Joe Rogers	Chief Geotechnical Branch
Earl Titcomb	Chief Geology Section
Jack Phillips	Chief Soils Section
Ted Hightower	Design Geologist
Cardwell Smith	Geologist

2. HISTORY OF THE CLEMSON UPPER DIVERSION DAM

2.1 General: The Clemson Diversion Dams were built as an adjunct to the construction of Hartwell Lake and Dam. During the initial planning for the Hartwell Project, plans were made to flood the entire Seneca River Basin. Minor relocations and earthwork (described in the Definite Project Report of December 15, 1952) were planned at Clemson to preserve such facilities as the University's football stadium and sewage treatment system. This would have resulted in the loss of agricultural land which Clemson University leaders considered indispensable to the University's function. The problem was restudied and the Clemson protective works redesigned to preserve these lands (Hartwell Reservoir DM 15, Relocations - Part 7A, dated August 21, 1959). The redesign included Upper and Lower Diversion Dams on the Seneca River and an 850 foot wide diversion channel through a (future) peninsula parallel to the general flow of the river.

2.2 Description of Original Structure: The dam is a rolled fill, homogeneous earth embankment containing an inclined chimney drain and a horizontal drainage blanket. The random fill embankment materials consist mostly of silty sand (SM) with smaller quantities of lean clay (CL) and fat clay (CH). The material specified for the chimney drain was a clean, angular, well graded, medium to coarse grained sand. The crest of the dam is at an elevation of 680 feet and the embankment has 1V on 4H upstream and 1V on 3H downstream slopes with a 50-foot wide berm at elevation 650 upstream and a 50-foot wide berm at elevation 640 downstream. Fill placed in the berms was uncompacted with the remainder of the embankment compacted to 90% maximum Standard Proctor Density. The structure is founded primarily on the Seneca River alluvium with the abutments on residual soil and rock. The design included a 15-foot wide core trench excavated to rock through the alluvium in the old Seneca riverbed, 45 feet upstream of the dam centerline. The plans indicate that this trench was excavated to elevation 597 $\pm$ MSL.

2.3 History of Problems, Previous Remedial Actions, and Changes to the Structure: This history, taken from Design Memorandum 33, is based on a review of available files and the memory of personnel with long-term association with the project. The occurences, as related below, cover 20-plus years of the project life, not all of which are fully documented or described in detail in the files. Where a hiatus existed, assumptions based on the implication of the written record and memory were used to fill in the missing information. Throughout the written record, different references are made to the abutments. For definition, the left abutment is also referred to as the north or east abutment and the right as the south or west abutment. Note: left or right side for the Upper Dam is determined by a person facing in the opposite direction from the lake impoundment, i.e. downstream.

Refer to Appendix XIV of Design Memorandum 33 for plans showing the locations of the activities described below.

2.3.1 Initial Problems and Repairs: The dam was complete by October of 1961 and full pool (elevation 660 feet MSL) was reached in April of 1962. By

October of 1963 a boil had been repaired by installation of a filter blanket and corrugated metal pipe; however, a new 3-inch boil had developed at the same location which had a piping channel extending back into the dam foundation. These boils were located in the general area of the toe of the dam at approximately Station 14+00. The extent and repair of the new boil in January 1964 was reported at the time as follows:

"As the dragline dug in the boil, it was found to be fed by a piping channel 3 inches in diameter which had developed approximately 1 foot below the 2-foot drainage blanket, and parallel to the natural ground surface in the direction of the reservoir. The "pipe" was followed for a distance of 23 feet perpendicular to the centerline of the embankment, which seemed to be the practical limit due to the depth of cut caused by digging into the embankment slope. A trapezoidal area in plan, 18 feet at the toe the embankment, by 5 feet, with an altitude of 23 feet, was treated to try and contain the flow of water so that the "pipe" would not break out at the toe and form a new boil. The treatment consisted of a 2-foot gravel layer with a perforated metal pipe in the center, and filter on the top, bottom, and upstream surfaces by a 2-foot sand layer. The treatment tapers off toward the toe, and only the gravel and metal pipe protrude slightly from the toe. The embankment slope was brought back to grade with clay and topsoil was to be placed on the scarred area as soon as possible."

2.3.2 <u>1964 Development of New Boils:</u> Despite this treatment, another boil had developed in the same area by March 1964. Small boils were also present in other areas downstream of the toe although not considered serious at the time. Also, during a March 1964 inspection, R.A. Barron of OCE stated that use of metal pipes extending into the dam was an unsound practice due to the potential for future rusting, and directed the removal of those metal pipes installed during the previous corrective measures. He recommended the installation of foundation relief wells along the downstream toe area and assessed the condition of the dam as "potentially dangerous because of piping".

In April 1964, a trip report was written stating that "the seepage of the embankment toe has increased" and reporting an active boil found for the first time near the north abutment and having "no resistance" (to penetration) "in the boil for a depth of 5 feet".

2.3.3 <u>Installation of Relief Wells:</u> In December of 1964, six relief wells (W-1 thru W-6) were installed. Also in December 1964, the corrugated metal pipes were removed as directed previously in March 1964 and the area of the excavation was backfilled with gravel.

Mr. R.A. Barron of OCE inspected the dam again in April 1965. At that time he concurred in a SAS proposal to install two additional relief wells near the right abutment and recommended that "the seepage zones along the berm toe be covered with gravel" to "improve conditions and prevent potential piping". The two additional relief wells (W-7 and W-8) were installed in November of 1965.

2.3.4 Development of More Seepage and Subsequent Repairs: In December 1965, a concentration of seepage was reported in a drainage ditch to the left of the old river channel and about 100 feet downstream of the toe which was "forming a pipe back toward the reservoir". SAS recommended corrective measures for the seepage area as follows:

"The area should be cleared and a dragline used to trace seepage concentration (pipe) a short distance toward the reservoir. The resulting ditch should be backfilled with gravel similar to that used previously to line the ditches along the embankment toe. Also, the entire old drainage ditch bottom should be lined with two (2) feet of gravel, and filled to the surrounding ground level with soil. An alternate solution for backfilling the work would be to use sand dug out of the river channel at the pump station and completely backfill the excavated ditch area with sand without using any gravel".

Remedial action in response to these recommendations was delayed due to weather and higher priority work, but was completed by the Reservoir Manager in November 1966 and is descibed as follows:

"The old drainage ditch at the Upper Diversion Dam was found to be just off the project lands on Clemson University property and, therefore, the seepage concentration (pipe) was not traced as recommended. Another drainage ditch was constructed approximately 20 feet from the old ditch, but not as deep as the old ditch. The new ditch was backfilled with sand on a level grade and will serve as the outfall ditch for the drainage ditch system below the Diversion Dam on this side of the Old Seneca Riverbed. Sand was hauled from the river at the pumping station and placed in all low areas in this area, including the old drainage ditch where the seepage concentration (pipe) was located". Other work simply described by the statement "The entire toe area of the Upper Diversion Dam has been leveled and all large rocks removed" was accomplished at this same time.

During a joint OCE, SAD, and SAS inspection in May 1967, Mr. R.W. Beene of OCE described widespread seepage along the downstream toe and stated that the relief wells have not eliminated the seeps and springs along the toe. He concluded that the dam required minor corrective action "to guard against development of foundation piping". He recommended placing a filter blanket on the seeps and springs and suggested consideration for "installation of one or two additional relief wells in an area of concentrated seepage in the vicinity of Station 17". No additional relief wells were installed and project files do not indicate that any additional blanketing was accomplished as a result of these recommendations.

SAD and SAS inspected the dam in November 1967 at which time a wet area was observed in the vicinity of relief well W-7 and flowing springs were noted in the area adjacent to the east abutment. The conclusions and recommendations as a result of this inspection were written as follows:

"The sand berm near the west abutment should be extended to the wet area in the vicinity of Station 5+00. When a drill rig is available, relief well W-7 should be cleaned out and surged to stimulate flow. Also, the sand berm should be raised approximately 1 foot in the vicinity of W-7. The small springs located near the east abutment should be blanketed with 1 foot of sand and then covered with 1 foot of gravel. This will insure that no fines are removed from the foundation. Sand for all the corrective work will be available after construction of the sand trap at the Lower Diversion Dam". There are no indications in the project files that any action was taken as a result of these recommendations; however, it is believed that it was accomplished.

Another joint OCE, SAD, SAS inspection was held in November 1968. During this inspection it was observed that "there are still wet areas at the toe of the Upper Diversion Dam" and it was decided to utilize material from the sand trap at the Lower Dam to blanket seepage at the Upper Dam. Although no specific reports of this activity are cited, it is a fact that sand from the Lower Dam source has periodically been placed and spread on wet areas of the Upper Dam.

The SAS report of the joint OCE, SAD, SAS inspection of April 1970 states simply that drainage to remove water from the toe of the dam is insufficient and such drainage should be improved.

The area around relief well W-7 continued to be wet and an inspection in April 1971 found 9.9 feet of sand in the well, indicating failure of the gravel pack. This led to packing of the well with gravel in July 1971 and the eventual replacement of the well in February 1973 and covering the surrounding area with a sand blanket.

2.3.5 Later Remedial Work: The most recent remedial work at the dam took place following the Resource Manager's Quarterly Surface Inspection report of early July 1977 which reported: "the area between relief well No. 7 and No. 8 in the vicinity of Piezometer No. B-4 is very wet and water is seeping from several locations in the immediate vicinity". Note: This report incorrectly identified the relief well numbers. W-2 and W-1 are the correct references. On recommendation, District representatives inspected the area and made recommendations, quoted in part, as follows:

"We recommend that an interceptor ditch be installed across the area of seepage near Piezometer B-4.

a. The ditch should be about 6 feet deep by 4 feet wide. The side slopes are shown vertical in the attached sketches, but may be inclined for ease of construction.

b. A 6" perforated drain pipe should be installed in the ditch with a "T" tying into a 6" nonperforated pipe which daylights above the invert of the existing creek.

c. A two-stage graded filter should be provided.

d. Some dewatering by portable pump will likely be required. We would suggest creating a sump at one end of the excavation or excavating a shallow ditch on the upstream side of the base of the excavation to facilitate collection of water for pumping. The sump or ditch should be backfilled with the specified sand.

After installation of the interceptor drain, the area should continue to be monitored and the effectiveness of the installation evaluated."

This work was accomplished by Resource Manager personnel in December of 1977.

No further remedial work has been accomplished at the dam; however, an April 1978 inspection indicated continuing wet areas near the toe to the left of the most recent work. The written record of this inspection concludes that "the recently installed drain appears to be performing satisfactorily"; however, "additional remedial work will be necessary to drain the other wet areas along the toe and the berm".

2.4 Site Meeting of November 1979: On November 15, 1979, a meeting was held at the site to discuss seepage problems of the Clemson diversion dams. OCE, SAD, and SAS representatives were in attendance. The conclusions reached at this meeting were that the conditions of the Upper Dam required studies to determine if remedial repair was needed to control seepage, or if some type of positive cutoff solution was warranted. At that time it was agreed by those present that the most desirable type of repair for the Lower Dam would be some type of positive cutoff; however, a definite statement with respect to the need for a positive cutoff at the Upper Dam could not be made at that time. It was noted that the Upper Dam also had a history of underseepage; however, the condition of the Upper Dam did not appear to be as severe as that at the Lower Dam.

2.5 Site Visit of August 13, 1981: Subsurface investigations of the Upper Dam had been completed by this time. Information gained showed that the stratification was similar to that present at the Lower Dam. It was felt by the District that a positive cutoff wall was needed; however, because detailed subsurface information was not available for review at the meeting, SAD and OCE representatives could not concur. They recommended that the District conduct a detailed analysis, using the information available from the subsurface study, which would consider all feasible solutions before making a final decision. It was pointed out that the installation of a continuous filter trench in conjunction with relief wells could be an alternate solution and should be considered by the District. Many types of remedial measures were later evaluated by the District and these are discussed in this report in Section 5.0 Design Considerations, and are described in more detail in Design Memorandum 33.

2.6 Status of Structure Prior to Rehabilitation: Prior to repair of the structure it was felt by the District that the potential for serious piping existed at the time of completion of the structure in 1962. The Clemson Upper Dam had experienced boiling and piping during its early years. Piecemeal remedial repairs had not been fully successful and some potential for serious piping still existed, particularly since the foundation gradient was well above the ground surface at the toe of the embankment. This potential was considered more serious in the light of the historical tendency of problems to be more frequent in earth dams about 20 years in age. In addition, a nontechnical consideration was that the upcoming remote operation of the pumping station at the Lower Dam would result in the reduction of Corps personnel at the dam to monthly inspections.

No boils or excessively wet areas were observed during an inspection of the dam on August 13, 1987, and all flow from relief wells and drainage blankets appeared clear. However, the lake level was 8.5 feet below normal pool on that date and this was probably a factor in the relatively dry conditions present.

3. FOUNDATION INVESTIGATIONS PRIOR TO CONSTRUCTION

3.1 General: A total of 51 borings were drilled in the embankment and foundation of the Upper Dam for the pre-construction subsurface investigation. Boring locations are shown on Plates 2 and 3. Forty-four of the borings were for piezometer or water well installations and 7 were exploration borings. Piezometer and exploration borings were drilled 6 inches in diameter. The pumping test well was drilled 24-inches in diameter. The purpose of the exploration program was to obtain disturbed and undisturbed samples from the embankment, abutments, alluvial soil, and the rock foundation to determine the classification of the soils and rock and make appropriate in-situ tests. The purpose behind this was to determine the present condition of the embankment and its appurtenances and to determine the adherence of the dam construction to the original design.

3.2 Drilling Equipment And Tools: Two Failing 314 truck mounted rotary drilling rigs were used to drill the exploration borings, piezometers, and water well borings. Tools used for advancing exploration, piezometer, and monitoring wells were a 6-inch fishtail, a 1 3/8-inch ID standard splitspoon, a 3-inch ID solid spoon, a 4 by 5 1/2-inch diamond bit core barrel, and a 6-inch rock bit (all tools were not used in each boring). The pumping test well was advanced with a 24-inch rock bit.

3.3 Soil Sampling: Overburden sampling of the embankment, the alluvial foundation, and the residual soils was performed using the continuous splitspoon standard penetration test method for disturbed sampling. Disturbed sampling was performed with a standard 1 3/8-inch ID splitspoon driven by a 140-pound hammer falling 30 inches, except in the basal sand and gravel unit where occasionally a 3-inch ID solid spoon was driven with a 300-pound hammer in order to secure more representative samples of the coarser grained material.

Undisturbed samples were obtained with a 5-inch Shelby tube or a 3-inch Osterberg fixed piston sampler. The Osterberg sampler is a hydraulically actuated sampling device used to push a thin-walled tube through the soil. Undisturbed samples, designated by "UD" on lab reports, were taken from auxiliary borings drilled alongside the logged boring to which the UD was assigned.

3.4 Lab Testing of Soils: Jar and undisturbed samples were tested at the South Atlantic Division Laboratory. Atterberg limits, mechanical analysis, and water content tests were run on jar and undisturbed samples. In addition, permeability (horizontal and vertical), triaxial compression, direct shear and pinhole tests were also run on the undisturbed samples.

3.5 Rock Sampling: The bedrock (granite gneiss) was sampled by coring with a 4-inch x 5 1/2-inch diamond bit. The rock core was placed in core boxes and stored at Hartwell Dam. RQD was computed for each run and recorded on the boring log. Six-inch flush joint casing was set to facilitate the use of the core barrel or other down-hole tools and/or installation of a piezometer. Upon completion of each recovery boring, the rock portion was backfilled with a neat cement mix tremmied into the boring by lowering the drill rods to the bottom of the bore hole and pumping the cement mix through them. Next, the remaining portion of the bore hole was bailed and backfilled with a material similar to that used in construction of the embankment. This was done in 5-foot lifts, with each lift being compacted with the weight of a 140-pound safety hammer drive weight being raised and dropped on each lift until compaction was achieved.

3.6 Lab Testing of Rock Samples: Rock core samples were taken from the bedrock beneath the Lower Dam earlier for Design Memorandum 32 and were tested at the South Atlantic Division Laboratory. Unconfined compression tests and petrograghic analyses were run on the samples. Because the rock at the Upper Dam is similar to the rock at the Lower Dam, no additional testing was performed. Lab test data and a petrographic analyses may be found in Appendix VIII of Design Memorandum 33.

3.7 Instrumentation Program: The first piezometers were drilled at station 7+75 and were numbered B-1, B-2, and B-3. They are refered to as the "old" (original) piezometers and were drilled in 1963.

The majority of the piezometers at the site were drilled much later, during 1980, 1981, and 1982. They were installed in groups of two and three. Piezometers with screens set in foundation bedrock were given the prefix "PF". Piezometers set in the lower portion of the alluvium, at or near the contact with the bedrock, are designated by the prefix "PC". The embankment piezometers were set in selected sandy zones within the embankment and were identified by "PE". Only the PF piezometers were logged at each piezometer group location. Those logs were then used to select the zones in which the embankment and alluvium piezometers were set. Piezometer screens were slotted 2-inch ID PVC no less than 2-feet long. Each piezometer was sealed with bentonite pellets above the screen. Risers are 3/4-inch PVC extending several feet above the ground surface.

Three additional piezometers were drilled during May of 1982. These were numbered UAP-1, UAP-2, and UAP-3.

Records of piezometer levels from piezometers for various dates from October 15, 1980 through March 20, 1982 may be found on Plate 10 of Design Memorandum 33. Readings from the "old" piezometers for dates from September 5, 1963 through August 27, 1981 are also shown.

Piezometric surface profiles, prior to cutoff wall construction, are shown on Plates 17, 19, and 21. These cross sections are representative of the right floodplain area, the old Seneca River channel, and the left flood plain area. A cross section constructed from the "old" piezometers is shown on Plate 23.

The following conclusions were drawn from interpretation of piezometer data available prior to cutoff wall construction:

a. Flow conditions occurred at and beyond the embankment toe during periods of high lake levels. These were evident in above-ground piezometric levels and seepage into ditches along the downstream toe near both abutments. These ditches were constructed to allow drainage from the 9 relief well outfall pipes (see Plates 2 and 3).

b. The alluvial piezometric surface slopes slightly inward from the abutments toward the Seneca River channel. This gradient, on April 17, 1981, from piezometers PC-205 to PC-201 was 0.016 and from PC-208 to PC-201 it was 0.005.

c. Alluvial piezometric levels did not appear to have changed since 1963. Examining long term data from the "old" piezometers, B-1, B-2, and B-3, showed that a given lake level today will still provide similar piezometer levels as those in the past.

d. The alluvial piezometric gradient from the dam centerline to the downstream berm did not appear to have changed since 1963. Data from "old" piezometers, B-1, B-2, and B-3, indicate little or no change in the gradient through time other than expected normal changes due to normal lake level fluctuations.

e. Based on information obtained from the most recently installed piezometers, UAP-1, UAP-2, and UAP-3, the high piezometric levels recorded at the Upper Diversion Dam originate in the lower, coarse basal unit of the alluvium and rock foundation.

f. The highest permeability of the alluvium foundation, as recorded in the pumping test, is located in the lower, coarse basal unit of the alluvium.

3.8 Pump Test: A pump test was conducted at Station 13+50 on the 50-foot wide downstream stability berm of the Upper Diversion Dam to obtain an indication of the permeability of the Seneca River alluvium below the dam. One pumping well, PW-3, and four observation wells, MW-9, MW-10, MW-11, and MW-12, were installed in the alluvial foundation below the berm to estimate permeabilities and flow quantities. These wells were located parallel to the dam axis (see Plate 3) and were spaced 50 feet apart. A detailed description of the well designs can be found in Design Memorandum 33.

The 25-hour test was started on May 19, 1981, and a constant discharge rate of 84 gpm was used. Test data were plotted as the test was in progress which limited the length of time the test was run to only the time necessary to develop the required data. Test data were analyzed using the Jacob Method. The overall mean transmissibility (T) was computed at approximately 30,000 gpd per foot width of aquifer and the permeability (K) was calculated at about 1,000 gpd per square foot. A description of the pumping test analysis can be found in Design Memorandum 33.

3.9 Pressure Tests: Open-hole water pressure tests were conducted in the bedrock portion of the exploratory borings as part of the Upper Dam investigation. The purpose of these tests was to evaluate the relative permeability of the bedrock mass in the formation. No water-take pattern was established with these tests; however, it was concluded that the permeability of the bedrock beneath the dam was low and was only a minor contributor to the seepage experienced at the dam.

4. GEOLOGY

4.1 Regional Geology: The Upper and Lower Clemson Diversion Dams are located in the upper Piedmont Province of South Carolina, near the foothill ranges of the Blue Ridge Mountains. Surface elevations in the area range from about 600 feet MSL in the valleys to 900 feet MSL on the hilltops. Elevations and relief increase sharply a few miles to the northwest. Surface drainage is through short trellised tributary streams with steep gradients that flow into the primary streams to form a dentritic drainage pattern. The more gentle slopes within the area are usually cleared and cultivated while the steeper slopes are heavily wooded with pine and hardwoods.

Bedrock which underlies the stream valleys and hills in the project vicinity is granite gneiss. The rock has an interlocking crystalline structure and generally fractures along foliation planes. When fresh, it has a very high compressive strength, very low primary permeability, and is insoluble. The gneiss is composed principally of feldspars, quartz, biotite, and muscovite.

Rock weathering in the Piedmont Province has produced residual soils in excess of 100 feet, the greatest thickness usually occurring on the crests of the hills and ridges and the minimum thicknesses usually in the valleys. Rock weathering can be found to varying depths beneath both hills and valleys, ranging from intense to fresh. Contact between soil and weathered rock is usually gradational. A typical residuum consists of 5 to 10 feet of sandy clay soil (CL to occasional CH) underlain by 20 or 30 feet of micaceous silty sand (SM), containing fragments and stringers of rock. This material grades downward through silty, oxidized rock to fresh, unaltered gneiss. The residual soil typically has a distinct reddish color. This material was the primary fill used in constructing the embankments of the diversion dams.

4.2 Site Geology: The only foundation which was exposed during construction on this rehabilitation project was that below the filter system downstream of the dam. Therefore, the site geology in this section is mostly interpreted from excavated material and core from drilling the site. It is not possible to produce the usual geologic map found in foundation reports.

4.2.1 Physiography: The Clemson Upper Diversion Dam was built in the Seneca River Valley between two ridges. The river meandered through this area, cutting a wide valley and depositing alluvium between the hills. The right abutment is on a knob that original topographic maps show to have crested at about 711 feet MSL, but now is flat topped at elevation 680 feet. Apparently 30 feet of material was removed, probably during dam construction. The river valley is approximately 1700 feet wide at the dam axis. The Seneca was almost 300 feet wide at this point. Its channel is in the foundation of the dam from about Station 9+00 to 11+00. Seneca Creek flowed around the base of the knob. It was about 25 feet wide and crossed the dam axis near what is now Station 3+50. The left abutment is set into the high ground on which the town of Clemson is built.

4.2.2 Description of Overburden: The overburden on hillsides at the Upper Dam was typical for this region. The upper layer, encountered in fence construction, was 3 or 4 inches of silty sand which included organic material. Below this was sandy silt, usually red or reddish brown, with some clay and mica. Below this was a lighter reddish or orange layer with more clay grading into saprolite with discernable relict rock structure.

4.2.3 Stratigraphy: The rock encountered in this work was almost exclusively a granitic gneiss of medium to coarse grain-size. Materials seen in the better samples from the excavation were feldspar (light-colored), quartz, muscovite, and biotite or clorite. Mafic minerals generally comprised 5 to 10% of the rock, but some samples containing 25% mafic minerals were retrieved. The material excavated was saprolitic except where chisels were used. Some quartz and coarse pegmatitic materials were excavated, probably from dikes in the gneiss. In the valley section of the wall, sand and gravel often occurred just above the bedrock. Where this material was coarse (cobbles up to the size of a loaf of bread were removed) saprolite was thin or absent. Above this in some areas, particularly close to the right abutment, was a 5 to 8 foot layer of sandy organic material which gave off a strong odor. Next was a very plastic, sticky, brown clay about 5 to 10 feet thick. This layer seemed to be persistent across the entire excavation. Above the brown clay was a hard, dark, brownish gray to black, silty material containing minor organics. This material broke almost subconchoidally, indicating that it was homogeneous and well indurated. Above this was the hard, red, micaceous silt and clay (with occasional sandy layers) of the Upper Dam.

4.2.4 Groundwater: Extensive pre-construction groundwater studies are summarized in DM-33 and Sections 3.7 thru 3.9 of this report. During excavation and construction of the downstream drainage system it was apparent that there was considerable flow from the high area behind the left abutment. The existing drainage ditches were extended to intercept this water, allowing compaction of fill material in the area. Also the area near the base of the knob on the right abutment was usually wet. No excavation or placement of fill was done in this area.

4.3 Unusual or Unanticipated Geologic Conditions Encountered during Construction: In general, there were no unusual or unanticipated geologic conditions encountered on this job. Most of the unexpected conditions were with man-made structures, such as the filling of the outlet drain under S.C. Highway 93 with logs, the curved condition of the drain, and the thickness of the riprap. Unexpected natural conditions were the presence of trees and/or poles under an extensive section of the cutcff wall and the extent of the groundwater flow from the high ground downstream of the left abutment. All these conditions are descibed in Section 6.

4.4 Character of Foundation Surface: The only foundation surfaces exposed during this rehabilitation work were those under the drainage system, described in Section 6.4. Information on the bedrock, gathered from material removed from the foundation by excavation or sampling, is described in Section 4.2.

5. DESIGN CONSIDERATIONS

5.1 General: Two general concepts were considered as potential remedial measures for the seepage problems at the Upper Dam. These were positive seepage cutoff and passive cutoff. Many methods and combinations of methods were evaluated with most of them being eliminated on gross evaluation because they were inappropriate for this application for reasons other than cost.

Positive seepage cutoff methods considered were the following:

1. Conventional slurry wall
2. Cement grout
3. Chemical grout
4. Piling
5. Panel-type slurry walls

Passive seepage control methods considered were the following:

1. Relief wells
2. Stability berm
3. Filter trenches, fully or partially penetrating
4. Filter blanket

From these methods, one positive seepage cutoff and three methods of passive seepage control were selected for further study. The positive seepage cutoff method selected was a concrete cutoff wall, constructed by the panel method using bentonite slurry techniques for excavation. The three passive control methods selected for further evaluation were the following:

1. Fully penetrating filter trench just beyond the toe
2. Partially penetrating filter trench just beyond the toe
3. Filter blanket from the toe out to SC Highway 93

The four different methods of repair were evaluated closely from both an engineering and cost viewpoint. Initially, two locations were considered for the cutoff wall; however, the downstream berm location was eliminated due to the fact that it would have penetrated the existing drainage blanket thereby negating its effectiveness. Constuction of a cutoff wall at the crest was weighed against the other three methods, listed above, and was eventually chosen for the rehabilitation. Estimated cost for the wall was $3,613,900.

5.2 Selected Remedial Method: A concrete cutoff using slurry wall panel construction techniques was the method proposed for controlling the seepage beneath the Upper Dam. Construction of such a wall was already underway at the Clemson Lower Dam and this method had been successfully used by the Walla Walla, Portland, and Nashville Districts. The benefit of the experience of the other Districts on their projects and this District on the Lower Dam was used in assessing the applicability of this technique at the Upper Clemson Dam.

6. CONSTRUCTION PROCEDURES FOR COMPONENT PARTS

6.1 General: There were two phases of construction on this project; the cutoff wall and the downstream drainage system. The cutoff wall primarily provides a positive cutoff of seepage through the basal gravel and sand alluvium. It was constructed on the dam centerline from dam Station 1+00 to Station 22+50. The top of the wall is at an elevation of 675 feet MSL and the wall extends approximately 5 feet into bedrock material. The wall is comprised of 90 panels that are usually 25 feet wide. It was built along the dam axis in two parts. The test section which includes Panels T-1 through T-10 extends from Station 4+50 to 6+00. The test panels were completed in numerical order. The remaining portion of the wall is comprised of 80 production panels. These were numbered in order from Station 1+00 to Station 22+50 and generally completed in reverse order. Excavation of the first test section panel (T-1) was begun on November 10, 1983, and concreting of the last production panel (P-1) was completed on May 23, 1984.

The downstream drainage system has two purposes. It provides subsurface drainage of groundwater and any remaining seepage not controlled by the cutoff wall, and the excavation and fill work provides a neat surface that can be easily inspected. This phase consisted of constructing a two-stage filter in the old Seneca riverbed and necessary drainage ditches that were also filled with filters (both two-stage and sand only). Both of these drainage features empty into a riprap catchment basin. After construction, fill was placed over them (sloped to drain into the basin) and the area was then grassed. A 36-inch reinforced concrete pipe was jacked under S.C. Highway 93 through the existing highway embankment. Water from the catchment basin flowed through this pipe to a manhole and storm drain where it entered an existing storm sewer system.

6.2 Construction Grades: The Clemson Upper Diversion Dam is approximately 2100 long and 16 feet wide at the crest. It is built on a 4:1 (horizontal:vertical) slope upstream and a 3:1 slope downstream. It is approximately 60 feet high with a variable foundation elevation near elevation 620 MSL. There are gravity berms upstream and downstream at elevations 650 MSL and 640 MSL respectively. The dam is composed primarily of random fill with a 5 foot wide inclined drain (at and below elevation 650 MSL) extending into a blanket drain which extends beneath the downstream berm where it terminates in a covered toe drain. The dam's upstream side is protected by a nominal 4 foot thick layer of riprap (during construction, this riprap was found to be 4 to 5 feet thicker than expected at the top of the dam). The downstream berm and toe drain is covered by dredged material which slopes very gradually downstream to the Seneca Valley. The Seneca River channel was protected from being filled-in by a steep rock revetment at the downstream toe of the berm. To the southwest of the Seneca River channel, a pile of brown silty material rose 8 to 10 feet above the general flat flood plain. On the other side of the channel, there was a shallow swampy area which was only partially drained into the channel by two ditches, both subparallel to the dam axis.

6.3 Construction Procedures for Cutoff Wall: The concrete cutoff wall was built along the dam axis in two parts. The test section, which includes Panels T-1 through T-10 extends from Station 4+50 to 6+00. The test panels were completed in numerical order. The remaining portion of the wall is comprised of 80 production panels. These panels were numbered in order from Station 1+00 to Station 22+50 and generally completed in reverse order. Excavation of the first test section panel (T-1) was begun on November 10, 1983 and concreting of the last production panel (P-1) was completed on May 23, 1984.

6.3.1 Site Preparation: Before construction of the concrete cutoff wall, the top 5 feet of the existing earth dam were to be removed and used as fill to build a working platform for construction equipment at elevation 675 MSL. The contractor requested and received permission to change the platform configuration to provide a more efficient, safer working surface (see Plate 5 for a detail drawing of the embankment degrading for work platform). He built the platform as designed to elevation 675 MSL from the downstream edge to about 5 feet upstream of the dam axis, but constructed the upstream portion (out of riprap) to elevation 677 MSL. The riprap had deteriorated to the point that it had 30% to 40% fines (fine gravel to sand size particles), so this made an excellent haul road. It was a nearly black, frangible biotite gneiss/schist. This road was 2 feet above the general excavation platform and remained dry when rainfalls and slurry spills would have turned the platform to deep mud. This excavation platform had a gradual slope to shed water toward the trench where it could be pumped off and disposed of.

The contract did not specify methods for a minimum level of compaction for this platform, so the contractor elected to spread the material as excavated and track-walk with bulldozers to compact it. The higher (elevation 677 feet MSL) upstream portion of the platform, built with riprap and associated deterioration products, was firm and held throughout the job. The downstream portion (at elevation 675 feet MSL), built of clayey, silty random material, was notched in places by runoff during the several heavy rains in the winter and spring.

6.3.2 Guidewalls: After digging a neat rectangular ditch, 2.5 feet deep and over 4 feet wide, centered on the dam axis, the contractor placed his guidewalls on each side of the future wall 26 feet apart in sections of 80 to 120 feet. These walls were 1 foot thick by 2.5 feet deep and were reinforced with 4 #3 and 2 #5 steel rods running the length of the section and rectangular #2 rods bent into stirrups every 2 or 3 feet along the section. The sections were tied to rod ends from the previous section each time before placement. The upper inside edge of the guidewalls were beveled to better guide the excavating clamshell.

6.3.3 Panel Excavation: The wall was designed as a positive cutoff seepage through the basal gravel and sand alluvium immediately above the usually saprolitic bedrock. The location of the alluvium-bedrock interface was the responsibility of Corps inspectors. The "top of bedrock" was defined as "the point where essentially only bedrock is excavated by the excavating bucket". Inspectors considered material to be bedrock when rock structure and fabric could be distinguished regardless of the discoloration or weathering condition. The wall was embedded 5 feet below this top of bedrock, with an option to embed the wall an additional 5 feet if the rock was intensely weathered, at the discretion of the inspector. The inspector could also allow less than 5 feet embedment after the contractor made "a diligent effort" to achieve the required five feet. Where the rock was less weathered the contractor used chisels (12 and 4.5 tons) to break and remove the rock. Panels in the area of Stations 1+00 to 5+15 were generally embedded between 2 and 5 feet due to the high sound rock surfaces. Panels P-75 thru P-80 were embedded 7 to 10 feet due to the extremely weathered nature of the first few feet of saprolitic bedrock encountered (see Plates 9 and 10).

"Kelly Clam" excavators on cranes were used to dig the panels. The clam buckets included two rounded jaws with triangular teeth which interlock as the jaws close. These buckets were attached to a hollow 8" square kelly bar 100 or more feet long which moved freely through a square sleeve attached to the excavating crane. The Kelly cranes seemed more efficient than the free-hanging clams used on the Clemson Lower Diversion Dam. Each Kelly crane operator had a laborer acting as "Kelly-man". He located the proper bite or digging area, set up aiming guides for the crane operaters, watched for equipment wear, and kept records.

The contractor was required to construct panels within a single section (not exceeding 400 feet) at a time. Panels were excavated in 8 to 11 foot long "bites" to full depth. When the panel was fully excavated, 2-foot diameter shoulder pipes (called "end pipes" in the contractor's construction report) were inserted in either end to give a smooth, semi-circular joint along which the next concrete could be placed. Panels were referred to as primary (shoulder pipes in both ends), secondary (no shoulder pipes), and bastard or running (one shoulder pipe). The contractor tried to use primary and secondary panels wherever possible, excavating every other panel in the section, placing them as primaries, then coming back to do the intermediates as secondaries. This was more efficient than using running panels, because it allowed the contractor to handle shoulder pipes in only half of the panels. Between panels P-16 and P-80 odd numbered panels are primary and even ones are secondary. Between P-1 and P-13 even panels are primary, odd ones are secondary. Panels P-14 and P-15 are running panels.

During excavation of Panel 53, the contractor inadvertently excavated an 8-foot bite from the right end of Panel 52 (secondary) thinking that he was excavating the 8-foot bite at the left end of Panel 53 (primary). This required some special handling to correct. The primary panel (No. 53) was extended so that it included the 8-foot bite that had been excavated from the adjacent secondary panel (No. 52). This resulted in a 33-foot primary panel and a 17-foot secondary panel. Three tremie pipes were used to place the concrete.

During the test section, the contractor experimented with excavating 2-foot diameter pilot holes at the edges of bites with a bucket auger. He hoped that this would improve the efficiency of his excavating clamshells by allowing them to take a bigger bite. This proved less productive because the clamshells were usually able to take maximum bites without the holes and because the bucket auger would not penetrate the alluvium.

The test section, originally positioned between Stations 3+50 and 5+00, was moved 100 feet down station to give the contractor an opportunity to experience both hard and soft digging. This worked well in that the panels near Station 4+50 had very little soft saprolite below the alluvium and required difficult chiseling while those near Station 6+00 were soft and allowed digging the 5 foot embedment with the bucket alone. The contractor used a 12-ton chisel and a 4.5-ton chisel, both of which had multiple-rayed star-shaped tips. The chisels were lost in the panels several times during the test section. This was prevented later by keeping a close eye on cable wear. Kelly clams were used to fish the chisels out. Throughout the job, chisel tips and clam buckets sustained considerable wear, necessitating repair. When the job was in its high production phase, one welder was engaged full-time in putting new metal on the chisels and clams.

The contract specifications cautioned the contractor to expect to encounter an old steel raw water pipe which had been left in the embankment during the initial dam construction. It was considered to be near the left side of the entrenched river channel which spanned from dam stations 9+00 to 12+00. He was also advised that remnants of old piping channels might be encountered in the excavations which might cause slurry losses. No firm evidence of these problems was encountered in the actual excavation. However, some anomalies were noted in digging Panel P-34 (Stations 10+75 to 11+00). When the crane was excavating on a bite of the panel at 10+89 to 11+00 at a depth of 40 to 45 feet the bucket struck a hard obstruction which could be moved around. Eventually chunks of concrete and large, coarse-grained pieces of quartz were removed. No steel was noted, but at this elevation the pipe obstruction had to be in the fill. A possible explanation for the encountered concrete could be that a large boulder of quartz included in the fill was moved enough by the excavating bucket in Panel P-35 (primary) to leave a pocket which was filled during the concreting of the panel. This bulb of concrete around the quartz boulder then possibly held it in place making it seem to be a fixed structure of relatively narrow cross section which was free on three sides. No slurry losses which might indicate the presence of old piping channels were experienced.

Logs and tree trunks were also encountered. A tree trunk and 6 to 8 feet of tap root were removed from Panel P-39. Sections of logs or poles were removed from several panels (P-40 to those numbered in the high 20's). Some of the pieces removed were noted to have no bark, and they seemed to be in a horizontal attitude. These were interpreted as fallen tree trunks which had been in the river for some time before incorporation in the alluvium.

The excavated material, accompanied by only a small amount of slurry, was stockpiled downstream in areas on the Seneca River floodplain which had been enclosed by windrowed earth. The contractor also experimented with different ways to transport this material from the excavation area to the stockpiles. The contractor specified removal by truck. However, this would have been difficult because the placement of the wall in the center of the dam left room downstream of the wall only for the excavating cranes. Disposal trucks would have had to have been loaded at the side of the crane and then would have had to cross the wall to get to the haul road.

In the beginning, the contractor tried to slide the excavated material down the ramp. This was facilitated by the fact that the working radius of the kelly cranes was such that it would excavate material from the trench and drop it over the edge of the working platform. The original ramp was the slope downstream of the dam lined with heavy double walled plastic sheeting. This worked poorly because irregularities in the slope slowed the excavated material to a stop before it reached the top of the berm. The contractor had incomplete success with the steel slide. Although the slide, which had a slightly higher incline and a smoother slip surface, got the excavated material to the berm well, it was not built strongly enough and required constant repair of damage sustained as it was moved by crane from panel to panel. Also the tracked front-end loader, which was used to take the material from the berm to the stockpile, deeply rutted and cut-up the berm. Finally, the contractor decided that this approach was too expensive and brought in a Link-Belt LS-518 crane with a 130+ foot boom. This crane could sit on the berm and work all the way from the top of the dam to the stockpiles. It placed a large, heavy-duty skip pan beside the Kelly crane to be filled, then swung the filled pan over the stockpile where it dropped the excavated material. The job was completed using this method.

The panels were required to be vertical to a 1% tolerance. This was to prevent possible windows between The panels. Verticality was checked at quarter-points using the Kelly Clam. A wire was run from a reel on the crane through a pulley on the Kelly bar sleeve and attached to an eyelet welded at the mid-point of the bucket width directly below the pulley. Since the bucket was the same width as the excavation, the wire was at the mid-point of the excavation at depth. Stress which might bow the bar was not allowed during this measurement. The attitude of the taut wire was checked with a plumb bob and measurements from the guidewall edges were taken to assure that the wire was centered to within the proper tolerance. If the angle off vertical exceeded that tolerance, the contractor had to shave the panel wall to bring the panel within vertical. P-57 was typical of those panels which had to be shaved. It was out 4 inches at its base. The shaving took several hours and concrete placed (and therefore the volume of the panel) was 15% higher than estimated. Depths of panels were checked to within 0.1 foot accuracy with a weighted fiberglass survey tape.

6.3.4 Panel Cleaning Prior to Concrete Placement: After excavation, the panels were cleaned. First, the bottom and sides were cleaned thoroughly with the Kelly Clam bucket. If the panel was a primary, shoulder pipes were placed at the ends. Then the bottom was cleaned with an airlift pump and the slurry was desanded. The airlift (powerful enough to lift 3" diameter rocks) was a contract requirement which was strongly contested by the contractor. He maintained that he could clean out the panels very well with only his clam bucket and desander. The airlift used was made of 10" pipe with a 2" diameter inlet which introduced air about 8 feet from the bottom of the pipe. Pressurized air was pumped through a 2" I.D. hose from a 450 CFM compressor into this inlet where it was introduced into the slurry inside the pipe, forming bubbles. As the lighter air bubbles rose and expanded, their buoyancy produced a strong flow of slurry which brought heavier objects to the surface with it. The airlift worked best when a "foot" (built like a rectangular box open at the bottom) was attached to the bottom of the pipe. At the top of the airlift was an elbow and an adapter that "necked" the pipe down from 10" to 4". This decreased the efficiency of the pump and was later replaced with a 10" diameter heavy duty hose which led the slurry into a 6'x 8'x 12' steel reservoir. This airlift was capable of easily lifting equidimensional 3" rocks and much larger slabs of earth. The contractor made a final alteration in the configuration of the airlift because his slurry pumps had inadequate capacity to keep up with the flow produced. He disconnected the 10" heavy duty hose, put a short "U" joint of 10" pipe on the upper end of the airlift, and hung a steel basket with 1"+ mesh under the open end. When he passed a foot over a panel bottom with the air flowing well, most of the solids at the bottom of the panel appeared to have been lifted to the top of the 10" pipe. The slurry, along with gravel, sand, and excavation cuttings, was passed from the open ended "U" joint into the basket where large solids were filtered out. The slurry then passed back into the panel. After the final alteration, the contractor agreed that the airlift was very efficient and intended to use it on similar jobs in the future.

After cleaning with the clam bucket and the airlift, the slurry was desanded. The slurry was actually exchanged with clean slurry from the slurry ponds. The sediment-laden slurry from the excavated panel was pumped from the bottom while sediment free slurry was added at the top of the panel. The slurry that was pumped from the panel was run through a Caviem-type desander where it passed through screens and a small cyclonic cone to remove particulates. This device was capable of extracting fine sand and some of the silt from the slurry.

If a panel had been taken through this entire cleaning sequence and could not be filled with concrete within two hours, the contractor had to repeat the process. In the case of secondary (and running) panels, the exposed joints had to be carefully rescraped with the rounded clam bucket.

6.3.5 Concrete Placement: Concrete for the project was supplied by the Metromont, Inc. Newry, South Carolina plant. It was transit-mixed and delivered in 10-cubic yard, front discharge trucks. These trucks made placement easier and safer, because the drivers were able to see the entire working area while they maneuvered. The concrete was a 3000 PSI (28-day strength) mix with maximum 3/4-inch aggregate. The slump requirement was 7.5

inches $\pm$ 1.5 inches. Entrained air was to be 5% $\pm$ 1.5%. The contractor's concrete mix is summarized in Table 6-1 at the end of this section.

Concrete was usually placed an hour or so after completion of desanding. Tremie pipes (10" diameter) were placed to within 1' of the panel bottom, less than 14 feet apart to allow not more than 7' of lateral travel for the concrete during placement. The tremies terminated at their upper ends in funnels about 4' in diameter. They were partially blocked by screens which would not pass particles over 3" in diameter. These screens prevented any large clumps of concrete from entering and plugging the tremie. In the early placements, there were concrete balls up to 10" in diameter in the trucks. Examination of these balls revealed that all ingredients were present and well mixed with the exception of water. During this period, slump of the concrete was also varying widely. The solution tried was to mix the concrete balls with part of the concrete for a short time before adding the remaining water. This also seemed to make the concrete quality more consistent from truck to truck thoughout the placement. Most production panels were placed using tremies. However, Panel 41 and the extra bite upstream of the stuck shoulder pipe (described in detail later in this section) required three tremies for placement. Placement was made from two concrete trucks at a time in all panels.

A "go-devil" was placed in the tremie to prevent premature contact between the concrete and slurry. A go-devil was defined as "a retrievable travelling plug". Pneumatic plugs were allowed, but the internal pressure had to equal or exceed the ambient pressure at the bottom of the tremie. An incompressible plug was desired to prevent flattening and subsequent mixing of concrete and slurry in the tremie. The contractor experimented with several types of go-devils including foam filled basketballs and short lengths of 8" PVC pipe with ends blocked with 1/4 " thick rubber membranes held in place with thin metal plates, and nuts and bolts. Although these were incompressable and free-floated with near 40% of their volume out of the slurry, they proved nearly irretrievable. The final solution was to use sawn lengths (usually 5" to 8" long) of a 6" to 8" diameter wooden pole with stiff, 10" diameter rubber membranes nailed firmly to either end. Although less than 25% of these go devils returned to the slurry surface, they were inexpensive to produce and if incorporated, did not span the 2-foot thick concrete panel.

Concrete was placed as rapidly as possible. Generally, the rate of placement was regulated by the capacity of the contractor's electrical slurry return pumps. These pumps were hung some 2 to 3 feet below the top of the guide wall and moved slurry up through the panel. When the slurry threatened to spill over, the contractor slowed placement to allow the pumps to catch up. All the slurry was pumped to the ponds except the last 5 to 10 feet which had been flocculated, thickened, and contaminated by contact with the concrete. This material was placed with the excavated material in the stockpile areas on the Seneca floodplain just beyond the toe of the downstream berm.

In concrete placement, the first concrete came through the tremie and flowed into the excavation, encountering slurry and becoming a frothy, contaminated mixture which was easily distinguished from the good, uncontaminated concrete just below. This material rode up on the concrete as it was placed to the top of the panel. The (rare) appearance of wall material in this frothy contamination on top of good concrete was considered to indicate possible caving during or after desanding. Another check on caving (also overexcavation) was the comparison of actual cubic yards of concrete placed versus the elevation reached for each pair of concrete trucks. At the end of a placement, the contractor overflowed the material until a bulb of good concrete was thrust above the top of the guidewall. A front-end loader was then used to level the top of the panel by back-dragging.

Two-foot diameter shoulder pipes were inserted in the ends of primary and running panels to the full depth of the panel prior to cleaning the panel and concrete placement. These had to be withdrawn after the concrete had time to set. The contractor used special hydraulic jacks with a circular gripper to do this. He would begin gradual movement of the pipes to prevent a tight bond as the concrete at depth reached its initial set. When the concrete at the surface had also reached initial set he would increase the rate of withdrawal. It took several hours to totally withdraw these pipes. Overall, the method worked well, but there were some problems encountered.

The contractor did not withdraw the shoulder pipes quickly enough in Panels P-47 and P-41. The pipe was eventually withdrawn from P-47 using a vibratory extractor (normally used to withdraw piling), but even this machine could not remove the pipe from P-41. The guidewall was broken out in front of this pipe and an 8-foot bite was excavated, extending Panel P-42. The concrete placement (Panel 42 plus a single upstream bite at the Panel 41 -42 juncture) was made monolithically using three tremie pipes. After placement, the pipe (pre-cut and tack-welded) was broken off below the top of Panel P-42. Later, water was pumped out to within 5 feet of the bottom of the pipe and it was filled with concrete.

The shoulder pipe located at the east end of Panel 23 broke while it was being removed; however, all of the pipe was recovered (see Photos 50 and 51, Appendix A). The adjacent secondary panel (No. 24) was immediately excavated to check for any damage or irregularities in the joint.

6.3.6 <u>Concrete Quality:</u> After the concrete had a minimum of seven days to cure, some of the panels were sampled to assure quality (see Table 6-2 at the end of this section). Logs of these borings may be found in Appendix C of this report. HQ coring equipment was used to sample the concrete. The subcontractor who drilled the production panels was required to drill the last run above foundation with a face discharge bit to improve the chance of retrieving samples of the concrete/foundation interface and had some success in doing this. The major problem in doing the work was staying inside the 2-foot thick panel for its entire length. The subcontractor, who drilled the holes quickly at high speeds and down-pressures, was able to do this in less than half the holes he drilled. Savannah District drillers, who sampled the test section, were able to stay within the panel in 7 of 8 holes using 4x5 1/2" equipment. The larger equipment undoubtedly helped the district driller's accuracy. In addition, the willingness to set up carefully and drill at a slow rate was important in achieving their success.

Results from this drilling were generally excellent. The concrete was dense and durable. Occasional segregation of aggregate was seen, but even this concrete was very strong. At the upper elevations were small vermiform areas where cement was weak or absent. These "wormholes" were considered to be places where fugitive bleed water worked its way up amd out of the concrete. When panels placed with concrete at higher slumps were completed, this water could be seen coming from the concrete, occasionally bringing small particles with it.

The concrete/foundation interface was recovered in several of the panels drilled. Most commonly there would be 1 or 3 tenths of a foot of reddish brown flocculated slurry which was plastic and felt greasy between the good concrete and bedrock. Often the bedrock could not be crushed in the hand. One of the holes drilled by the district crew penetrated the joint between two test panels. This joint was a very thin (perhaps one-sixteenth of an inch), slightly circular seam of bentonite between two very well-fitting wedges of core.

After the coring was completed, two of the holes were used in inclinometer installation. The rest were filled with neat cement grout (less than 1:1 water/cement ratio by volume). Application of grout was repeated several times to fill the holes.

Concrete strength tests were conducted at 7 days and 28 days. The average strength at 7 days for all panels was 2859 psi and the average strength at 28 days was 4075 psi. Results for each panel may be found in Table 6-3.

6.4 Construction Procedures for Drainage System: The Clemson Upper Dam rehabilitation design included a drainage system downstream of the cutoff wall. The concrete membrane wall was designed to cutoff seepage through the alluvium under the Seneca River floodplain and 5 feet of "bedrock" below that. Other seepage (through deeper saprolite) and groundwater would be collected immediately downstream of the Clemson Upper Dam by an underground drainage system. This system was designed and constructed to furnish an easy path for excess water into the artificial oxbow lake (created by the routing of Lake Hartwell through the original 850 foot diversion channel) and then to the Lower Diversion Dam pumping station. This also should help to keep the downstream area neat and easy to monitor under the Corps' routine dam inspection system.

Before construction of the cutoff wall, most of the area from the toe of the berm to S.C. Highway 93 was wet. Downstream of the center of the dam was a stagnant remnant of the old Seneca River. Near the left abutment, two drainage ditches (wet during normal dry weather) parallel to the axis of the dam emptied into the old Seneca channel and there was a fairly large swampy area downstream of the lower ditch. The area downstream of the right abutment was somewhat dryer, but there was water running in the ditch system also. A 150 foot collection ditch ran along the toe of the dam. Another ditch ran from the center of this collection ditch bank to the toe of the South Carolina Highway 93 fill, where it turned at a right angle and then ran into the channel. There were also small swampy areas at the toe of the flattened knob (the right abutment) and between the collection ditch and the old channel.

The designer intended to improve drainage in the half of the downstream area near the left abutment. To do this, he would channel all surface and subsurface water to a central collection point from which the water would be carried under South Carolina Highway 93, then into the existing storm drainage system. For subsurface drainage he specified construction of a two-stage filter in the old channel, filling of the two drainage ditches with sand, and placement of fill over the entire area. A low swale was to be constructed in the fill placed over the subsurface drain to move surface water. The central collection point was to be at the approximate center of the channel against Highway 93 fill. From there, a 36-inch reinforced concrete pipe was to be jacked through the fill (parallel to and about 20 feet from an existing pipe and on the other side of Highway 93) and be tied into the existing storm drainage.

There was no provision for alteration of the area downstream of the right side of the dam in the original contract. However, during drain system construction, the contract was modified to require the contract to level this side of the downstream area and slope it to drain. This would allow easy monitoring of the embankment in future years.

No work was allowed in the upstream area until the cutoff wall was completed. After the area was cleared and grubbed, the contractor was to drain the Seneca River channel, excavate the soft material to a firm bottom (which would be inspected and approved by Corps personnel), and fill the channel with a two-stage filter system. The system was to be comprised of two perforated 12" diameter, 200± foot long, PVC pipes wrapped with coarse filter which was then wrapped with fine filter (see gradations on Table 6-4 at the end of this section). The drainage ditches downstream of the left abutment were to be cleaned and filled with sand. The entire system was to be filled to within 1 foot of the final design surface, with material from the cutoff wall excavation compacted sufficiently to allow a pickup truck to traverse the fill without rutting or pumping. The top 1 foot was constructed of select off-site borrow compacted to 95% of standard effort.

At first, the contractor tried to drain the Seneca River channel with one 6-inch pump. When the pond surface was near an elevation of 620 feet MSL, this pump was able to lower the water level approximately 1 inch per hour. However, as the surface moved below the groundwater table (about elevation 616 or 617) the pump had less effect. Equilibrium was reached well before the water level got to the channel bottom (about elevation 610 MSL). A second pump (3-inch) was added when the contractor realized that the first was inadequate. This lowered the water level further, but not to the point where the contractor could work in the dry. After some argument that draining the channel as visualized in the design was impossible and being denied permission to place sand filter through the river water, he proposed that he be allowed to work with a low water level, chasing the sloppy material and water mix toward the lowest part of the pond where it could be removed with a dragline. He intended to do this with the earth pile available at the southwest edge of the channel. He was allowed to try this in the presence of construction and design personnel, and the method was approved.

The final procedure was to push fill with a bulldozer slowly into the pond at one edge, moving soft material toward the deeper part where a dragline picked it up and loaded it onto the trucks. After an appreciable area had been filled, the contractor used a backhoe to remove fill from the edge of the pond where the process started and to pile it where the dozer could move it to the leading edge of the fill and use it to chase muck again. An effort was made to push out the leading edge and then fill-in immediately behind it before the water and muck could break back into the low spot. This prevented excessive contamination of good fill with the organic muck. The backhoe excavated fill down to firm bottom, removing any soft bottom material as well. The foundation material upon which filter sand was placed was a clean, gray, fine sand which seemed to pass water very well. During this process, springs and boils arose from the bottom and occasionally from the fill itself, but the water was relatively clear and the boils would subside if the water level reached 1 or 2 feet above them. Small springs and seeps were also seen in the rock revetment against the berm toe at the head of the channel. In all cases, the foundation material was clearly visible before any water broke through and any filter material that was placed in the wet was placed in puddles of clean water.

This procedure was followed to place the lower layers of sand in the the filter area. The backhoe excavated the fill in broad strips migrating from the southwestern edge of the channel to the northeastern edge where the dragline worked. The foundation was inspected and sand filter placed in the same manner. The sand was placed in 12" lifts (with only traffic compaction) in rows 8 to 10 feet wide with a tracked front-end loader. Care was taken to assure that sand as placed was tied into previously placed sand at the same level. The contractor began the work with a river sand which was the coarse end of the required gradation. Two or three weeks into the work, he switched to a finer sand (meeting S.C. Highway Department Classification FA-11) which transmitted less water, but was adequate for drainage.

After the lower layer of sand was placed to the correct level, the contractor began coarse filter placement. The contract drawings showed a 2 foot thick blanket of sand which bulged above and below the 12" pipe to give a 1-foot minimum cover around the pipe. To simplify his placement procedures, the contractor excavated a ditch in the top of the sand layer to 1 foot below the pipe grade, filled it with the coarse filter, placed the pipe on top, and then placed 2+ feet of coarse filter on top of that. This changed the geometry to place the invert of the pipe close to the bottom of the main coarse blanket (which was slightly thicker than designed) with a minimum 1 foot thick cover around the pipe. He then completed the upper sand layer as designed.

In the original design, the existing ditches were to be filled with sand. After on-site excavation, the ditch closest to the berm toe was given a coarse filter core wrapped with sand from the channel edge to just upstream of the last relief well followed by another 100 feet of sand only. The ditch closest to S.C. Highway 93 was also altered to have a coarse core for a short distance. Due to the amount of groundwater encountered, auxillary ditches were dug to the south and east of this ditch and connecting with it (see Plate 24) in an attempt to get the area dry enough to compact the fill as required. These auxillary ditches were filled with sand. All the above ditches were excavated to a clean gray sand like that present in the Seneca channel, except the small "T" shaped ditch which had quartz sand mixed with white clay at its bottom.

After these ditches were dug or cleaned and filled, the material excavated from the cutoff wall was placed over them and compacted to build a surface sloping from elevation 625 upstream and downstream to an elevation of 623 feet in the central swale. Most of this area received 1 to 3 feet of fill, followed by 1 foot of select off-site borrow. After placement of the local fill, the contractor had cut out boggy patches in several places on the northeast side of the channel and replaced them with good dry material. Filter material in the channel itself was built to within 1 foot of final grade, then received select borrow. The area southwest of the Seneca channel was graded evenly and sloped to drain. On both sides of the channel, the local fill was compacted sufficiently to bear a full-sized pickup truck without rutting or pumping. Then the upper foot was off-site borrow which was compacted to 95% of standard effort.

The ditches around the graded area, southwest of the channel, were improved as much as the available drop in elevation would allow and the 15" sewer pipe under the central road was replaced with 30" R.C. pipe. The two-stage drain in the Seneca channel was continued to within 10 to 30 feet of S.C. Highway 93 fill, where a lining of filter cloth and hand-placed riprap were used to allow seepage from the sand without erosion. The perforated PVC pipes from the coarse filter core were extended through the riprap to allow outflow into this collection area.

Since the existing sewer pipe under the Highway 93 fill was not carrying water satisfactorily (it was partially filled with logs and debris), a new one was placed. The contract called for 36" R.C. pipe to be jacked under the road fill, 20 feet NE of the old pipe. This pipe had to be moved to a position 20 feet further when it was discovered that the old pipe was curved to the northeast and that the openings between joints resulting from this curvature had not been caulked. This movement also entailed extension of the collection basin (on the dam side of Highway 93), a longer connection into the existing drain system, and partial rebuilding of the connection box. This work was done by modification under the "changed site condition" general provision.

To get the new pipe under S.C. Highway 93, the contractor excavated a steep face into the existing road fill, shored up around the pipe location, and set his jacking frame in the excavation. Instead of jacking the reinforced concrete pipe itself, he jacked a 48" steel pipe and inserted the R.C. pipe. After the R.C. pipe was positioned correctly, the contractor filled the annulus between the two pipes with sanded cement grout at either end. He then constructed the rest of the sewer system addition, including a new manhole, as required.

<u>TABLE 6-1</u>

<u>CONTRACTOR'S CONCRETE MIX</u>

Cement, Type I, Blue Circle	500 lbs.
Fly Ash, Monier, Plant Bowen	120 lbs.
ASTM, C-33 #6, Coarse Aggregate, Vulcan, Liberty Plant	1540 lbs.
ASTM, C-33 Fine Aggregate, Camden, Becker Sand and Gravel	1280 lbs. S.S.D.
Water	325 $\pm$
Air Content, W.R. Grace, Airlon 2-3 oz./yd.	5.0 $\pm$ 1.5%
Slump	7.5 $\pm$ 1.5"
Type A Admix, ASTM 494, Pozzolith 300 N	18 oz.
Type D Admix, ASTM 494, Pozzolith 300 R	18 oz.
W/C (Section A, 7.1.2)	0.49
7 day test, average of 3 (test without retarder)	3075
28 day test, average of 3 (test without retarder)	3915

TABLE 6-2

LIST OF CONCRETE QUALITY CONTROL CORE HOLES

PANEL NO.	STATION	HOLE NO.	DEPTH (FT)
T1	4+79	T-1-1	84.5
	4+82	T-1-2	84.8
T4	5+34	T-4-1	88.4
T5	5+90.5	T-5-1	86.5
T6	4+95.5	T-6-1	84.0
T7	5+80.5	T-7-1	62.2
	5+82	T-7-2	89.7
T10	4+73	T-10-1	85.5
3	1+62	3	29.3
9	3+21	9	59.2
26	8+94	26	58.6
	8+90	26A	89.2
30	9+85	30	87.1
	9+95	30A	57.7
	9+92	30B	67.5
	9+93	30C	62.4
	9+87	30D	80.7
	9+83	30E	69.0
	9+81	30F	74.1
	9+89	30G	89.3
	9+82	30H	83.7
39	12+12	39	39.9
	12+11	39A	39.1
	12+11	39B	59.5
	12+11	39C	14.6
	12+20	39D	34.3
	12+10	39E	83.7
42	12+75	42	92.2
53	15+53	53	98.0

TABLE 6-2 (Continued)

LIST OF CONCRETE QUALITY CONTROL CORE HOLES

PANEL NO.	STATION	HOLE NO.	DEPTH (FT)
57	16+63	57	98.4
	16+64	57A	90.8
60	17+37.5	60	98.1

TABLE 6-3

CONCRETE STRENGTH TEST RESULTS

PANEL NO.	RESULTS AT 7 DAYS (psi)	RESULTS AT 28 DAYS (psi)
1	2830	4095
2	2760	4175
3	3010	4170
4	2760	3875
5	2090	3465
6	2690	4035
7	2510	3920
8	3310	4635
9	2900	4115
10	3790	5095
11	2900	4315
12	3710	4670
13	2900	4475
14	3460	4620
15	3340	4510
16	3250	4230
17	3310	4660
18	3490	4875
19	3010	4680
20	3010	4220
21	2340	3625
22	2920	4150
23	2460	4035
24	2230	3370
25	2670	4285
26	2550	3825
27	3080	4530
28	3010	4140
29	2530	3975
30	2620	4330
31	2510	4095
32	2780	4175
33	2410	3400
34	2550	3595
35	3150	4395
36	3010	4085
37	2370	3925
38	2790	4225
39	2510	3875
40	2650	3505
41	2550	4015

TABLE 6-3 (Continued)

CONCRETE STRENGTH TEST RESULTS

PANEL NO.	RESULTS AT 7 DAYS (psi)	RESULTS AT 28 DAYS (psi)
42	2640	4455
43	2950	4525
44	2830	3970
45	2620	4085
46	2720	4060
47	2740	4065
48	2550	3895
49	2780	3955
50	2720	4090
51	3360	4465
52	2460	3710
53	2720	4060
54	2530	3830
55	2850	4130
56	3135	4295
57	2340	3640
58	3500	4610
59	2720	4190
60	3180	4385
61	3250	4140
62	3540	4590
63	2760	4310
64	3110	4475
65	2690	4065
66	3500	4370
67	2790	3870
68	2870	3695
69	2760	4085
70	3380	4380
71	3220	3605
72	2790	4120
73	2830	3840
74	2620	4015
75	2510	3610
76	2810	4240
77	3010	3840
78	2900	3940
79	2690	4145
80	2650	4060
AVERAGE	2859	4075

TABLE 6-4

GRADATIONS FOR "FINE" FILTER AND "COARSE" FILTER PLACED AROUND 12" PVC PIPE

SAND FILTER

Sieve Size U.S. Standard Square Mesh	Percent By Weight Passing
3/8 inch	100
No. 4	90-100
No. 8	75-100
No. 16	50-95
No. 30	28-75
No. 50	10-30
No. 100	0-5
No. 200	0-3

GRAVEL FILTER

Sieve Size U.S. Standard Square Mesh	Percent By Weight Passing
3/4 inch	100
1/2 inch	80-100
3/8 inch	45-100
No. 4	15-75
No. 8	2-20
No. 16	0-7
No. 100	0-3

7. INVESTIGATIONS DURING CONSTRUCTION

7.1 Observation of Excavated Material: The material that was excavated during cutoff wall construction was comprised of embankment fill, alluvial deposits, saprolite, and crystalline rock. The lithology of these materials is described in Sections 4.2.2 and 4.2.3 of this report. Photo 42 of Appendix A shows some typical rock that was recovered. Much of the rock was saprolitic and highly weathered. Inspectors at the site considered material to be bedrock when rock structure could be distinguished regardless of any discoloration or weathering.

Logs and tree trunks were also recovered in some panels. A tree trunk and 6 to 8 feet of tap root were found in Panel P-39. In addition, chunks of concrete and large, coarse grained pieces of quartz were recovered during excavation of Panel P-34 (see Section 6.3.3).

7.2 Concrete Quality Control Borings: Quality control core borings were done on test and production panels. A total of 8 borings were done in the test panels and 24 holes were drilled into the production panels (see Table 6-2). Logs of these borings may be found in Appendix C. Concrete quality is discussed in Section 6.3.6.

8. INSTRUMENTATION

8.1 Installation of "New" Piezometers: Nine piezometers (PC-201, PE-201, PF-201, PC-205, PE-205, PF-205, PC-208, PE-208, and PF-208) were located on or near the centerline of the dam prior to cutoff wall construction. Due to excavation of the top 5 feet of the dam and the construction of the cutoff wall at their location, these piezometers had to be abandoned and redrilled upstream.

The "new" piezometers were drilled during December of 1983 and in January and February of 1984. They are located 28.5 to 30.0 feet upstream of the dam centerline and were numbered PC-201A, PE-201A, PF-201A, PC-205A, PE-205A, PF-205A, PC-208A, PE-208A, and PF-208A (see Plates 2 and 3). Each piezometer consisted of 3/4" PVC riser pipe and a 2-foot long well screen. Logs of these borings may be found in Appendix B, Volume II of this report.

8.2 Comparison of Piezometric Surfaces Before and After Cutoff Wall Construction: Plates 11 thru 16 show piezometric surfaces before and after installation of the cutoff wall. The readings before cutoff wall construction were taken on May 5, 1982, and the readings after the rehabilitation were taken on April 9, 1984.

Plates 11 and 12 show piezometeric surface contours from readings of piezometers installed in embankment material. Comparison of these plates shows a decrease in elevation of about 9 feet in the western portion of the downstream toe area (vicinity of PC-207) and a decrease of 2 to 3 feet in the central and eastern downstream toe area. In the western area, this resulted in the new piezometric surface being about 9 feet below the ground surface after the cutoff wall had been in place approximately 2 years. Before construction, this surface was at about an elevation of 627 feet and the ground elevation was also at about 627 feet.

Plates 13 and 14 show the elevation of the piezometric surface resulting from screens set at or just above the contact between embankment material and the dam's foundation rock. Plate 13 shows the surface before installation of the cutoff wall and Plate 14 shows the surface afterwards. The plates show that the cutoff wall had considerable influence on the piezometric surface levels in the eastern and western portions of the downstream toe area, but did not affect the surface much in the central portion. The elevation of the piezometric surface in the western area (vicinity of UAP-1) was lowered approximately 6 feet and readings show a decrease of about 8 feet in the area around PC-209.

Plates 15 and 16 show that the hydrologic conditions of the foundation rock were similarly affected. In the western part of the downstream area (near PF-207) the piezometric surface was approximately 6 feet lower with the cutoff wall in place. The elevation of the piezometric surface was lowered approximately 3 feet in the central portion of the toe area (vicinity of PF-203) and about 7 feet in the eastern part of the downstream toe area.

8.3 Inclinometers: Plots of inclinometer readings may be found in Appendix E in Volume II. Before construction of the cutoff wall, movement of the embankment was monitored by two inclinometers installed 55 feet downstream at stations 11+00 and 16+00. After construction of the wall, two additional inclinometers (3U and 4U) were put in the wall at stations 9+90 and 15+53 (see Plates 2 and 3).

Inclinometers 1U and 2U were read on October 25, 1983, during the start-up of construction activities. The most recent reading was taken on November 22, 1988. During this time period, inclinometer 1U indicates approximately 1.5 inches of movement towards the northeast and inclinometer 2U plots show movement of about 2.0 inches towards the southeast. The initial reading of inclinometer 3U was on February 13, 1985. Readings since that date show movement of about 5/8 of an inch towards the northwest. Inclinometer 4U has been read since November 8, 1984, and indicates movement of about 3/4 of an inch towards the southwest. Readings to date are within acceptable tolerances. Additional readings will be made periodically to assess future movement.

9. SITE RESTORATION

9.1 Embankment Reconstruction: After construction of the concrete cutoff wall, the material cut from the top of the dam and used for the working platform was replaced. The contractor cleaned off the surface, cut down to just below the guidewall on the downstream side (taking out any contaminated pockets), and then rebuilt the top of the dike using the ML-MH material from the downstream platform plus a small amount of off-site borrow. A few feet of fill immediately upstream of the dam axis was placed on the riprap (because the layer was thicker than expected). The riprap had sufficient fines filling-in between the larger stones to prevent loss of fill. The excavated surface, at approximately elevation 675 feet, was scarified and moistened and then fill placed in 6" layers. The moisture was blended in with a disc harrow and compacted with a Caterpiller 815 self-propelled roller with rectangular plug feet (not pads) to 95% or better of standard effort. Rebuilding of the dike was completed by July 31, 1984.

The contractor had more than enough riprap to rebuild the 4 foot riprap layer as designed. He reprocessed the existing riprap, pushing it upstream with a bulldozer and lifting the boulder-size and larger rocks (with a few fines) into place with a backhoe. He then reworked the material with the backhoe to get a reasonably even distribution of sizes. Any greatly oversized stones were pushed below the lake level (elevation of 660 feet).

9.2 Final Site Work in the Downstream Area: Final work in the downstream toe area included additional clearing and grubbing, mucking and filling-in the swampy area in the central portion of the downstream area, constructing drainage ditches, placement of a drain pipe under SC Highway 93, and final grading of the entire area. During September of 1984, topsoil was placed and the area was grassed.

10. POSSIBLE FUTURE PROBLEMS

10.1 Conditions That Could Produce Problems: The problems encountered during construction and any modifications that were made in building the cutoff wall are described in this report. The most significant trouble occurred during placement of concrete in Panel 41 when a shoulder pipe could not be removed (see Section 6.3.5). Also, modifications in panel lengths had to be made due to excavation errors in Panels 52 and 53 (see Section 6.3.3). None of the problems that occurred have had any adverse effects on the dam and the cutoff wall seems to be functioning well (see Section 8.2). No future problems are expected.

10.2 Recommended Observations: All instrumentation at the site should be monitored on a regular basis. The embankment surface and the entire downstream toe area should also be inspected periodically. The frequency of these obsrevations and the procedures followed should be in accordance with the current publication of DR 385-1-6.

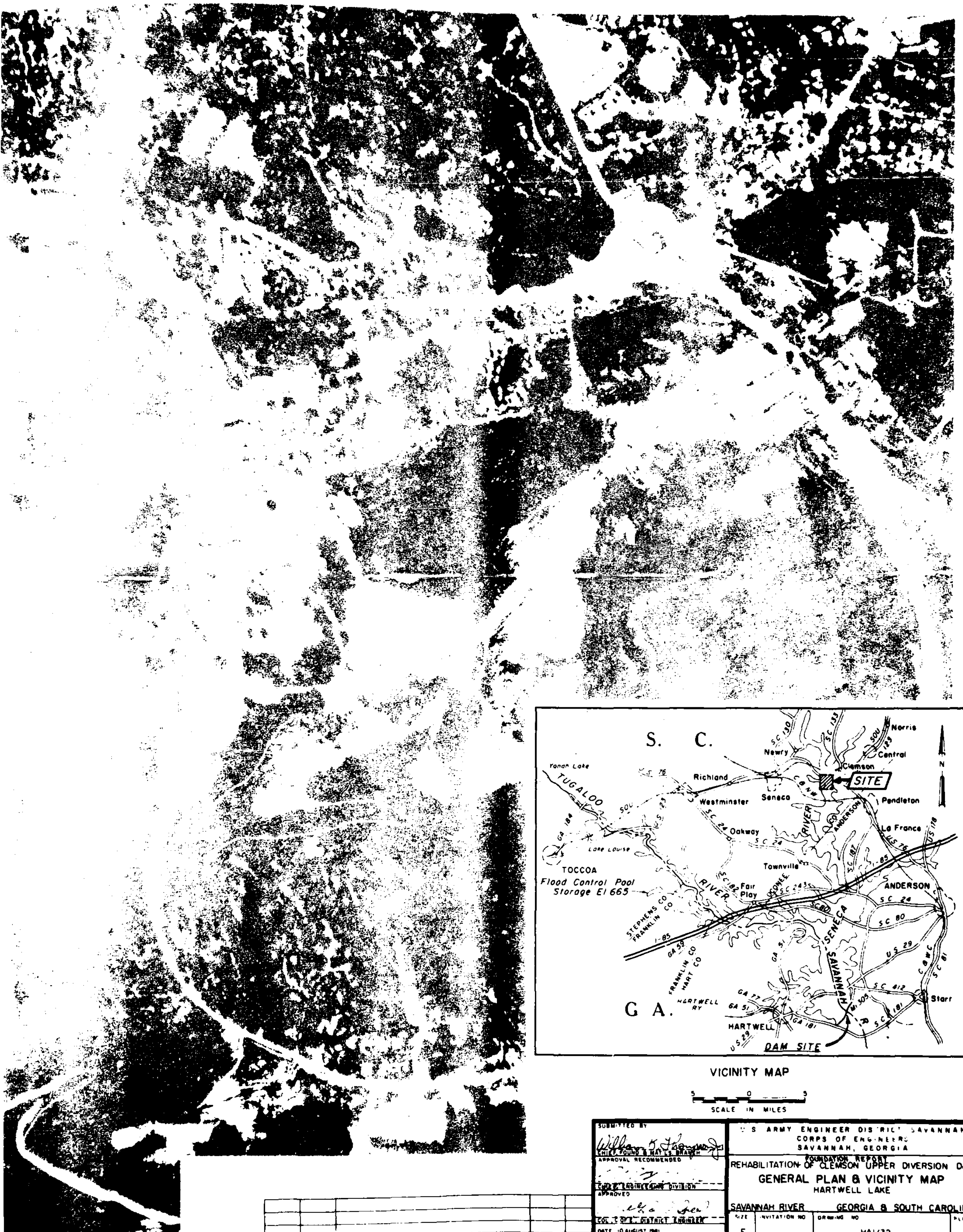
11. REFERENCES

Soletanche and Rodio, Inc., 1984, Rehabilitation of Clemson Upper Diversion Dam, Hartwell Lake, Georgia and South Carolina, Contract No. DACW21-83-C-0066, Concrete Cutoff Wall: Construction Report, McLean, Virginia.

U.S. Army Corps of Engineers, 1982, Rehabilitation of Clemson Upper Diversion Dam: Design Memorandum 33, Savannah District, Savannah, Georgia

PLATES

A



VICINITY MAP

5 0 5

SCALE IN MILES

SUBMITTED BY	U S ARMY ENGINEER DISTRICT SAVANNAH CORPS OF ENGINEERS SAVANNAH, GEORGIA
William T. Thompson Jr. CHIEF, FOUND & MAT'LS BRANCH	FOUNDATION REPORT ~~REHABILITATION~~ OF CLEMSON UPPER DIVERSION DAM GENERAL PLAN & VICINITY MAP HARTWELL LAKE
APPROVAL RECOMMENDED CHIEF, ENGINEERING DIVISION	SAVANNAH RIVER GEORGIA & SOUTH CAROLINA
APPROVED COL, C OF E, DISTRICT ENGINEER	SIZE: F · INVITATION NO: · DRAWING NO: HA1/32 · PLATE: 1
DATE 10 AUGUST 1981	SCALE AS SHOWN · SHEET 1

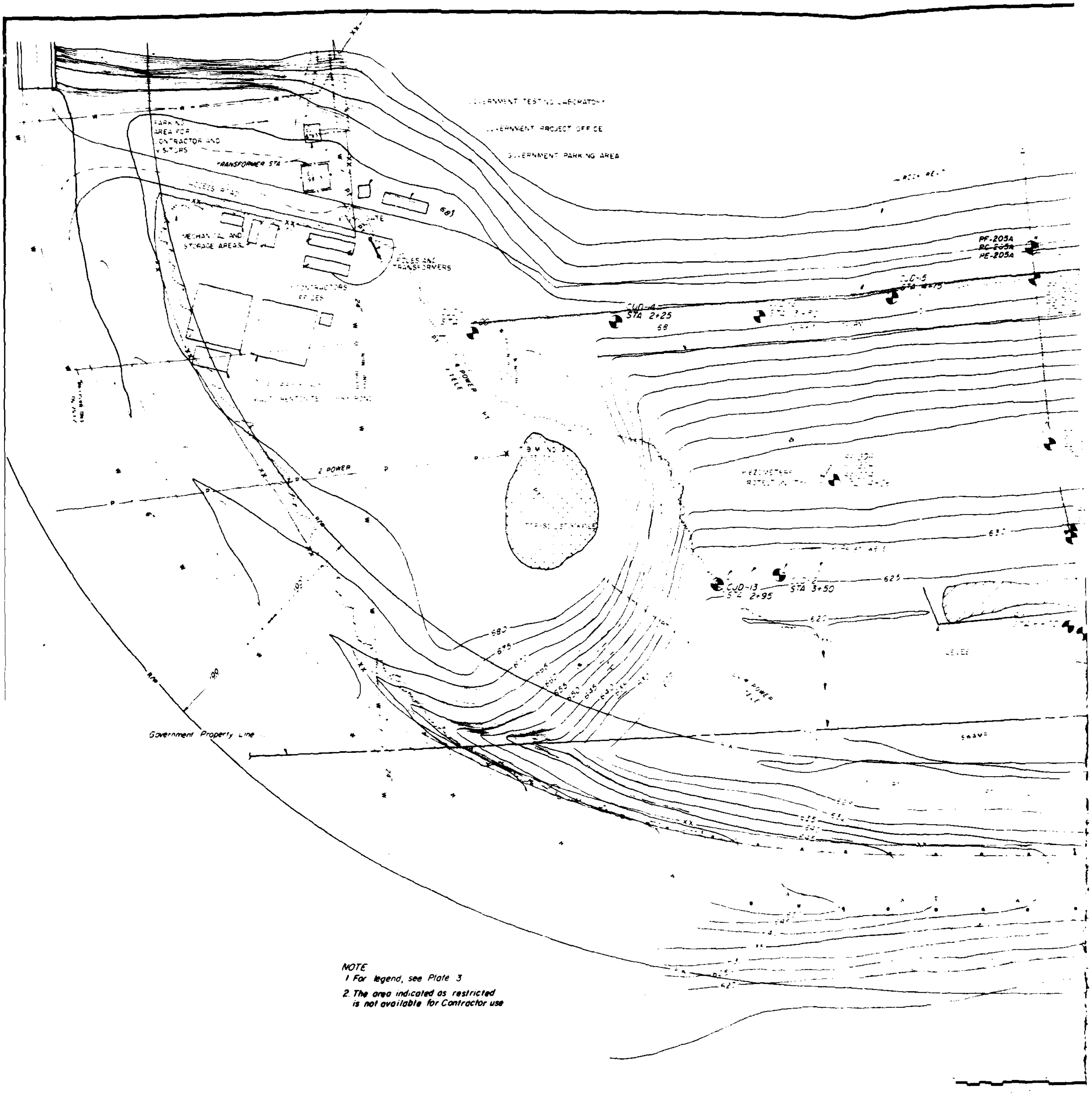
SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

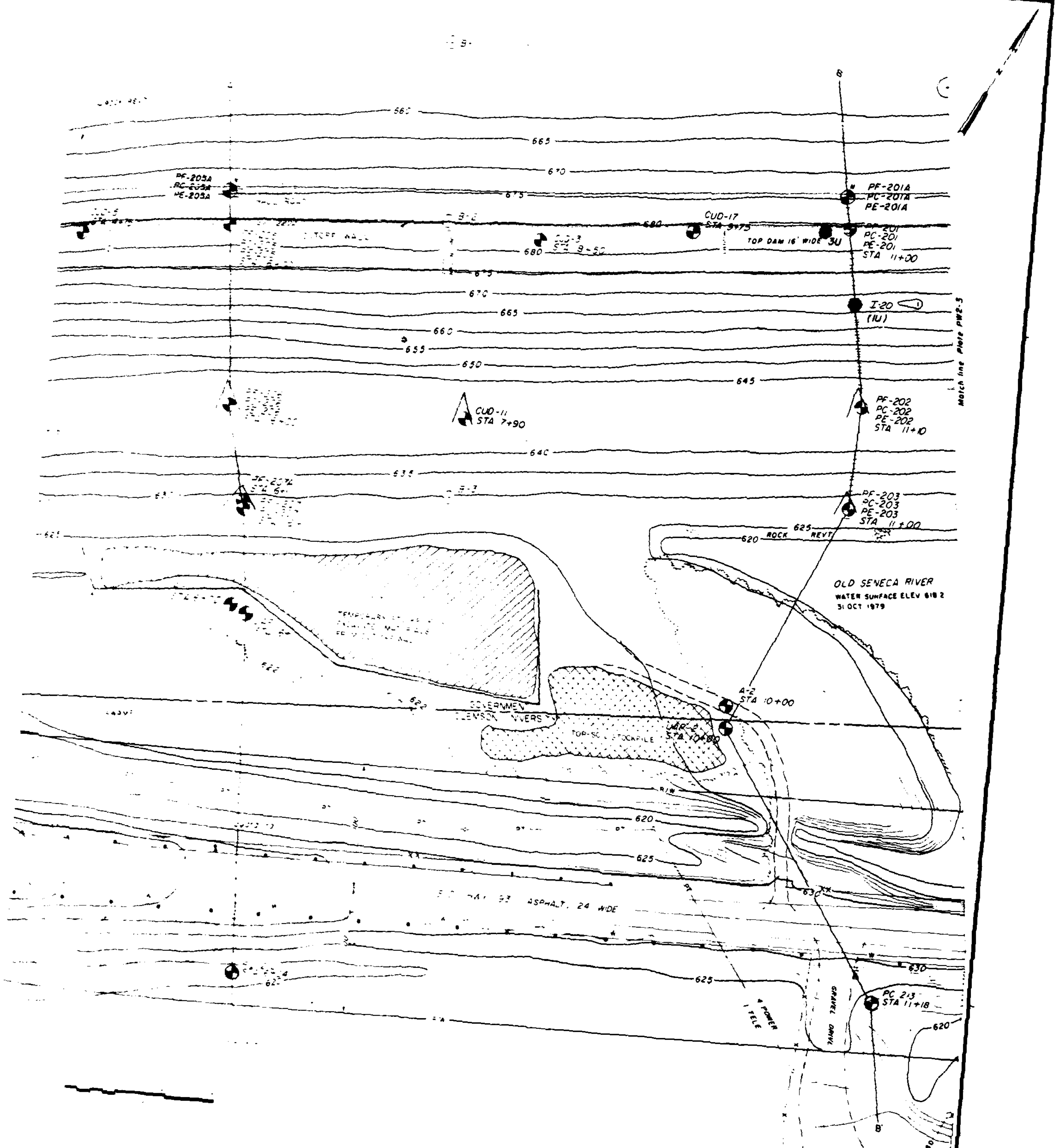
(1)

1

p



NOTE
1. For legend, see Plate 3
2. The area indicated as restricted is not available for Contractor use



PLANE TABLE SHEET, HARTWELL NO. 48-1,2
SURVEYED OCTOBER 1979
UPPER DIVERSION DAM

HORIZ. & VERT. CONTROL DATA
T.B.M. NO. 3, EL. 681.91, 1-20P NAIL IN POWER POLE

SYMBOL	ZONE	DESCRIPTION	DATE	BY
1		REVISED IN ACCORDANCE WITH AMENDMENT NO. 0004	23 JUNE 83	JSP

REVISIONS

U. S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

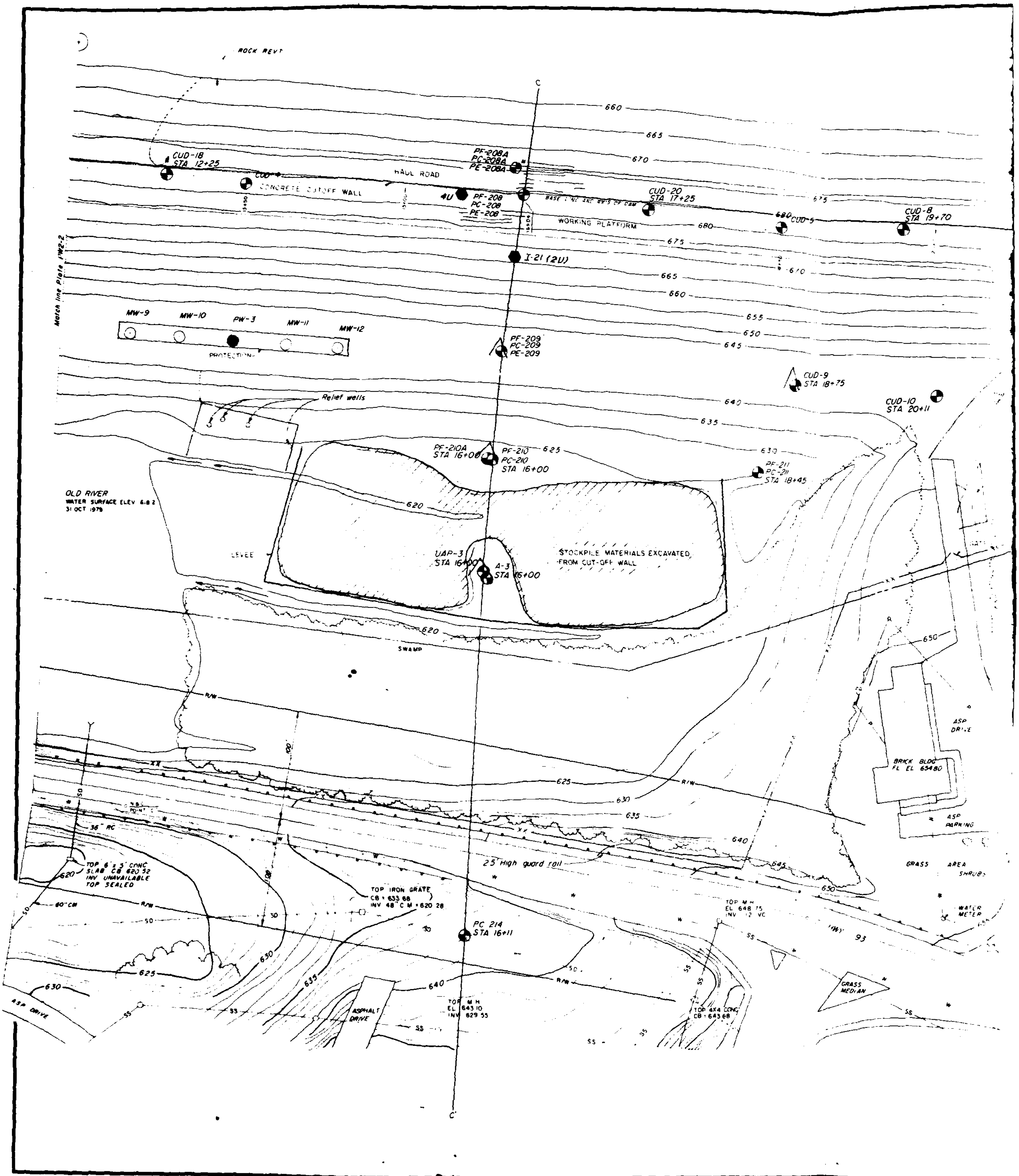
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
BORING PLAN AND SITE UTILIZATION
SHEET 1 OF 2

SAVANNAH RIVER HARTWELL LAKE GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO.	FILE NO.	PLATE
F	DACW21-83-B-0011	HA21C-046	2
SCALE 1"=40'		SHEET 2	

19

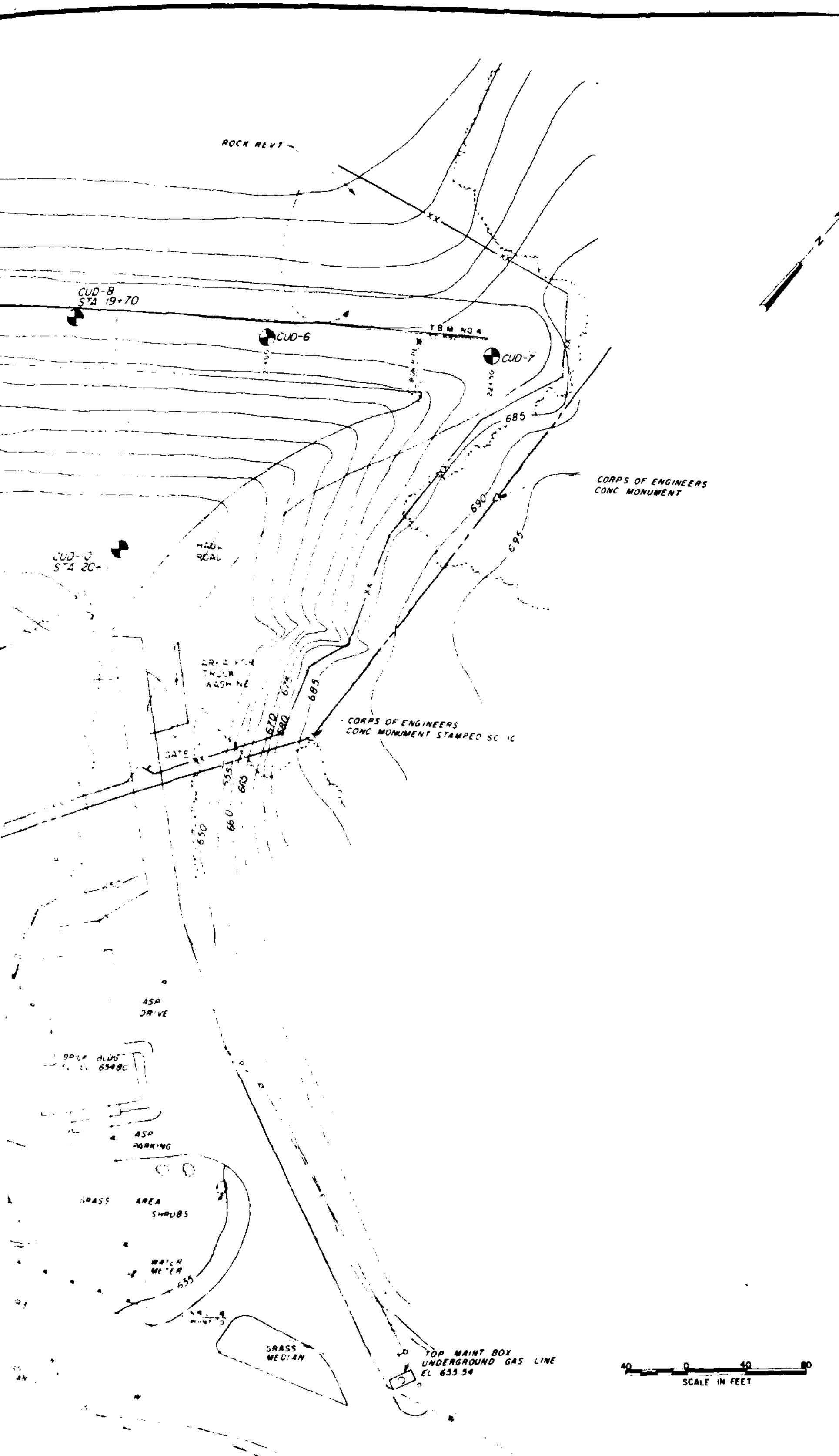
2



ROCK REVT
CUD-18
STA 12+25
PF-208A
PC-208A
PE-208A
HAUL ROAD
CONCRETE CUTOFF WALL
4U
PF-208
PC-208
PE-208
CUD-20
STA 17+25
CUD-5
CUD-8
STA 19+70
WORKING PLATFORM
I-21 (2U)
Match line Plate 1W2-2
MW-9
MW-10
PW-3
MW-11
MW-12
PROTECTION
PF-209
PC-209
PE-209
CUD-9
STA 18+75
CUD-10
STA 20+11
Relief wells
PF-210A
STA 16+00
PF-210
PC-210
STA 16+00
PF-211
PC-211
STA 18+45
OLD RIVER
WATER SURFACE ELEV 618.2
31 OCT 1979
LEVEE
UAP-3
STA 16+00
A-3
STA 16+00
STOCKPILE MATERIALS EXCAVATED
FROM CUT-OFF WALL
SWAMP
R/W
ASP DRIVE
BRICK BLDG
FL EL 654.80
ASP PARKING
36" RC
TOP 6' x 3' CONC
SLAB CB 620.32
INV UNAVAILABLE
TOP SEALED
60" CM
25' High guard rail
TOP IRON GRATE
CB = 633.68
INV 48" C M = 620.28
PC 214
STA 16+11
TOP M H
EL 648.75
INV 12" VC
HWY 93
GRASS AREA
SHRUBS
WATER METER
GRASS MEDIAN
ASPHALT DRIVE
TOP M H
EL 643.10
INV 629.55
TOP 4X4 CONC
CB = 643.68
ASP DRIVE
C
C'

IX

1



LEGEND

⬢	Inclinometer
PF-201A	New Piezometer
	Piezometers and exploration borings
	Old piezometers
●	Aquifer test pumping well
○	Aquifer test monitor well
—W—	Water line
—P—	Power line
—PT—	Power and Telephone

PLANE TABLE SHEET, HARTWELL NO 46-1.2
SURVEYED OCTOBER 1979
UPPER DIVERSION DAM

HORIZ & VERT CONTROL DATA
T B M NO 3, EL 661.91, 1-20d NAIL IN POWER POLE

REVISED IN ACCORDANCE WITH AMENDMENT NO 0001	23 JUNE 83	JGP
DESCRIPTION	DATE	BY

REVISIONS

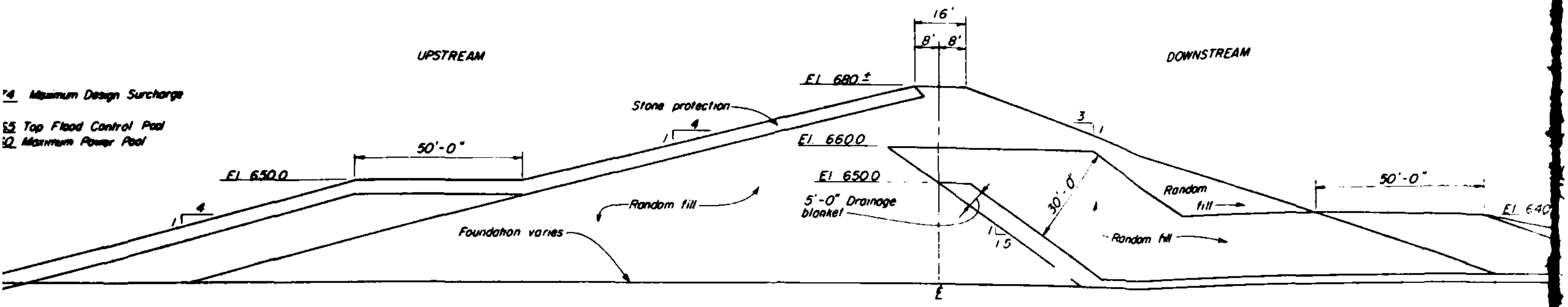
U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
BORING PLAN AND SITE UTILIZATION
SHEET 2 OF 2
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	SOLICITATION NO	FILE NO	PLATE
F	DACW21-83-B-0011	HA?IC-047	3
SCALE 1"=40'		SHEET 3	

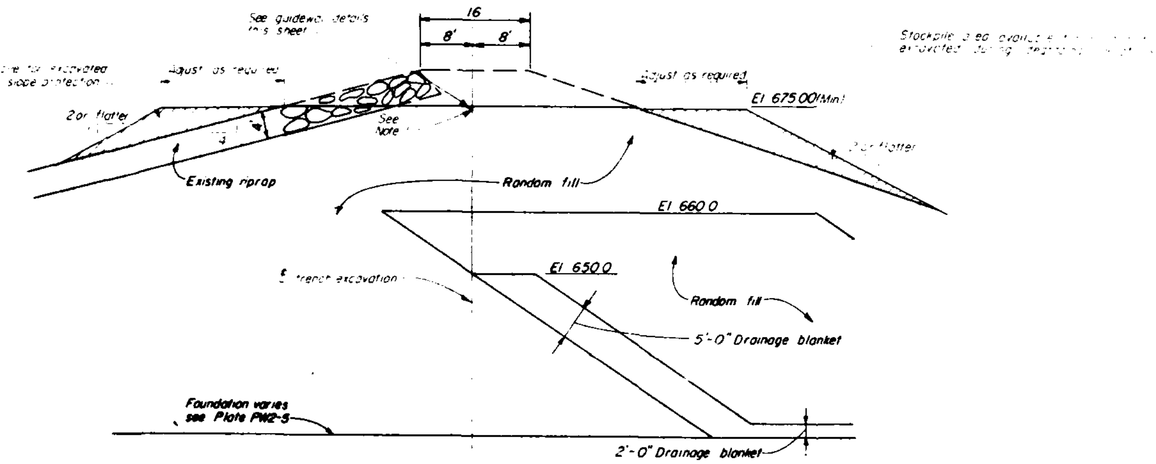
(3)

B



TYPICAL EXISTING EMBANKMENT CROSS-SECTION

SCALE 1" = 20'

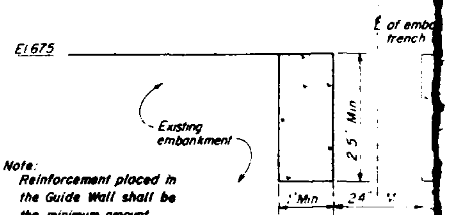


EMBANKMENT DEGRADING FOR WORK PLATFORM

SCALE 1" = 10'

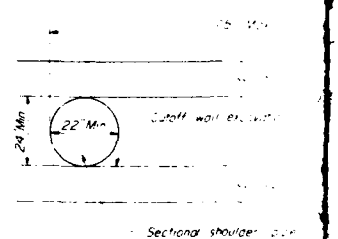
Note

1 Stones from original slope protection placement may be encountered in the upper portion of trench and guide wall excavation



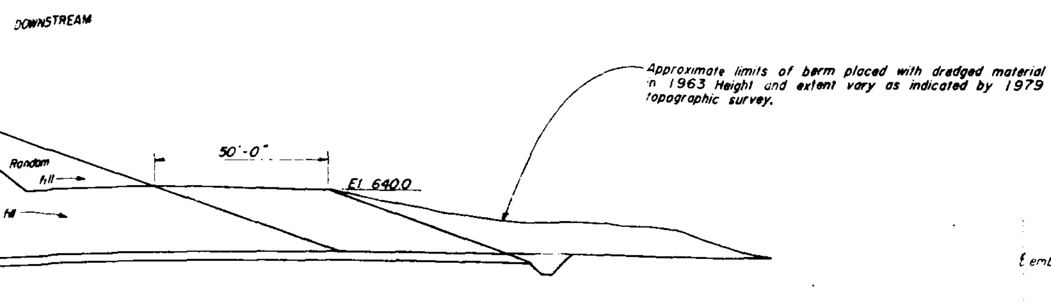
Note:
Reinforcement placed in the Guide Wall shall be the minimum amount and size to prevent cracked sections from falling into the excavation.

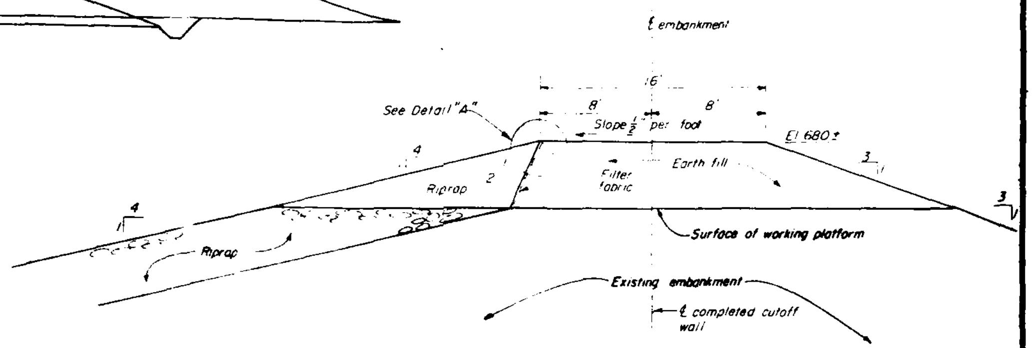
GUIDE WALL DE



SHOULDER PIPE DE

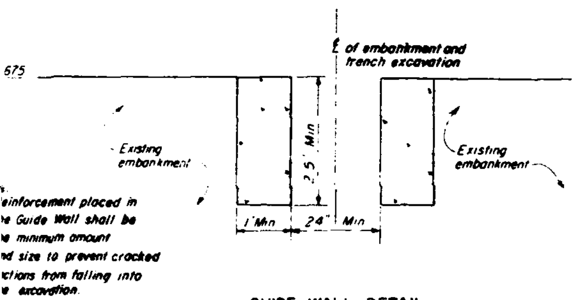
SCALE 1" = 2'





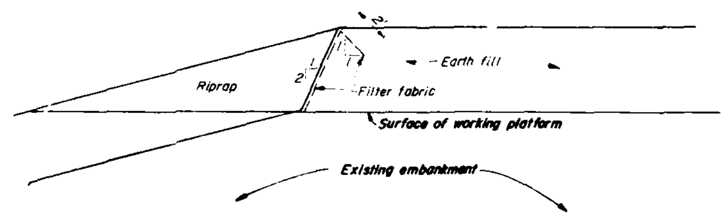
DETAIL OF EMBANKMENT RECONSTRUCTION

SCALE: 1" = 5'



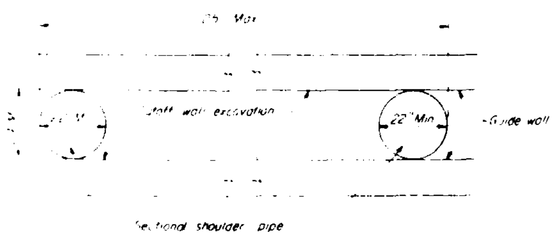
GUIDE WALL DETAIL

SCALE 1" = 1'



DETAIL "A"

SCALE: 1" = 4'



SHOULDER PIPE DETAIL

SCALE 1" = 2'

SYMBOL	ZONE	DESCRIPTION	DATE	BY
		REVISIONS		

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

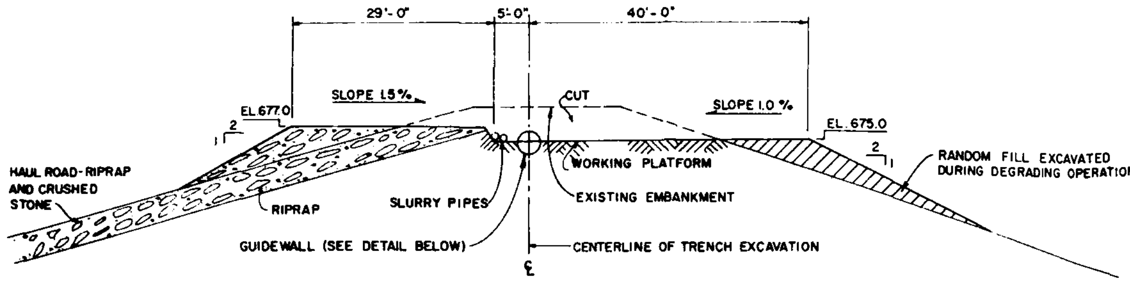
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

SECTIONS & DETAILS (AS DESIGNED)

HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

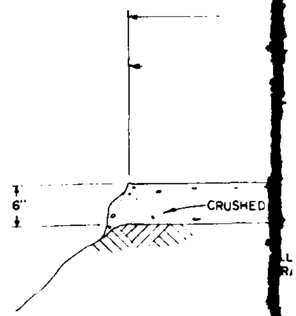
SIZE	INVITATION NO	FILE NO.	PLATE
F	DACW21-80-B-0011	HA21C-048	4
SCALE AS SHOWN			SHEET 4

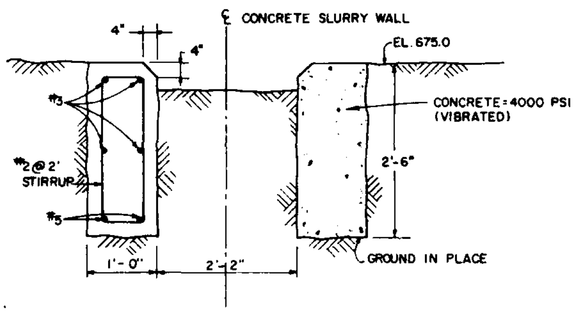
4



EMBANKMENT DEGRADING FOR WORK PLATFORM

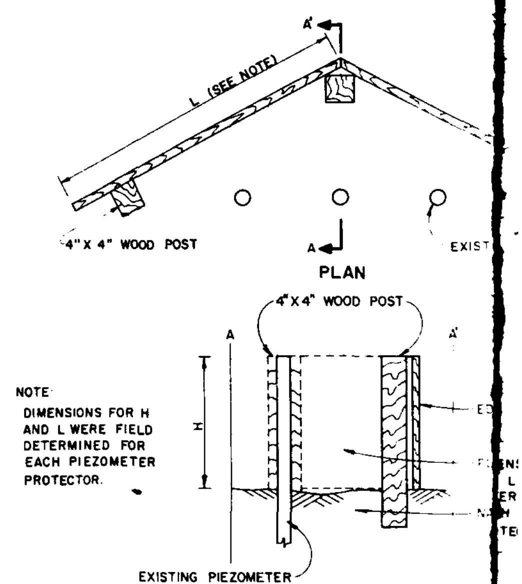
SCALE: 1"=10'-0"





GUIDE WALL DETAIL

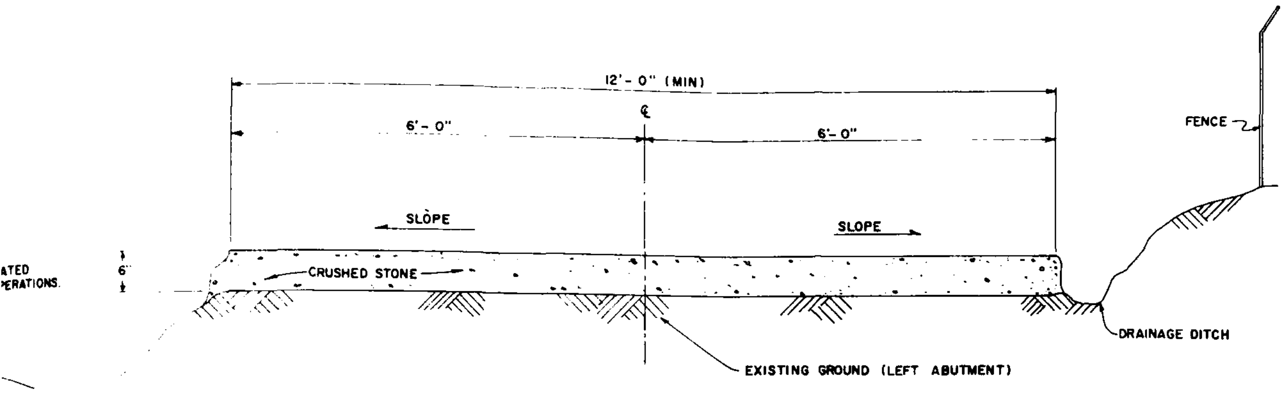
SCALE: 1"=1'-0"



PIEZOMETER PROTECTION (TYP)

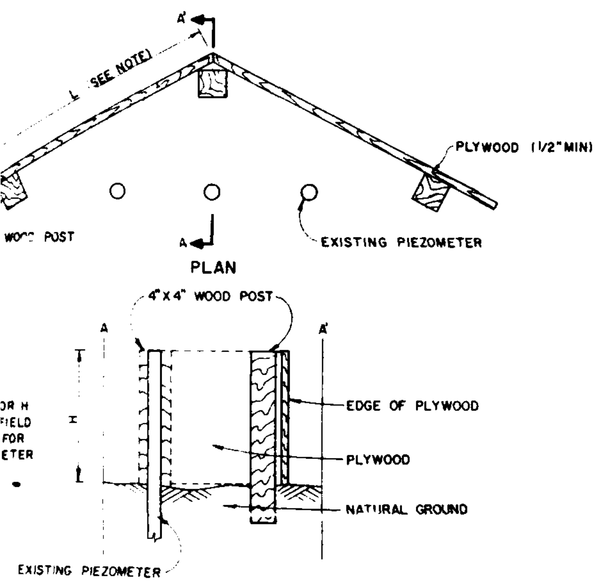
NO SCALE

A



EAST EXIT HAUL ROAD (TYP.)

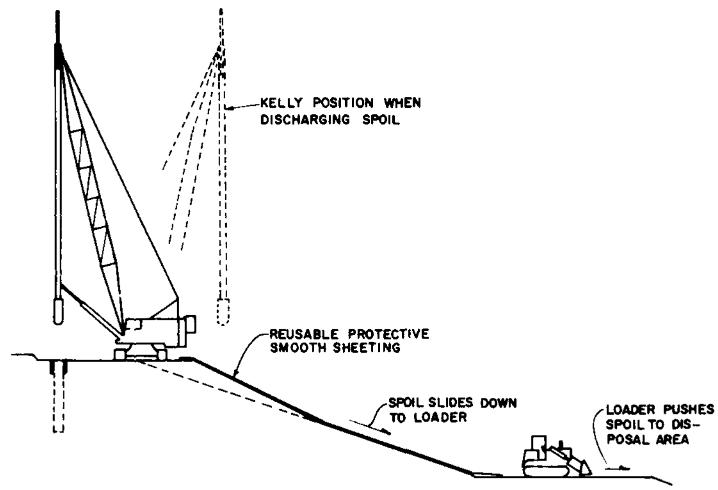
SCALE: 1"=1'-0"



A-A'

PIEZOMETER PROTECTION (TYP.)

NO SCALE



DISCHARGE OF EXCAVATED MATERIALS

NO SCALE

SYMBOL	ZONE	DESCRIPTION	DATE	BY
		REVISIONS		

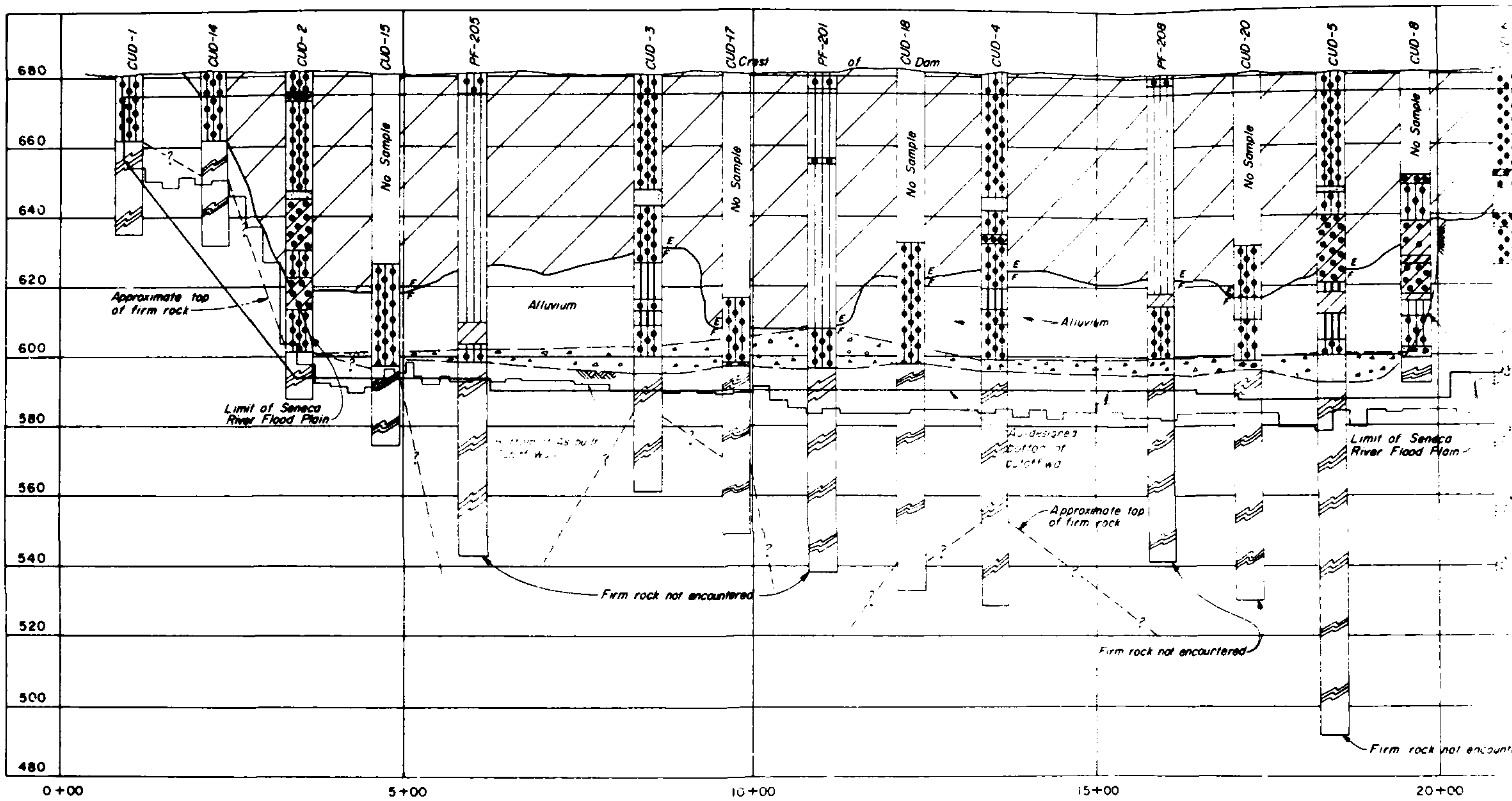
U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
DETAILS RELATING TO CUTOFF WALL
CONSTRUCTION (AS-BUILT)
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	DRAWING NO	PLATE
F			5

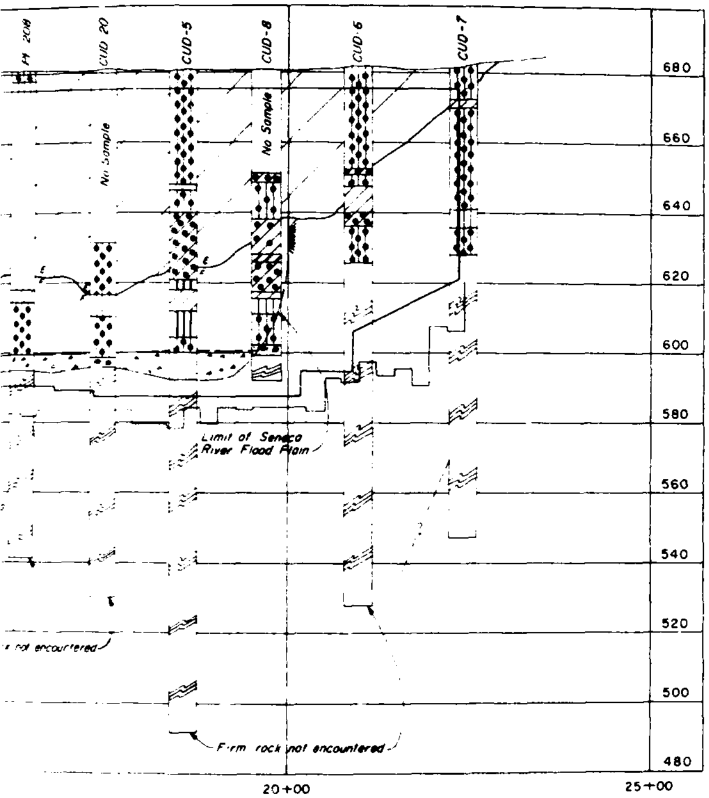
SCALE AS SHOWN | SHEET 5

5



SECTION ALONG ℄ CLEMSON UPPER DIVERSION DAM

SCALE 1" = 100' HORIZ
1" = 20' VERT



NOTES:

1. Soils field classified in accordance with the Unified Soil Classification System.
2. Water table levels during drilling and 24 hours after boring was completed can be found in the boring logs.
3. Alluvium with gravel as indicated by this symbol (See legend below), is generally gravelly sand or sandy gravel but may include lenses of silt, sand, clay, gravel, or combinations of same or all.
4. Firm rock is rock which cannot be crushed or broken with the bare hand. It is generally moderately weathered, but may also include some badly weathered and slightly weathered zones.
5. The embankment/foundation contact was plotted using survey data from original cross sections made during construction and as interpreted from boring logs.
6. The elevations of the base of the cutoff wall shown are approximate only, based on interpolation between borings and shall not be construed as final. The depth of the cutoff wall shall be determined in the field based on conditions encountered as specified in SECTION: CONCRETE CUTOFF WALL of specifications.
7. Other logs of borings made in the vicinity are available for viewing in the District Office.
8. Bottom of "as-built" cutoff wall plotted using information from Contractors excavation reports.

LEGEND

BORING LOG

- Silty sand (SM)
- Clayey sand (SC)
- Gravel and sand (GP)
- Sand (SP)
- Clayey silt (MH)
- Inorganic silts (ML)
- Lean clay (CL)
- Granite gneiss (bedrock) (Quartz-feldspar-biotite gneiss)

SECTION SYMBOLS

- Bedrock or residuum
- Contact, embankment/foundation See Note 5
- Top of firm rock (approximate)
- G Contains gravel
- Alluvium with gravel, see Note 3. (Probable high permeability)
- Dam embankment
- Approximate bottom of concrete cutoff wall.
- As-built bottom of concrete cutoff wall.

SYMBOL	ZONE	DESCRIPTION	DATE	BY
1		REVISED IN ACCORDANCE WITH AMENDMENT NO 0001	23 JUNE 85	JBE

REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

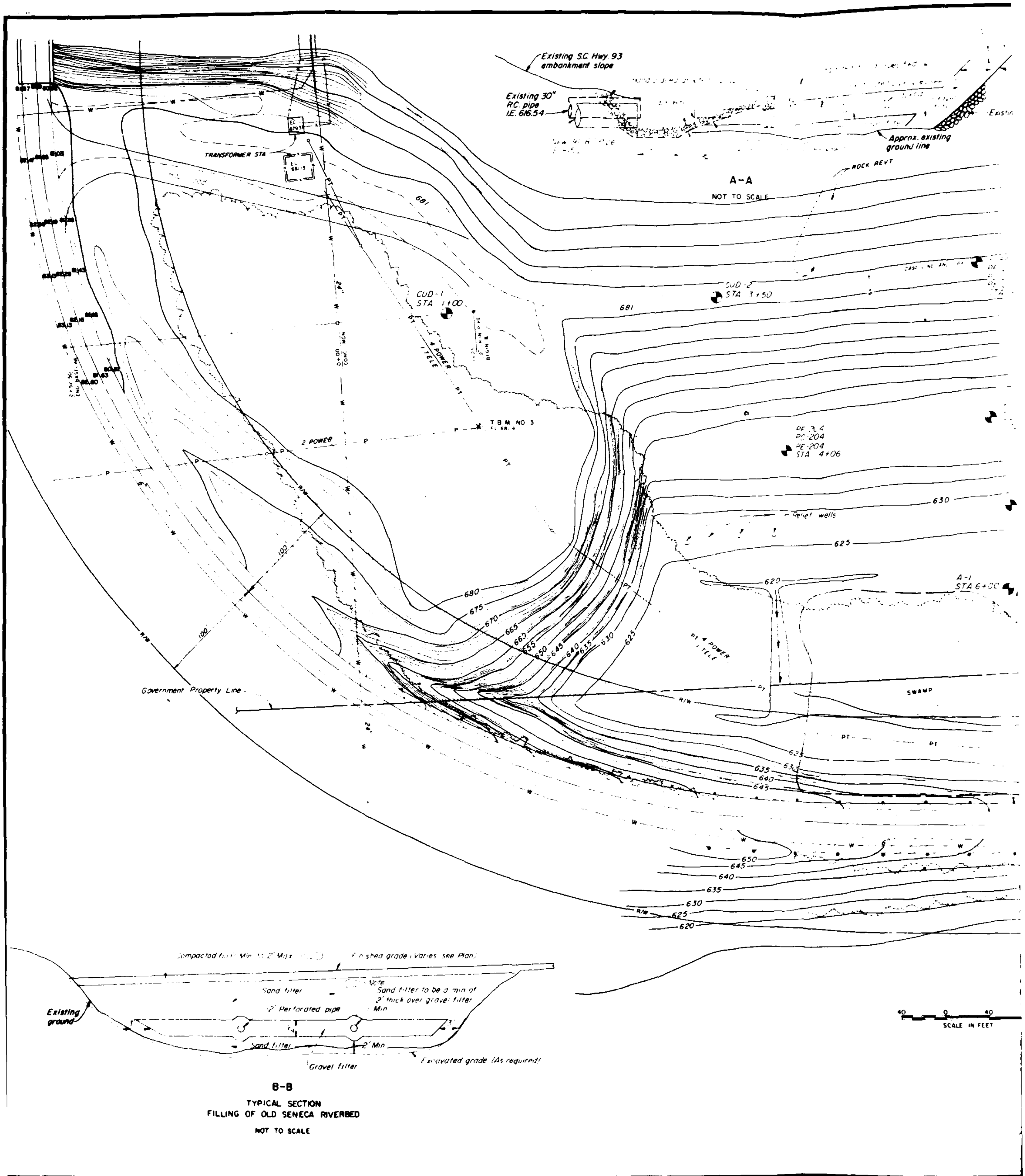
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

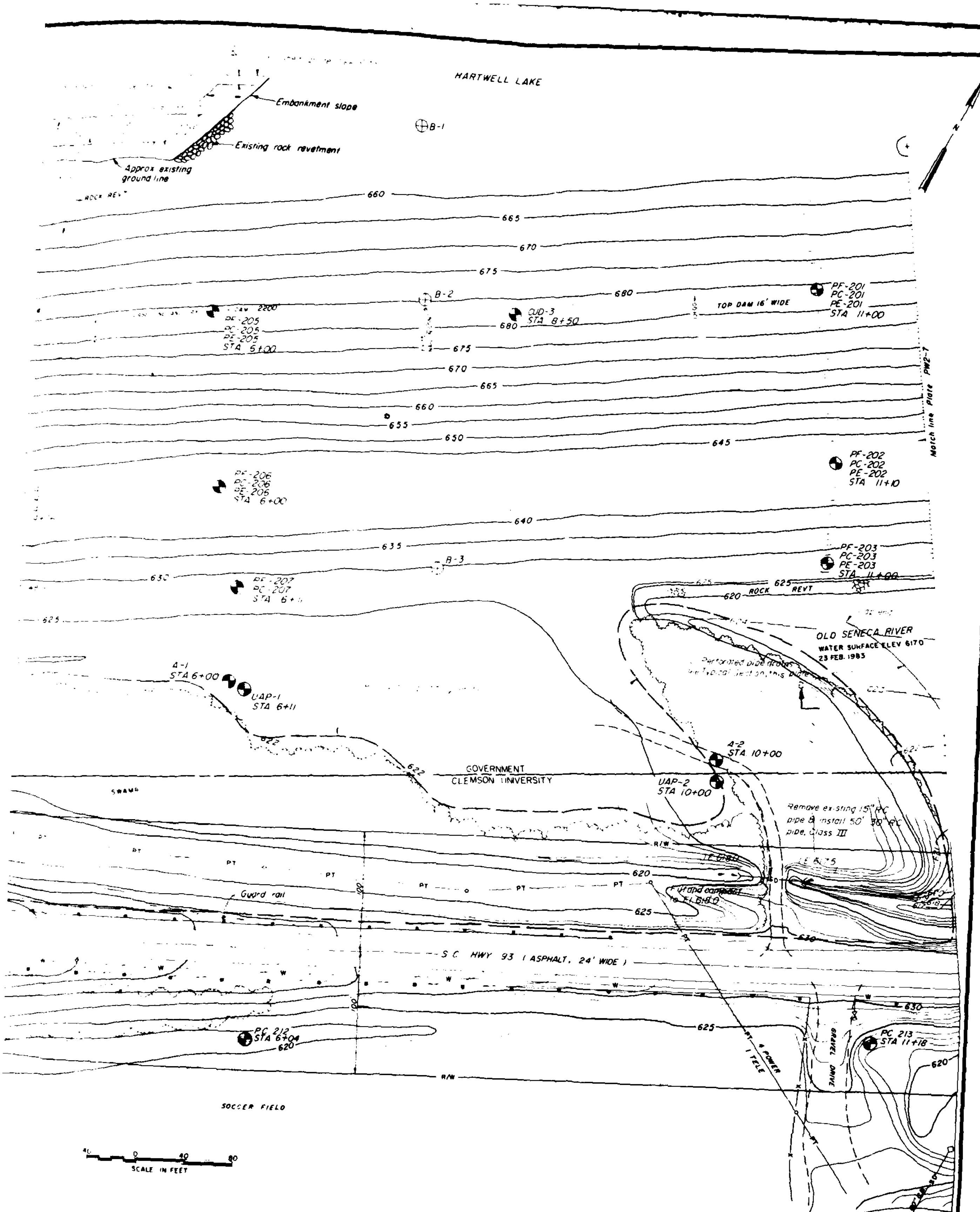
GEOLOGIC PROFILE
WITH "AS-BUILT" BOTTOM OF CUTOFF WALL

HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	DRAWING NO	PLATE
F	DACW21-85-B-0011	HA21C-049	6

SCALE AS SHOWN SHEET 6


Existing S.C. Hwy. 93 embankment slope
Existing 30" R.C. pipe I.E. 616.54
Approx. existing ground line
ROCK REVT
A-A
NOT TO SCALE
TRANSFORMER STA
CUD-1 STA 1+00
CUD-2 STA 3+50
T B M NO 3
2 POWER
4 POWER 1 TELE
PE-204 PC-204 PE-204 STA 4+06
Relief wells
A-1 STA 6+00
SWAMP
Government Property Line
R/W
681
680
675
670
665
660
655
650
645
640
635
630
625
620
100
Compacted fill 1' Min. to 2' Max.
Finished grade (Varies, see Plan)
Sand filter
Note
Sand filter to be a min. of 2' thick over gravel filter
2" Perforated pipe
Min
Existing ground
Sand filter
2' Min
Gravel filter
Excavated grade (As required)
B-B
TYPICAL SECTION
FILLING OF OLD SENECA RIVERBED
NOT TO SCALE
40
0
40
SCALE IN FEET



PLANE TABLE SHEET, HARTWELL NO 46-1,2
SURVEYED OCTOBER 1979
UPPER DIVERSION DAM

HORIZ & VERT CONTROL DATA
TBM NO 3, EL 681.91, 1-20d NAIL IN POWER POLE

SYMBOL	ZONE	DESCRIPTION	DATE	BY
1		REVISED IN ACCORDANCE WITH AMENDMENT NO. 0001	23 JUNE 83	JW

REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

GRADING AND DRAINAGE
SHEET 1 OF 2

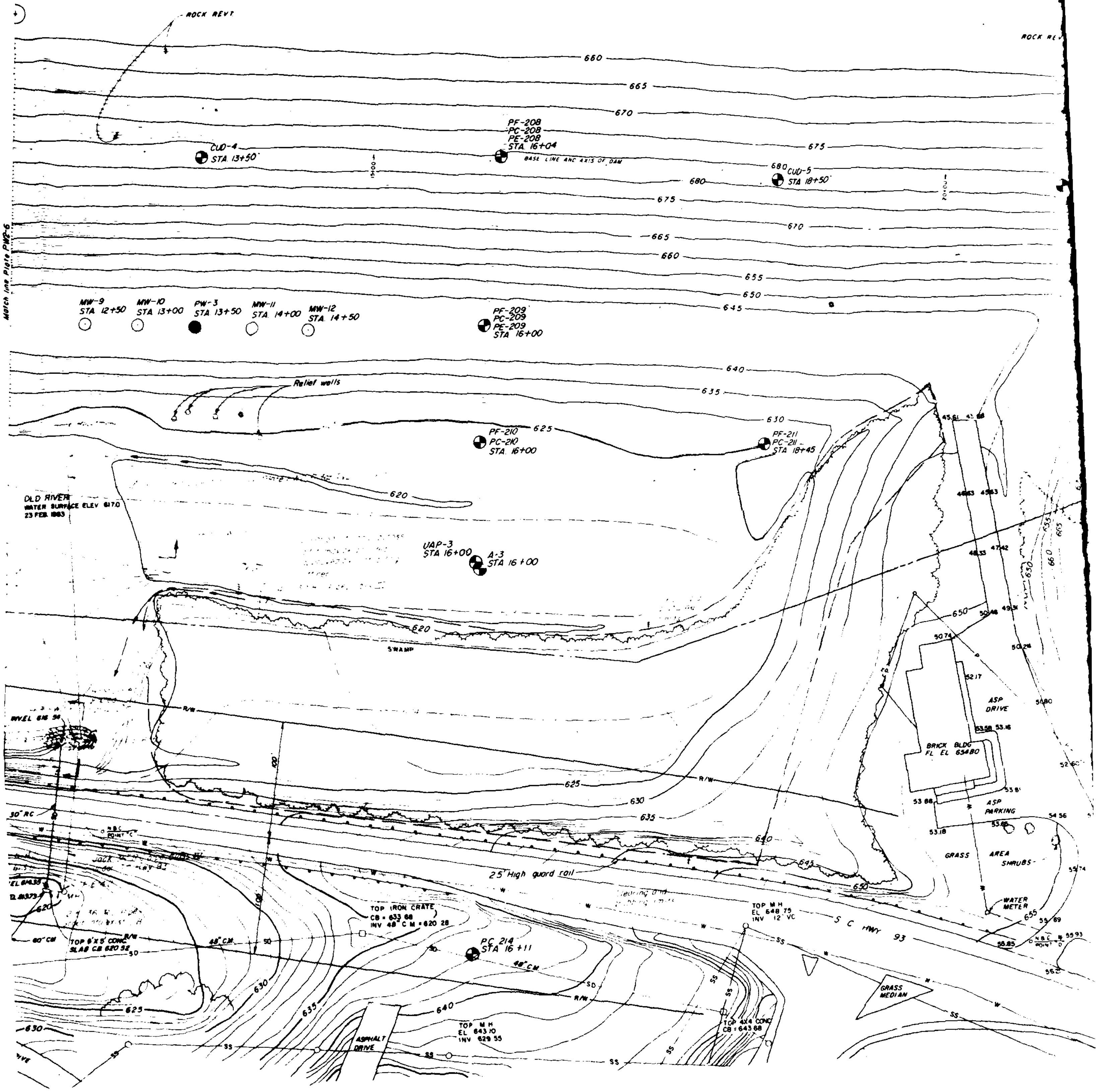
SAVANNAH RIVER — HARTWELL LAKE — GEORGIA & SOUTH CAROLINA

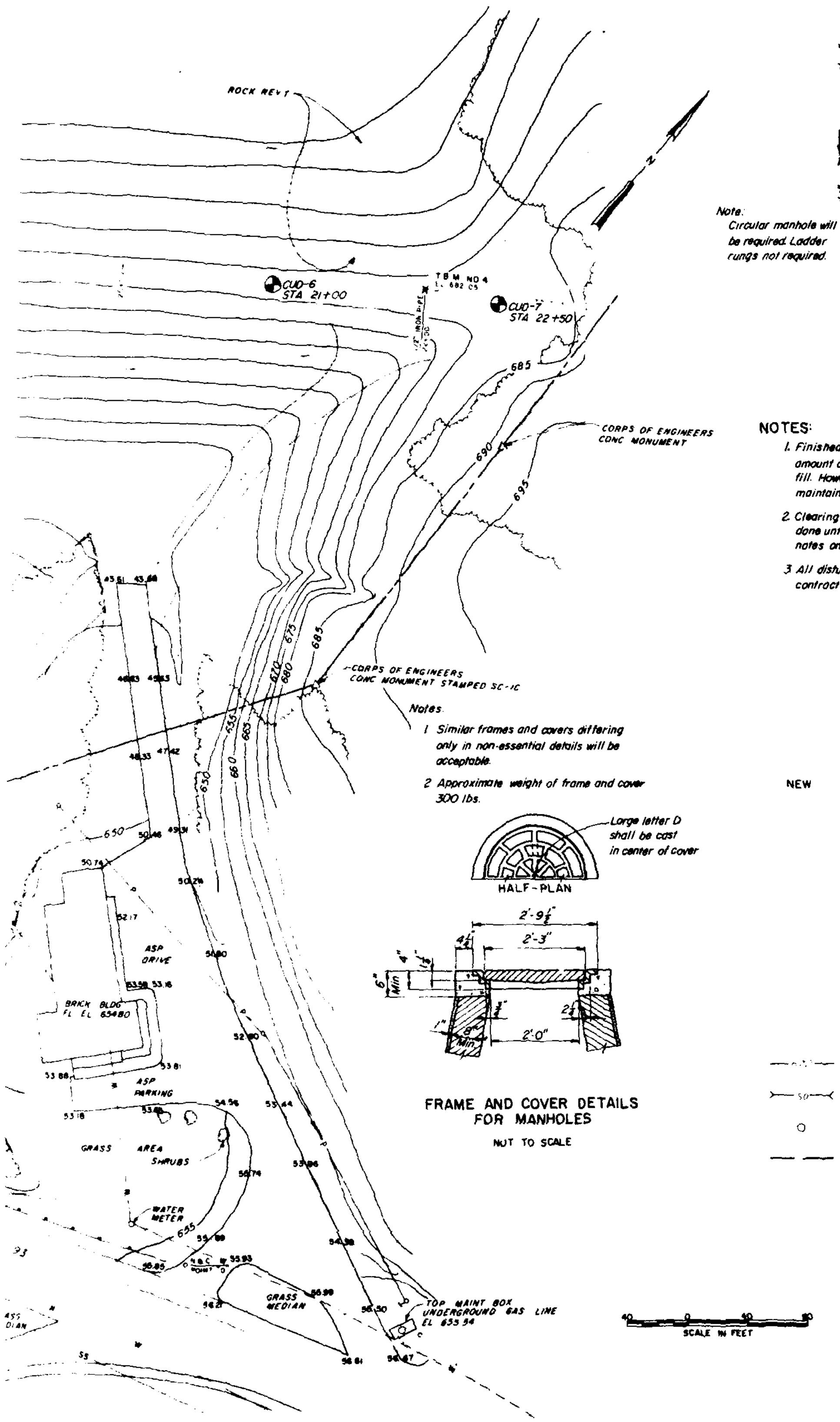
SIZE	INVITATION NO	FILE NO	PLATE
F	DACW 21-83-B-0011	HA21C-050	7

SCALE 1" = 40'

SHEET

7


ROCK REVT
660
665
670
675
680
CUD-4
STA 13+50
PF-208
PC-208
PE-208
STA 16+04
BASE LINE AND AXIS OF DAM
CUD-5
STA 18+50
Match line Plate PW2-6
655
650
645
640
635
630
625
620
MW-9
STA 12+50
MW-10
STA 13+00
PW-3
STA 13+50
MW-11
STA 14+00
MW-12
STA 14+50
PF-209
PC-209
PE-209
STA 16+00
Relief wells
PF-210
PC-210
STA 16+00
PF-211
PC-211
STA 18+45
OLD RIVER
WATER SURFACE ELEV 617.0
23 FEB 1983
UAP-3
STA 16+00
A-3
STA 16+00
SWAMP
R/W
BRICK BLDG
FL EL 654.80
ASP DRIVE
ASP PARKING
GRASS
AREA
SHRUBS
WATER METER
25' High guard rail
S C HWY 93
TOP IRON GRATE
CB = 633.68
INV 48" CM = 620.28
TOP 6'X5' CONC SLAB CB 620.52
48" CM
60" CM
30" RC
PC 214
STA 16+11
TOP M H
EL 648.75
INV 12" VC
TOP M H
EL 643.10
INV 629.55
TOP 4X4 CONC
CB = 643.68
GRASS MEDIAN
ASPHALT DRIVE
SS
SD
W
N B C POINT "C"
N B C POINT "D"



Notes

1 Similar frames and covers differing only in non-essential details will be acceptable.

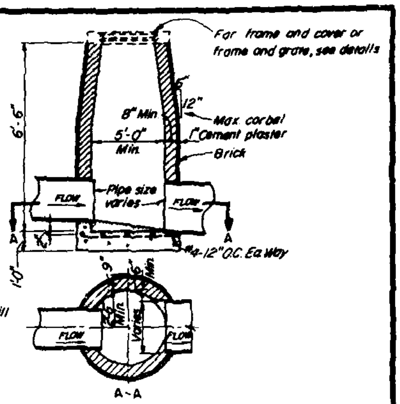
2 Approximate weight of frame and cover 300 lbs.

Large letter D shall be cast in center of cover

HALF-PLAN

FRAME AND COVER DETAILS FOR MANHOLES

NOT TO SCALE



Note:
Circular manhole will be required. Ladder rungs not required.

DETAILS FOR MANHOLE

NOT TO SCALE

NOTES:

1. Finished grade may vary from that shown on plan due to actual amount of material excavated from the dam and available for fill. However, grading will be done in such a manner as to maintain positive drainage.

2. Clearing and grubbing and filling south of the dam will not be done until the dam cut-off wall is completed. Refer to applicable notes on Plate 3.

3. All disturbed earth areas shall be grassed in accordance with contract specifications.

LEGEND

NEW	EXISTING	
	⊕	Piezometers and exploration borings
	⊕	Old piezometers
	●	Aquifer test pumping well
	⊙	Aquifer test monitor well
	—w—	Water line
	—P—	Power line
	—PT—	Power and Telephone
	A——A'	Line of Piezometer Cross Section
—670—	—670—	Contours
>—50—<	>—50—<	Pipe culvert
○		Manhole
— —		Clearing and grubbing limits

40 0 40 80
SCALE IN FEET

PLANE TABLE SHEET, HARTWELL NO. 46-1,2
SURVEYED OCTOBER 1979
UPPER DIVERSION DAM

HORIZ & VERT CONTROL DATA
T B M NO. 3, EL 681.91, 1-20d NAIL IN POWER POLE

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
GRADING AND DRAINAGE
SHEET 2 OF 2
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	FILE NO.	PLATE
F	[illegible]	HA21C-051	8

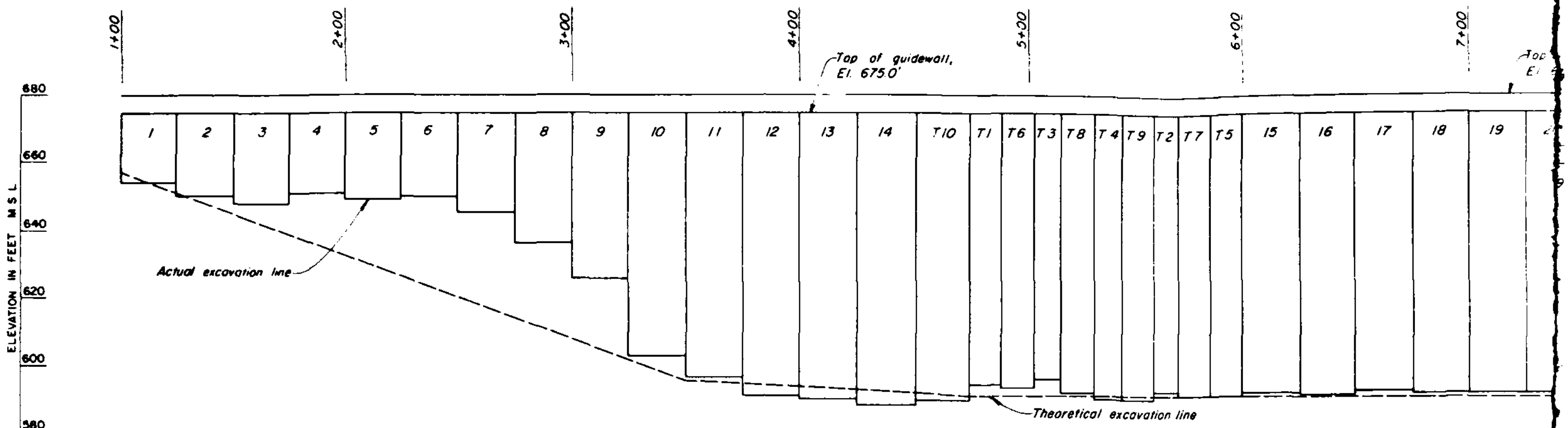
SCALE 1"=40' SHEET 8

SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

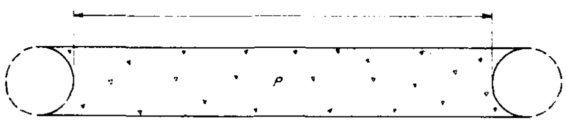
PLAN

SCALE 1" = 30'

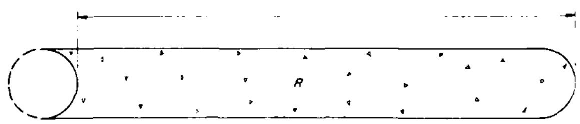


ELEVATION

SCALE: 1" = 20' VERT.
1" = 30' HORIZ



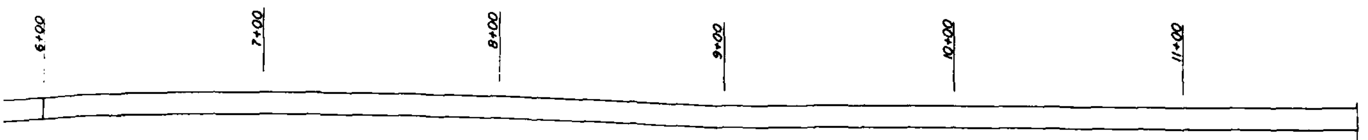
PRIMARY PANEL



RUNNING PANEL

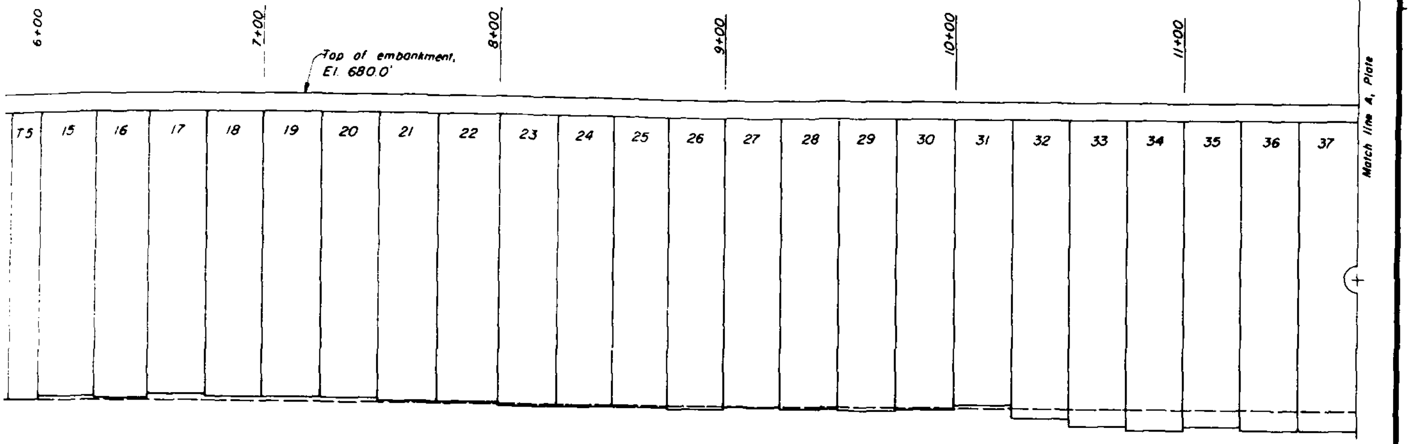
	PANEL NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	T10
	PANEL TYPE	S	P	S	P	S	P	S	P	S	P	S	P	S	R	S
	PANEL LENGTH	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	26.0	25.0
	SEQUENCE	90	79	89	78	88	73	87	72	86	71	84	70	85	69	8
	TOP OF ROCK	17.3	24.0	23.3	21.3	24.0	20.5	28.7	33.7	46.3	65.7	76.3	77.7	81.0	82.7	82.4
EXCAVATION	START DATE-84	5-20	5-14	5-20	5-14	5-20	5-8	5-20	5-7	5-15	5-3	5-19	5-2	5-18	5-1	12-7
	END DATE	5-22	5-15	5-21	5-15	5-20	5-9	5-20	5-7	5-16	5-7	5-20	5-3	5-21	5-1	12-13
	THEO DEPTH	21.0	27.0	33.0	39.0	45.0	51.0	57.0	63.0	69.0	75.0	79.0	80.0	81.0	82.0	84.7
	ACTU DEPTH	21.3	25.0	26.3	24.3	26.0	25.5	29.3	38.3	49.0	71.0	78.0	82.3	83.3	85.8	83.0
	S A SQ FT	534.0	625.0	659.0	614.0	650.0	636.0	736.0	959.0	1236.0	1775.0	1943.0	2059.0	2084.0	2232.5	2075.0
CONCRETE	DATE-84	5-23	5-17	5-23	5-16	5-22	5-11	5-22	5-10	5-22	5-9	5-21	5-8	5-21	5-4	12-15
	THEO VOL C Y	42.0	43.3	52.0	43.0	51.0	44.2	59.0	66.8	98.0	123.0	153.5	142.8	165.3	165.2	157.0
	ACTU VOL C Y	40.0	50.0	56.0	50.0	56.0	46.0	60.0	74.0	108.5	155.0	179.0	200.0	185.0	190.0	184.0
	OVER (%)	-5.5	15.5	7.7	16.3	9.8	4.1	1.7	10.8	10.7	26.0	16.6	40.1	11.9	15.0	14.7

	PANEL NO	T1	T6	T3	T8	T4	T9	T2	T7	T5	15	16	17	18	19
	PANEL TYPE	P	S	P	S	P	S	P	S	P	R	S	P	S	P
	PANEL LENGTH	12.0	15.0	12.0	15.0	12.0	15.0	12.0	15.0	15.2	26.0	25.0	25.0	25.0	25.0
	SEQUENCE	1	7	4	10	6	9	2	5	3	68	83	67	82	66
	TOP OF ROCK	77.0	77.4	76.0	77.5	79.5	79.5	79.0	75.0	77.0	78.0	78.0	77.0	78.7	79.0
EXCAVATION	START DATE-84	11-10	12-6	11-30	12-15	12-5	12-13	11-17	12-2	11-29	4-27	5-17	4-27	5-16	4-25
	END DATE	11-17	12-6	12-1	12-19	12-6	12-15	11-28	12-3	11-29	4-30	5-18	4-28	5-17	4-27
	THEO DEPTH	83.4	83.0	83.0	81.0	82.5	82-5	82.0	82.0	82.0	82.0	82.0	82.0	82.0	82.5
	ACTU DEPTH	79.7	80.5	78.7	83.0	84.6	84.4	82.5	83.6	83.4	82.5	83.0	82.0	82.0	82.0
	S A SQ FT	956.4	1207.5	944.4	1245.0	1015.2	1266.0	990.0	1254.0	1267.7	2141.0	2075.0	2075.0	2050.0	2050.0
CONCRETE	DATE-84	11-22	12-12	12-2	12-19	12-7	12-16	11-29	12-3	12-1	5-1	5-19	4-30	5-18	4-28
	THEO VOL C Y	71.0	90.5	70.0	90.0	75.0	94.0	73.0	93.0	93.0	158.5	163.3	142.3	161.3	142.0
	ACTU VOL C Y	73.0	119.0	75.0	118.0	78.0	124.0	77.5	110.0	88.0	185.0	180.0	165.0	180.0	175.0
	OVER (%)	2.8	23.9	7.1	23.7	3.8	24.2	6.2	15.4	-5.4	16.7	10.2	16.0	11.6	23.2



PLAN

SCALE 1" = 30'

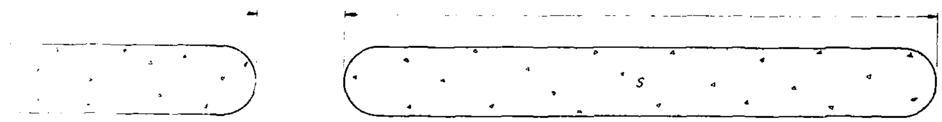


ELEVATION

SCALE 1" = 20' VERT
1" = 30' HORIZ

NOTES:

1. Depth of top of rock is the average across panel.
2. Actual excavation depths shown are average across panel.
3. "?" indicates that no data was available.



PANEL SECONDARY PANEL

T5	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
P	R	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P
15.2	26.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
3	68	83	67	82	66	81	64	80	63	65	62	77	61	74	60	75	58	76	50	59	49	56	48
77.0	78.0	78.0	77.0	78.7	79.0	79.7	76.7	78.0	81.7	79.0	?	82.0	80.0	79.0	79.0	80.5	79.0	81.0	84.0	84.0	84.0	84.0	85.0
11-29	4-27	5-17	4-27	5-16	4-25	5-15	4-24	5-13	4-23	4-26	4-21	5-10	4-20	5-9	4-18	5-8	4-16	5-7	4-6	4-17	4-4	4-13	4-3
11-29	4-30	5-18	4-28	5-17	4-27	5-17	4-24	5-15	4-24	4-26	4-23	5-12	4-20	5-10	4-20	5-9	4-18	5-10	4-7	4-18	4-5	4-14	4-4
82.0	82.0	82.0	82.0	82.0	82.5	82.5	83.0	83.0	84.5	84.5	84.5	84.5	84.5	84.0	83.5	83.5	83.0	83.0	83.0	83.0	83.0	83.0	83.5
83.4	82.5	83.0	82.0	82.0	82.0	82.3	83.0	83.3	84.0	84.0	84.0	84.7	84.3	84.7	85.0	84.3	83.0	87.0	89.0	90.0	89.0	90.0	90.0
1267.7	2141.0	2075.0	2075.0	2050.0	2050.0	2059.0	2075.0	2084.0	2100.0	2100.0	2100.0	2116.0	2116.0	2118.0	2118.0	2109.0	2075.0	2170.0	2225.0	2250.0	2225.0	2250.0	2250.0
12-1	5-1	5-19	4-30	5-18	4-28	5-18	4-26	5-17	4-25	4-27	4-24	5-16	4-23	5-12	4-21	5-12	4-19	5-15	4-9	4-20	4-7	4-16	4-6
93.0	159.5	163.3	142.3	161.3	142.0	165.2	144.0	164.3	145.7	165.0	145.7	166.5	146.5	166.0	148.4	166.0	144.0	171.0	154.4	177.0	154.4	177.1	156.0
89.0	185.0	180.0	165.0	180.0	175.0	195.0	175.0	183.0	160.0	175.0	159.0	175.0	179.0	175.0	184.0	172.0	159.0	195.0	200.0	205.0	180.0	198.5	193.0
5.4	16.7	10.2	16.0	11.6	23.2	20.0	21.5	11.4	9.8	12.1	9.1	5.1	22.2	5.4	24.0	3.6	10.4	14.0	29.5	15.8	16.6	12.1	23.7

SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

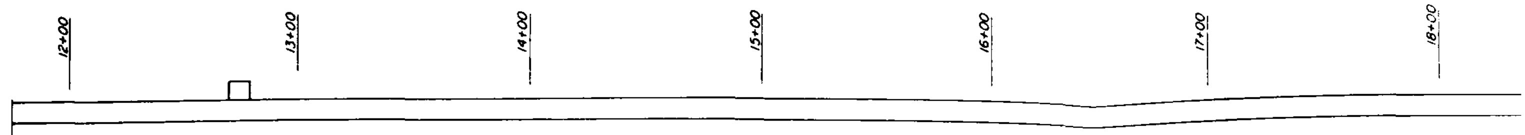
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

CUTOFF WALL PROFILE & DATA-SHEET 1

HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

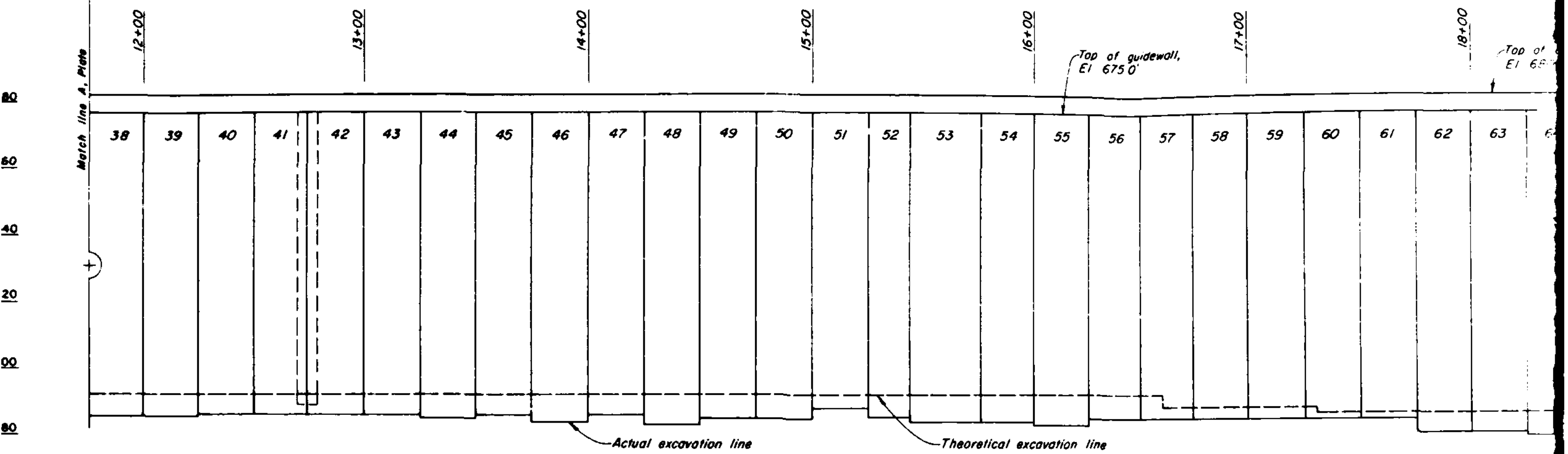
SIZE	INVITATION NO	FILE NO	PLATE
F			9

SCALE SHEET 9



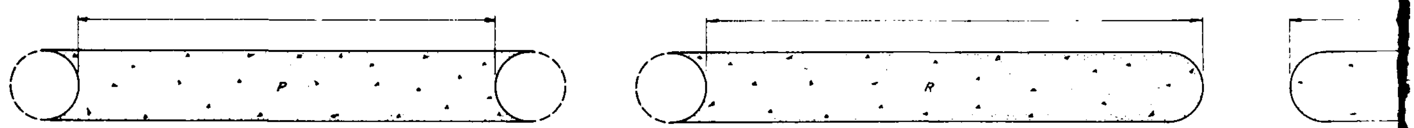
PLAN

SCALE 1" = 30'



ELEVATION

SCALE: 1" = 20' VERT.
1" = 30' HORIZ.



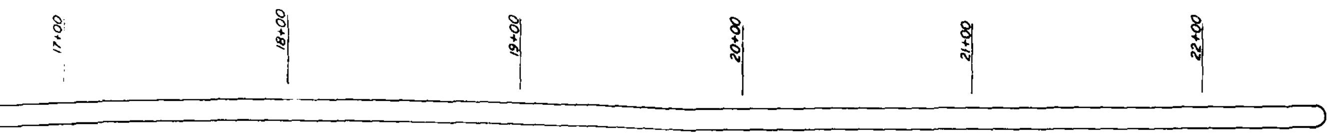
PRIMARY PANEL

RUNNING PANEL

	PANEL NO	38	39	40	41	42	43	44	45	46	47	48	49	50	51
	PANEL TYPE	S	P	S	P	S	P	S	P	S	P	S	P	S	P
	PANEL LENGTH	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	SEQUENCE	55	47	54	46	57	45	53	44	52	43	51	34	42	33
	TOP OF ROCK	85.0	85.0	84.0	?	83.0	84.5	84.0	85.0	?	85.0	?	?	85.0	83.0
EXCAVATION	START DATE-84	4-12	4-2	4-11	3-30	4-16	3-29	4-10	3-28	3-30	3-28	4-9	3-16	3-26	3-15
	END DATE	4-13	4-3	4-12	4-2	4-17	3-29	4-11	3-29	4-10	3-28	4-9	3-16	3-27	3-15
	THEO DEPTH	84.0	84.5	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0	84.0
	ACTU DEPTH	91.0	90.6	90.0	90.0	90.0	90.0	91.0	90.0	92.0	90.0	93.0	91.0	91.0	88.0
	S A SQ FT	2275.0	2266.0	2250.0	2250.0	2250.0	2250.0	2275.0	2250.0	2300.0	2250.0	2325.0	2275.0	2275.0	2200.0
CONCRETE	DATE-84	4-14	4-5	4-13	4-4	4-18	4-3	4-12	4-2	4-11	3-30	4-10	3-20	3-29	3-19
	THEO VOL CY	179.1	157.0	177.1	156.0	177.0	156.0	179.0	156.2	181.0	156.0	183.0	157.9	179.0	152.7
	ACTU VOL. CY	198.5	182.0	188.0	193.0	224.0	178.0	210.0	177.0	235.0	177.0	235.0	180.0	200.0	173.0
	OVER (%)	10.6	15.9	6.2	23.7	26.6	14.1	17.3	13.3	29.8	13.5	28.4	14.0	13.3	13.3

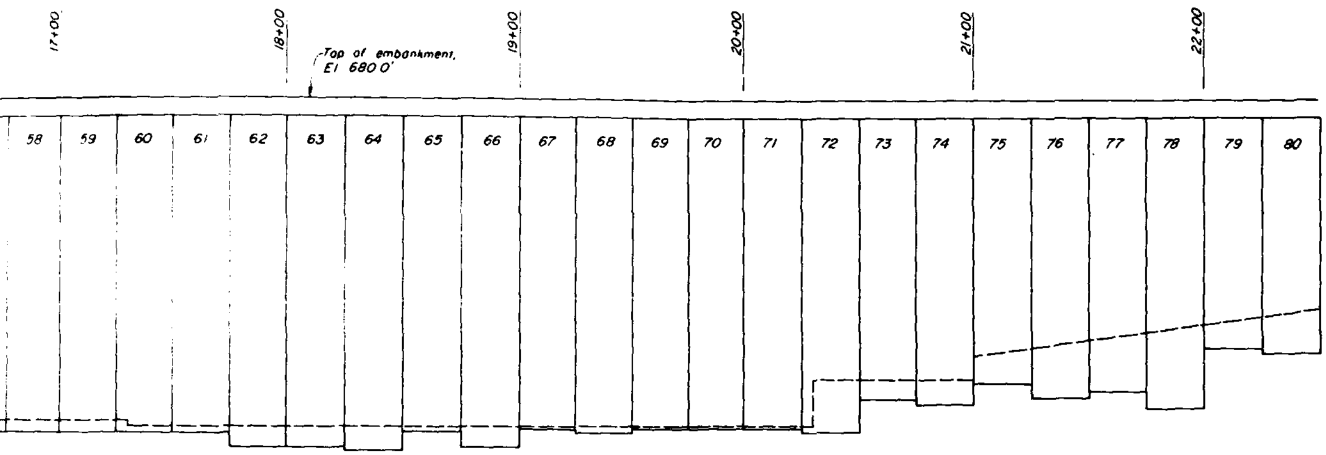
	PANEL NO	52	53	54	55	56	57	58	59	60	61	62	63	64	65
	PANEL TYPE	S	P	S	P	S	P	S	P	S	P	S	P	S	P
	PANEL LENGTH	18.5	31.5	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	SEQUENCE	41	32	40	31	39	30	38	59	38	28	36	27	35	18
	TOP OF ROCK	86.0	85.0	86.0	87.0	87.0	86.5	85.0	85.0	86.0	86.7	?	89.5	?	84.5
EXCAVATION	START DATE-84	3-26	3-14	3-23	3-13	3-22	3-12	3-21	3-10	3-20	3-8	3-19	3-7	3-18	2-14
	END DATE	3-26	3-14	3-23	3-13	3-22	3-12	3-21	3-10	3-20	3-9	3-19	3-7	3-19	2-15
	THEO DEPTH	84.0	84.0	84.0	84.0	84.0	85.3	87.0	87.0	88.3	89.0	89.0	89.0	89.0	89.0
	ACTU DEPTH	91.0	91.7	92.0	93.0	91.0	91.0	91.0	91.0	91.0	91.0	95.0	95.0	96.0	90.5
	S A SQ FT	1683.5	2889.0	2300.0	2325.0	2275.0	2275.0	2275.0	2275.0	2275.0	2275.0	2375.0	2375.0	2400.0	1904.0
CONCRETE	DATE-84	3-28	3-16	3-27	3-15	3-26	3-14	3-23	3-13	3-22	3-12	3-22	3-10	3-21	2-23
	THEO VOL CY	135.0	203.0	181.0	161.4	179.0	158.0	179.0	158.0	179.0	158.0	187.0	158.0	199.5	143.0
	ACTU VOL. CY	152.0	220.0	220.0	177.0	197.0	180.0	200.0	180.0	187.0	185.0	193.0	185.0	219.0	155.0
	OVER (%)	12.6	8.4	21.5	9.7	10.1	13.9	11.7	13.9	4.5	17.1	3.2	17.1	9.8	8.4

A.



PLAN

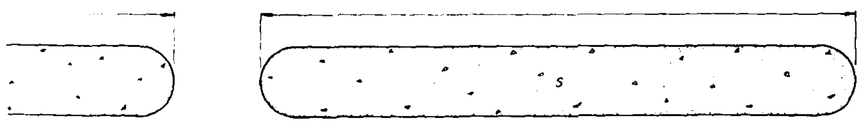
SCALE 1" = 30'
0 30'



ELEVATION

LE 1" = 20' VERT
1" = 30' HORIZ

NOTES:
1. Depth of top of rock is the average across panel.
2. Actual excavation depths shown are average across panel.
3. "?" indicates that no data was available.



SECONDARY PANEL

59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S
25 0	25 0	25 0	25 0	25 0	25.0	25 0	25 0	25 0	25.0	25 0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
59	38	28	36	27	35	18	26	17	25	16	24	15	22	14	23	13	21	12	20	11	19
85 0	86 0	86 7	?	89 5	?	84.8	88 7	84.6	85.0	83.5	84.7	83.0	83 7	75.0	75 0	65 6	74 0	56.0	69.8	61.8	64.3
3-10	3-20	3-8	3-19	3-7	3-18	2-14	3-6	2-9	3-2	2-7	2-29	2-6	2-23	2-2	2-28	2-1	2-23	1-31	2-21	1-30	2-16
3-10	3-20	3-9	3-19	3-7	3-19	2-15	3-6	2-10	3-5	2-9	3-2	2-7	2-25	2-2	2-29	2-1	2-25	1-31	2-23	1-31	2-16
87 0	88 3	89 0	89 0	89 0	89 0	89 0	89 0	89 0	89 0	89.0	89 0	89 0	83.0	81.0	81 0	68.0	65.5	63.0	61.0	59.0	56.0
91 0	91 0	91 0	95 0	95 0	96.0	90 5	95 3	90.0	91.0	90.0	90.0	89 5	90.0	81.5	83 0	77 0	81.0	79.3	84.0	67 5	68.2
2275 0	2275 0	2275 0	2375 0	2375 0	2400 0	1904 0	2764.0	1890.0	2639.0	1890.0	2610.0	1879.5	2610.0	1712 6	2407.0	1617.0	2349 0	1664 3	2436.0	1428.0	1923.0

3-13	3-22	3-12	3-22	3-10	3-21	2-23	3-8	2-22	3-7	2-21	3-6	2-15	3-2	2-10	3-5	2-9	2-28	2-7	2-25	2-3	2-24
158 0	179 0	158 0	187 0	158 0	199.5	143 0	201 7	142 8	192 5	142 8	190.5	140.0	190.4	129.0	176.0	122.2	171.4	126.0	178 0	108.0	130.0
180 0	187 0	185 0	193 0	185 0	219 0	155 0	226.0	154.0	216 0	155 0	220 0	150 0	206.0	144 0	192.0	132.2	192.0	147 0	185 0	123.0	135.0
13 9	4 5	17 1	3 2	17 1	9 8	8 4	12 0	7 8	12 2	8.5	15 5	7 1	8 2	11 6	9 1	8.2	12 0	16 7	3.9	13.8	3.8

SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

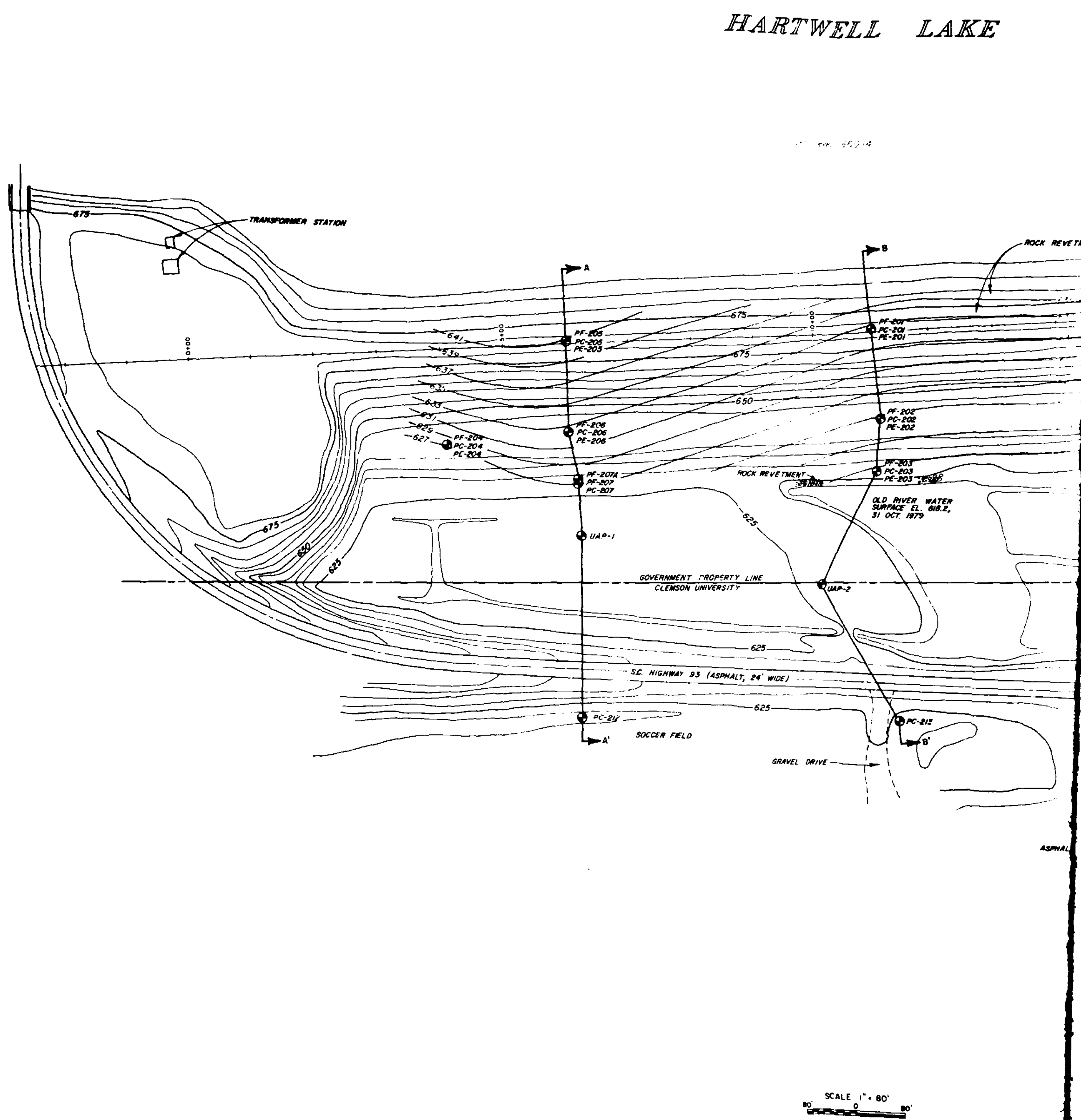
CUTOFF WALL PROFILE & DATA-SHEET 2

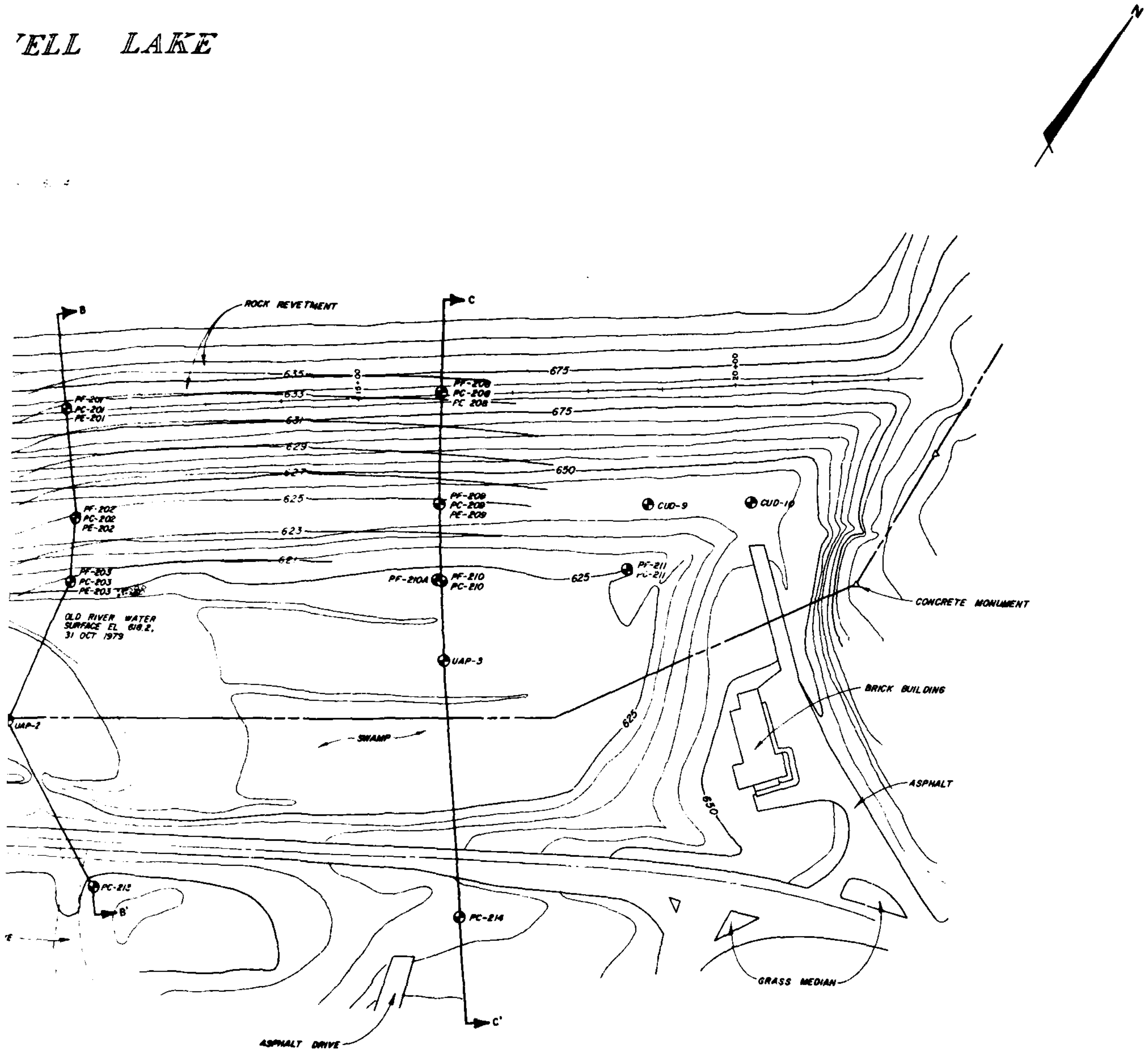
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	FILE NO	PLATE
F			10
SCALE		SHEET 10	

10

13


HARTWELL LAKE
TRANSFORMER STATION
A
B
PF-205
PC-205
PE-205
PF-201
PC-201
PE-201
PF-206
PC-206
PE-206
PF-204
PC-204
PF-207A
PF-207
PC-207
PF-202
PC-202
PE-202
PF-203
PC-203
PE-203
ROCK REVETMENT
OLD RIVER WATER SURFACE EL. 618.2, 31 OCT. 1979
UAP-1
UAP-2
GOVERNMENT PROPERTY LINE
CLEMSON UNIVERSITY
S.C. HIGHWAY 93 (ASPHALT, 24' WIDE)
SOCCER FIELD
A'
B'
GRAVEL DRIVE
675
650
625
SCALE 1" = 80'
80'
0
80'



NOTES

Piezometer surface contours were derived from readings taken on 5 May 1982

2 Contour interval 2.0 ft Elevation above M.S.L.

LEGEND

——— Piezometer contour

SCALE 1" = 80'

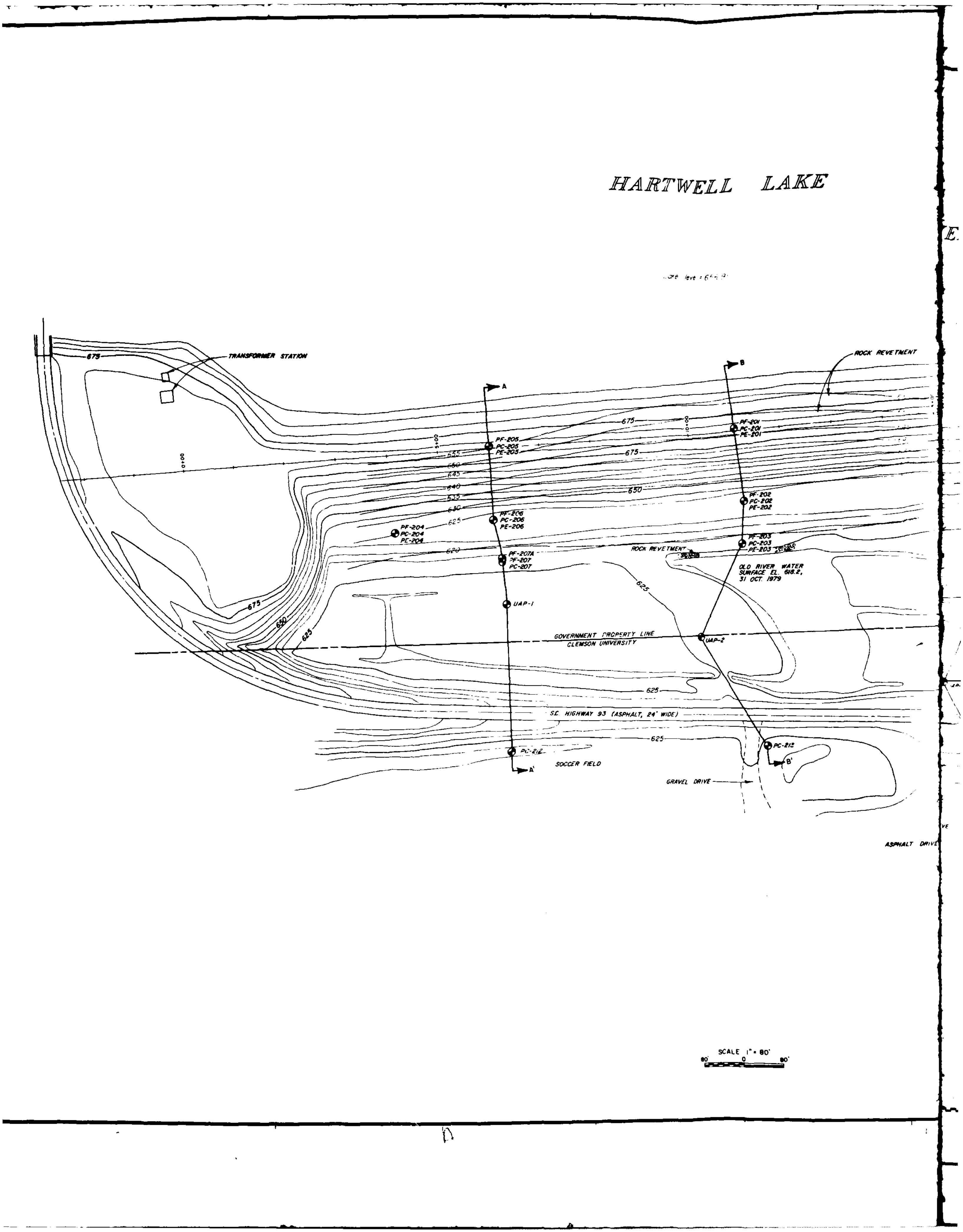
0 80'

SYMBOL	ZONE	DESCRIPTION	DATE	BY
REVISIONS				

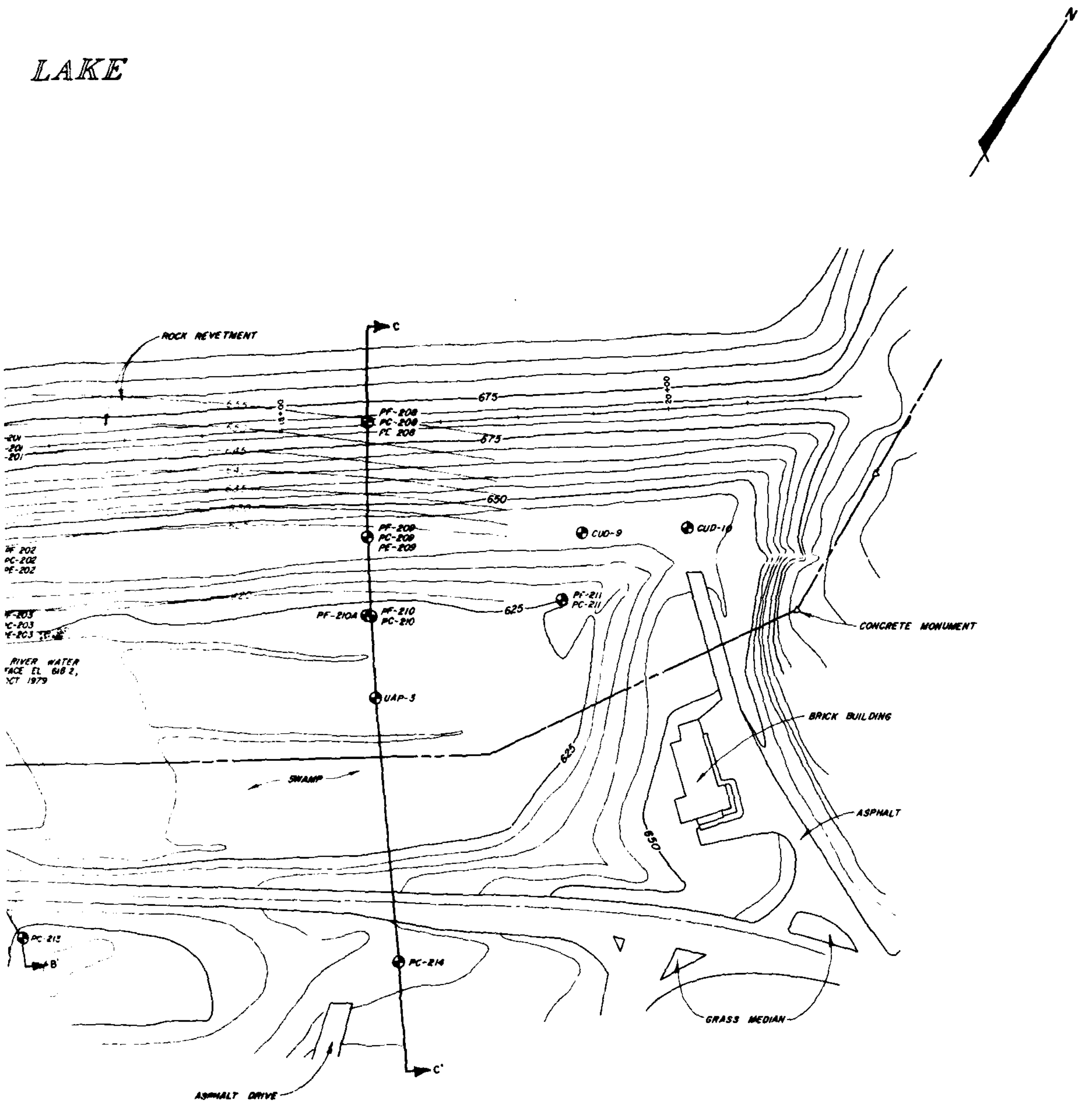
U. S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
PIEZOMETRIC SURFACE CONTOURS BEFORE WALL-EMBANKMENT
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	FILE NO	PLATE
F			
SCALE		SHEET	



HARTWELL LAKE
TRANSFORMER STATION
ROCK REVETMENT
675
650
625
620
630
635
640
645
655
0+00
5+00
10+00
A
A'
B
B'
PF-201
PC-201
PE-201
PF-202
PC-202
PE-202
PF-203
PC-203
PE-203
PF-204
PC-204
PE-204
PF-205
PC-205
PE-205
PF-206
PC-206
PE-206
PF-207A
PF-207
PC-207
UAP-1
UAP-2
PC-212
PC-213
OLD RIVER WATER SURFACE EL. 618.2, 31 OCT. 1979
GOVERNMENT PROPERTY LINE
CLEMSON UNIVERSITY
S.C. HIGHWAY 93 (ASPHALT, 24' WIDE)
SOCCER FIELD
GRAVEL DRIVE
ASPHALT DRIVE
SCALE 1" = 80'
80'
0
80'



NOTES

1 Piezometer surface contours were derived from readings taken on 9 April 1986
2 Contour interval=50' (Elevation above M.S.L.)

LEGEND

——— Piezometer contour
— — — Inferred

SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

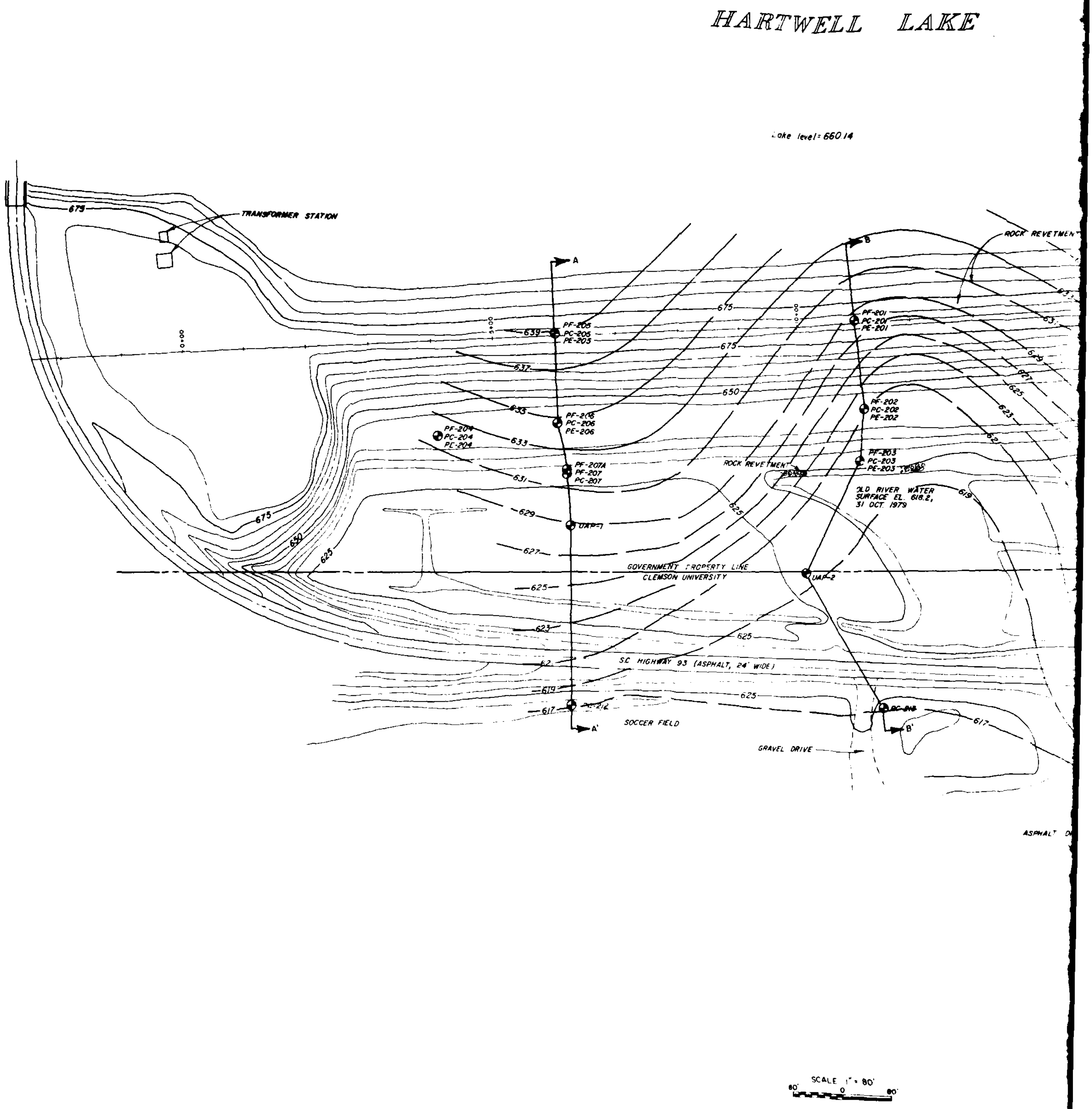
PIEZOMETRIC SURFACE CONTOURS AFTER WALL-EMBANKMENT

HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

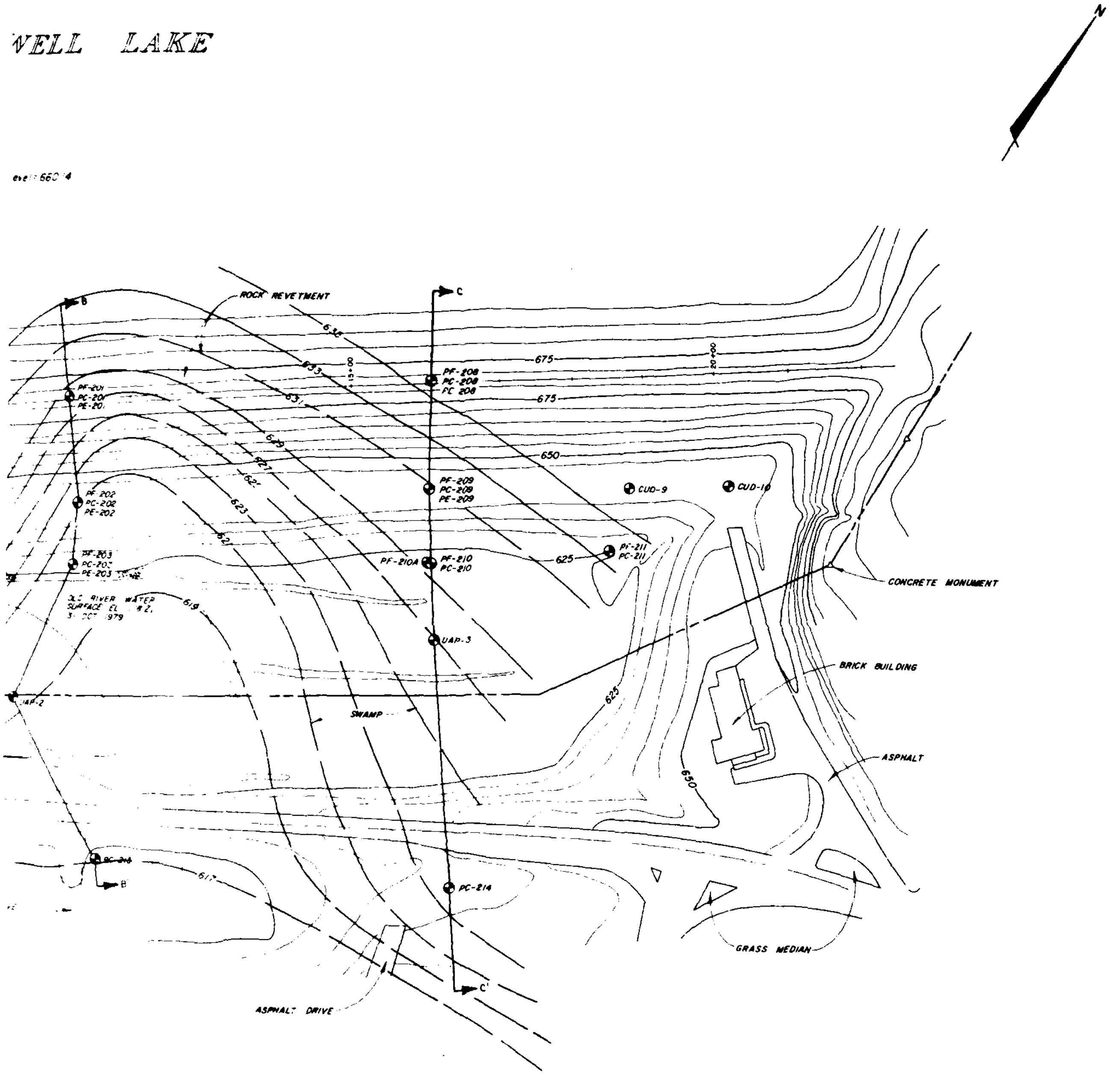
SIZE	INVITATION NO	FILE NO	PLATE
F			12

SCALE | SHEET

12


HARTWELL LAKE
Lake level = 660.14
TRANSFORMER STATION
ROCK REVETMENT
PF-205
PC-205
PE-205
PF-201
PC-201
PE-201
PF-206
PC-206
PE-206
PF-204
PC-204
PE-204
PF-202
PC-202
PE-202
PF-203
PC-203
PE-203
PF-207A
PF-207
PC-207
ROCK REVETMENT
OLD RIVER WATER SURFACE EL. 618.2, 31 OCT. 1979
UAP-1
UAP-2
GOVERNMENT PROPERTY LINE
CLEMSON UNIVERSITY
SC HIGHWAY 93 (ASPHALT, 24' WIDE)
SOCCER FIELD
GRAVEL DRIVE
SCALE 1" = 80'

A



NOTES

1 Piezometer surface contours were derived from readings taken on 5 May 1982

2 Contour interval = 2.0' (Elevation above M S L)

LEGEND

——— Piezometer contour

— — — Inferred

SYMBOL	ZONE	DESCRIPTION	DATE	BY
		REVISIONS		

U S ARMY ENGINEER DISTRICT, SAVANNAH
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SAVANNAH, GEORGIA

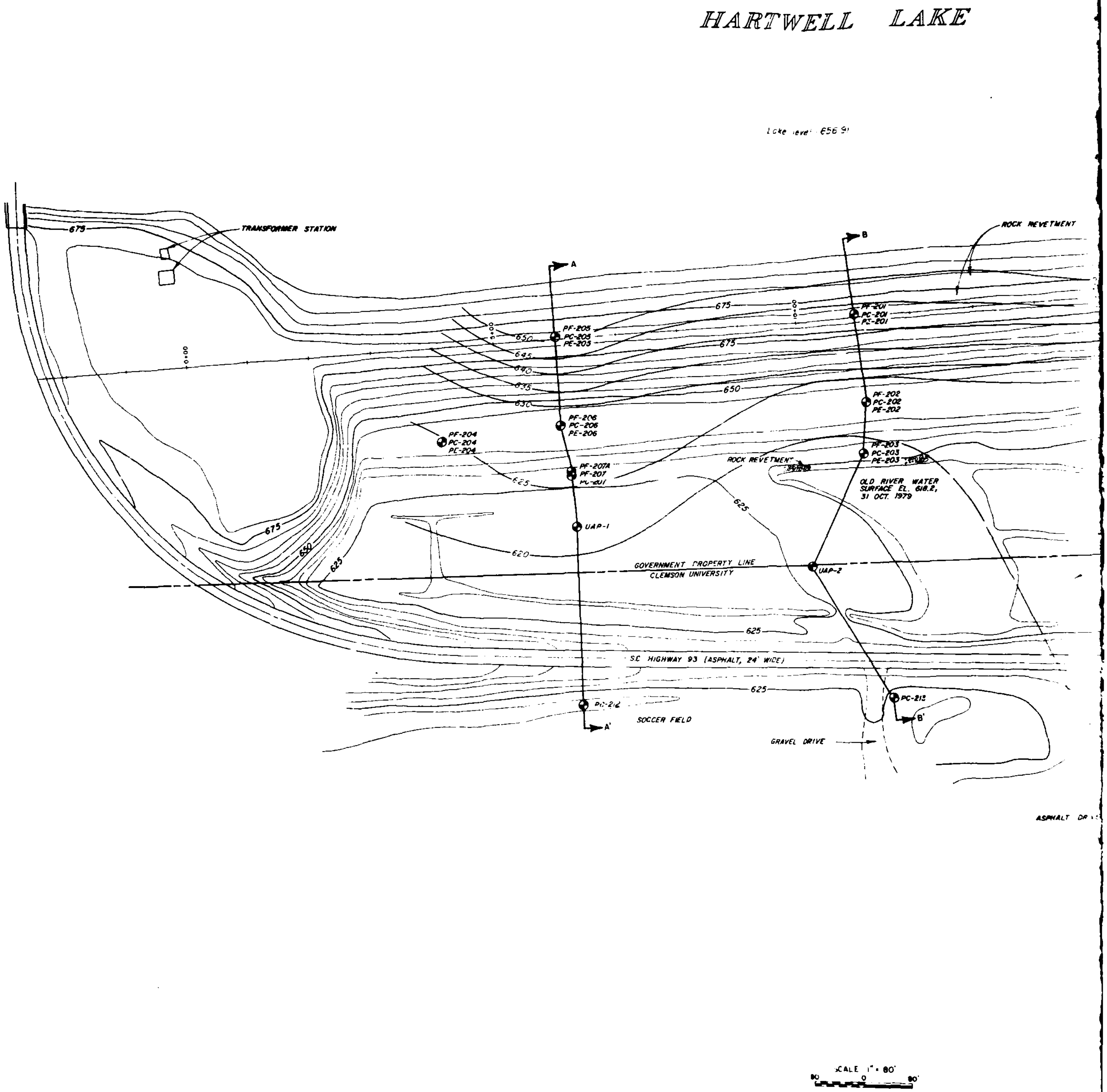
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

PIEZOMETRIC SURFACE CONTOURS BEFORE WALL-CONTACT

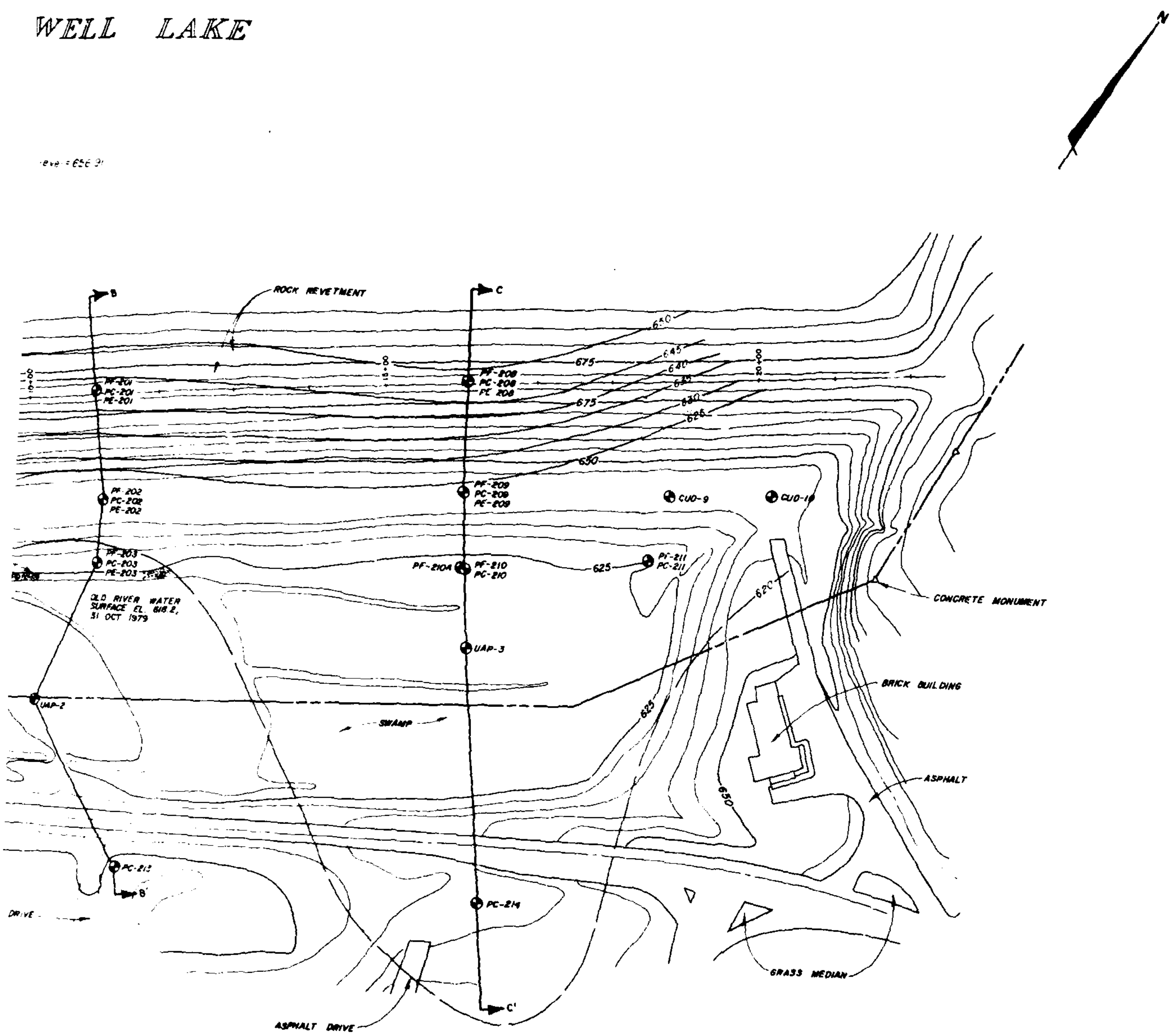
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	FILE NO	PLATE
F			13
SCALE			SHEET 13

13



HARTWELL LAKE
Lake level 656.9'
TRANSFORMER STATION
ROCK REVETMENT
A
B
0+00
5+00
10+00
675
650
645
640
635
630
625
620
PF-205
PC-205
PE-205
PF-201
PC-201
PE-201
PF-202
PC-202
PE-202
PF-203
PC-203
PE-203
PF-204
PC-204
PE-204
PF-206
PC-206
PE-206
PF-207A
PF-207
PC-207
UAP-1
UAP-2
OLD RIVER WATER
SURFACE EL. 618.2,
31 OCT. 1979
GOVERNMENT PROPERTY LINE
CLEMSON UNIVERSITY
SC HIGHWAY 93 (ASPHALT, 24' WIDE)
PC-212
PC-213
A'
B'
SOCCER FIELD
GRAVEL DRIVE
ASPHALT DR
SCALE 1" = 80'
80
0
80'



NOTES:

1. Piezometer surface contours were derived from readings taken on 9 April 1986
2. Contour interval=5.0' (Elevation above M.S.L.)

LEGEND

——— Piezometer contour
– – – Inferred

SYMBOL	ZONE	DESCRIPTION	DATE	BY
		REVISIONS		

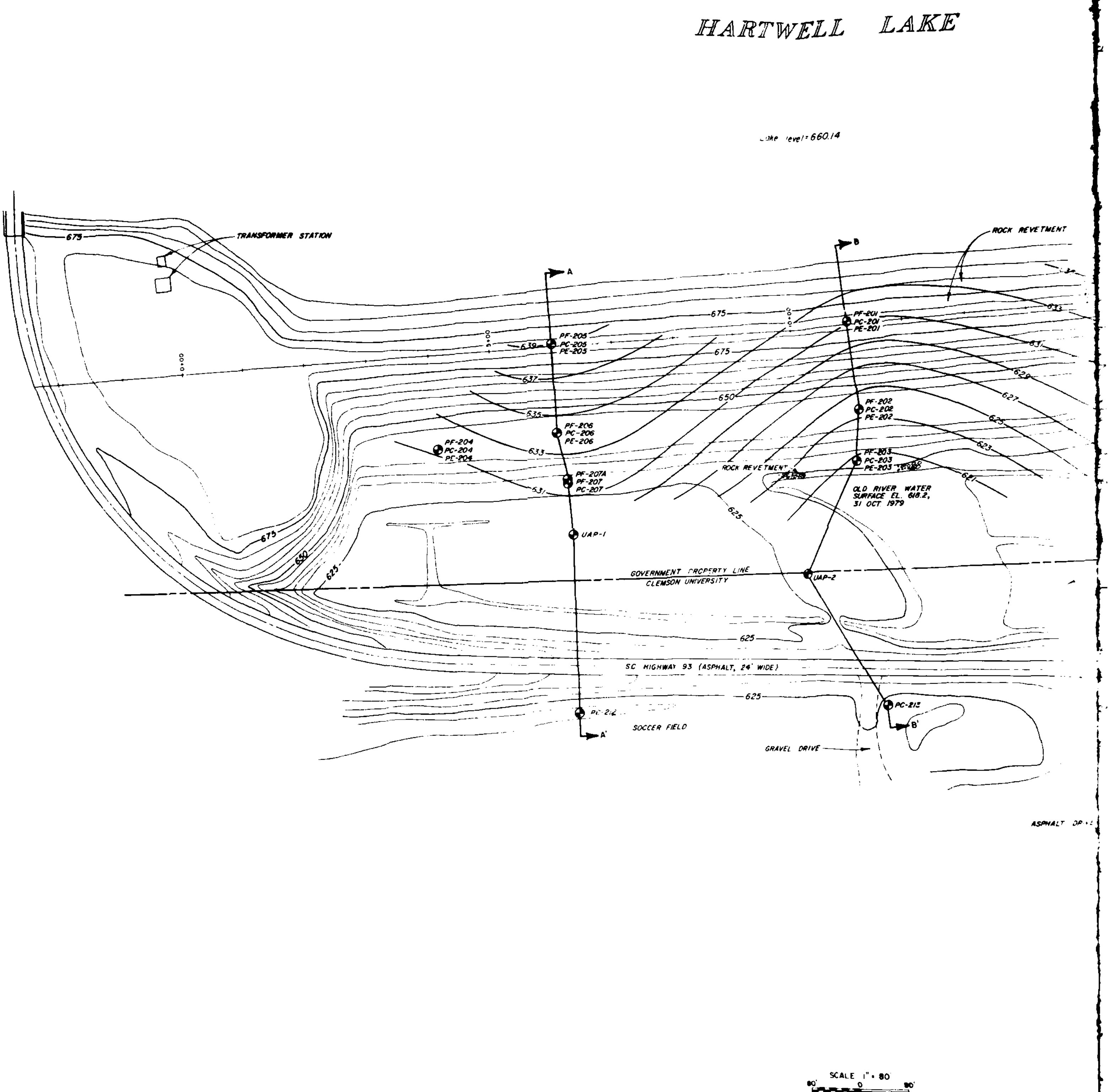
U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

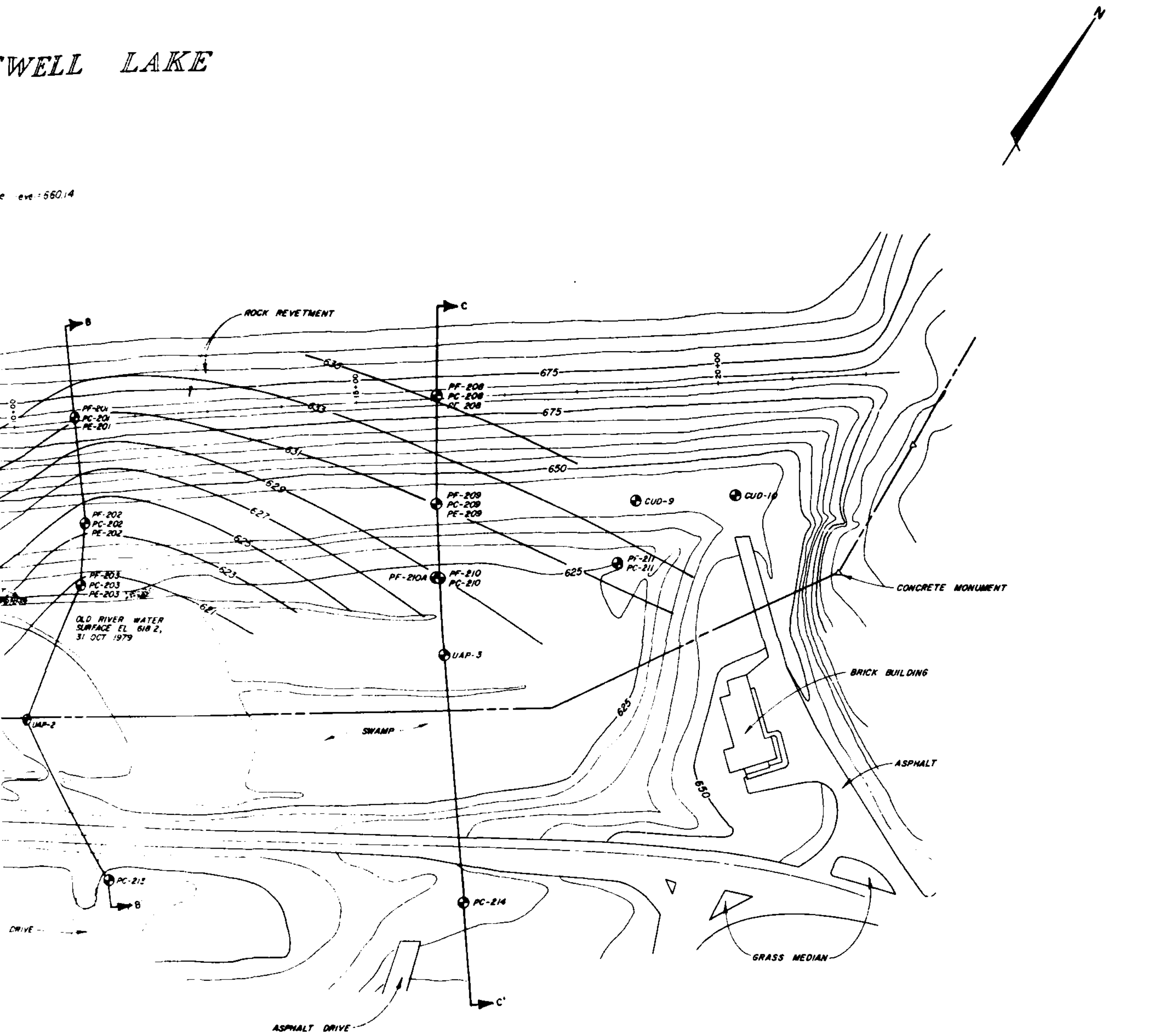
PIEZOMETRIC SURFACE CONTOURS AFTER WALL-CONTACT

HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	FILE NO	PLATE
F			14
SCALE		SHEET 14	



HARTWELL LAKE
Lake level = 660.14
TRANSFORMER STATION
ROCK REVETMENT
A
B
PF-205
PC-205
PE-205
PF-201
PC-201
PE-201
PF-206
PC-206
PE-206
PF-204
PC-204
PE-204
PF-207A
PF-207
PC-207
PF-202
PC-202
PE-202
PF-203
PC-203
PE-203
OLD RIVER WATER SURFACE EL. 618.2, 31 OCT 1979
UAP-1
UAP-2
GOVERNMENT PROPERTY LINE
CLEMSON UNIVERSITY
SC HIGHWAY 93 (ASPHALT, 24' WIDE)
PC-212
PC-213
A'
B'
SOCCER FIELD
GRAVEL DRIVE
SCALE 1" = 80'



NOTES

1 Piezometer surface contours were derived from readings taken on 5 May 1982.
2 Contour interval=2.0' (Elevation above M.S.L.)

LEGEND

——— Piezometer contour

SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

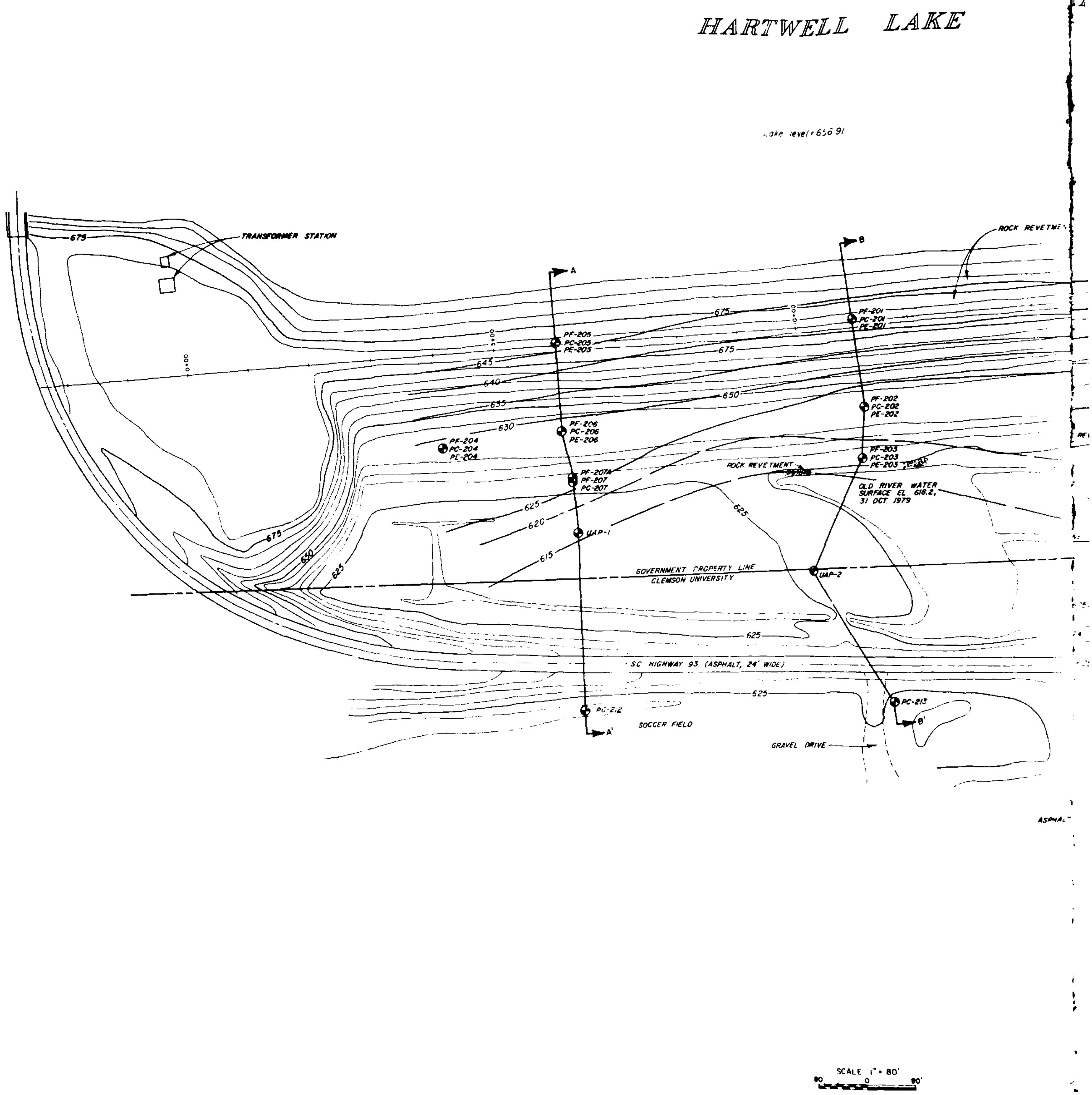
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
PIEZOMETRIC SURFACE CONTOURS BEFORE WALL-FOUNDATION
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

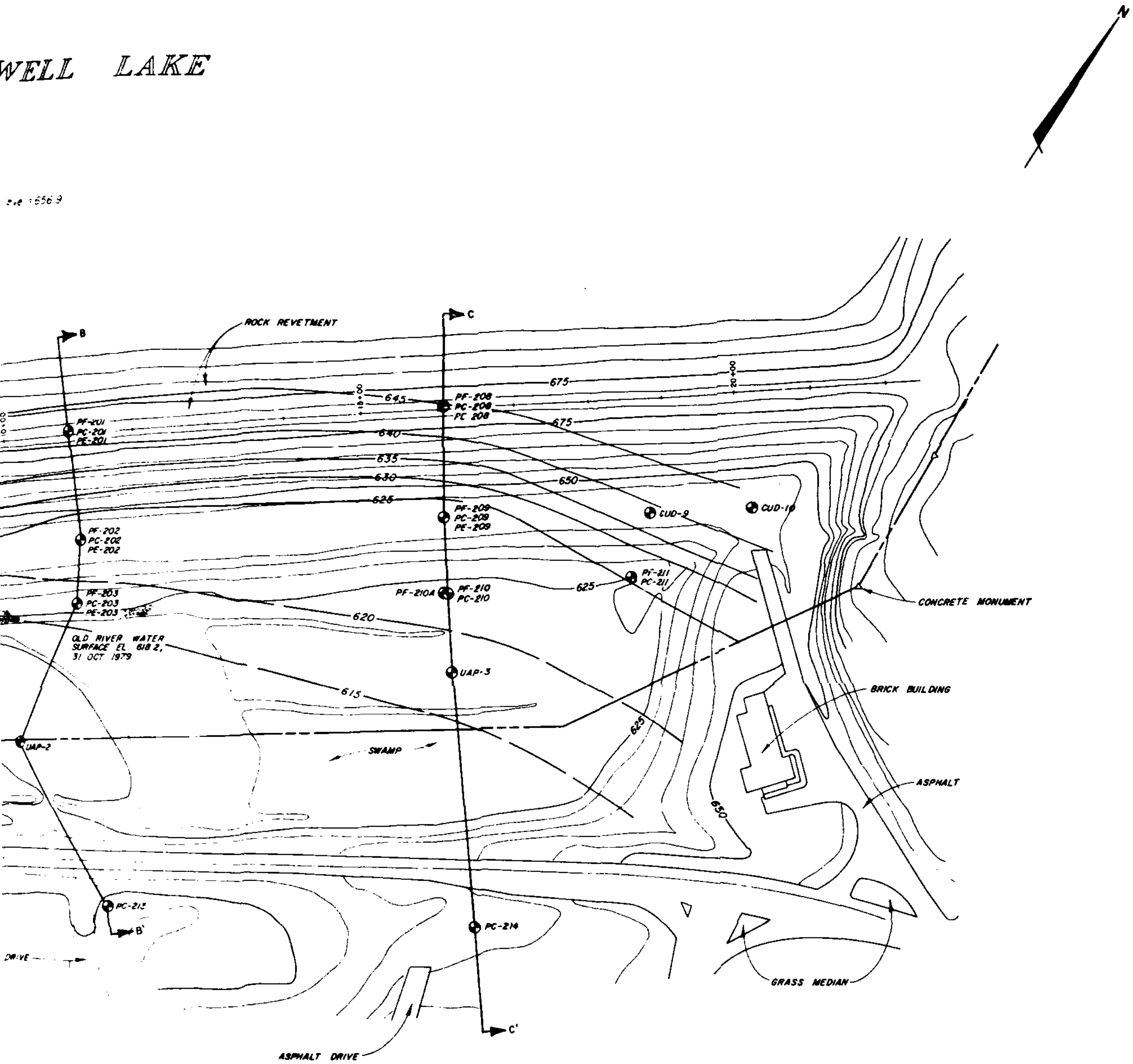
SIZE	INVITATION NO	FILE NO	PLATE
F			15

SCALE

SHEET 15

15


HARTWELL LAKE
TRANSFORMER STATION
ROCK REVETMENT
PF-205
PC-205
PE-205
PF-201
PC-201
PE-201
PF-202
PC-202
PE-202
PF-203
PC-203
PE-203
PF-204
PC-204
PE-204
PF-206
PC-206
PE-206
PF-207A
PF-207
PC-207
UAP-1
UAP-2
ROCK REVETMENT
OLD RIVER WATER
SURFACE EL. 618.2,
31 OCT. 1979
GOVERNMENT PROPERTY LINE
CLEMSON UNIVERSITY
SC HIGHWAY 93 (ASPHALT, 24' WIDE)
SOCCER FIELD
GRAVEL DRIVE
PC-213
675
645
640
635
630
650
625
620
615
SCALE 1" = 80'
80
0
80'



NOTES:

1. Piezometer surface contours were derived from readings taken on 9 April 1986
2. Contour interval=5.0' (Elevation above M.S.L.).

LEGEND

- Piezometer contour
- Inferred

SCALE 1" = 80'

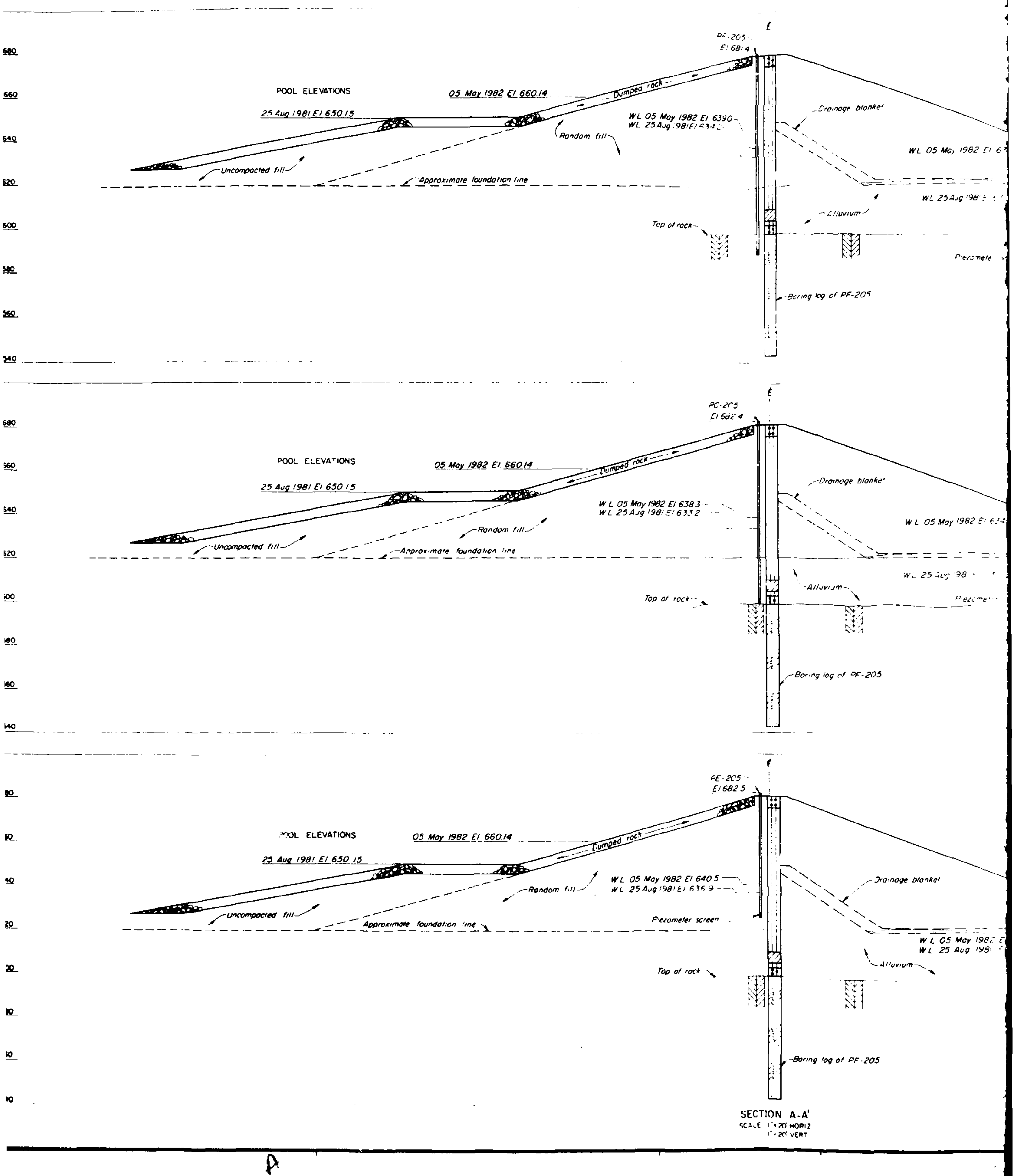
SYMBOL	ZONE	DESCRIPTION	DATE	BY
		REVISIONS		

U.S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

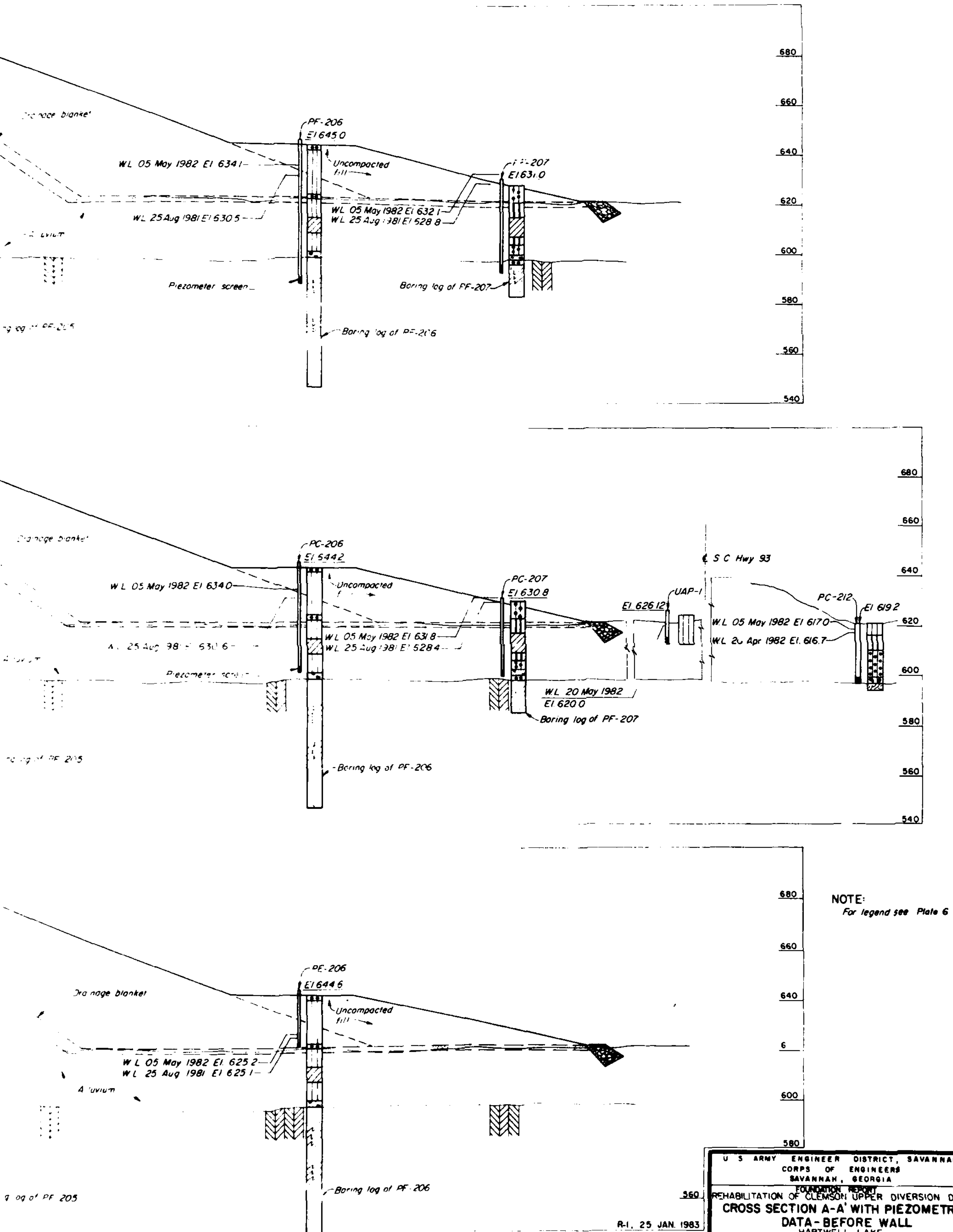
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

PIEZOMETRIC SURFACE CONTOURS AFTER WALL-FOUNDATION
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	FILE NO	PLATE
F			16
SCALE		SHEET	



POOL ELEVATIONS
05 May 1982 El 660.14
25 Aug 1981 El 650.15
Dumped rock
Random fill
Uncompacted fill
Approximate foundation line
Drainage blanket
Alluvium
Top of rock
Boring log of PF-205
Piezometer screen
SECTION A-A'
SCALE 1" = 20' HORIZ
1" = 20' VERT



R-1, 25 JAN. 1983

SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

U. S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

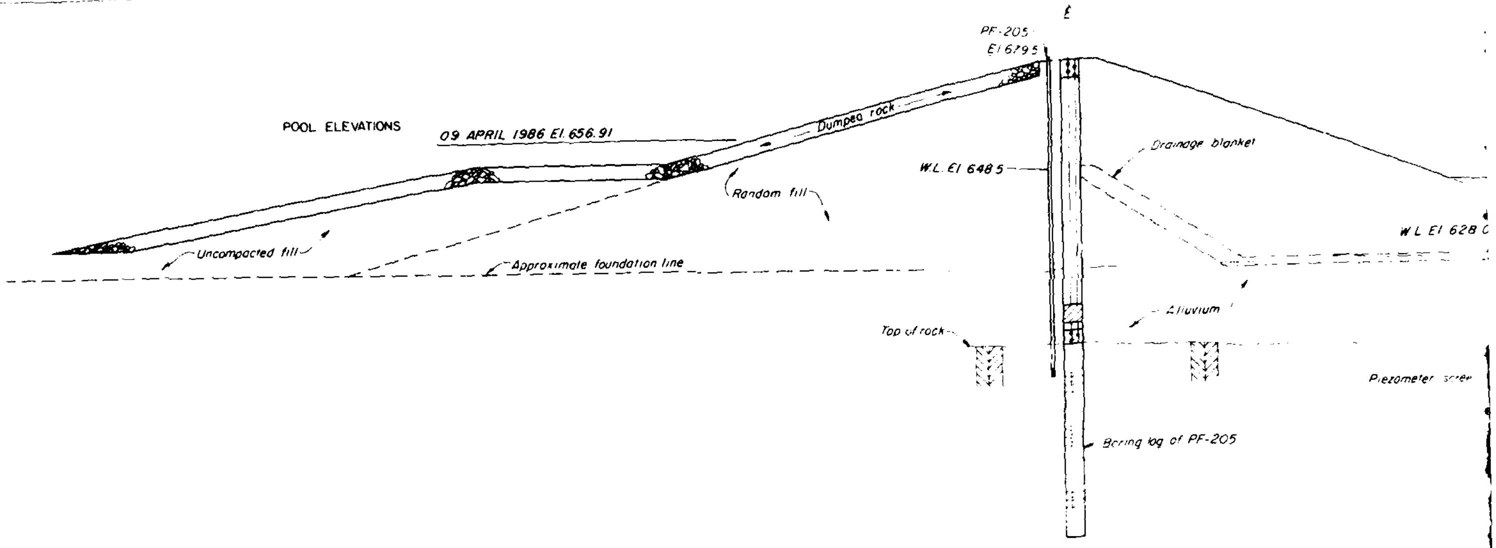
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

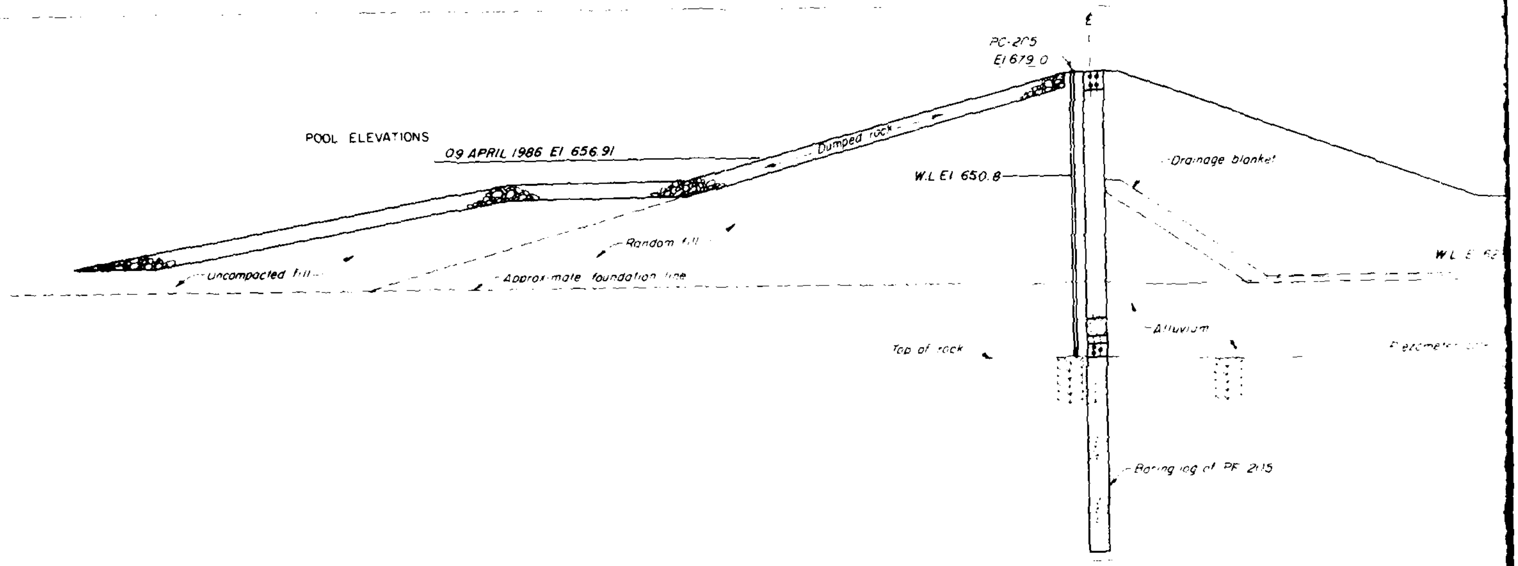
CROSS SECTION A-A' WITH PIEZOMETRIC DATA-BEFORE WALL

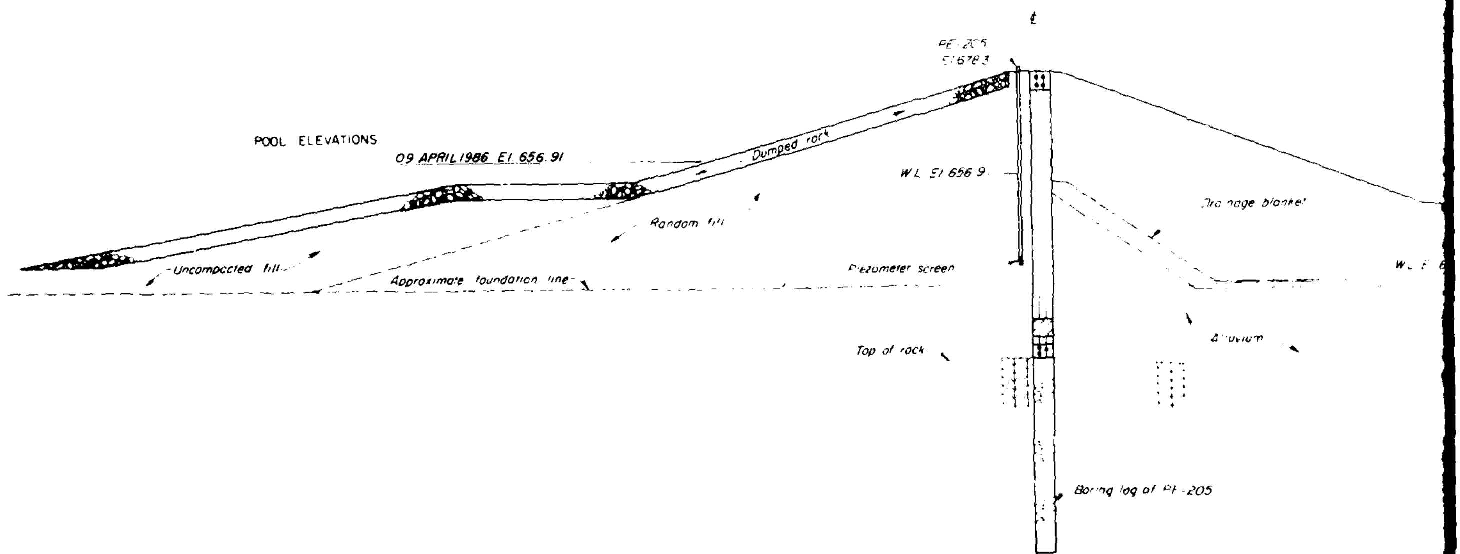
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	DRAWING NO	PLATE
F		HWI/33	17

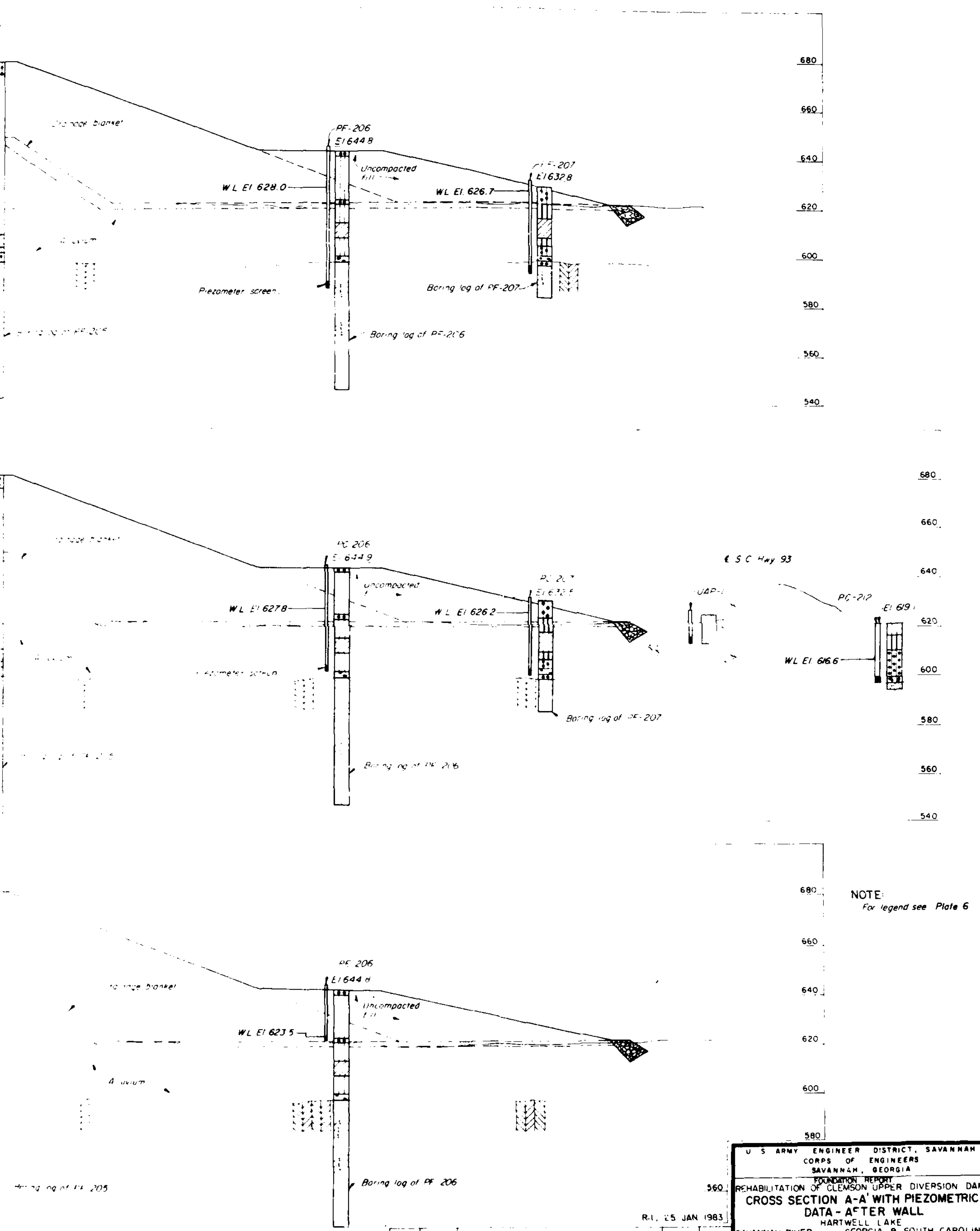
SCALE AS SHOWN | DATE | SHEET 17







SECTION A-A'
SCALE 1" = 20' HORIZ
1" = 20' VERT



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SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

CROSS SECTION A-A' WITH PIEZOMETRIC DATA - AFTER WALL

HARTWELL LAKE

SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

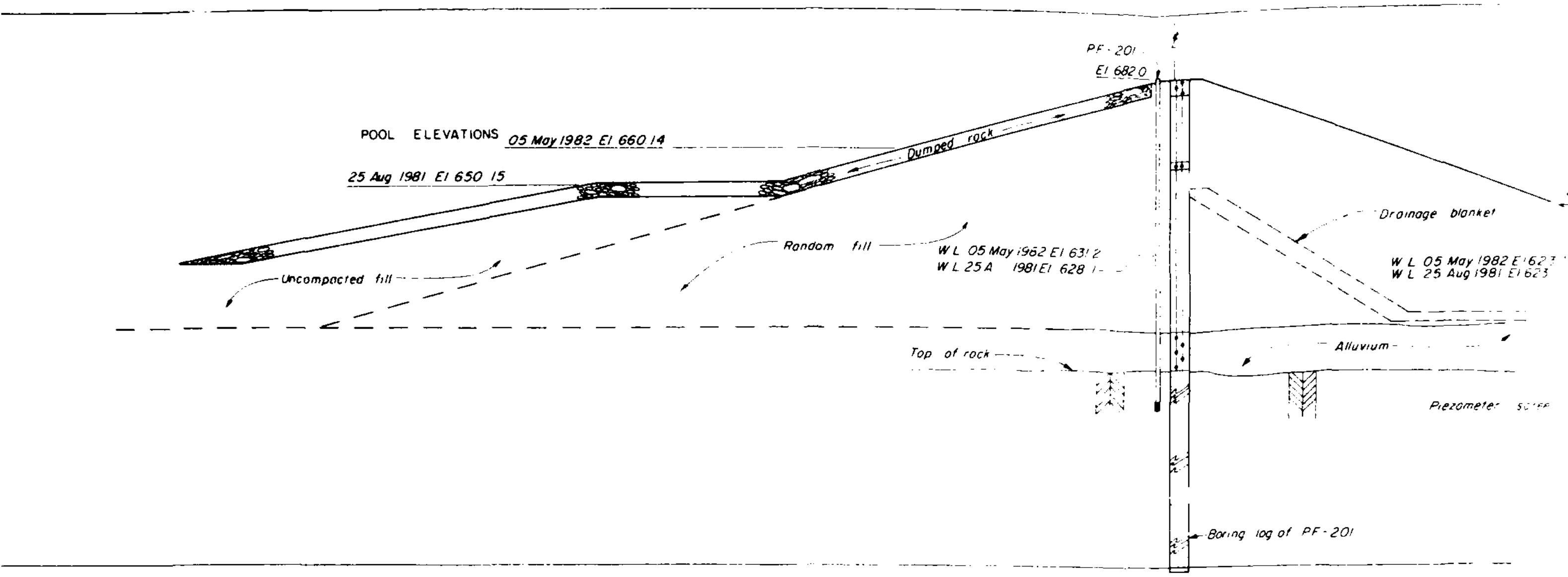
R-1, 25 JAN 1983

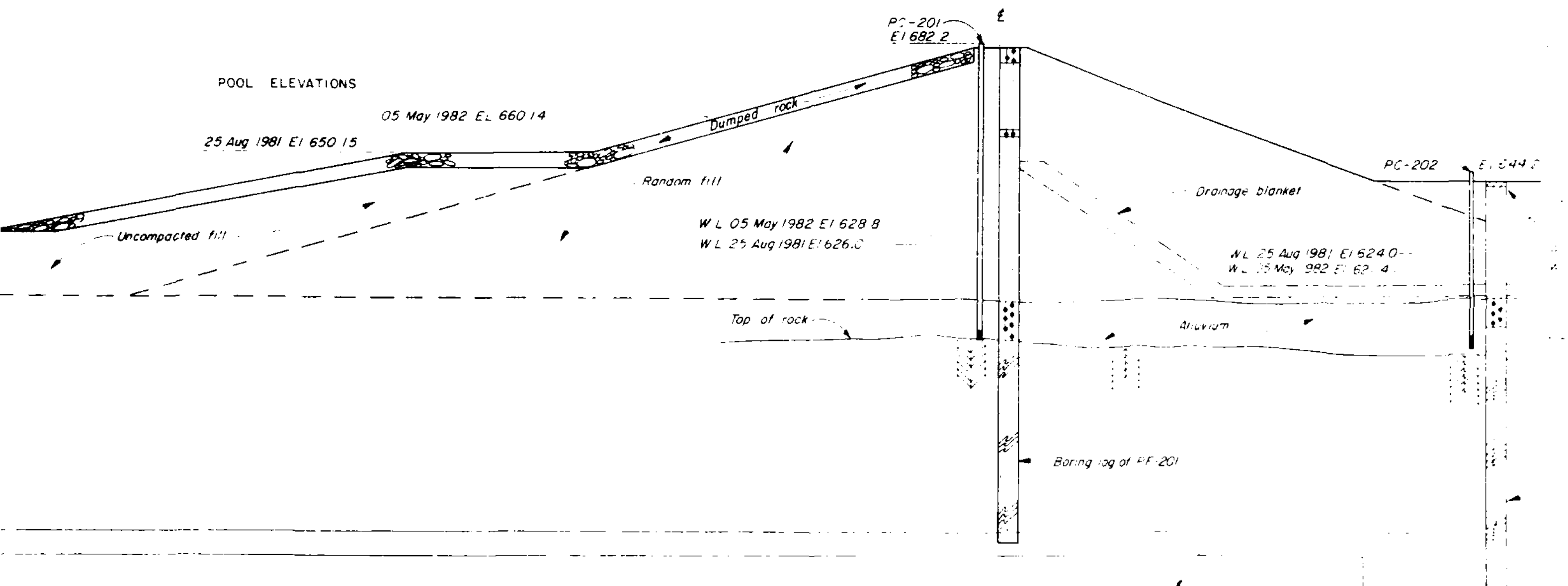
SIZE		DRAWING NO.	PLATE
F		HW1/33	18

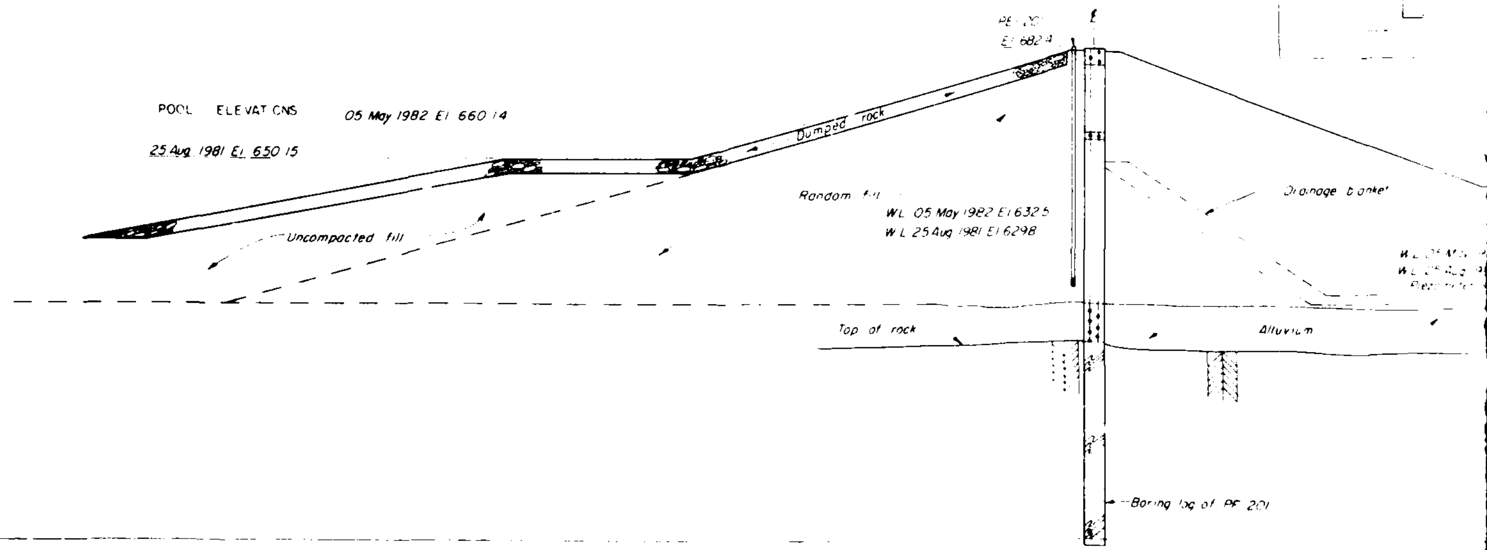
REVISIONS

SHEET 18

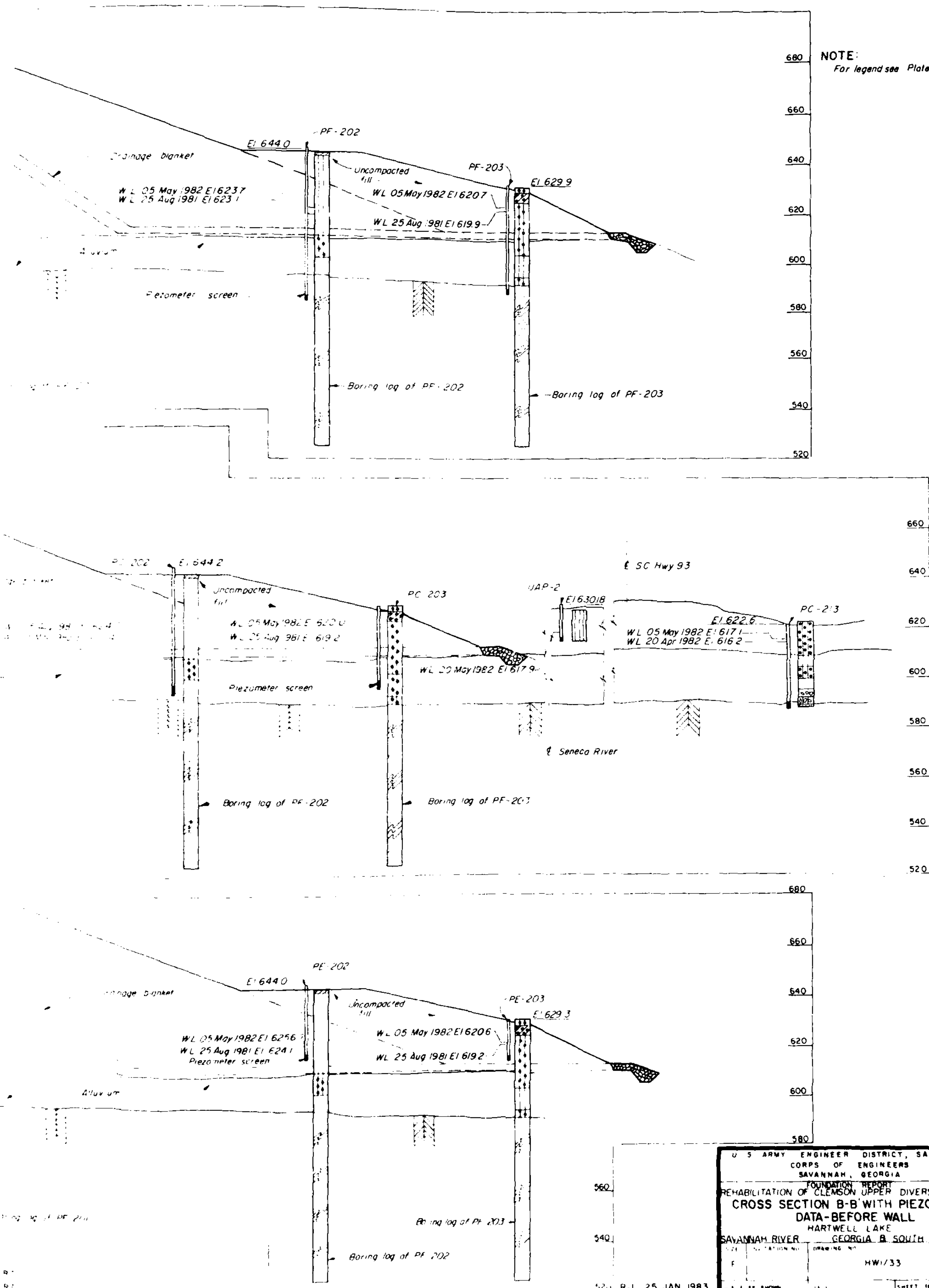
(18)







B-B'
SCALE 1" = 20' VERT
1" = 20' HORZ



U. S. ARMY ENGINEER DISTRICT, SAVANNAH
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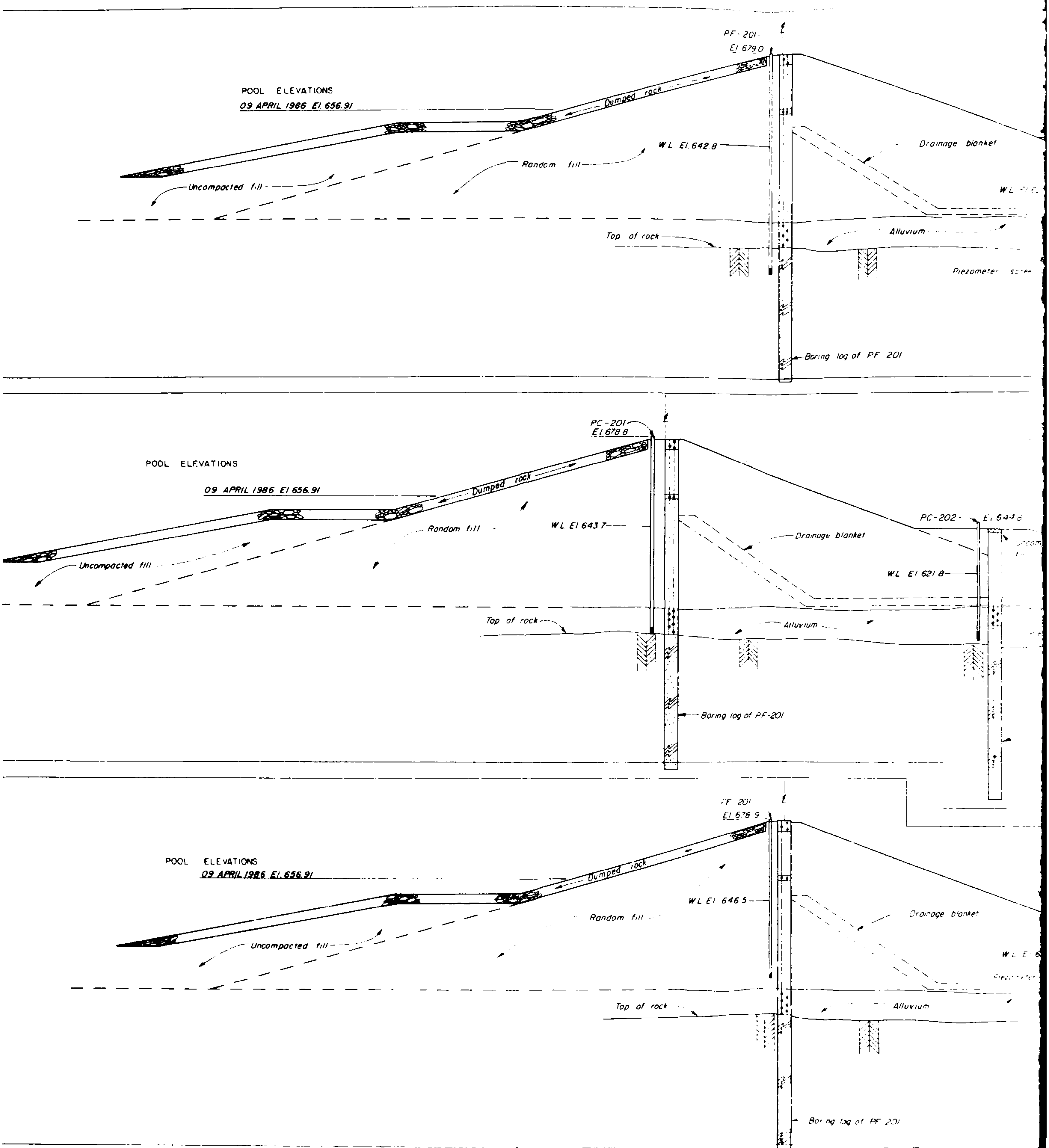
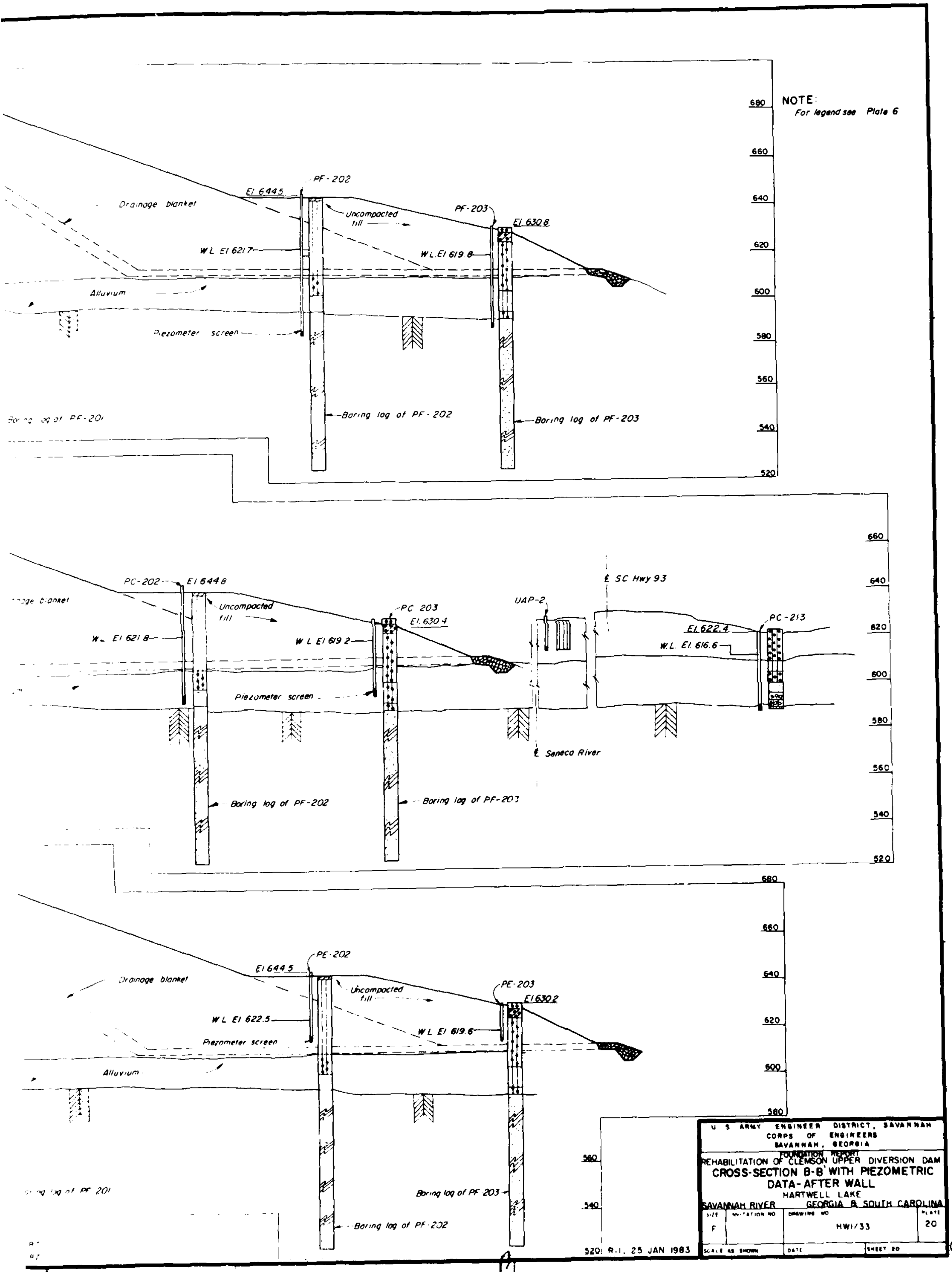
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
CROSS SECTION B-B' WITH PIEZOMETRIC DATA-BEFORE WALL
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

F		HWI/33	PLATE 19
SCALE AS SHOWN			SHEET 19



B-B'
SCALE 1" = 20' VERT
1" = 20' HORZ

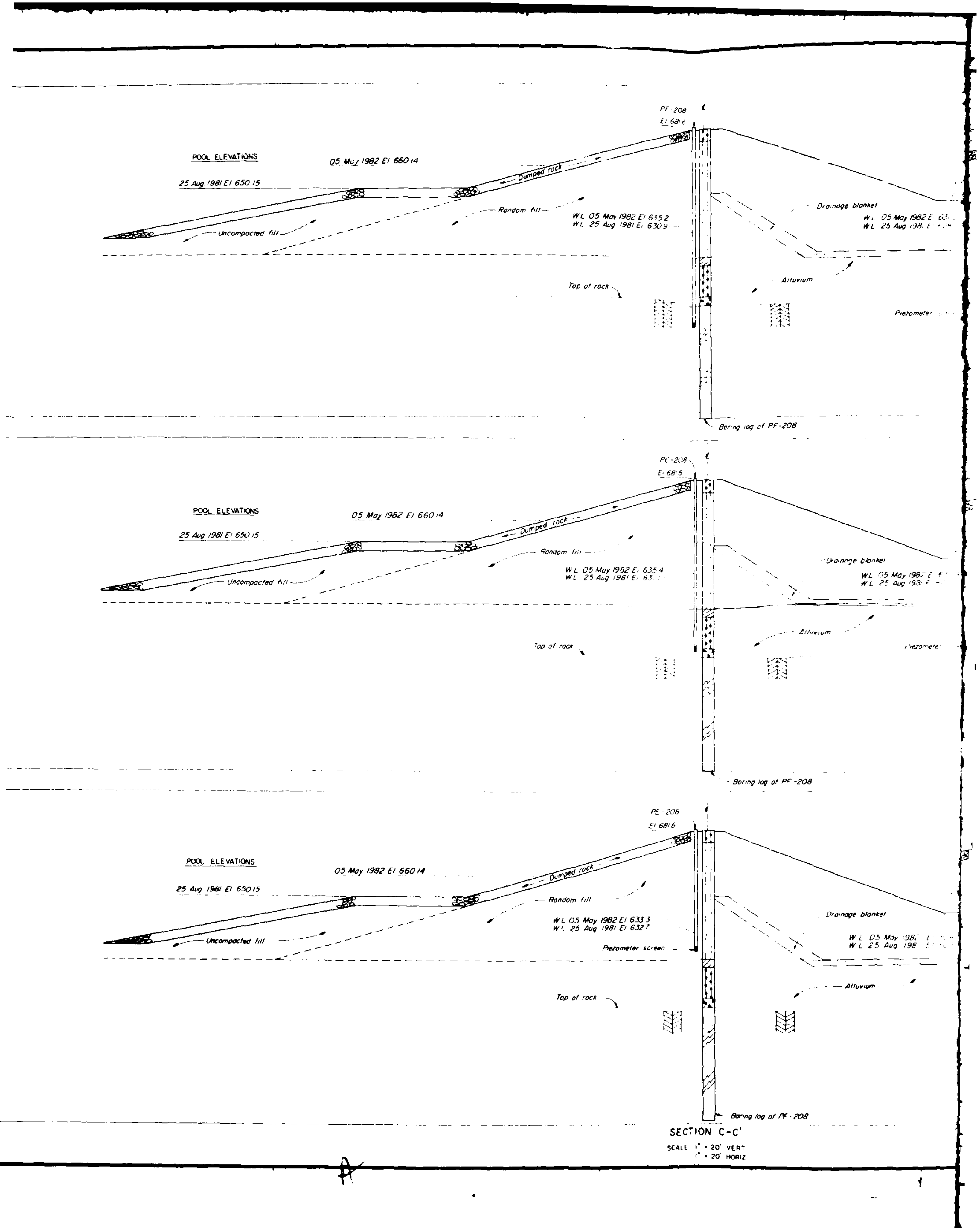


U.S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
CROSS-SECTION B-B' WITH PIEZOMETRIC DATA-AFTER WALL
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

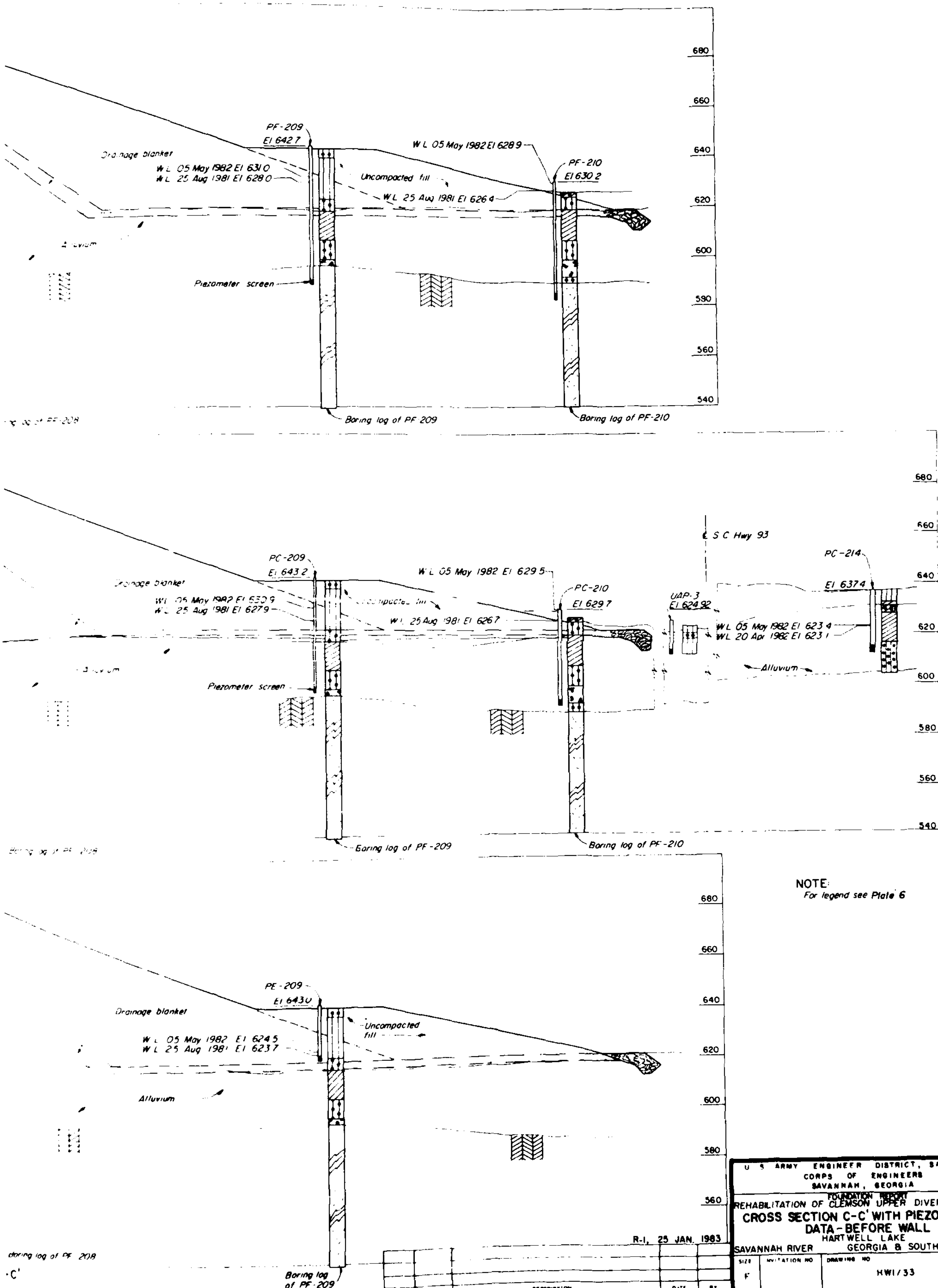
SIZE	INVITATION NO.	DRAWING NO.	PLATE
F		HWI/33	20

SCALE AS SHOWN | DATE | SHEET 20



SECTION C-C'

SCALE 1" = 20' VERT
1" = 20' HORIZ



NOTE:
For legend see Plate 6

R-1, 25 JAN. 1983

SYMBOL	ZONE	DESCRIPTION	DATE	BY

REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

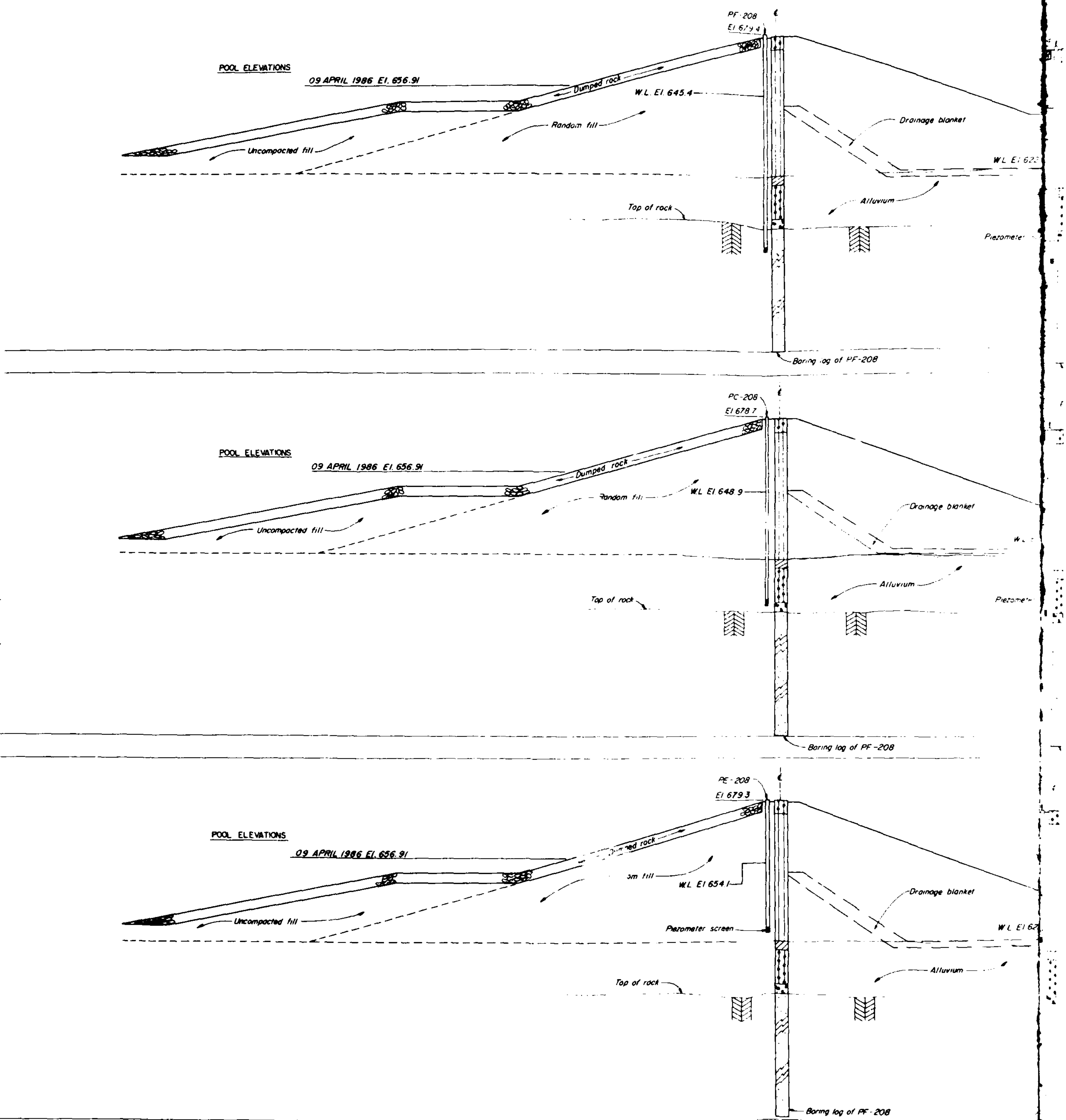
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM

CROSS SECTION C-C' WITH PIEZOMETRIC DATA-BEFORE WALL

HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

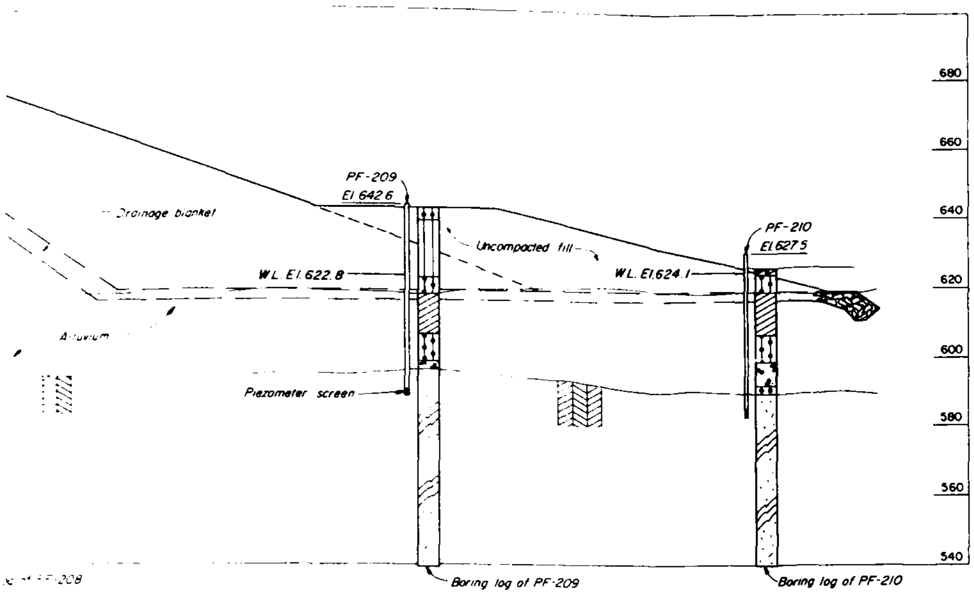
SIZE	INVITATION NO	DRAWING NO	PLATE
F		HWI/33	21
SCALE AS SHOWN		DATE	SHEET 21

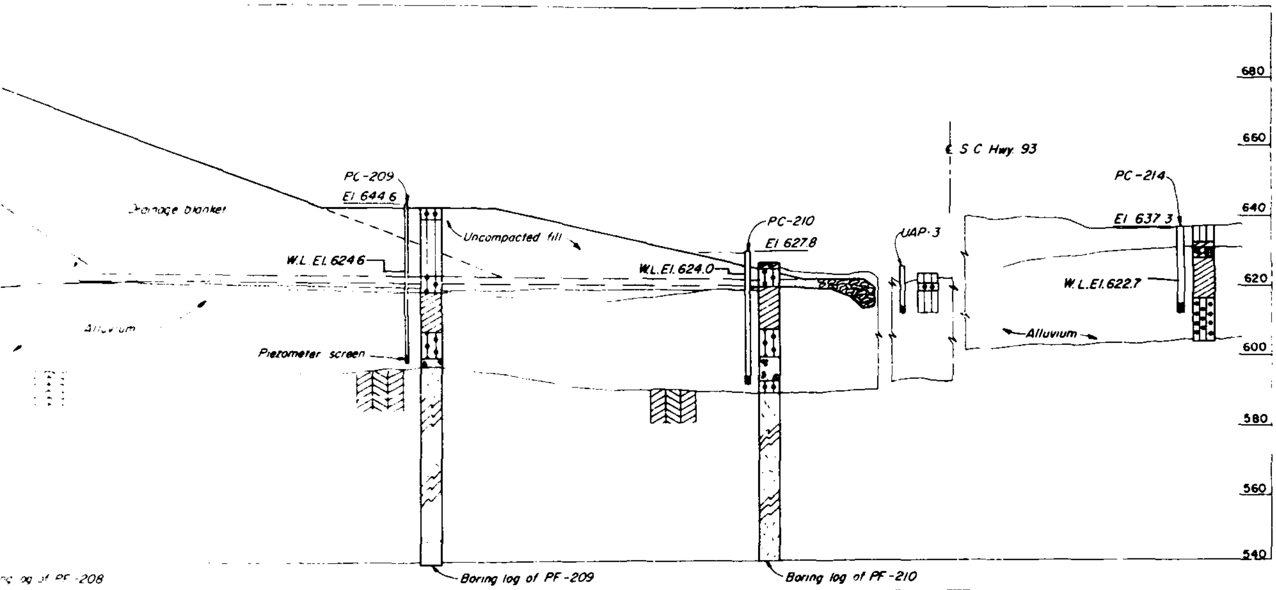
21

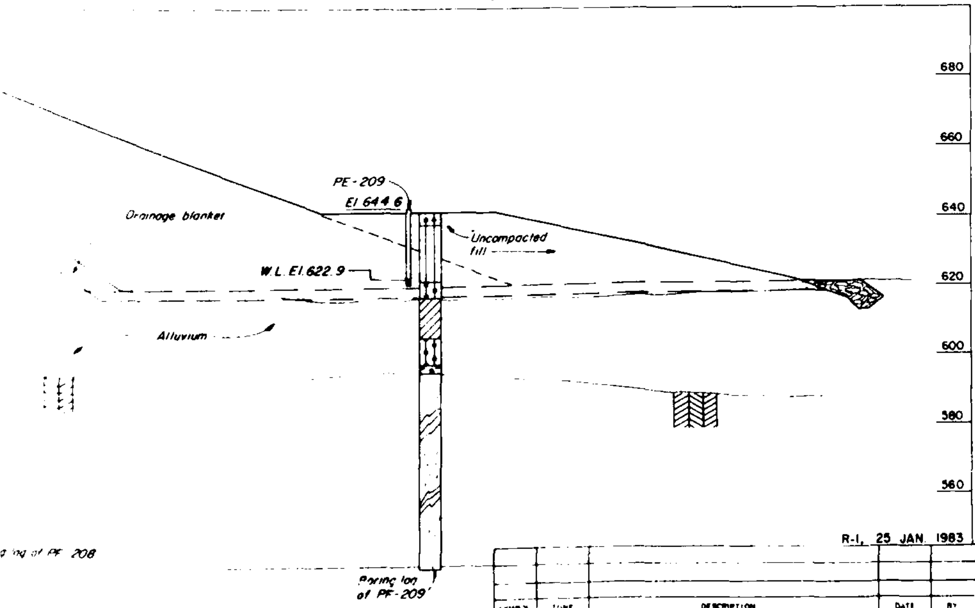


SECTION C-C'

SCALE 1" = 20' VERT
1" = 20' HORIZ







NOTE:
For legend see Plate 6

R-1, 25 JAN. 1983

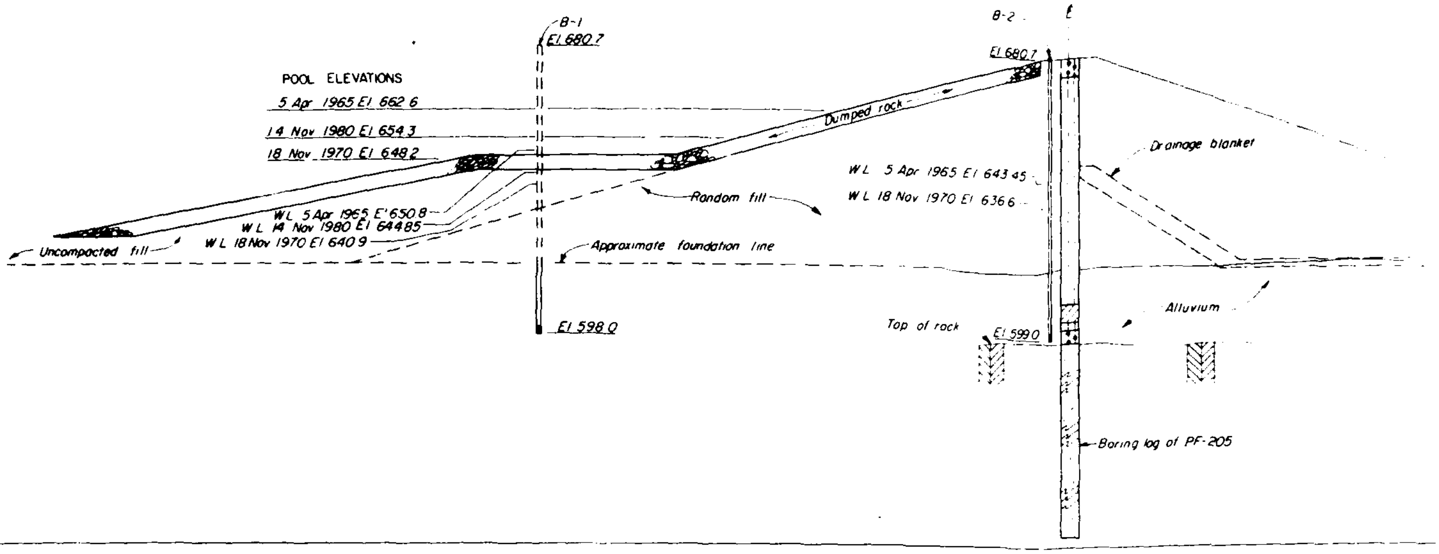
SYMBOL	ZONE	DESCRIPTION	DATE	BY
		REVISIONS		

U. S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

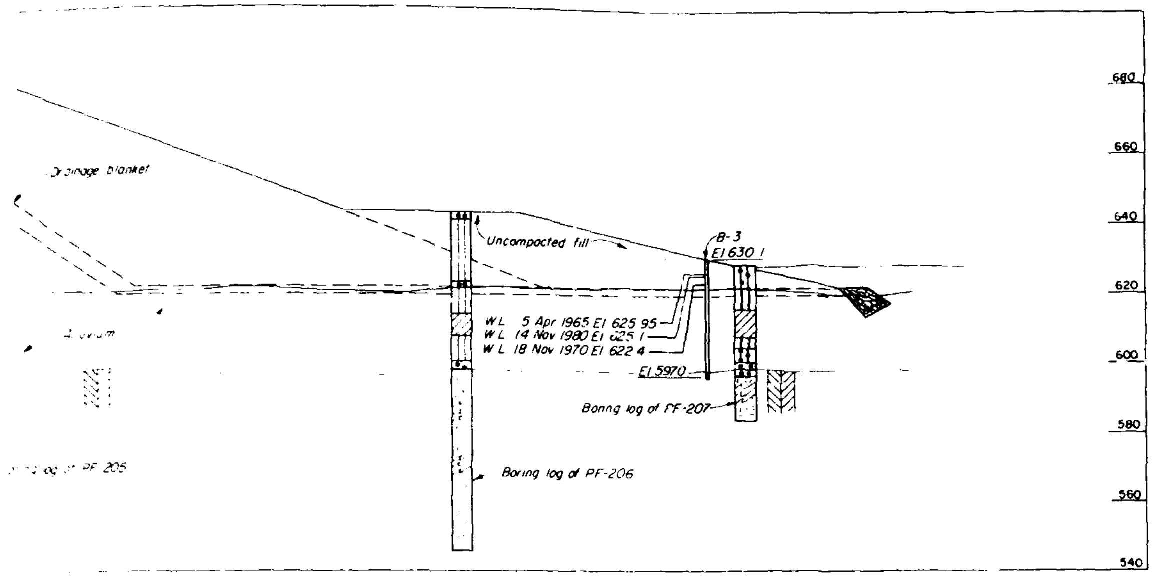
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
CROSS-SECTION C-C' WITH PIEZOMETRIC DATA-AFTER WALL
HARTWELL LAKE
SAVANNAH RIVER GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	DRAWING NO	PLATE
F		HWI/33	22
SCALE AS SHOWN	DATE	SHEET 22	

(22)



SCALE 1" = 20' Vert
1" = 20' Horiz



NOTE:
For legend see Plate 6.

R-1-25 Jan 83

SYMBOL	ZONE	DESCRIPTION	DATE	BY

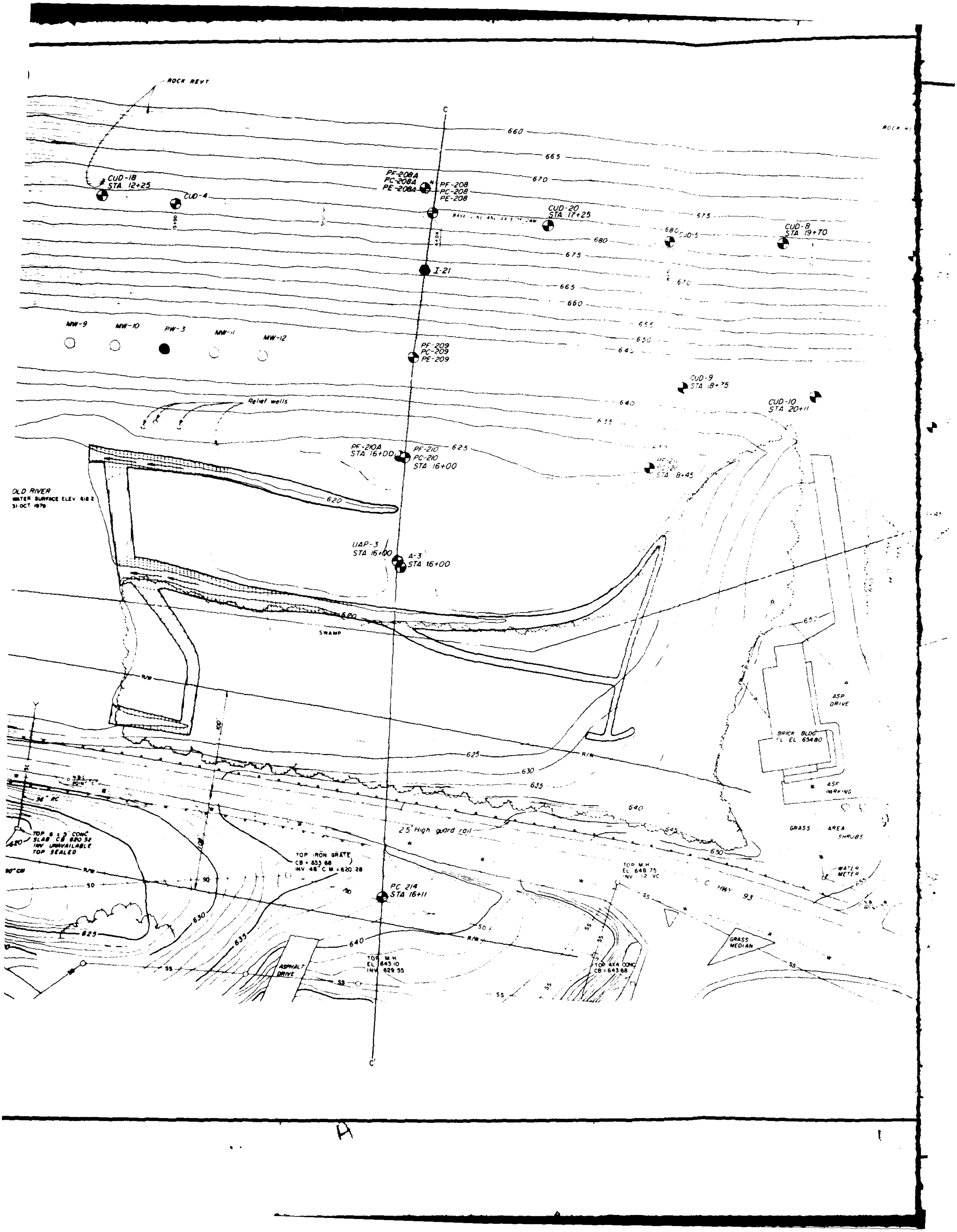
REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

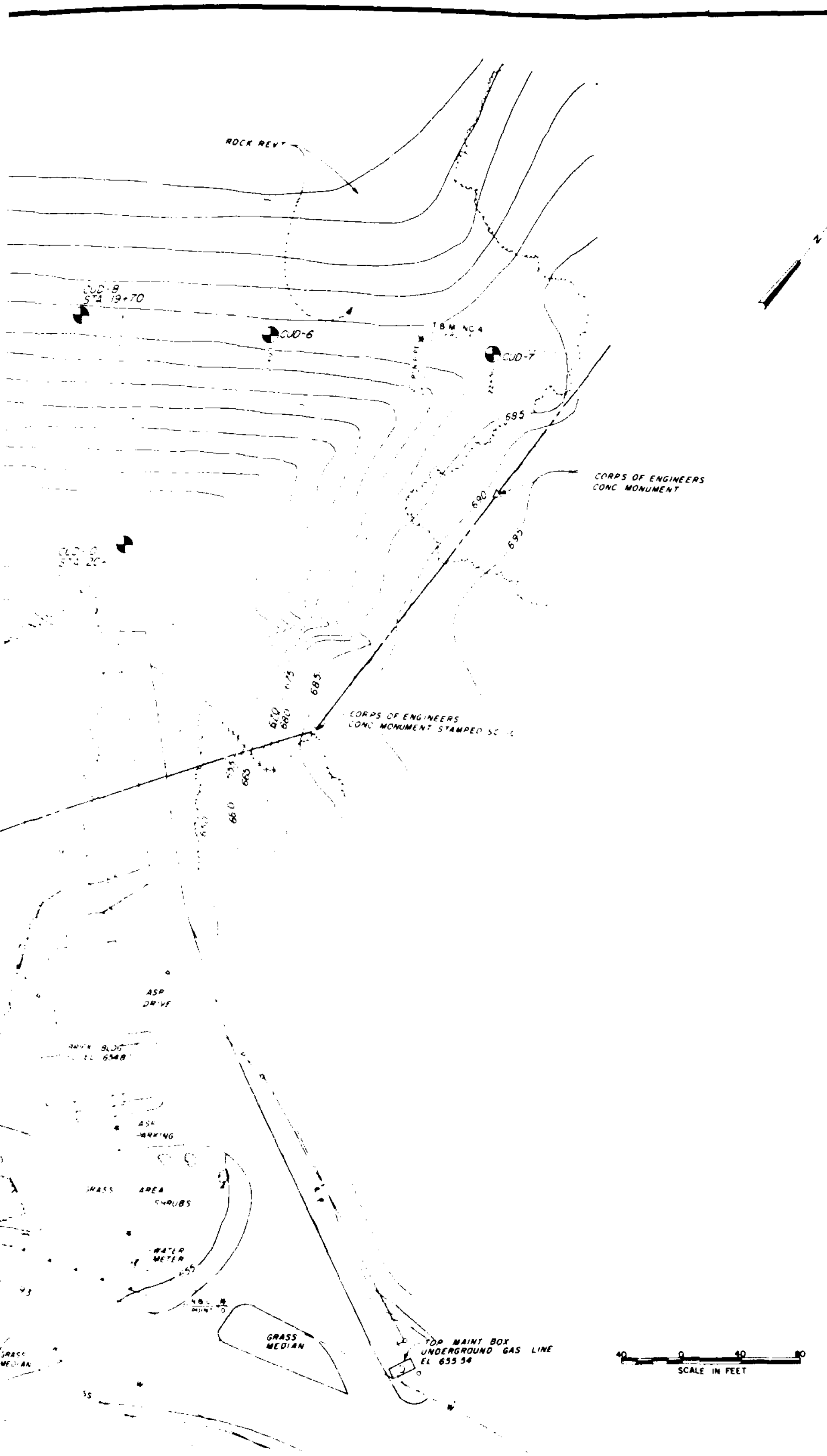
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
OLD PIEZOMETER CROSS SECTION AT STA. 7+75 SHOWING PIEZOMETER DATA
HARTWELL LAKE
SAVANNAH RIVER GEORGIA AND SOUTH CAROLINA

SIZE	INVITATION NO	DRAWING NO	PLATE
F		HWI/33	23

SCALE AS SHOWN | DATE | SHEET 23



ROCK REVT
C
660
665
670
675
680
CUD-18
STA 12+25
CUD-4
PF-208A
PC-208A
PE-208A
PF-208
PC-208
PE-208
CUD-20
STA 17+25
CUD-5
CUD-8
STA 19+70
I-21
MW-9
MW-10
PW-3
MW-11
MW-12
PF-209
PC-209
PE-209
CUD-9
STA 18+75
CUD-10
STA 20+11
Relief wells
PF-210A
STA 16+00
PF-210
PC-210
STA 16+00
OLD RIVER
WATER SURFACE ELEV 618.2
31 OCT 1979
UAP-3
STA 16+00
A-3
STA 16+00
SWAMP
R/W
625
630
635
640
645
650
ASP DRIVE
BRICK BLDG
ASP PARKING
GRASS AREA
SHRUBS
WATER METER
2.5' High guard rail
TOP IRON GRATE
PC 214
STA 16+11
TOP M.H.
C HWY 93
GRASS MEDIAN
ASPHALT DRIVE
SS
C'
A



LEGEND

- Inclinometer
- PF-201A — New Piezometer
- Piezometers and exploration borings
- Old piezometers
- Aquifer test pumping well
- Aquifer test monitor well
- —W— Water line
- —P— Power line
- —P,— Power and Telephone

SUBSURFACE DRAINAGE SYSTEM

- Sand filled ditch
- Coarse filter and sand filled ditch

PLANE TABLE SHEET, HARTWELL NO. 46-1,2
SURVEYED OCTOBER 1979
UPPER DIVERSION DAM

HORIZ & VERT CONTROL DATA
T B M NO. 3, EL 681.91, 1-20d NAIL IN POWER POLE

SYMBOL	ZONE	DESCRIPTION	DATE	BY
1		REVISED IN ACCORDANCE WITH AMENDMENT NO 0001	23 JUNE 82	JBP

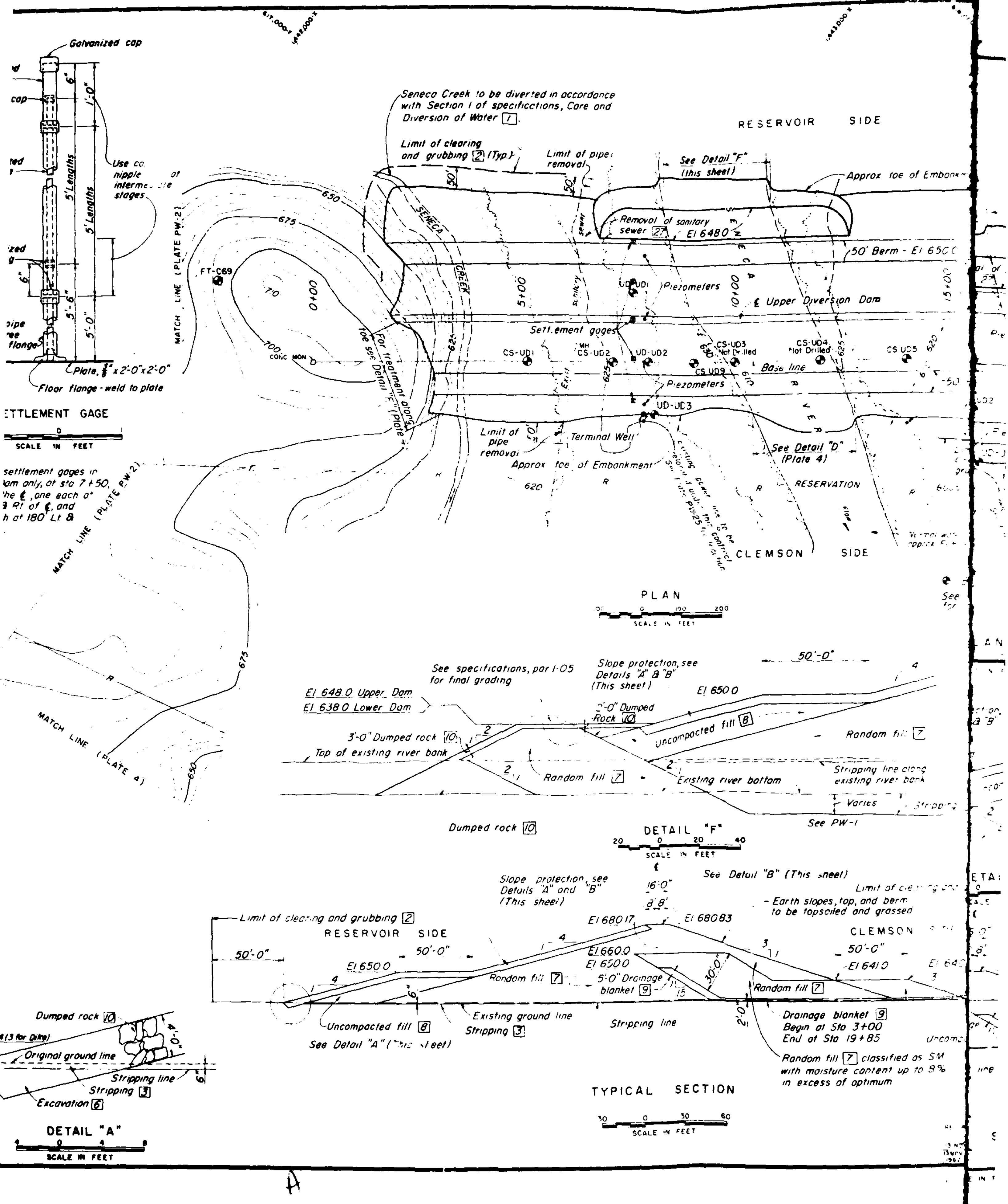
REVISIONS

U S ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH, GEORGIA

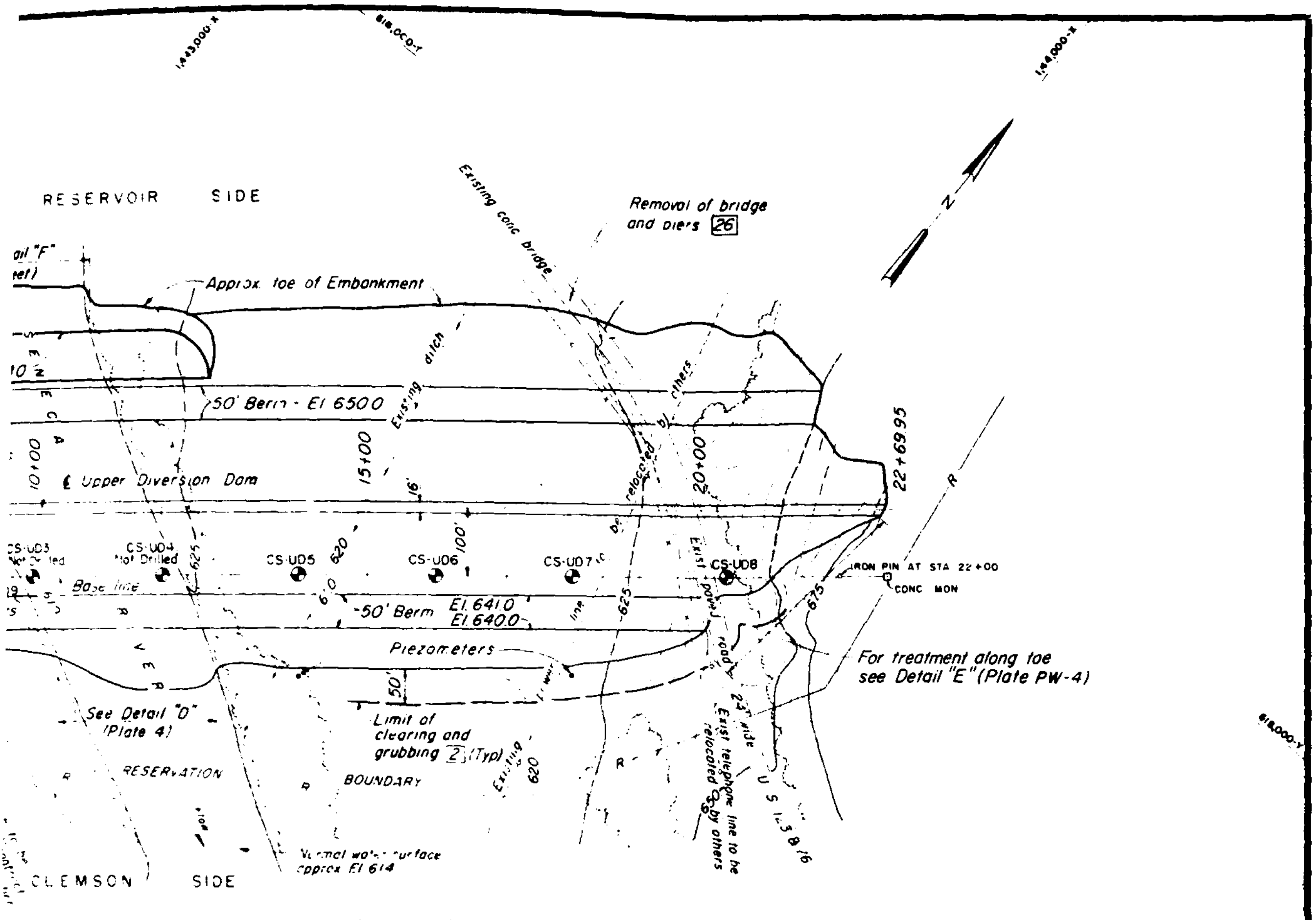
FOUNDATION REPORT
REHABILITATION OF CLEMSON UPPER DIVERSION DAM
LOCATION OF SUBSURFACE DRAINAGE SYSTEM
HARTWELL LAKE
SAVANNAH RIVER — GEORGIA & SOUTH CAROLINA

SIZE	INVITATION NO	FILE NO	PLATE
F			24

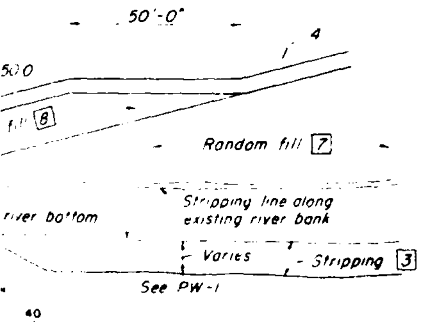
SCALE 1"=40' — SHEET 24

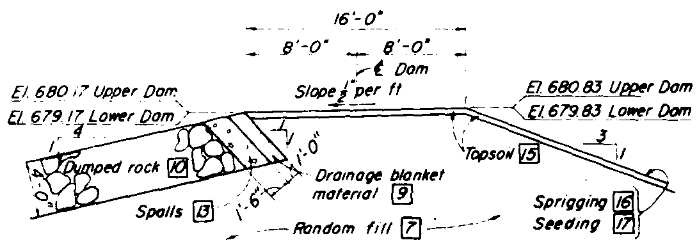


Galvanized cap
Use co. nipple at interme... stages
5' Lengths
Plate, 3/8" x 2'-0" x 2'-0"
Floor flange - weld to plate
SETTLEMENT GAGE
SCALE IN FEET
settlement gages in dam only, at sta 7+50, the ℄, one each at ... Rt of ℄, and ... at 180' Lt &
MATCH LINE (PLATE PW-2)
MATCH LINE (PLATE 4)
Seneca Creek to be diverted in accordance with Section I of specifications, Care and Diversion of Water [1].
Limit of clearing and grubbing [2] (Typ.)
Limit of pipe removal
See Detail "F" (this sheet)
Approx toe of Embankment
RESERVOIR SIDE
Removal of sanitary sewer [27]
El 648.0
50' Berm - El 650.0
SENECA CREEK
FT-C69
CONC MON
For treatment along toe see Detail "F" (Plate
0+00
5+00
10+00
15+00
Piezometers
℄ Upper Diversion Dam
Settlement gages
CS-UD1
CS-UD2
UD-UD2
CS-UD3 Not Drilled
CS-UD4 Not Drilled
CS-UD5
CS-UD9
Base line
Piezometers
UD-UD3
Limit of pipe removal
Terminal Well
Approx toe of Embankment
See Detail "D" (Plate 4)
RESERVATION
CLEMSON SIDE
PLAN
SCALE IN FEET
See specifications, par 1-05 for final grading
Slope protection, see Details "A" & "B" (This sheet)
El 648.0 Upper Dam
El 638.0 Lower Dam
2'-0" Dumped Rock [10]
El 650.0
50'-0"
3'-0" Dumped rock [10]
Top of existing river bank
Uncompacted fill [8]
Random fill [7]
Random fill [7]
Existing river bottom
Stripping line along existing river bank
Varies
See PW-1
Dumped rock [10]
DETAIL "F"
SCALE IN FEET
Slope protection, see Details "A" and "B" (This sheet)
See Detail "B" (This sheet)
16'-0"
8'-8"
Limit of clearing and grubbing [2]
Earth slopes, top, and berm to be topsoiled and grassed
El 680.17
El 680.83
RESERVOIR SIDE
CLEMSON SIDE
50'-0"
50'-0"
50'-0"
El 650.0
El 660.0
El 650.0
El 641.0
Random fill [7]
5'-0" Drainage blanket [9]
Random fill [7]
30'-0"
Existing ground line
Stripping [3]
Stripping line
Uncompacted fill [8]
See Detail "A" (This sheet)
Drainage blanket [9] Begin at Sta 3+00 End at Sta 19+85
Random fill [7] classified as SM with moisture content up to 8% in excess of optimum
TYPICAL SECTION
SCALE IN FEET
Dumped rock [10]
(3 for Dike)
Original ground line
Stripping line
Stripping [3]
Excavation [6]
DETAIL "A"
SCALE IN FEET



● Boring location
See Plates PW-14, -15 & -16 for logs of these borings

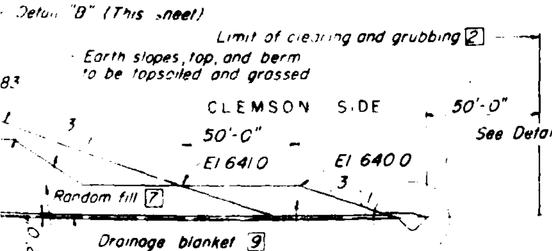




DETAIL "B"

SCALE IN FEET

Detail "B" (This sheet)



Drainage blanket 9
Begin at Sta 3+00
End at Sta 19+85

Uncompacted fill 8

Random fill 7 classified as SM with moisture content up to 8% in excess of optimum

Topography on this sheet was compiled from Cross Section notes

Date	No	Description	Made	Chkd	Rcmd	Appd
26 OCT 1960	2	Provide for use of random fill with a moisture content of up to 8% over optimum	RLB			
28 JUN 1960	1	REVISED IN ACCORDANCE WITH ADDENDUM NO 3				
		ISSUED UNDER SERIAL NO CIVENG 09-133-60-41				

REVISIONS

SAVANNAH RIVER BASIN, SAVANNAH RIVER GEORGIA AND SOUTH CAROLINA
HARTWELL PROJECT
CLEMSON COLLEGE PROTECTIVE WORKS

UPPER DIVERSION DAM
PLAN, SECTION AND DETAILS

SCALE AS SHOWN

U. S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS

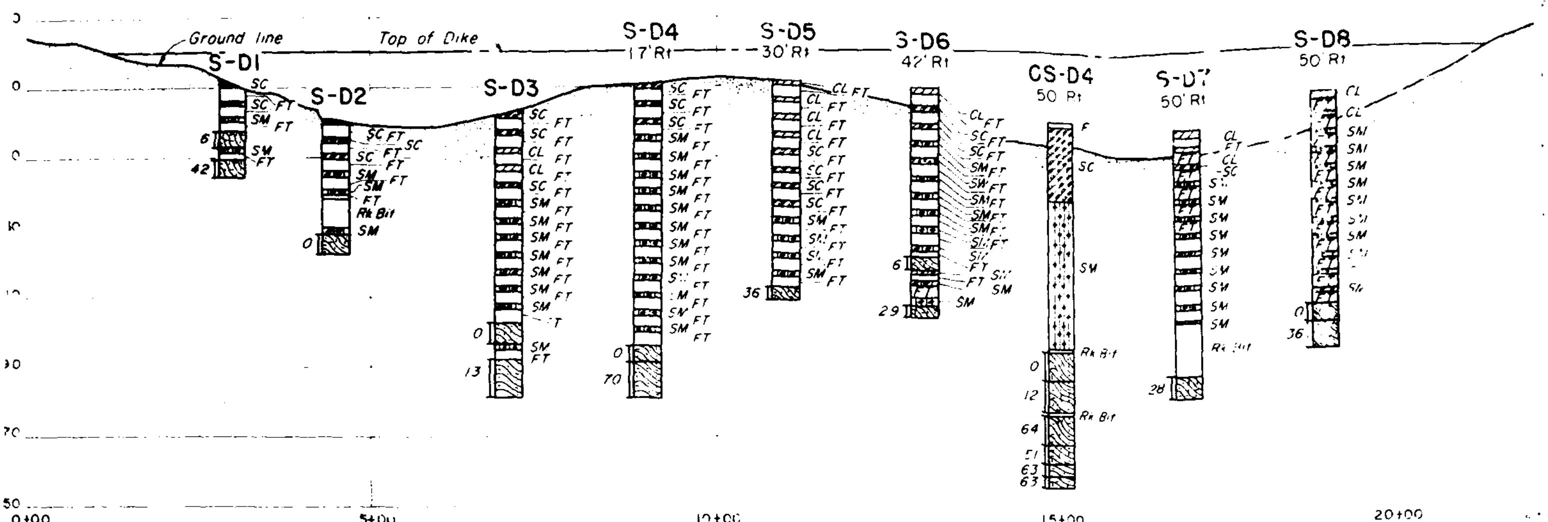
SAVANNAH, GA — 1 JUNE 1960

SUBMITTED: Chief, Foundations & Soils Section
APPROVAL RECOMMENDED: Chief, Found & Mat Branch
APPROVED: Chief, Engineering Division
APPROVED: Col, Corps of Engineers, District Engineer

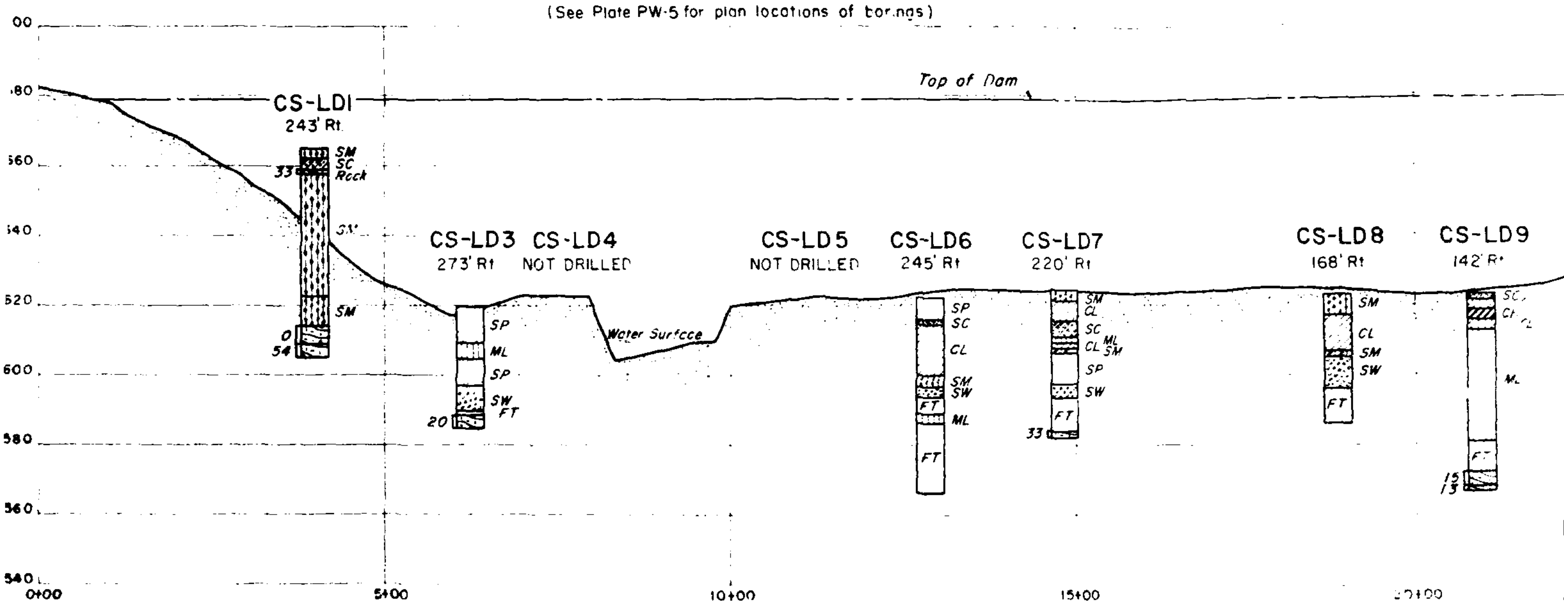
RECORD DRAWING AS CONSTRUCTED UNDER CONTRACT DA-09-133-CIVENG-60-65
Resident Engineer
13 NOVEMBER 1962
13 NOV 1962 | 3 | Revised as constructed

TO ACCOMPANY SPECIFICATIONS ISSUED UNDER SERIAL NO CIVENG 09-133-60-41

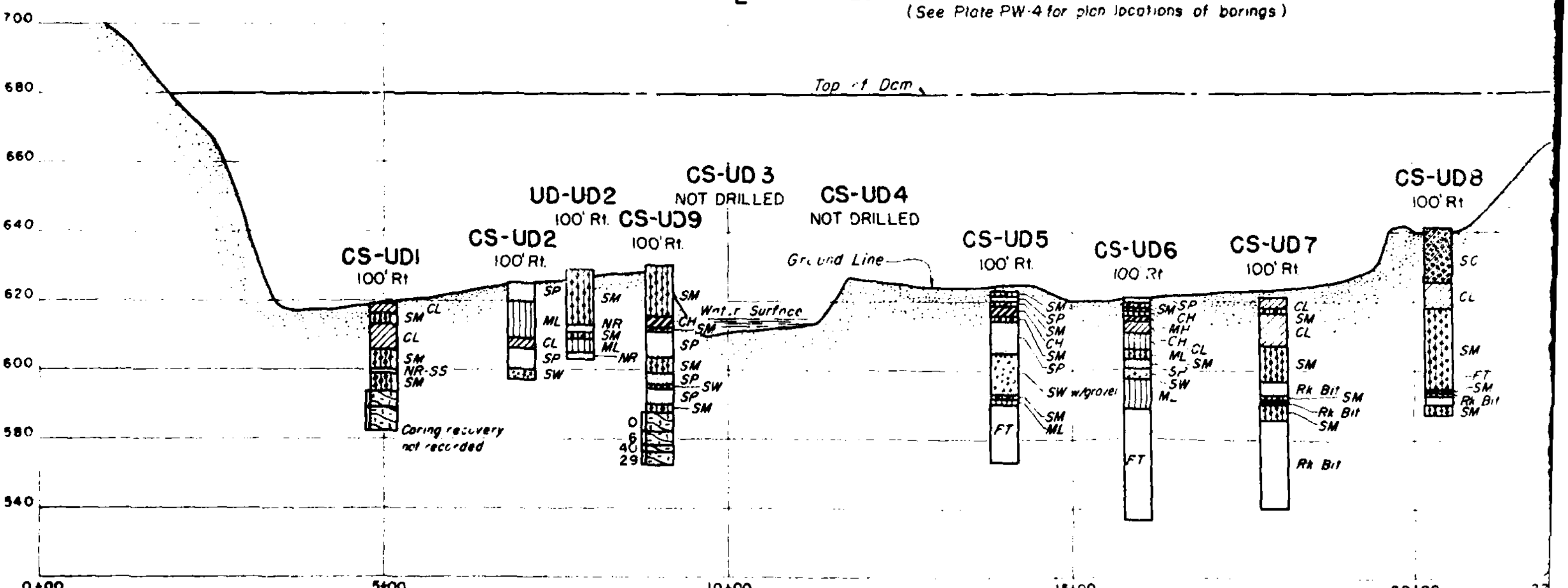
FILE NO HA21C-0043



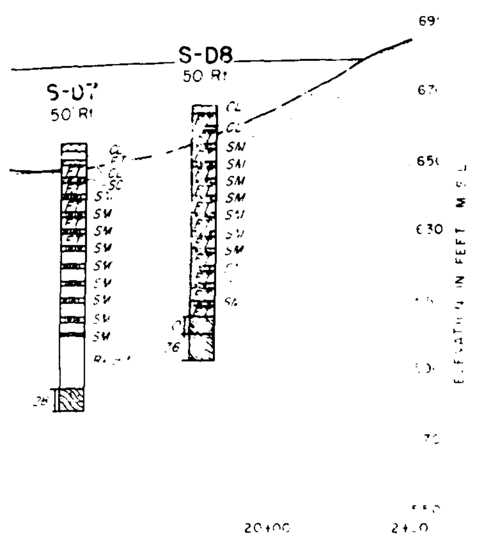
℄ PROFILE DIKE
(See Plate PW-5 for plan locations of borings)

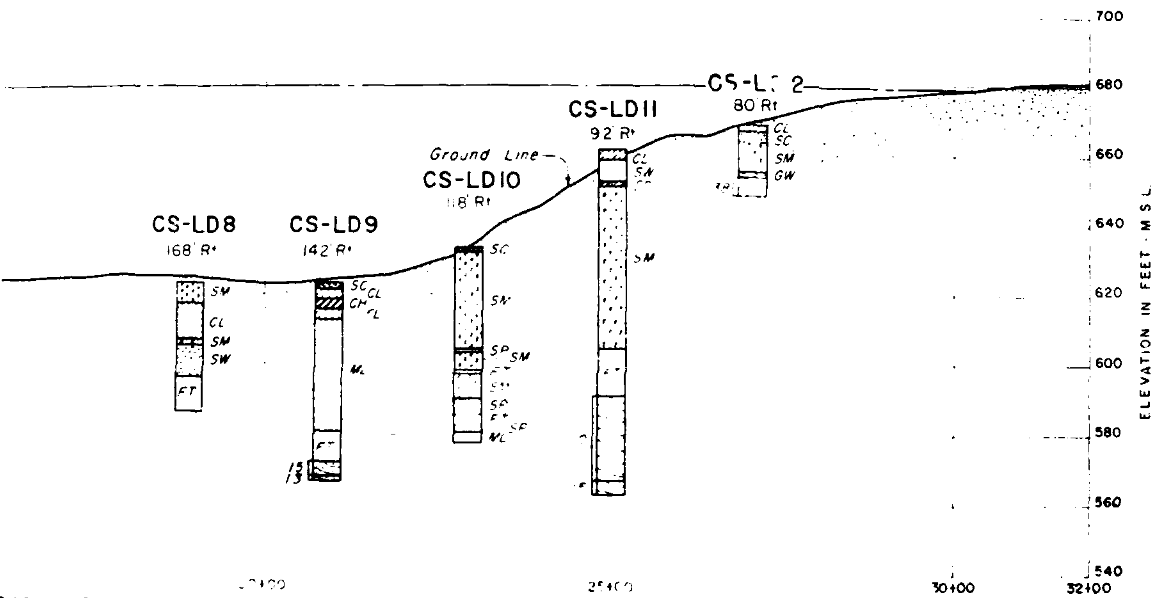


℄ PROFILE LOWER DIVERSION DAM - LOOKING DOWNSTREAM
(See Plate PW-4 for plan locations of borings)

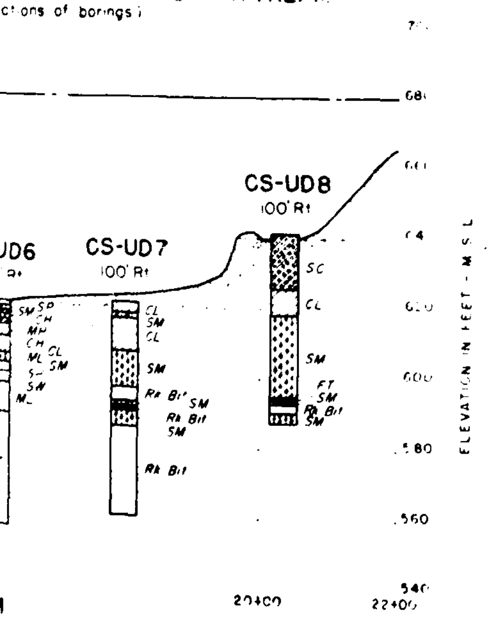


℄ PROFILE UPPER DIVERSION DAM - LOOKING UPSTREAM
(See Plate PW-3 for plan locations of borings)





...LOOKING DOWNSTREAM
(...ctions of borings)



NOTE
See Plate PW-19 & PW-20 for splitspoon penetration resistances in these borings

SEE FIELD LOGS OF BORINGS AND ROCK CORES WHICH WILL BE DISPLAYED FOR INSPECTION AS NOTED IN SPECIFICATIONS

FOR LEGEND OF BORINGS AND NOTES SEE PLATE PW-16

RECORD DRAWING AS CONSTRUCTED UNDER CONTRACT DA-09-133-CIVENG-60-65
13 NOVEMBER 1962 — RESIDENT ENGINEER

DATE	NO	DESCRIPTION	MADE	CHKD	RCMD	APVD
13 NOV 1962	1	Signed as constructed	RMM	RGM		

REVISIONS

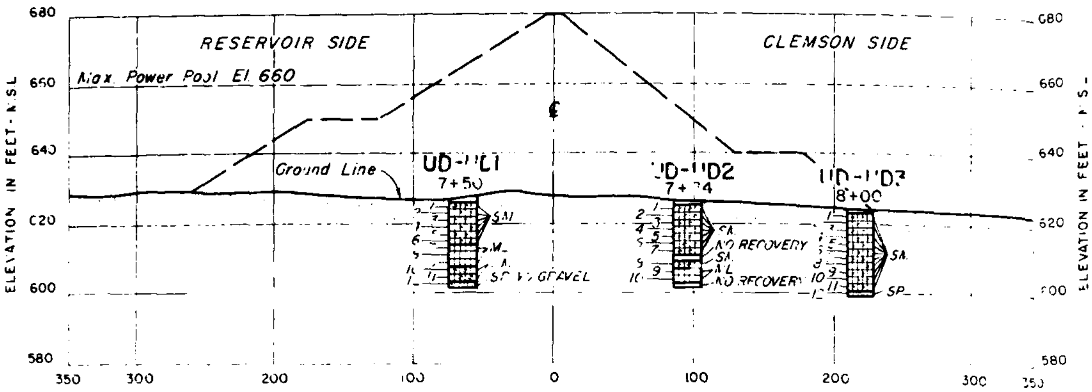
SAVANNAH RIVER BASIN SAVANNAH RIVER GEORGIA AND SOUTH CAROLINA
HARTWELL PROJECT
CLEMSON COLLEGE PROTECTIVE WORKS
DIVERSION DAMS AND DIKE
PROFILES AND LOGS OF BORINGS
SCALE AS SHOWN
U. S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS
SAVANNAH GA — 1 JUNE 1960

SUBMITTED: CHIEF FOUNDATIONS & SOILS SECTION
APPROVAL RECOMMENDED: CHIEF FOUNDATIONS & MATERIALS BRANCH
APPROVED: CHIEF ENGINEERING DIVISION
APPROVED: COL CORPS OF ENGINEERS DISTRICT ENGINEER

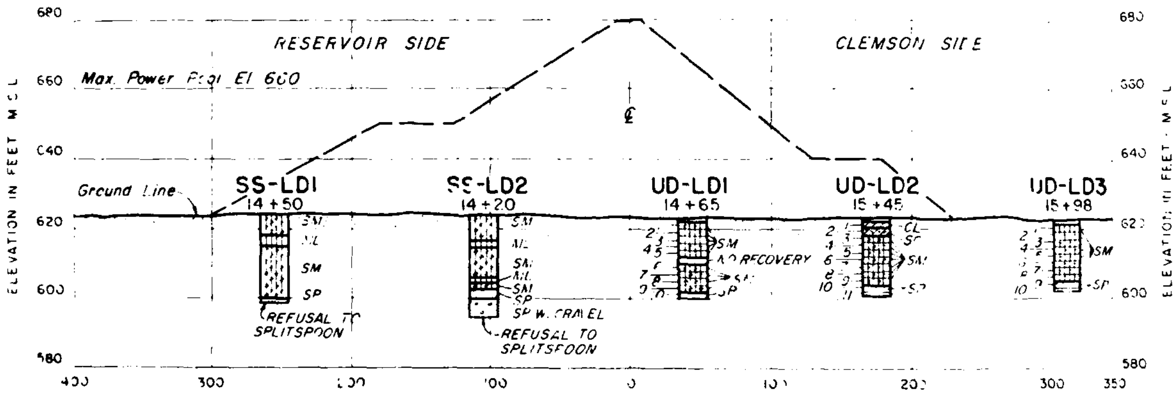
TO ACCOMPANY SPECIFICATIONS ISSUED UNDER SERIAL NO CIVENG 09-133-60-41
FILE NO HA21C-0161

SHEET 26 — PLATE 26

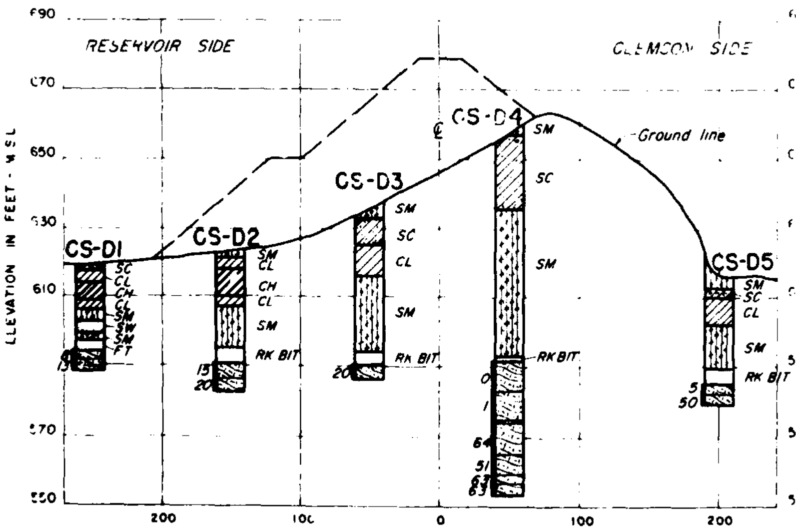
(26)



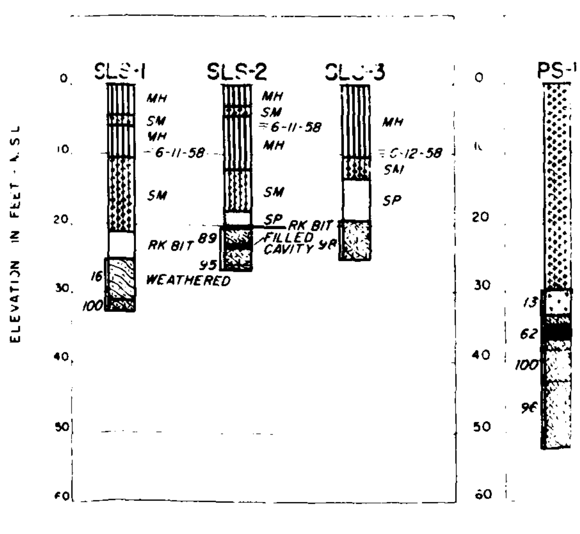
SECTION - UPPER DIVERSION DAM
IN VICINITY OF STATION 7+75
(See Plate PW-5 for plan locations of borings)



SECTION - LOWER DIVERSION DAM
IN VICINITY OF STATION 15+00
(See Plate PW-4 for plan locations of borings)



SECTION - DIKE
STATION 15+00
(See Plate PW-5 for plan locations of borings)



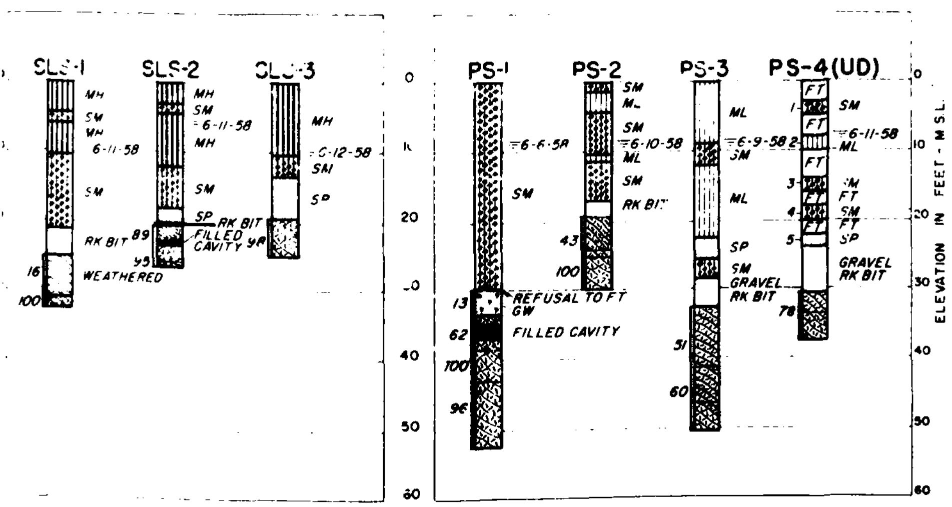
PUMPING STATION AR
(See Plate PW-22 for plan locations

LEGEND

Boring number	CS-C10	
Station number or distance offset right or left of section, if projected	8+00 23' Rt.	
Gravel, well graded, coarse to fine, with sand		GW
Gravel, fine, poorly graded with sand		GP
Well graded sand		SW
Fine, poorly graded sand		SP
Silty sand		SM
Clayey sand		SC
Silt, low plasticity, clayey and/or micaceous		ML
Silt, high plasticity, clayey and/or micaceous		MH
Lean clay		CL
Fat clay		CH
Drilled with Fishtail Bit, no sample recovered	FT	
Drilled with "Vicksburg" type Auger, mixed sample recovered	A	
Drilled with Roller Rock Bit (hard stratum), no sample recovered		RK BIT
Splitspoon drive with no sample recovery		SS-NR
Water table and date recorded (not determined in all borings)	Water 9-16-58	
Undisturbed sample locations and number	2 / 3	
Coring run with percent recovery	85	GRANITE GNEISS

Notes

1. Soil classifications shown on Plates PW-8 thru PW-16 are field classifications in accordance with the Unified Soil Classification System.
2. In borings with prefix "FT", overburden was drilled with "Fishtail" bit and no soil samples recovered.
3. In borings with prefix "S", "LS" or "SS" overburden was sampled with 1.5" I.D. splitspoon sampler. Where soil symbols are shown, samples were obtained with the splitspoon. See Plates PW-17 thru PW-20 for penetration resistances.
4. Undisturbed soil samples were taken from borings with prefix "UD" by means of 5.5" piston sampler.
5. Prefixes are portions of the boring numbers to the left of hyphens.
6. Borings prefixed "UD" were terminated at refusal of piston sampler under 500 psi pressure.
7. In borings with prefix "D", samples were taken, to refusal, with 6 inch "Denison" core barrel.



PUMPING STATION AREA

(See Plate PW-22 for plan locations of borings)

RECORD DRAWING AS CONSTRUCTED UNDER CONTRACT DA-09-133-CIVENG-60-65

13 NOVEMBER 1962 — RESIDENT ENGINEER

DATE	NO	DESCRIPTION	MADE	CHKD	RCMD	APVD
13 NOV 1962	1	Signed as constructed	RMM	PSM		

REVISIONS

SAVANNAH RIVER BASIN, SAVANNAH RIVER GEORGIA AND SOUTH CAROLINA

HARTWELL PROJECT

CLEMSON COLLEGE PROTECTIVE WORKS

DIVERSION DAMS AND DIKE
SECTIONS WITH LOGS OF BORINGS

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS

SAVANNAH, GA — JUNE 1960

SUBMITTED: CHIEF, FOUNDATIONS & SOILS SECTION

APPROVAL RECOMMENDED: CHIEF, FOUND & MAT. BRANCH

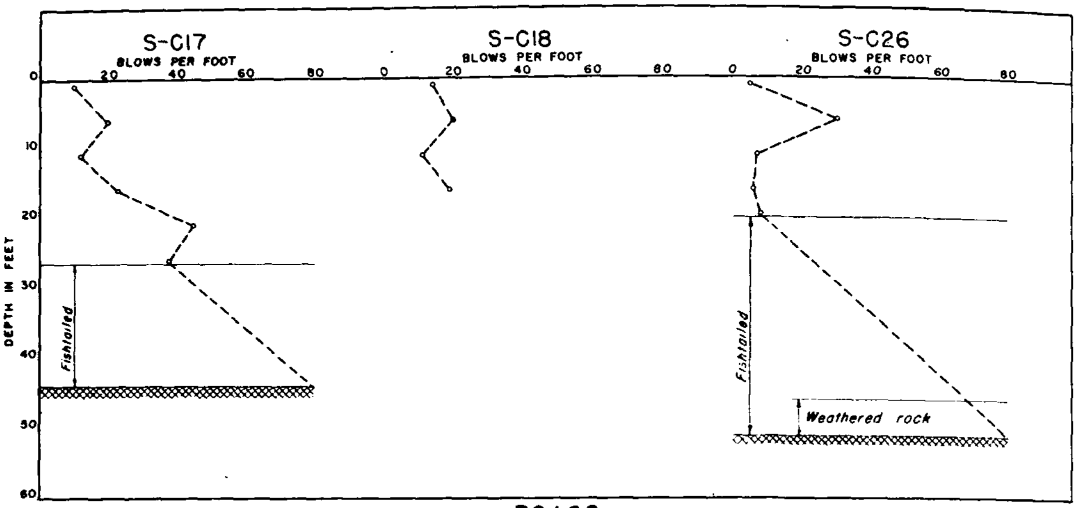
APPROVED: CHIEF, ENGINEERING DIVISION

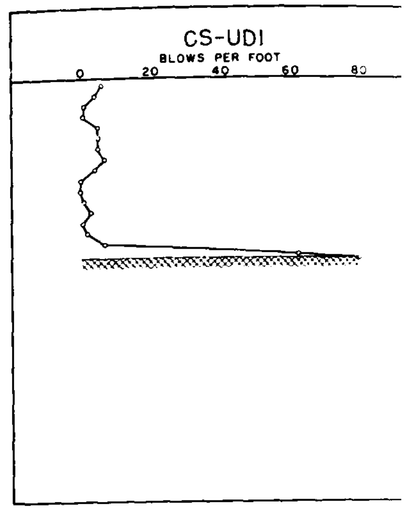
APPROVED: COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

TO ACCOMPANY SPECIFICATIONS ISSUED UNDER SERIAL NO. CIVENG 09-133-60-41

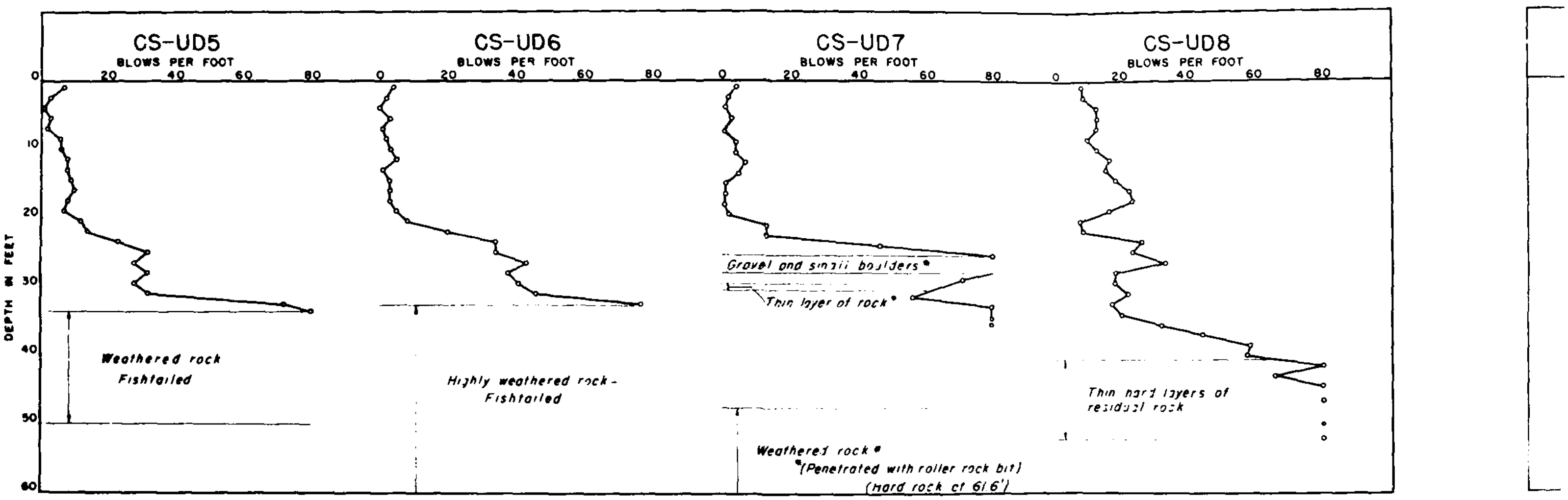
FILE NO HA21C-0171

27

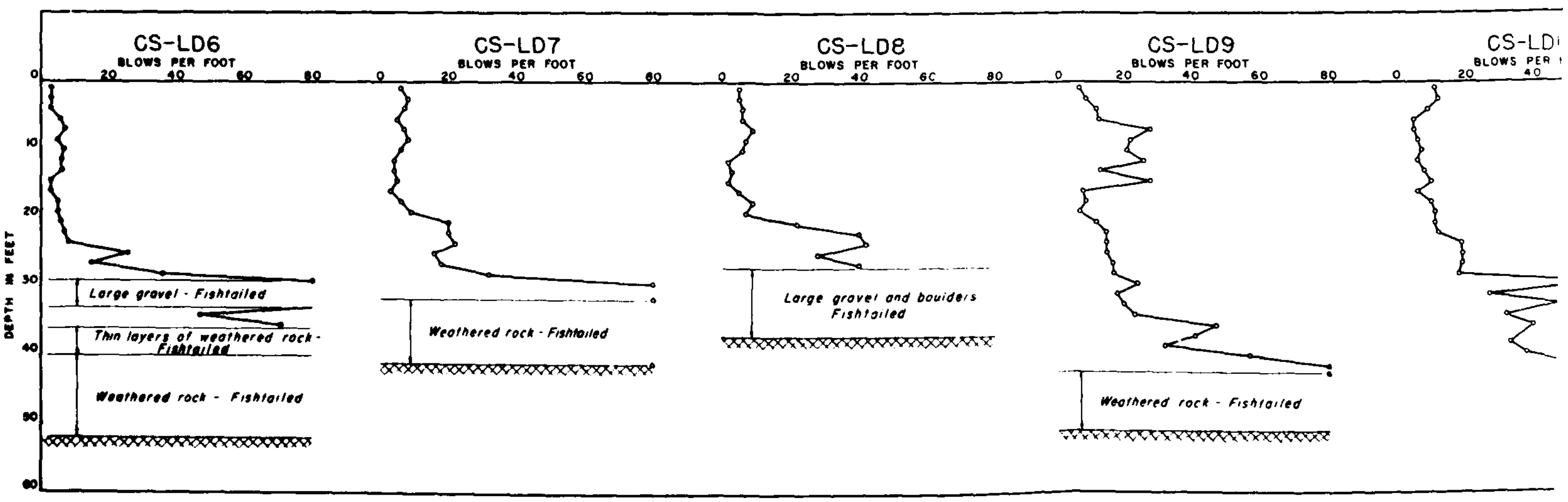




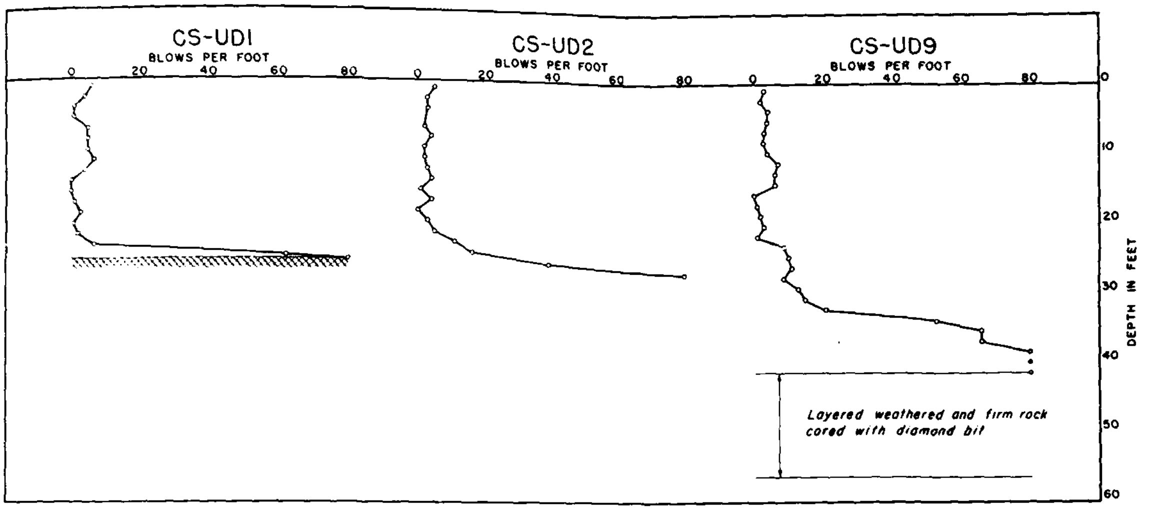
30+00
DIVERSION CHANNEL



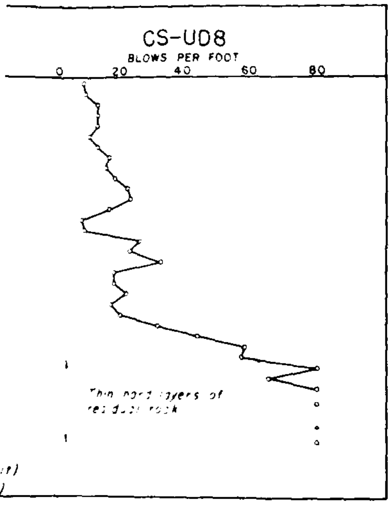
UPPER DIVERSION DAM

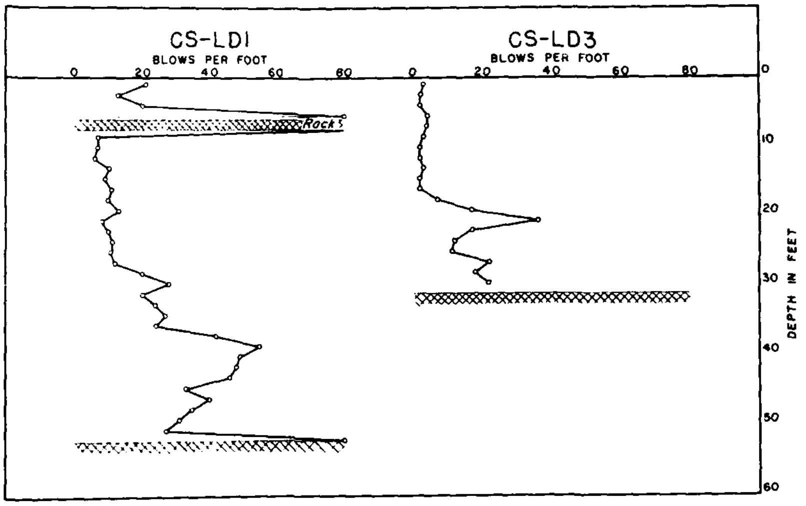


LOWER DIVERSION DAM

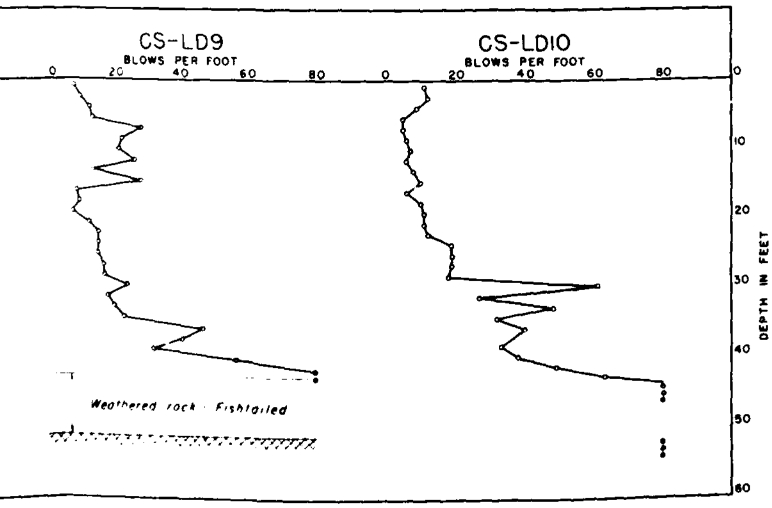


UPPER DIVERSION DAM





LOWER DIVERSION DAM



AM

RECORD DRAWING AS CONSTRUCTED UNDER CONTRACT DA-09-133-CIVENG-60-65							
13 NOVEMBER 1962			RESIDENT ENGINEER				
13 NOV. 1962	1	Signed as constructed	RMM	RGM			
DATE	NO	DESCRIPTION	MADE	CHKD	RCMD	APVD	

REVISIONS

SAVANNAH RIVER BASIN SAVANNAH RIVER, GEORGIA AND SOUTH CAROLINA

HARTWELL PROJECT

CLEMSON COLLEGE PROTECTIVE WORKS

SOIL BORING DATA

SPLITSPOON PENETRATION RESISTANCES

DIVERSION CHANNEL & UPPER & LOWER DIVERSION DAMS

SCALE: AS SHOWN

U.S. ARMY ENGINEER DISTRICT, SAVANNAH
CORPS OF ENGINEERS

SAVANNAH, GA. 1 JUNE 1960

SUBMITTED: CHIEF, FOUNDATIONS & SOILS SECTION

APPROVAL RECOMMENDED: CHIEF, FOUND & MAT BRANCH

APPROVED: CHIEF, ENGINEERING DIVISION

APPROVED: COL., CORPS OF ENGINEERS, DISTRICT ENGINEER

REVIEWED BY

TO ACCOMPANY SPECIFICATIONS ISSUED UNDER SERIAL NO CIVENG 09-133-60-41

FILE NO HA21C-0201

28

REHABILITATION OF CLEMSON UPPER DIVERSION DAM

CONSTRUCTION FOUNDATION REPORT

APPENDIX A

Project Photos

APPENDIX A

REHABILITATION OF CLEMSON UPPER DAM PROJECT PHOTOS

Photo 1 - North end of dike viewed from printing shop drive prior to construction (September 16, 1983)

Photo 2 - Dike as seen from printing shop drive (September 16, 1983)

Photo 3 - Area below dike prior to construction (September 16, 1983)

Photo 4 - North end of dike (September 16, 1983)

Photo 5 - Upstream side of dike, viewing southwest. Note Highway 93 bridge in background (September 16, 1983)

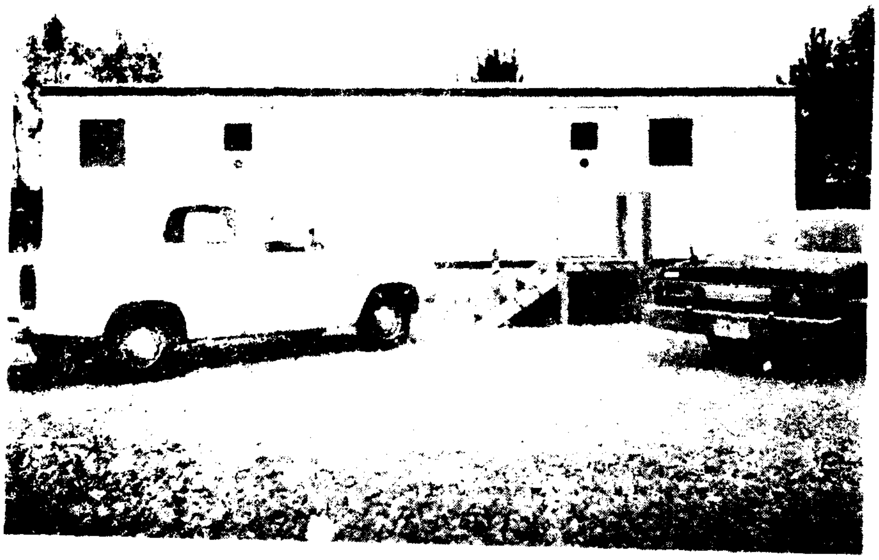


Photo 6 - C.O.E. field office (October 19, 1983)

Photo 7 - Starting excavation looking east (October 19, 1983)

Photo 8 - Degrading dike at station 15+25 looking west (October 31, 1983)

Photo 9 - Slurry pond with desander (October 1983)

Photo 10 - Downstream slope compacted with dozer (November 2, 1983)

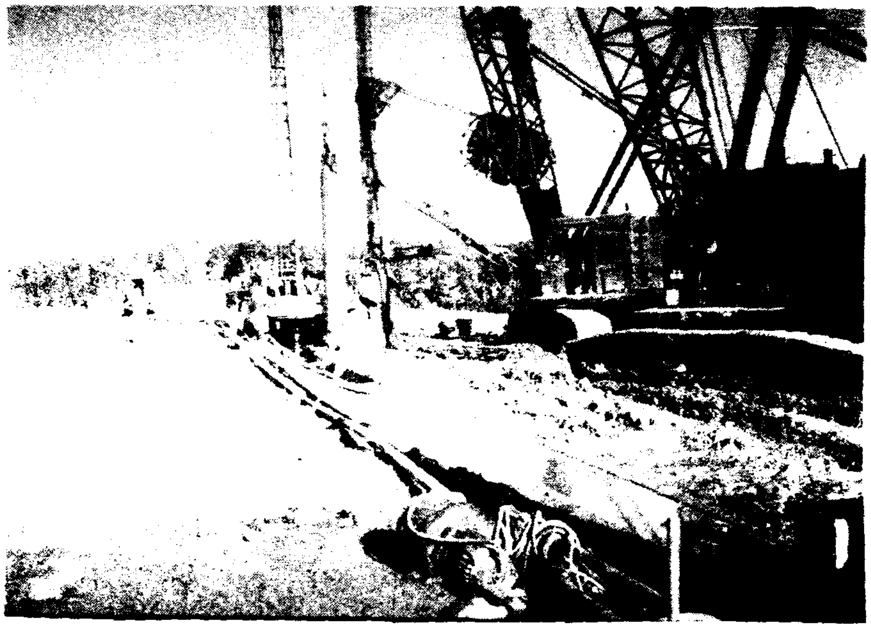


Photo 11 - Excavating with chisel on Panel T-2 (November 22, 1983)

Photo 12 - Forming guidewall at station 1+00 to 1+65 (November 9, 1983)

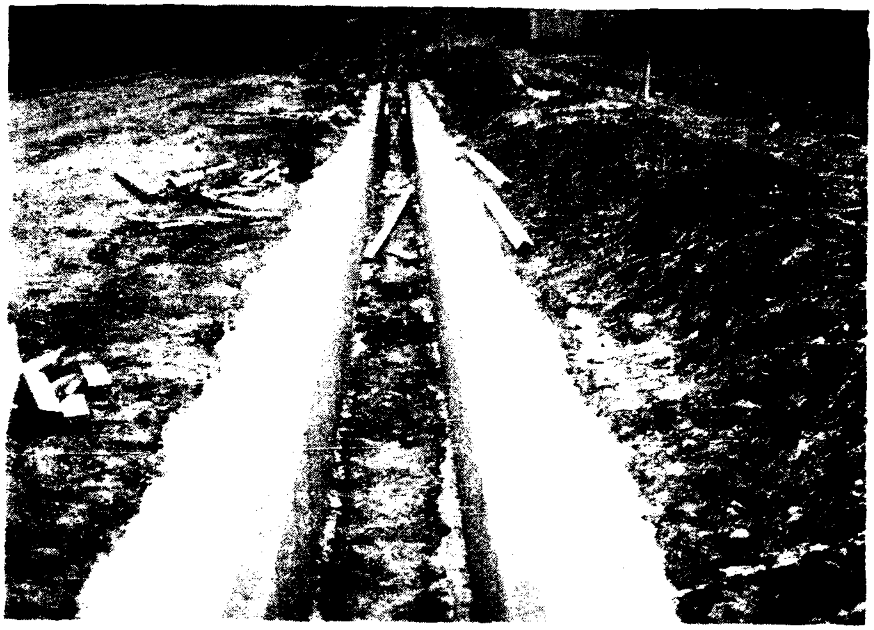


Photo 13 - Second placement of concrete for guidewall, station 4+10 to 5+50. (November 2, 1983)

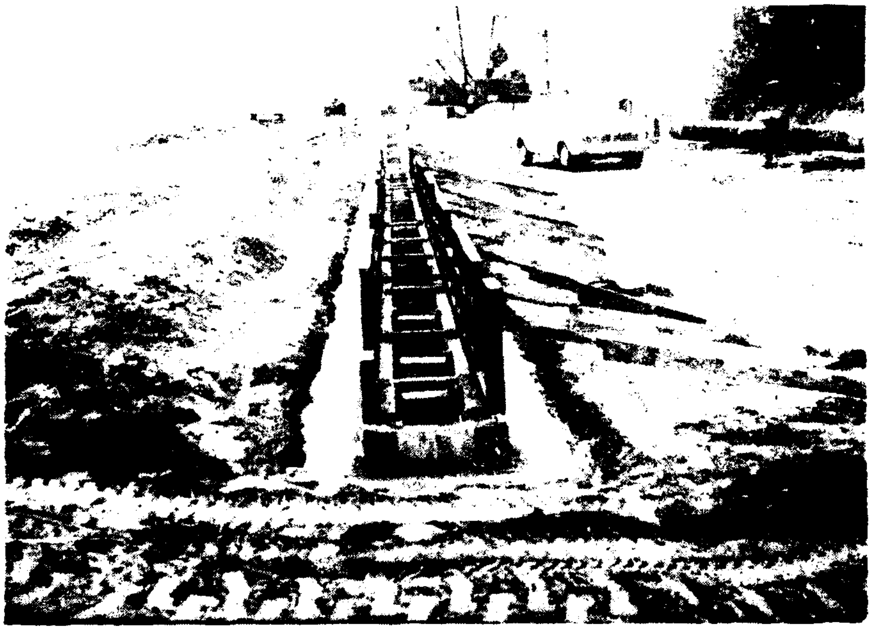


Photo 14 - Last concrete placement at west end of guidewall. (November 10, 1983)

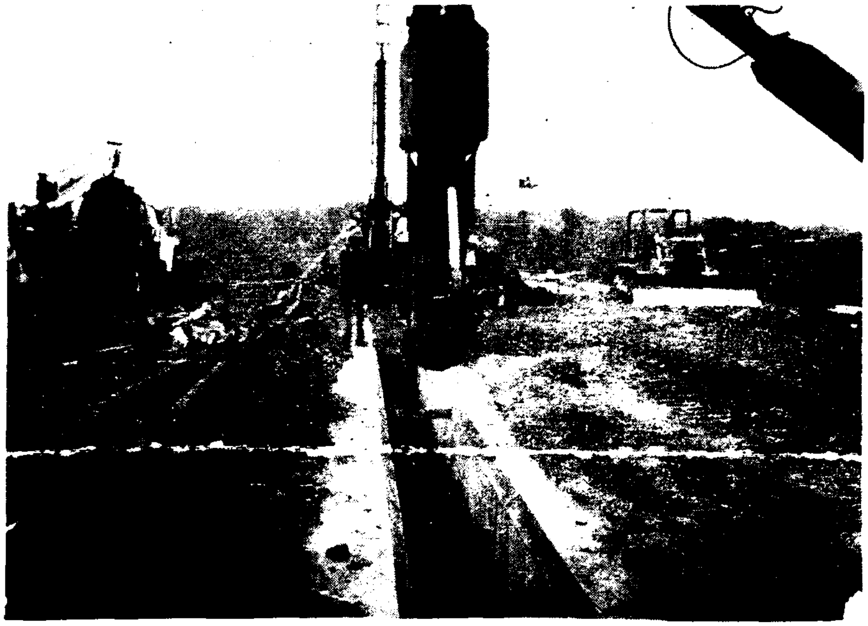


Photo 15 - First bite with hydrolically operated kelley bar crane (November 10, 1983)

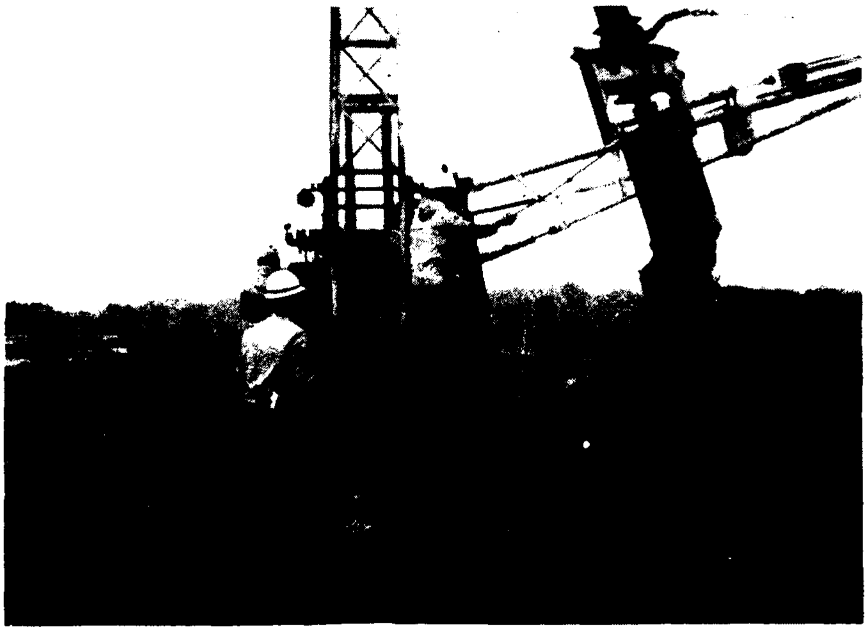


Photo 16 - Auger excavation of cutoff wall at Panel T-2

Photo 17 - Excavation with auger in test panels (November 9, 1983)

Photo 18 - Haul road wash-out after heavy rain - east end, station 22+25 (November 28, 1983)

Photo 19 - Stockpile area after heavy rain (November 28, 1980)

Photo 20 - Stockpile area (November 28, 1983)

Photo 21 - Seepage pond after heavy rain (November 28, 1983)

Photo 22 - View from test section area. Note chute which was initially used to slide excavated material down the ramp for subsequent removal with a tracked front-end loader (November 1983)

Photo 23 - Chute that was used to remove excavated material from top of dike. This method was later replaced by use of a Link-Belt LS-518 crane with a 130-foot boom (November 19[illegible]3)

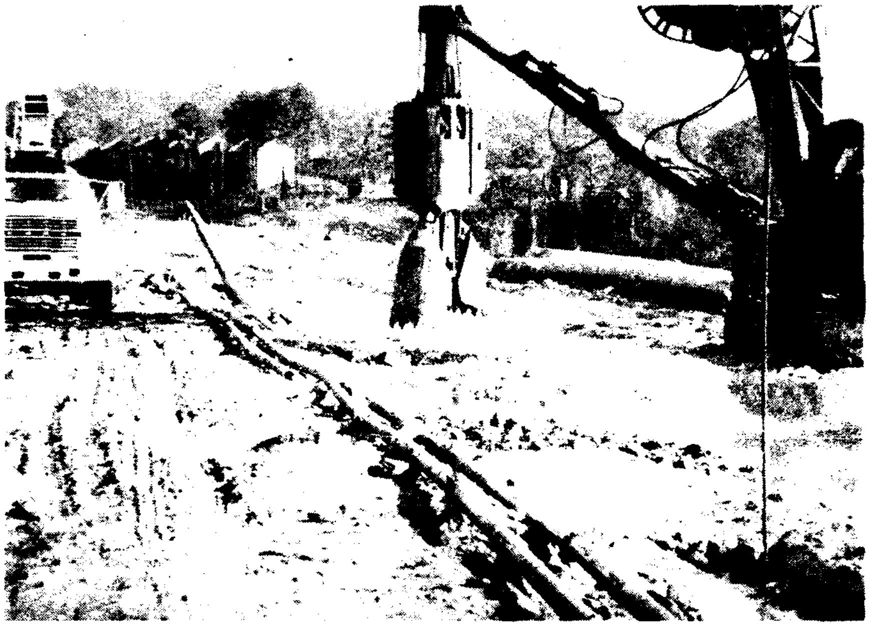


Photo 24 - Test section area panel excavation (December 1983)

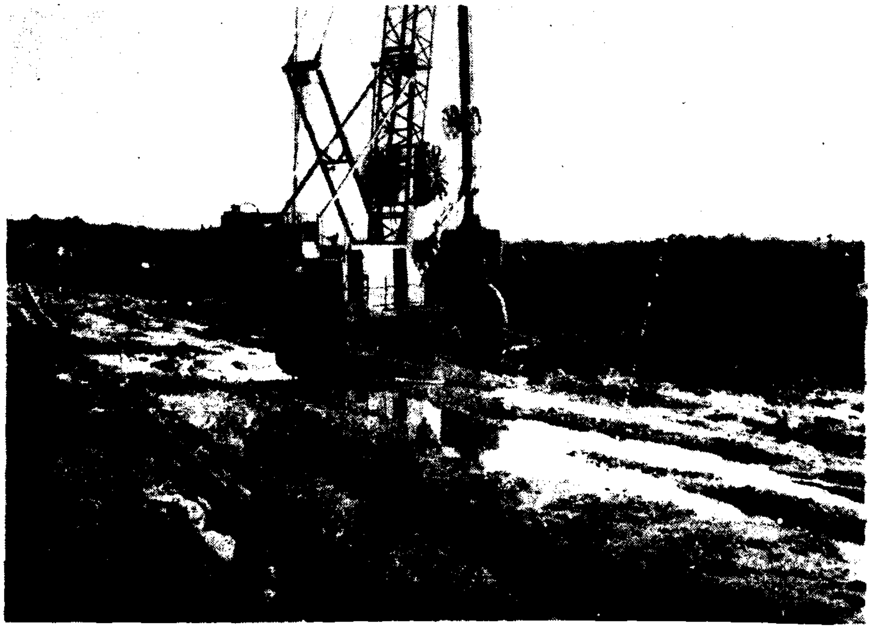


Photo 25 - Test section area panel excavation (December 1983)

Photo 26 - Pouring concrete for panels in test section area (December 1983)

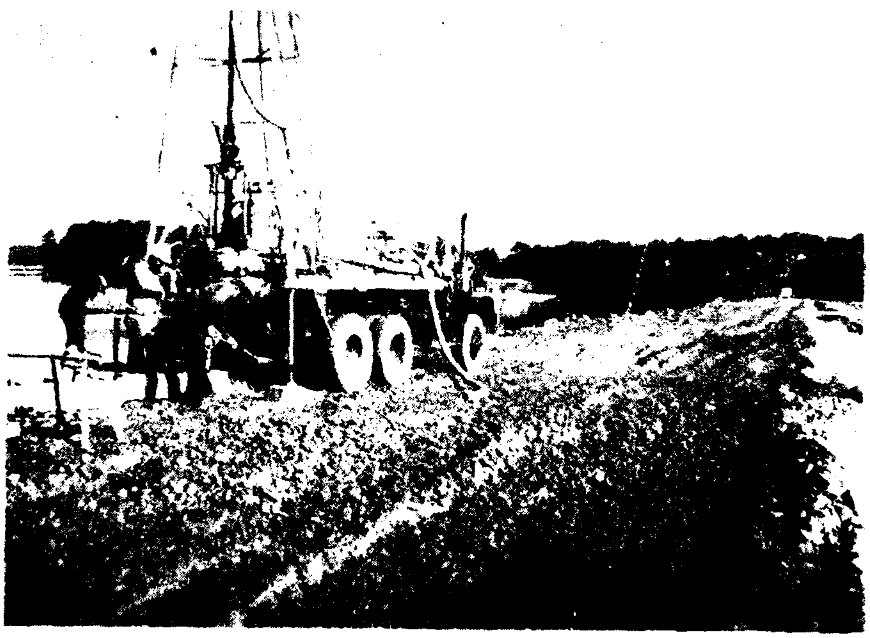


Photo 27 - C.O.E. Explorations Unit drilling in test section area (December 1983)

Photo 28 - Placing concrete for guidewall at station 20+25 to 21+30 (January 6, 1984)

Photo 29 - Drainage at station 19+00 using flex hose (January 3, 1984)

Photo 30 - Initial improvements of haul road (January 29, 1984)

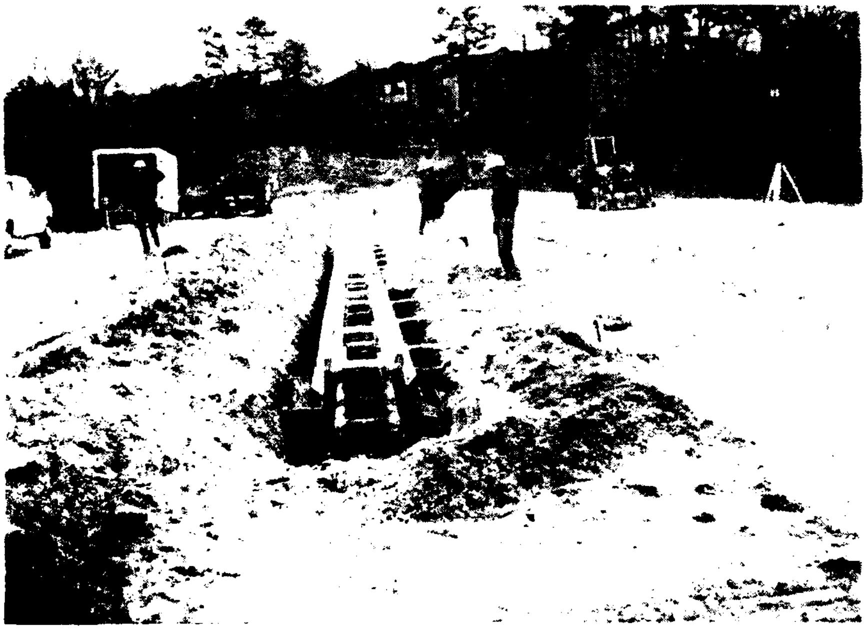


Photo 31 - Guidewall before concreting (January 23, 1984)

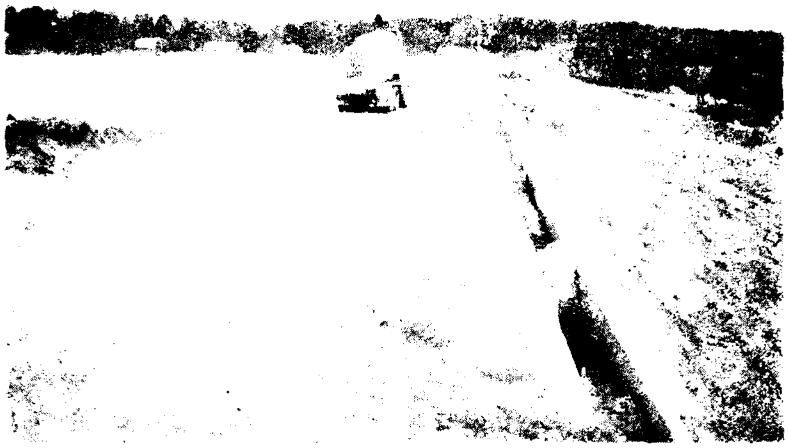


Photo 32 - Haul road improvements (February, 1984)

Photo 33 - Overflow of bentonite slurry looking toward Highway 93
from desander (February 10, 1984)

Photo 34 - Wash-out downstream looking upstream towards working platform at station 4+60 (February 29, 1984)

Photo 35 - Hole left by shoulder pipe (March 2, 1984)

Photo 36 - Go-devil (March 2, 1984)

Photo 37 - General overview, note chute in center of photo
(March 2, 1984)

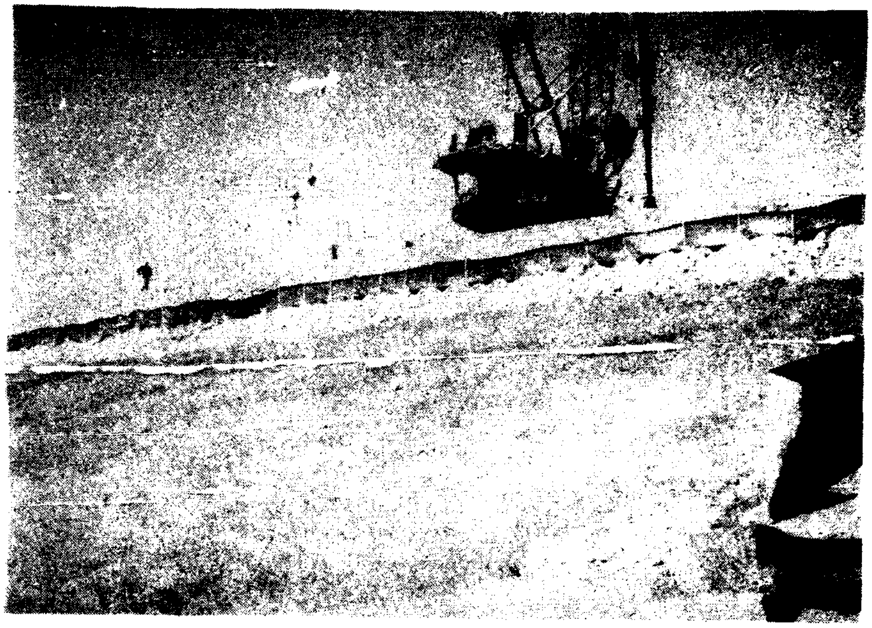


Photo 38 - First panel (no.53) using LS-518 crane with skip pan for removal of excavated material (March 14, 1984)

Photo 39 - Contractor checking slump on concrete (March 23, 1984)

Photo 40 - Excavation of Panel 54 with kelley crane (March 23, 1984)

Photo 41 - Excavation of Panel 54 with kelley crane (March 27, 1984)

Photo 42 - Rock samples from 86, 89, and 90 feet in Panel 39
(April 4, 1984)

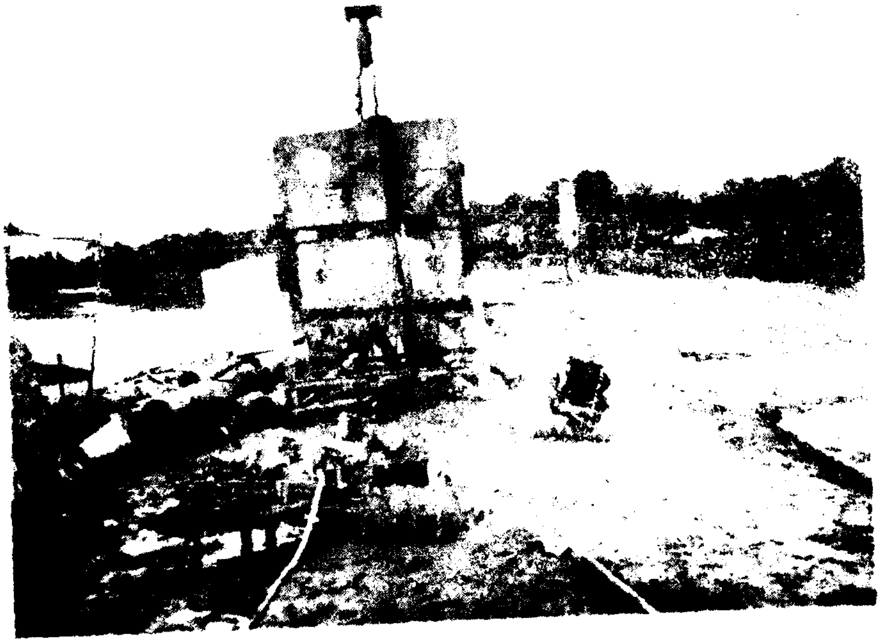


Photo 43 - Vibratory hammer used for extracting stuck shoulder pipe
(April 4, 1984)

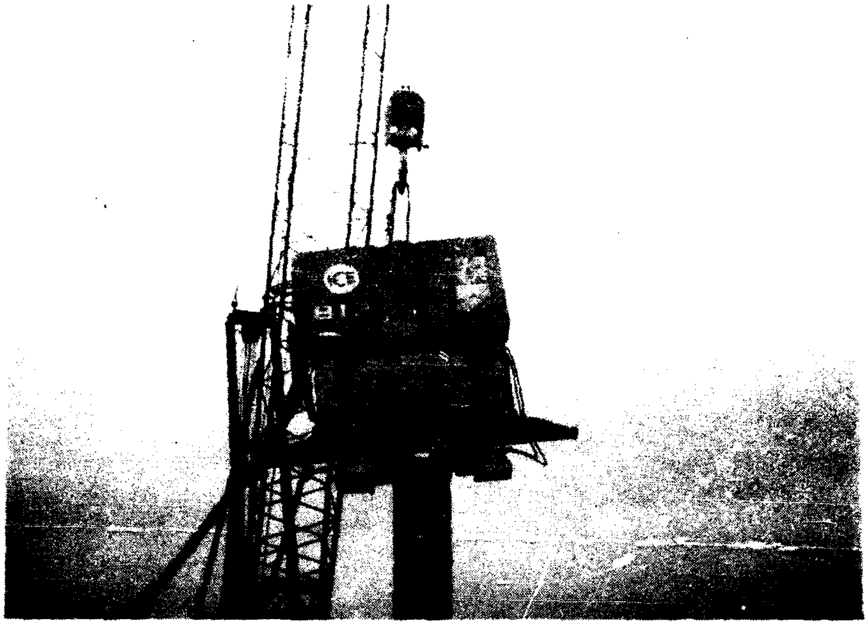
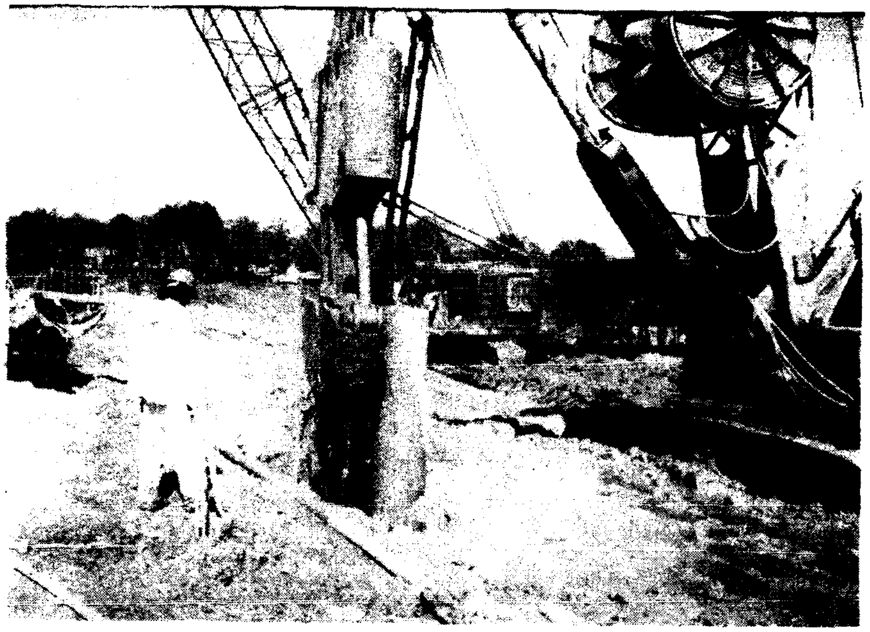


Photo 44 - Vibratory hammer extracting shoulder pipe from Panel 47 (April 5, 1984)

Photo 45 - Excavation around stuck shoulder pipe in Panels 41 and 42 (April 12, 1984)



Panel 46 - Excavation around stuck shoulder pipe in Panels 41 and 42 (April 12, 1984)

Panel 47 - Unloading bentonite (April 23, 1984)

Photo 48 - Bentonite slurry Pond-A, next to Highway 93
(April 23, 1984)

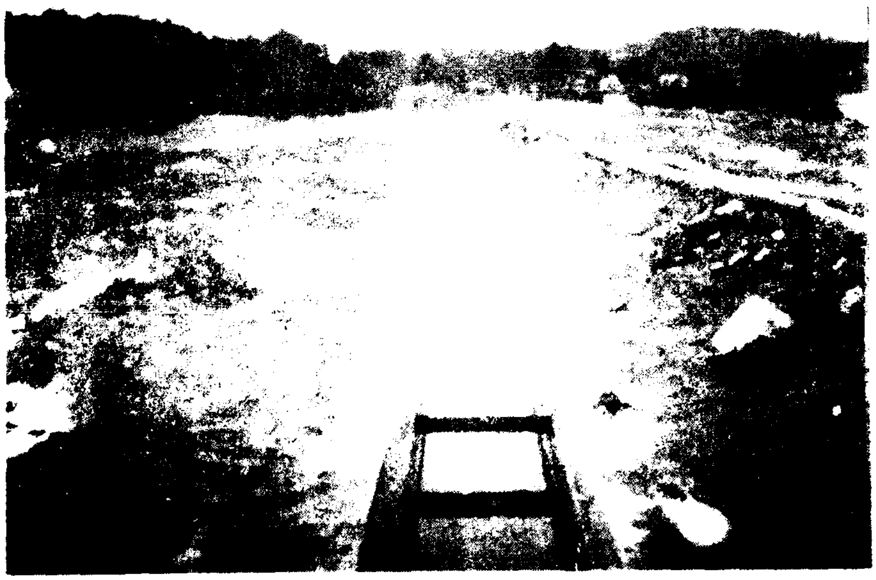


Photo 49 - Completed guidewalls looking west from station 8+00
(April 23, 1984)

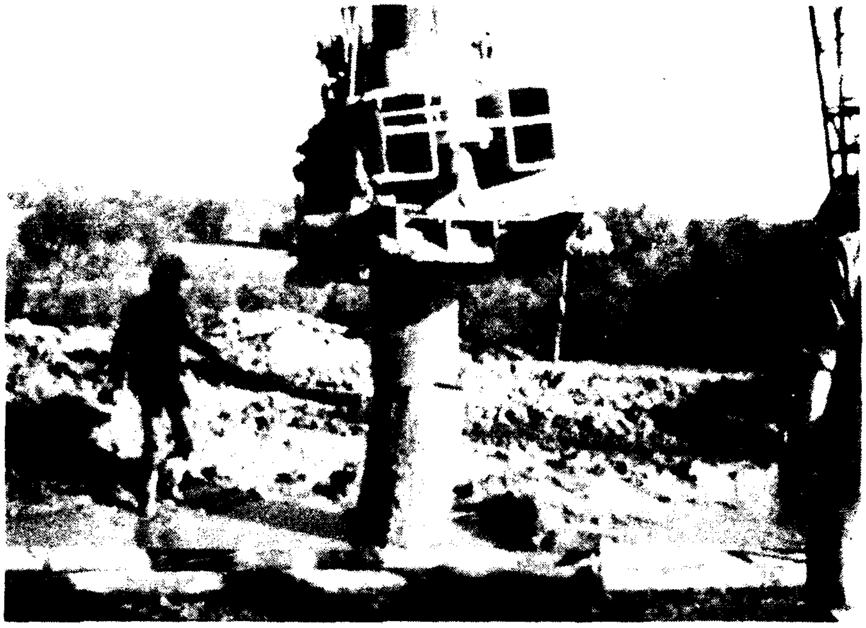


Photo 50 - Broken shoulder pipe in Panel 23 (April 25, 1984)

Photo 51 - Broken shoulder pipe extracted from Panel 23
(April 25, 1984)

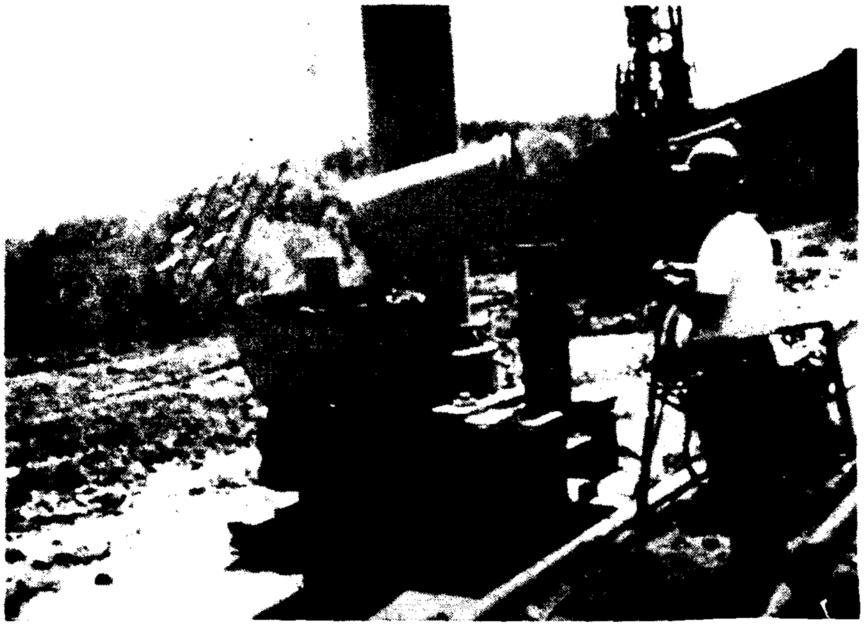


Photo 52 - Placing concrete in Panel 23 (April 25, 1984)

Photo 53 - Pouring concrete in Panel 1 (May 23, 1984)

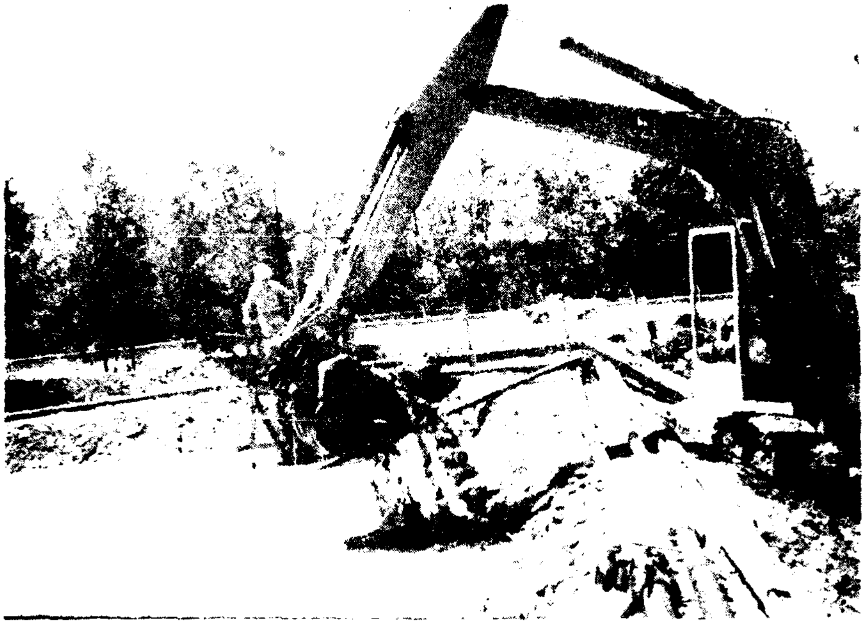


Photo 54 - Cleaning out slurry Pond-B (May 1, 1984)

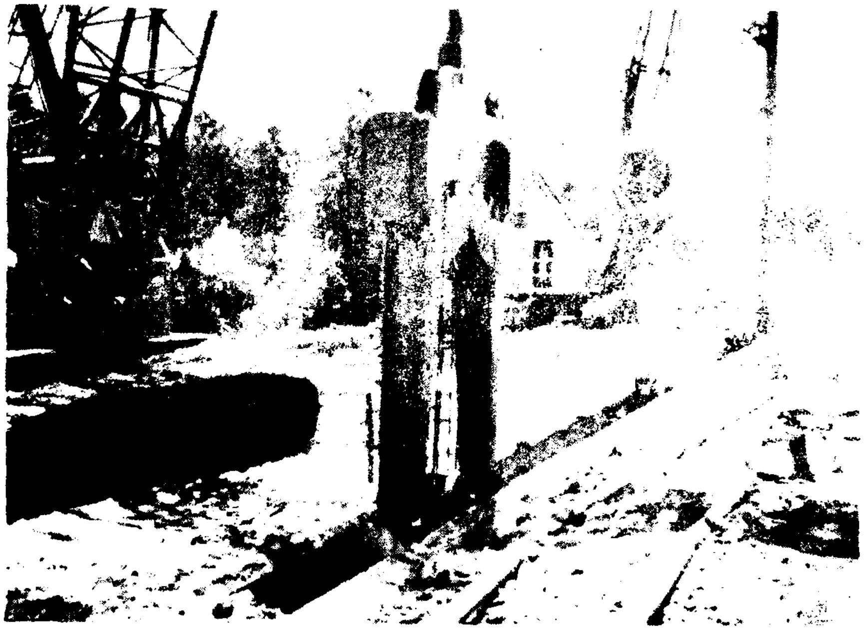


Photo 55 - Cutting rock with clam bucket in Panel 12 (May 5, 1984)

Photo 56 - Chisel used on rock in Panel 12 (May 5, 1984)

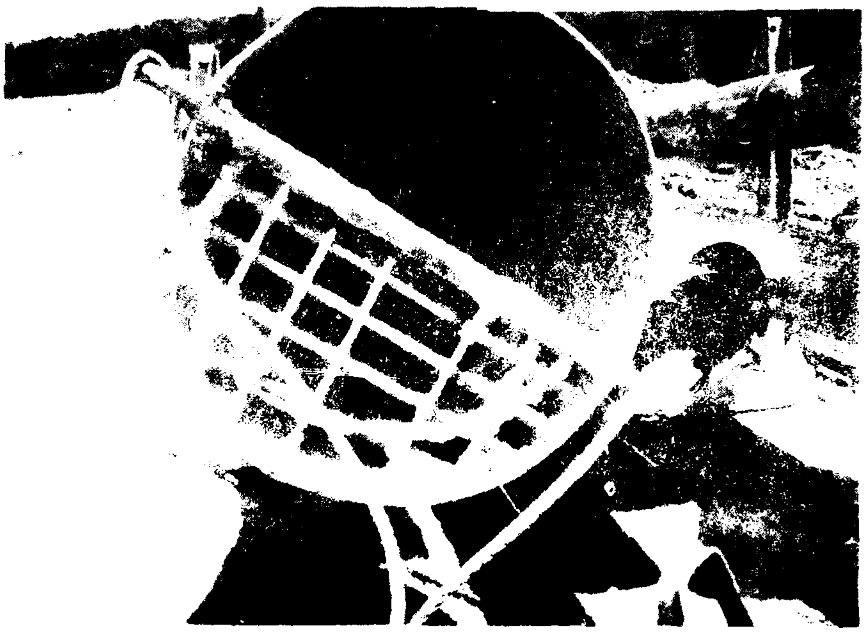


Photo 57 - Tremie hopper (missing one bar) used to remove lumps (May 5, 1984)

Photo 58 - Cherry picker tipped over (May 14, 1984)

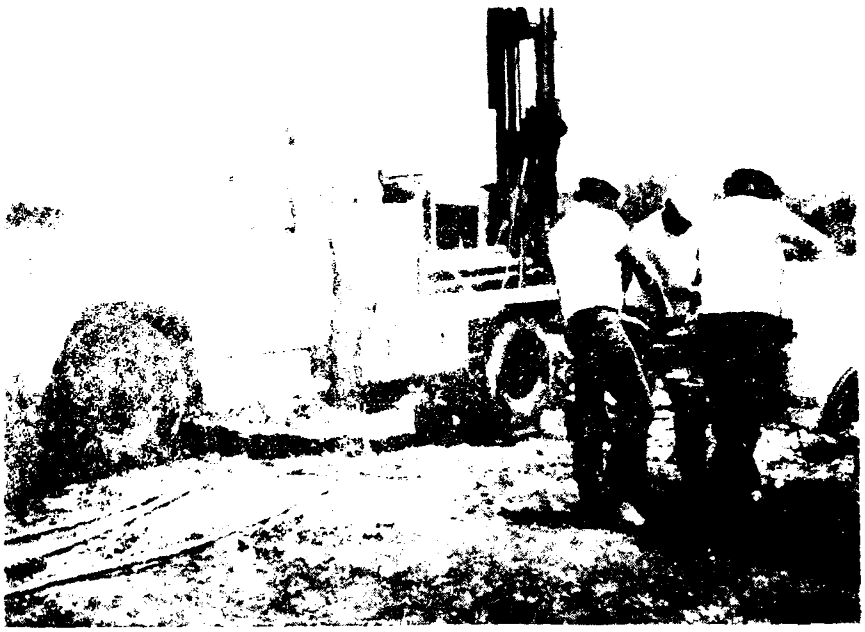


Photo 59 - Second phase of core drilling on Panel 30 (May 23, 1984)

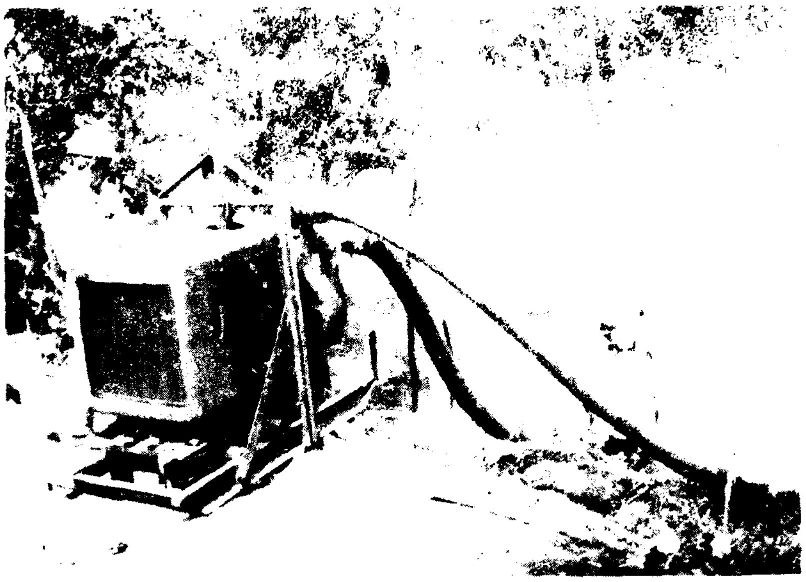


Photo 60 - Water pump used for dewatering pond (June 6, 1984)

Photo 61 - Area downstream after clearing and grubbing (June 11, 1984)

Photo 62 - Clearing and grubbing (June 11, 1984)

Photo 63 - Cleared area downstream toe (June 1984)

Photo 64 - Cleared area downstream toe (June 1984)

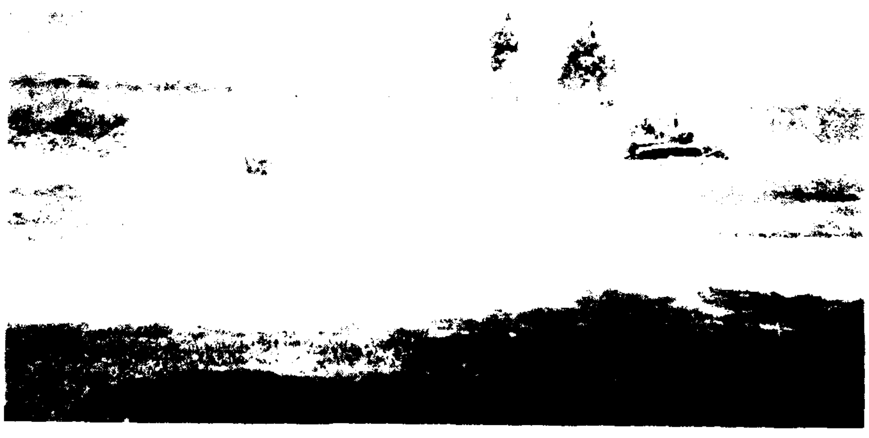


Photo 65 - Cutting topsoil (June 14, 1984)

Photo 66 - Cleared drainage ditch (June 14, 1984)

Photo 67 - Pushing into swamp (June 18, 1984)

Photo 68 - Overview to the west (June 14, 1984)

Photo 69 - Overview center of toe area (June 14, 1984)

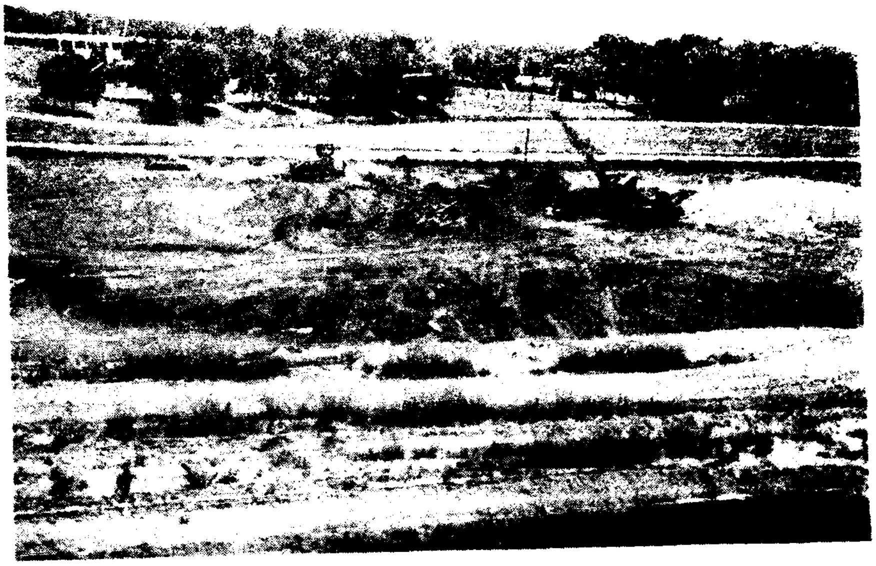


Photo 70 - Overview of toe area (June 14, 1984)

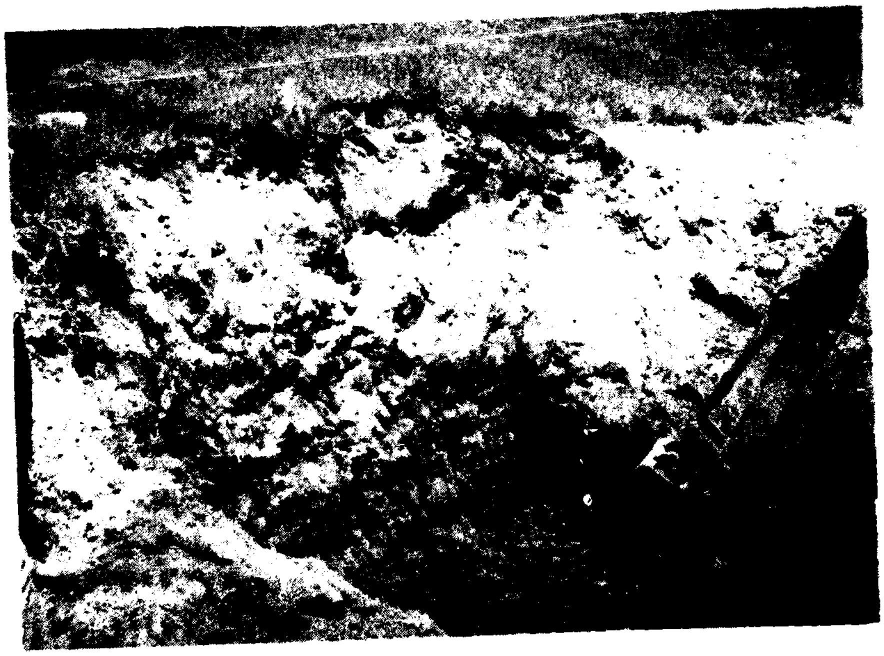


Photo 71 - Excavation of pit for EZ Bore site (June 25, 1984)

Photo 72 - Alignment for boring under Highway 93
(July 5, 1984)

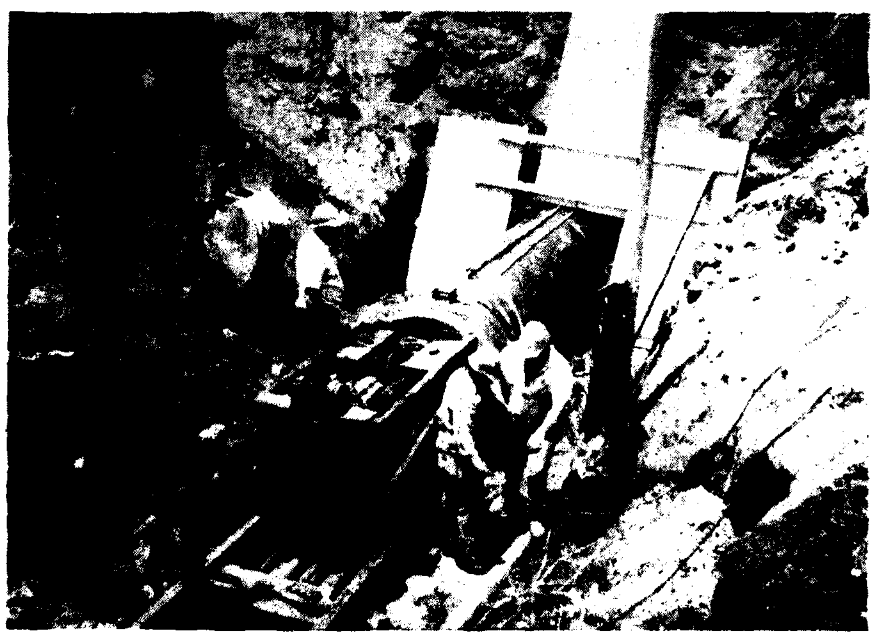


Photo 73 - Boring operations (July 5, 1984)

Photo 74 - Boring underway (July 5, 1984)

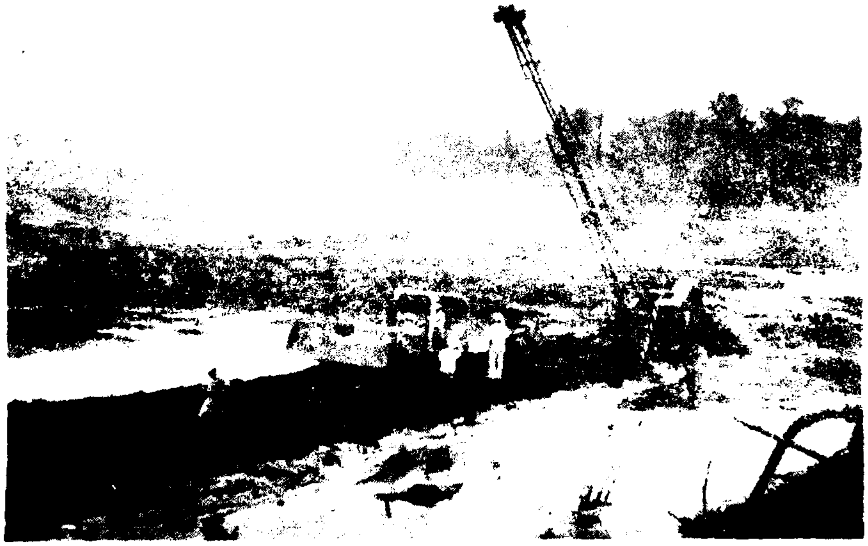


Photo 75 - Working into swamp (July 2, 1984)

Photo 76 - Mucking swamp (July 2, 1984)

Photo 77 - Drainage ditch after cleaning (July 4, 1984)

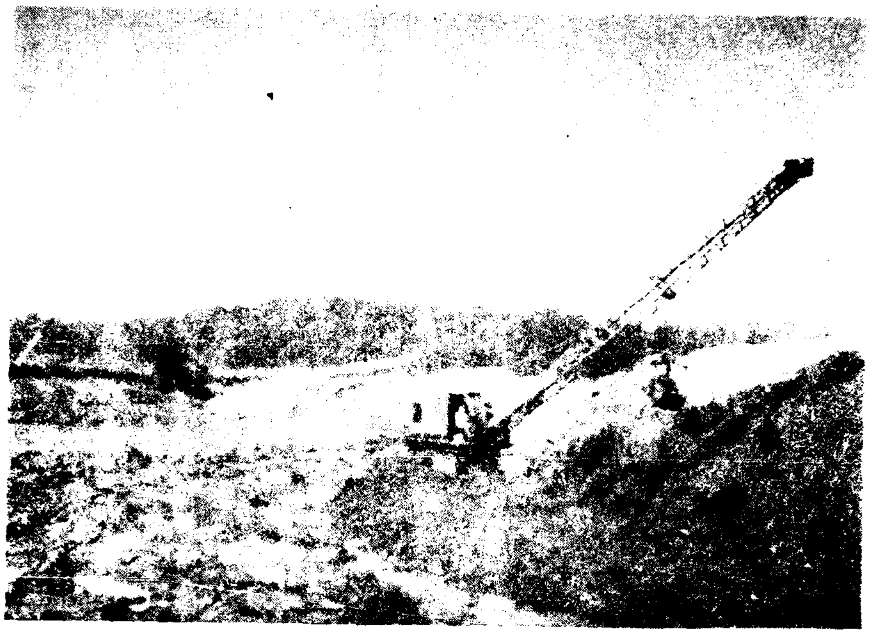


Photo 78 - Dragline cleaning east ditch (July 9, 1984)

Photo 79 - Pushing topsoil (July 9, 1984)

Photo 80 - Overview after site restoration (November 1985)

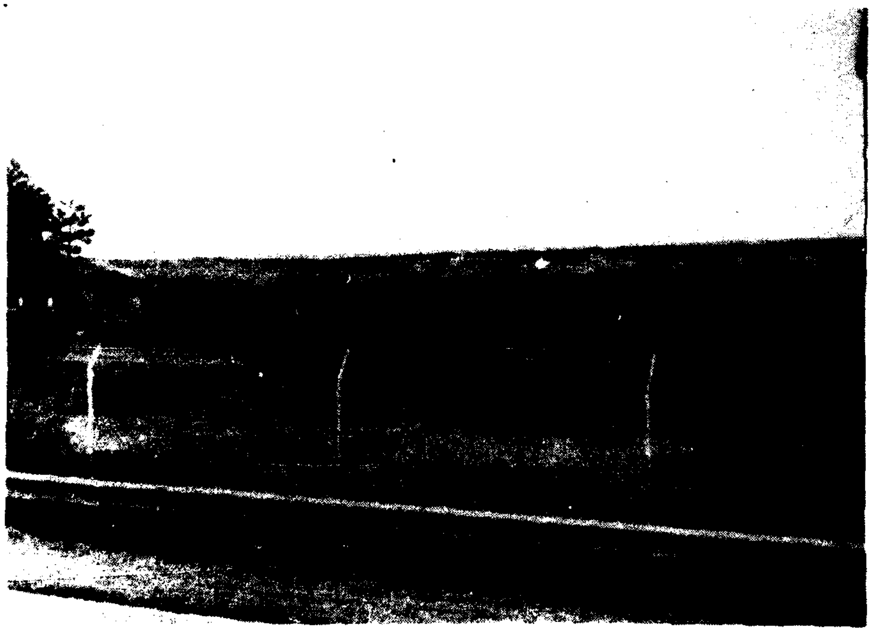


Photo 81 - Overview after site restoration (November 1985)