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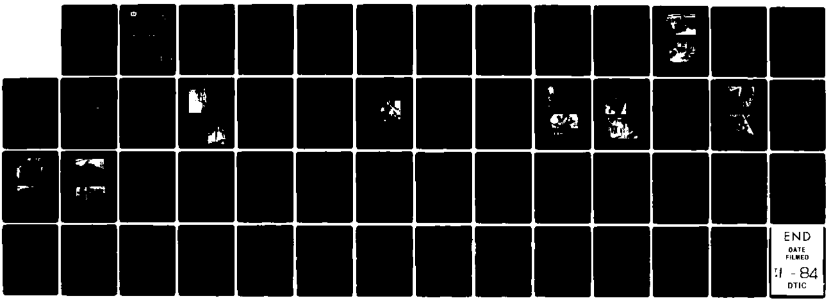

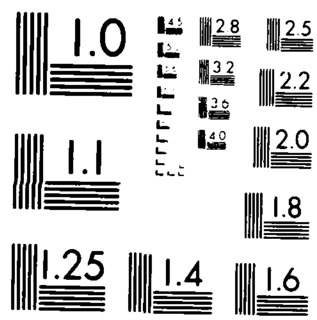

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US Army Corps of Engineers
Fort Worth District

FINAL FOUNDATION REPORT

AMISTAD POWERPLANT
DEL RIO, TEXAS

OCTOBER 1983

(12)

CORPS OF ENGINEERS

FORT WORTH DISTRICT, TEXAS

FINAL

FOUNDATION REPORT

AMISTAD POWER PLANT

BY

ALAN J. MARR

GEOLOGIST

OCTOBER 1983

PREFACE

This report was prepared by the Geotechnical Branch, Engineering Division, Fort Worth District, Corps of Engineers. The report was written by Staff Geologist, Alan J. Marr, under the supervision of the Chief of the Geology Section, Melvin G. Green, and the Chief of the Geotechnical Branch, Wayne E. McIntosh.

Colonel Donald Palladino and Colonel Theodore Stroup served as District Engineers during construction of the Amistad Power Plant. Chief of Engineering Division, SWF, was Mr. Shigeru Fujiwara. Mr. Ronald Zunker served as Resident Engineer during construction.

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I INTRODUCTION

1. Project Location and Description. Amistad Dam is located at approximate river mile 567 on the Rio Grande about 12 miles upstream from Del Rio, Texas. The location of the project is shown on plate 1.

The dam consists of a 950-foot long concrete spillway section in the main river channel flanked by non-overflow concrete sections and earth embankments on each side of the spillway section, and an earth dike extending about 2.2 miles east of the United States end of the main dam. The non-overflow concrete sections of the dam include a 225 foot long power intake section on the United States side and a 223-foot long power intake section on the Mexico side. Maximum height of the dam is 254 feet with crest elevation of the spillway section at elevation 1086.4 feet above mean sea level.

2. Construction Authority. Construction of the Amistad project was authorized by Public Law 286, 74th Congress, approved 19 August 1935, and the 1944 water treaty (Treaty Series 994) between the United States of America and Mexico, effective on 8 November 1945 (Articles 5, 7, and 24), and the Public Law 605, 86th Congress, 2d Session, approved 7 July 1960.

3. Purpose of Report. This report has been prepared in accordance with requirements as set forth by the Office, Chief of Engineers, in ER 1110-1-1801. This report provides a complete record of foundation conditions encountered during construction of the Amistad Power Plant. Information contained in this report will be valuable when evaluating (1) necessary remedial action required to prevent or repair any failures resulting from foundation deficiencies, (2) contractor claims related to foundation conditions or alleged change of conditions, and (3) planning and design of future comparable construction projects.

A copy of this report will be included in the permanent records maintained at the project office.

4. Project History. Construction of Amistad Dam began in 1963 and was completed in November 1969. The purposes of the dam were flood control and irrigation, with the generation of hydroelectric power as a future capability. Therefore, the basic design determinations for immediate and ultimate hydroelectric power plant installation were made before construction of the dam.

Construction of the dam included a 225-foot long United States power intake section in the left abutment of the main river channel. The power intake section included five intake monoliths having a 14.5-foot diameter penstock at the center of each monolith. Total length of the

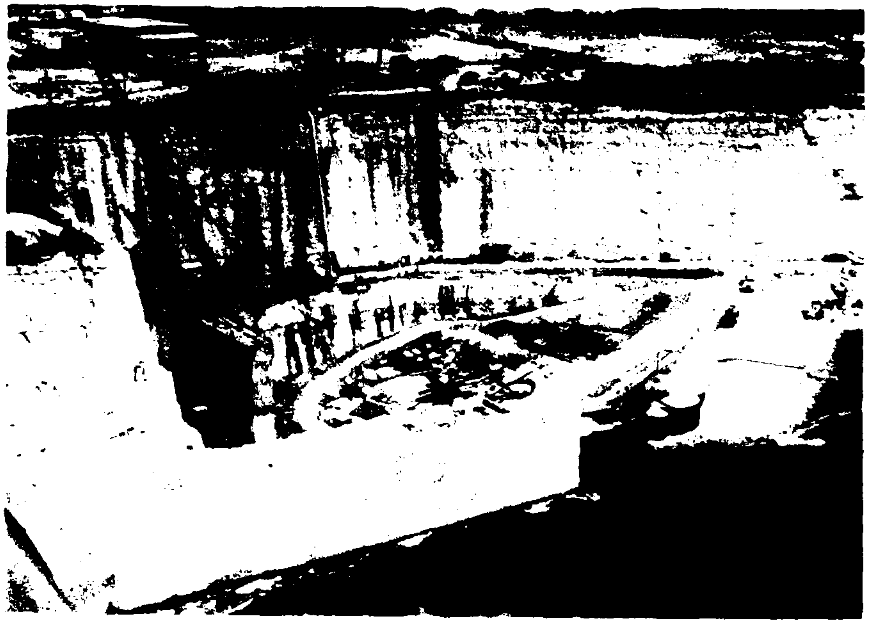

Figure 1 Work area and cofferdam viewed from observation deck at Amistad Dam

Figure 2 Powerhouse excavation - October 1981

II FOUNDATION EXPLORATIONS

1. Investigations Prior to Construction. Foundation investigations for the design and construction of the Amistad Power Plant were conducted simultaneously with investigations for design and construction of Amistad Dam. The drilling program, which included investigations of the powerhouse site, began in 1960 and was concluded in May 1962. The Plan of Borings is shown on plate 3 and logs of the borings located within the powerhouse site are presented on plate 8.

2. Investigations During Construction. No unanticipated foundation conditions or problems were encountered during construction that required additional subsurface investigations.

II FOUNDATION EXPLORATIONS

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2. Investigations During Construction. No unanticipated foundation conditions or problems were encountered during construction that required additional subsurface investigations.

III GEOLOGY

1. Physiography and Regional Geology. Amistad Dam is located on the southern edge of the Edwards Plateau section of the Great Plains physiographic province. The dam crosses a relatively steep-walled, 1100-foot wide canyon carved by the Rio Grande River through thick-bedded limestone. In the vicinity of Amistad Dam, the Rio Grande River flows near the axis of a wide, southeast trending synclinal trough which has gently dipping limbs. The flanks of this broad syncline are occasionally modified by minor flexures and faults whose origins are structurally attributed to a westward extension of the Balcones Fault Zone.

Amistad Dam is founded on strata belonging to the Cretaceous age Georgetown Limestone Formation. The Georgetown Limestone Formation outcrops at the surface, supports the concrete portion of the dam, and also forms the abutment through which the five power intake monoliths and penstocks were tunneled. At Amistad Dam the formation reaches a total thickness of about 500 feet and consists of thick-bedded to massive, fine-grained, stylolitic limestone. Correlation of persistent marker beds within the Georgetown Limestone Formation in the vicinity of Amistad Dam indicate a strike of N 48° W and a dip to the southwest at approximately 50 feet per mile.

2. Geology of the Powerhouse Site.

a. General. The Amistad Power Plant is founded in a manmade notch incised in the left abutment of Amistad Dam. Excavation for the power plant foundation was accomplished during construction of the main dam using the pre-split method of rock excavation. The powerhouse facility is founded on strata belonging exclusively to the Gerogetown Limestone Formation.

b. Description of the Overburden. All overburden was removed from the powerhouse site during the construction for the main dam. Logs of borings indicate that overburden in the powerhouse site consisted of a very thin cover of residual soil capping the limestone abutment. About 6 feet of silt, which had accumulated in the powerhouse stilling basin site, was removed after construction of the cofferdam and dewatering of the stilling basin.

c. Bedrock Stratigraphy. The Georgetown Limestone Formation at Amistad Dam reaches a total thickness of about 500 feet with approximately 30 to 45 feet of transitional, argillaceous limestone and marl capping the section and grading upward into the Del Rio Formation. Boring 6C2C-R-43, located near dam centerline station 170+00, encountered the contact between the Georgetown Formation and the underlying Kiamichi Formation at elevation 605.2, approximately 240 feet below the base of the power plant.

Figure 5. Powerhouse excavation. Note [illegible]° dipping "Stilling Basin Fault" partially grouted at top of excavation.

d. Bedrock Lithology. The Georgetown Limestone Formation consists of thick-bedded to massive, light gray to bluish-gray, moderately hard to hard, very fine-grained, slightly fossiliferous, occasionally pyritic limestone. Tight, hairline styolites are common. In the powerhouse area the limestone beds are separated occasionally by horizontal, soft to hard, variably calcareous shale laminations and bands up to 0.2 feet thick. The persistency of these shale bands in the powerhouse area makes them useful as stratigraphic markers for correlation.

e. Bedrock Structure. Strata comprising the Amistad powerhouse foundation are very nearly horizontal. The dip of the limestone beds beneath the structure, is variable in direction, and always less than 5° from horizontal. Two minor faults occur in the limestone foundation rock within the limits of the powerhouse structure (see plate 4). Both are normal faults striking in a NW-SE orientation and dipping toward the southeast. Displacement across both faults is minor (less than 0.3 ft) resulting in only a slight change in bedding dip. Jointing and fracturing associated with the faults are generally oriented parallel to the faults. Joints and cracks are tightly sealed, and tend to dissipate abruptly both horizontally and vertically.

A major fault, locally known as the "stilling basin fault" passes across the powerhouse stilling basin floor, up the rock face behind the stilling basin retaining wall, across the powerhouse access road and up the rock face on the east side of the powerhouse (figure 3). The fault strikes NE-SW and dips southeastward at an angle of 48°. Displacement across the fault was 12.0 feet in the rock face behind the stilling basin retaining wall. The location of the fault is shown on plate 4.

For safety purposes the brecciated zone along the fault plane overlooking the powerhouse site was cleaned of loose material and sealed with shotcrete during or shortly after the main dam construction. Weepholes were constructed through the shotcrete to drain the fault zone (see figure 3).

Zones of tight, closely spaced, parallel, vertical joints were exposed in the floor of the sump area excavation and in the floor of the generator bay area excavation. The joint zones were unrelated, occurring at different levels of the excavation. Other more isolated, random joints were exposed in the powerhouse foundation. Bedrock structure is shown on plate 4.

f. Bedrock Weathering. The Amistad Powerhouse foundation is below the base of bedrock weathering by about 50 feet. Orange staining noted in the powerhouse foundation bedrock was caused by silt which accumulated in the stilling basin immediately downstream of the five unused penstocks. Cleaning of the bedrock with compressed air and water failed to completely remove the orange stain. However, all components of the powerhouse facility were founded on competent, unweathered rock.

g. Ground Water. The occurrence and movement of ground water within the strata supporting the Amistad Powerhouse is restricted to openings caused by fracturing and/or faulting networks within the rock, or where

Figure 4 Vertical jointing in exposed vertical Georgetown Limestone cut

Figure 5 Seepage emitting from fault is caught in collection box and carried to excavation sump

solutionized joints or bedding planes occur, i.e., secondary permeability. The limestone itself, where unbroken, is highly impermeable.

A small flow of water, estimated at 2 to 3 gallons per minute, emitted from the fault exposed in the rock face behind the stilling basin retaining wall (see figure 5). This flow continued at a nearly constant rate throughout the construction period. Based upon a number of factors, i.e., low rainfall, constant seepage rate and the northwest orientation of the fault into the left abutment toward the reservoir, the source of the seepage is believed to be the reservoir. Upon a recommendation from SWFED-F two additional weep holes were constructed through the concrete retaining wall at the seepage emission point to specifically care for the water emitting from the fault. One weephole was constructed exactly at the point where the seepage emitted, and another was constructed in the fault plane about 1 foot higher than the first weephole. Other minor intermittent seeps emitted from joints and bedding planes in the pre-split rock face. A build-up of algae growth usually accompanied these seeps.

3. Engineering Characteristics of the Primary Materials. Materials testing prior to design and construction of the Amistad Power Plant was conducted simultaneously with testing for the design and construction of Amistad Dam. Results of all testing are presented in Section III of the Amistad Dam Design Memorandum No. 1 (Revised), March 1965. The following shows the range of values and the average values obtained from tests on the Georgetown Formation:

	Average	Maximum	Minimum
Dry Density (pcf)	158.0	164.1	153.6
Unconfined Compressive Strength (psi)	7,756	12,803	3,660
Modulus of Elasticity (10^6 psi)	5.78	9.90	2.60

The limited thickness of the shale seams within the Georgetown Limestone Formation made it difficult to obtain shale specimens which would yield reliable test results. The seams are composed of highly compressed clay of high plasticity which would lose considerable strength should variations in moisture content occur. Therefore, it was recommended that the shale seams not be permitted to remain beneath any concrete structure at shallow depths with a low degree of confinement.

IV EXCAVATION PROCEDURES

1. Excavation Grades. The majority of the excavation for the Amistad Power Plant was accomplished concurrent with construction of the main dam. As a result, excavation under the current contract was limited to fine-cutting to final design grade using jackhammers. Actual foundation conditions encountered during excavation for the Amistad Powerhouse were essentially as described in the contract plans and specifications. The designed slopes in the Georgetown Limestone Formation were achieved and maintained without difficulty. Some minor variations (overexcavation) from the designed grade lines occurred. Final sections across the rock foundation and geological mapping were accomplished by a government survey team supervised by the project geologist. Final excavation grades and slopes in the powerhouse foundation are presented on plate 5. Geologic sections are presented on plate 6.

2. Dewatering Provisions. A contract was awarded to Reece Albert, Inc. of San Angelo, Texas to construct a cofferdam and dewater the powerhouse site. Work began in April 1980. A 24 feet high by 365 feet long cofferdam was constructed from the left training wall of the main dam concrete spillway section across the powerhouse stilling basin and connected to the limestone abutment which formed the left side of the stilling basin. The cofferdam was completed and dewatering began in September 1980 using two 10-inch diameter and two 6-inch diameter electric pumps.

During construction a 6-inch diameter electric pump removed water that entered into the work area. Project personnel estimated the inflow to be approximately 200 gpm. The main sources of the inflow were seepage through and around the cofferdam, leakage through penstock No. 4 in the main dam, the spring emitting from the fault described in Section III-2(f) of this report and weepholes in the training wall of the main dam concrete spillway section. All seepage was collected in a sump located just outside the limits of powerhouse structure and eventually pumped out of the work area. All concrete placements were on surfaces free of water.

3. Rock Excavation. As previously noted, the excavation of all overburden and the majority of the foundation rock for the powerhouse foundation was accomplished concurrent with the construction of the main dam using the pre-split method of rock excavation. During the pre-splitting the Contractor was required to leave the rock below the excavation grade undamaged. As a result, the rock surfaces comprising the foundation were left somewhat rounded and irregular. Final cutting and shaping of these irregular areas were accomplished during the powerhouse construction contract using pneumatic tools either operated by hand or mounted on a rubber-tired CASE 580C front-end loader/backhoe as shown in figure 6.

The amount of overexcavation which occurred in the limestone foundation was minor, generally the result of two conditions. The first condition was the occurrence of one of the horizontal shaly laminations immediately below designed grade. The Contractor was directed to remove the shaly zone where it occurred near grade. The second condition where overexcavation occurred

Figure 6 Rock excavation using jack-hammer mounted on back hoe

was in areas of faulting or severe jointing and fracturing. The Contractor was required to remove all loose or drummy rock from the surface before concrete encasement. Plate 4 shows the locations of faults and joints within the powerhouse foundation.

4. Foundation Preparation. The Georgetown Limestone Formation which comprised the Amistad Power Plant foundation was not sensitive to exposure to atmospheric conditions, therefore, no restrictions were placed on the length of exposure time of the foundation rock. The final foundation surfaces were shaped using hand tools such as jackhammers, picks, and shovels. All loose or drummy rock was removed and the surfaces were cleaned with a high pressure air-water jet. Structural concrete was placed directly against or on the rock surfaces.

5. Safety. The limestone rock faces of the powerhouse excavation were sufficiently competent to stand on the designed slopes. The slopes generally showed no significant deterioration since their initial exposure over 15 years earlier. All rock faces within the excavation were scaled of loose material prior to the start of construction in the powerhouse site and no difficulty was encountered from slides or rockfalls during construction.

An extensive area of vertical jointing associated with the "stilling basin fault" described in III-2(d) of this report was exposed by the pre-splitting excavations on the upstream end of the rock face to be encased by the retaining wall (see figure 4). Immediately after completion of pre-splitting operations, rock bolts were installed to insure the stability of the jointed rocks. All of the rock bolts appeared intact and undisturbed, indicating the jointed zone has remained in a stable condition since its initial exposure. The jointed zone does not occur within the limits of the powerhouse foundation.

V FOUNDATION ANCHORS

1. General. Foundation anchors were installed in the powerhouse foundation and in the rock face behind the concrete retaining wall. Permanent foundation anchors were installed to a depth of 30 feet below the generator bay, erection bay, and sump areas. The locations of these anchors are shown on plate 5. Behind the retaining wall the anchors were spaced on 10-ft centers and installed to a depth of 10 feet. No pull-out tests were performed.

2. Equipment. All holes for the rock anchors were drilled using the AT3100B track-mounted pneumatic drill shown in figure 7. Anchors installed in the powerhouse foundation consisted of No. 11 Dywidag threadbars anchored with cartridge packaged polyester resin manufactured by Celtite, Inc., Cleveland, Ohio. Rock anchors in the limestone face behind the concrete retaining wall consisted of No. 11 rebar grouted by the Slit Perfo method of grout distribution. The water-cement ration of the grout was 0.28.

3. Procedures.

a. Powerhouse Foundation Anchors. Rock anchor holes in the powerhouse foundation were drilled to a depth of 30 feet using a pneumatic percussion drill with a 1-7/8-inch diameter button bit. Each hole was sealed with a wooden plug after completion of drilling; installation of anchor bars commenced after all holes had been drilled. After cleaning the holes with air, Celtite polyester resin cartridges consisting of heat sealed polyester tubes (sausages) containing both the resin and the catalyst, separated by a barrier which prevents chemical interaction until installation of the bar, were placed in the anchor holes (see figure 8). Three cartridges of fast setting (Type MV 90) resin for point anchorage were dropped in the hole first, followed by approximately 25 (the number required to fill the hole) slow setting (TYPE MV 1530) resin cartridges for corrosion protection. One-inch Dywidag threadbars were then screwed into the resin-filled holes as shown on figure 9. The threadbar entry, which normally took 4 or 5 minutes, penetrated the resin cartridges, mixed the resin and catalyst, and initiated the hardening of the resin. Immediately after completing the threadbar entry, a hydraulic jack was attached to the bar and it was tension stressed to 80 K or 133 K as specified (see figure 10). Bar tension was applied after the fast-setting resin had cured, but before the slow-setting resin had cured, thereby distributing the stress over the entire length of the anchor. Stress was applied at the surface against a 12" x 12" x 2-1/2" steel bearing plate set on a flat grout pad. After stressing, a hex nut was screwed down on the threaded bar against the bearing plate to permanently retain the stress.

Shortly after completing the installation of the 64 rock anchors in the generator bay area, project personnel observed water flowing from beneath the bearing plates on some of the anchors. Since water under varying amounts of pressure was encountered during the drilling of most of the

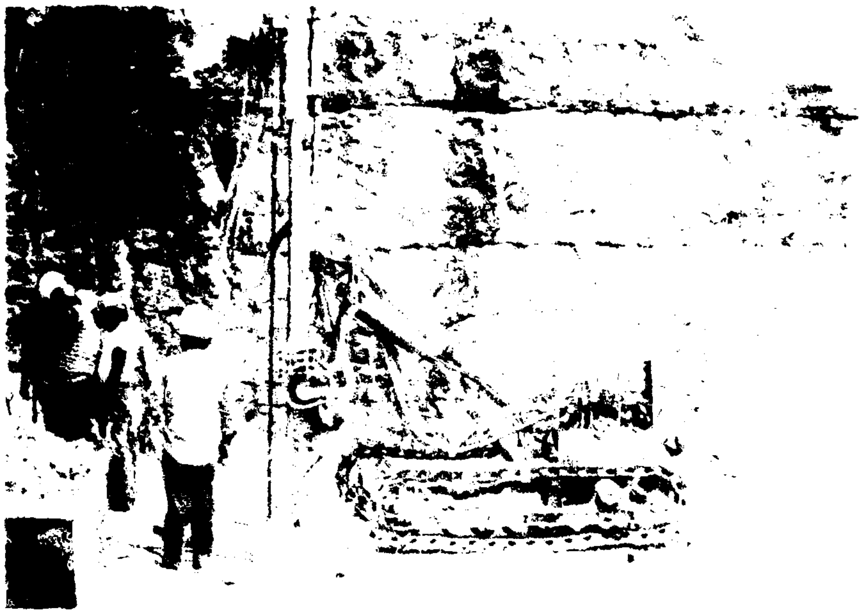


Figure 7 Drilling rock anchor holes with AT 3100B track-mounted pneumatic drill

Figure 8 Loading epoxy cartridges into anchor hole

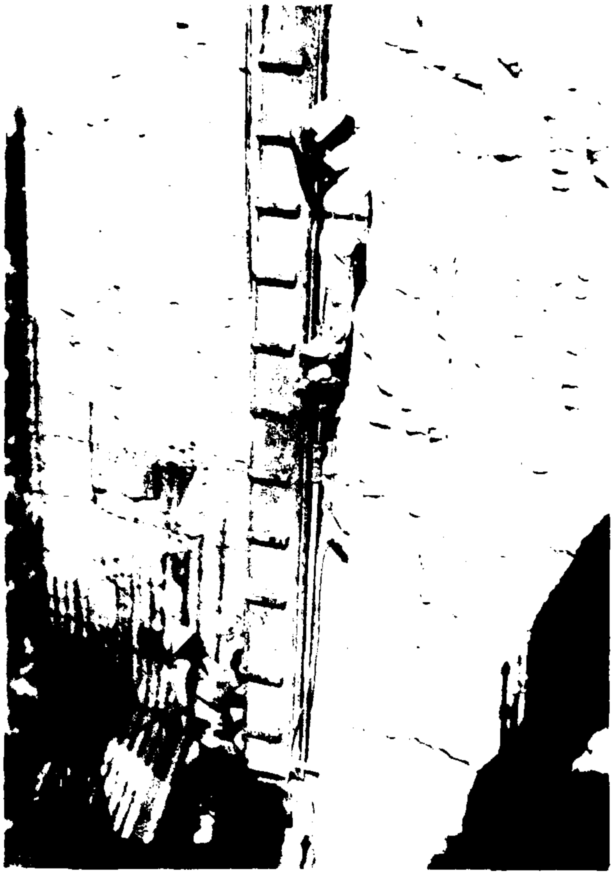
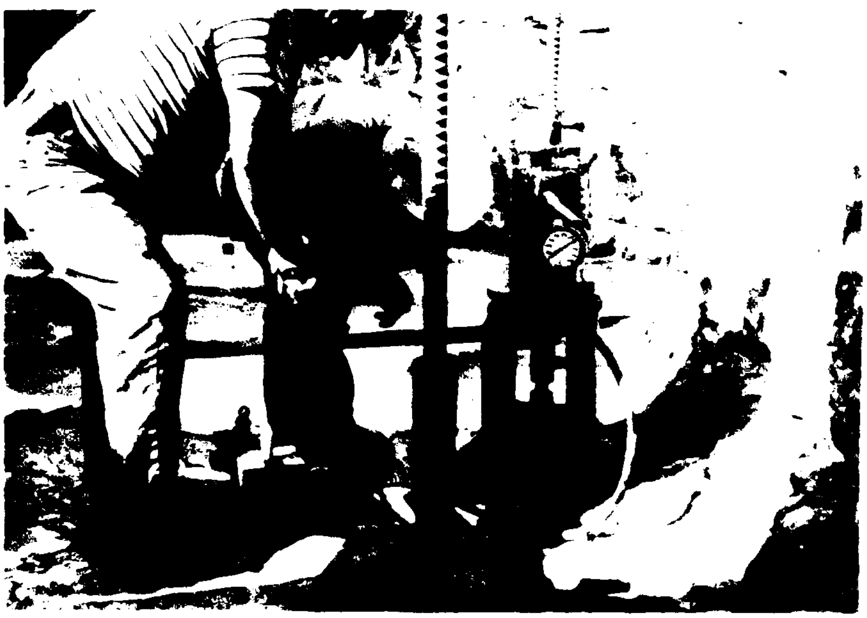


Figure 9 Dywidag threadbar is screwed into anchor hole using electric drill



anchor holes, it was assumed that the water was flowing upward in the borehole, either between the limestone and the epoxy gel or between the epoxy gel and the threadbar. The latter case could shorten the effective life span of the foundation anchor due to oxidation of the threadbar. Geotechnical personnel from SWF and SWD visited the project and the decision was made to de-stress the anchors that were emitting water, remove the bearing plates, and inspect the threadbar anchorage. On 15 of the 17 anchors inspected, the epoxy gel surrounding the threadbar was below the surface (figures 11 and 12). The maximum depth of the void annular space was 6.1 feet. Based on these findings, the decision was made to de-stress all of the anchor bars and inspect for similar voids. Void annular space was found on 58 of the 64 anchors in place. The void annular space on each anchor was cleaned using jetted air and water, and filled to the surface with neat cement grout. All of the rock anchors were then re-stressed to their designed load of 80 K.

The cause of the voids was an improper hole diameter drilled by the Contractor. The Contractor used a 1-7/8-inch button bit to drill the anchor holes while Celtite, Inc., recommends a borehole diameter of 1-3/8 inches to 1-5/8 inches when using a nominal 1-inch diameter Dywadag threadbar.

b. Retaining Wall Anchors. Rock anchor holes in the limestone face behind the concrete retaining wall were drilled to a depth of 10 feet. In order to get to the anchor locations on the 4 V on 1 H rock face, the drill was mounted on a platform suspended by an overhead crane. Contract plans required 10-foot embedment of 1-3/8-inch diameter rebar spaced at 10 feet center-to-center each way in a 6-inch diameter hole. A contract modification was proposed by the Contractor, and approved by SWF, whereby the anchor hole size was changed from 6-inch diameter to 1-7/8-inch diameter, and the Slit-Perfo method of cement grout distribution was used for anchorage of the bars. With the Slit-Perfo method, perforated cannisters are filled with cement grout and inserted into the clean borehole. Rebar is then inserted through the cannisters, displacing the grout and forcing it out through the perforations into the annular space in the borehole.

The 10-foot center-to-center grid spacing of the wall anchors placed a few of the anchor locations directly over the horizontal, soft shale seams which separated the more massive, hard limestone layers. Where this occurred the Contractor was directed to move the anchor locations down 1 foot to insure anchor installations in firm rock.

4. Pull-Out Tests. The contract plans and specifications did not require pull-out tests on either the pre-stressed foundation anchors or the retaining wall anchors. Pull-out tests were, however, considered because of the experience with the foundation anchors. It was decided they were not necessary because each anchor installation had been closely inspected and the wall would receive additional permanent reinforcement from anchors that will be installed in the wall to support the concrete forms during placement.

Figure 11 Void space around threadbar

Figure 12 Void space around threadbar and beneath bearing plate

VI CHARACTER OF THE FOUNDATION

1. General. The Amistad Power Plant is founded on hard, unweathered limestone belonging to the Cretaceous age, Georgetown Limestone Formation. A detailed geologic map of the powerhouse foundation is presented on plate 4. Engineering characteristics of the primary strata are presented in Section III of this report.

2. Foundation Surface. After final shaping and cleanup, the limestone foundation surface exhibited varying degrees of unevenness. Where final grade occurred along one of the horizontal shaly seams within the formation, the soft shaly material within the seam was removed leaving the finished limestone surface relatively flat. This condition occurred in the generator bay foundation area at elevation 845. In most cases, however, the surface was uneven to a degree of ±0.5 feet, due to the massive and hard nature of the limestone. In general, the characteristics of the limestone foundation surface are moderately hard to hard, gray to dark gray, very fine grained and massive. Typical limestone surfaces on which concrete was placed are shown on figures 13 through 16.

3. Condition of the Foundation. All limestone surfaces against which concrete was placed were unweathered. There was no evidence of large scale solutioning of the limestone, although some of the exposed joints and faults which emitted water could eventually develop into larger cavities. Faulting and jointing exposed in the limestone was minor and did not significantly alter the integrity of the rock. There were no large brecciated or fractured zones associated with the faults and all jointing was tightly healed with secondary mineralization.

4. Water. The occurrence and flow of water within the powerhouse foundation bedrock is through openings in the rock caused by faults, joints, or bedding planes. Several algae-choked wet areas are visible on the walls of the powerhouse excavation where flows ranging from a seep to as much as 2 to 3 gallons per minute are emitting. The smaller seeps are intermittent, flowing only after periods of rainfall. The 2-3 GPM flow emitting from the fault behind the concrete retaining wall is fairly consistent suggesting that its source may be the reservoir (see Section III-2(f) in this report). There are also isolated, trapped pockets of water under pressure within the limestone. When drilling the first foundation anchor hole in the generator bay area, one of these pockets was encountered and reportedly water initially gushed 16 feet into the air.

Figure 13 Typical limestone foundation surface prior to concrete placement (erection bay area at elevation 865±)

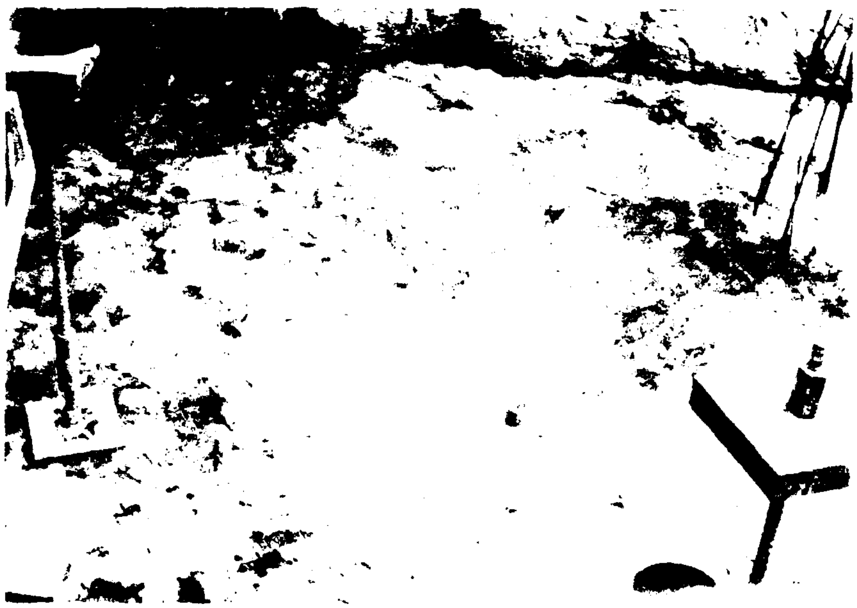


Figure 14 Typical limestone foundation surface prior to concrete placement (erection bay area at elevation 865±)

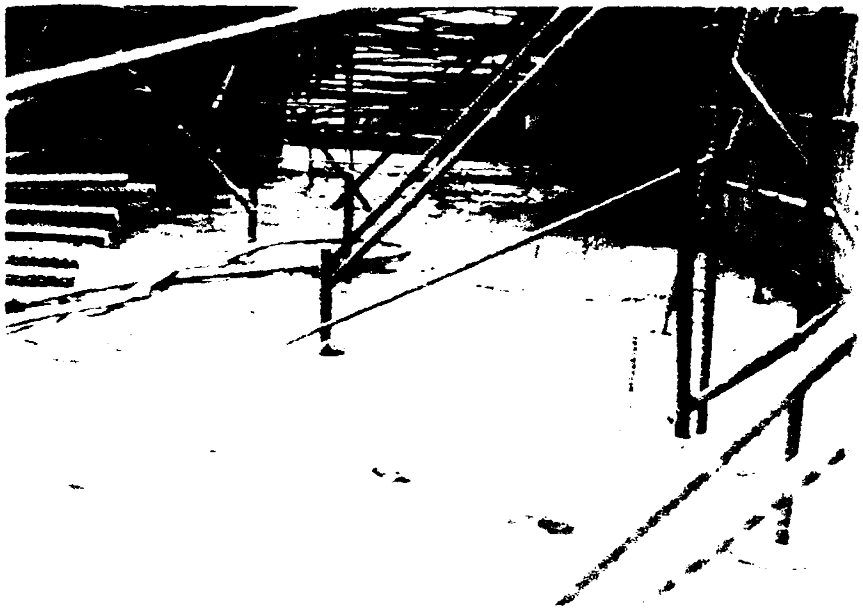


Figure 15 Typical limestone foundation surface prior to concrete placement (generator bay area at elevation 845±)

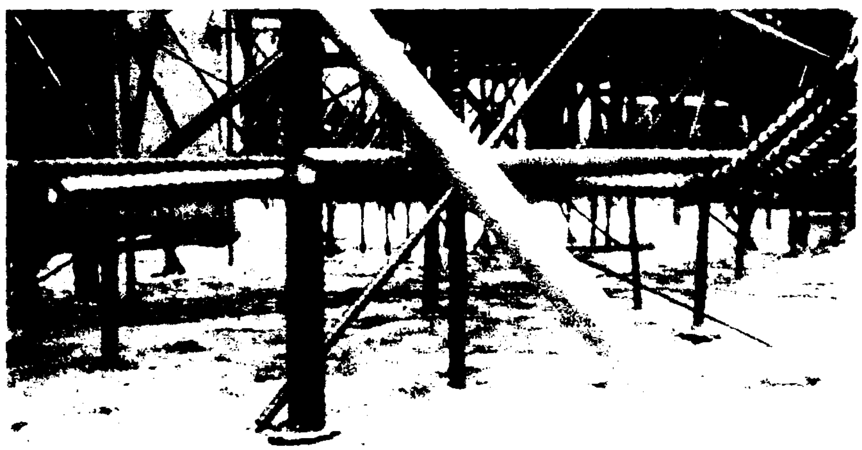


Figure 16 Typical limestone foundation surface prior to concrete placement (generator bay area at elevation 845±)

VII RECORD OF FOUNDATION APPROVAL

1. General. All rock surfaces which became a part of the foundation of the Amistad Power Plant were inspected, mapped, and approved by a SWF geologist prior to encasement in concrete. In some cases, final approval relating to the cleanliness of the surface was given by project personnel immediately prior to concrete placement, whereas the geologist had inspected the rock at an earlier date. A record of foundation approval is provided, in chronological order as each section of the foundation was approved, in the following paragraphs. Final elevations and a geologic map of the excavation are shown on plates 4 and 5.

2. Record of Approval.

a. Erection Bay Area. The foundation bedrock between dam stations 157+40 and 157+56, and Powerhouse stations 12+87 and 13+65 was inspected and approved on 29 September 1981. The area had been overexcavated to as much as 30 inches below the design grade elevation of 906. It was the Contractor's intent to place concrete to elevation 906, and in the process, give his batch plant a trial run. Concrete was placed in the area on 30 September 1981. Final elevation shots were taken by the Contractor's survey crew. Final elevation shots in all other areas mapped were taken by a government-contracted survey crew supervised by the SWF geologist.

b. Erection Bay Area. The area between dam stations 157+67 and 157+90, and Powerhouse stations 12+87 and 13+09 was inspected and approved on 5 October 1981. The Contractor had also overexcavated in this area and wanted to fill with lean concrete to elevation 906. Concrete was placed in the area on 7 October 1981.

c. Generator Bay Area. The portion of this area outside of the limits of the draft tubes between dam stations 158+25 and 159+10, and Powerhouse stations 13+10 and 13+80 was mapped and inspected on 7 October 1981. Removal of some loose, drummy rock was required before approval. Concrete was placed in this area on 9 October 1981. The area beneath the draft tubes was mapped and inspected on 21 October 1981. Concrete placement in this area was delayed until 29-30 October 1981 due to the problem with foundation anchors as described in Section V.

d. Sump. The floor and walls of the sump were mapped and inspected on 12 October 1981. Subsequent approval and concrete placement occurred on 17 October 1981.

e. Erection Bay Area. The floor and walls in the area between dam stations 157+67 and 158+25, and Powerhouse stations 13+09 and 13+65 at approximate elevations 871 and 866 were mapped and inspected on 12 November 1981. The western edge of this area where it dropped down into the generator bay area contained a large amount of loose rock which was required to be removed. Removal of the loose material necessitated the relocation of two rock anchors. Final cleanup and approval of the area occurred immediately prior to concrete placement on 2 December 1981.

f. <u>Elevation 906 "Bench" and Above</u>. The floor and walls of this area between dam stations 158+90 and 159+10 and Powerhouse stations 12+85 and 13+10 were mapped and inspected on 5 February 1982. Final clean-up, approval, and concrete placement in the area occurred on 9 February 1982.

g. <u>The Retaining Wall Between Powerhouse Stations 13+65 and 17+60</u>. The exposed limestone face on the left side of the powerhouse stilling basin was inspected and mapped on 12 May 1982. The surface was mapped from the top of the nearly vertical cut at approximate elevation 920 to its base formed by the stilling basin floor and the edge of the earthen access ramp sloping off of the cofferdam. Some loose rock removal from the wall was required. Several small seep areas in the exposure had formed deposits of algae which also required removal. The surface was cleaned, approved, and encased in concrete in several small sections between 19 July 1982 and 26 May 1983.

VIII CONTRACT MODIFICATIONS

The Amistad Power Plant Plans and Specifications did not detail the equipment and procedures to be used for the prestressed anchors in the powerhouse foundation. On 25 June 1981 the Contractor proposed using DYWIDAG threadbar rock bolts set in a fast curing polyester resin grout. A description of the system was presented in Section V of this report. Literature published by DYWIDAG Systems International and Celtite, Inc., was furnished. After SWF review, the proposal was approved on 10 July 1981.

On 18 August 1981, the Contractor submitted a proposal to use the Slit Perfo System in grouting the rock bolts in the limestone face behind the concrete retaining wall. The proposal was approved by SWF on 8 September 1981.

As a result of a recommendation by SWF Geotechnical Branch, two additional weep holes were installed in the concrete retaining wall to drain seepage from a fault. It was felt that without the weep holes, water could be trapped behind the wall possibly resulting in damage to the wall or the stability of the powerhouse access road subbase above.

VIII CONTRACT MODIFICATIONS

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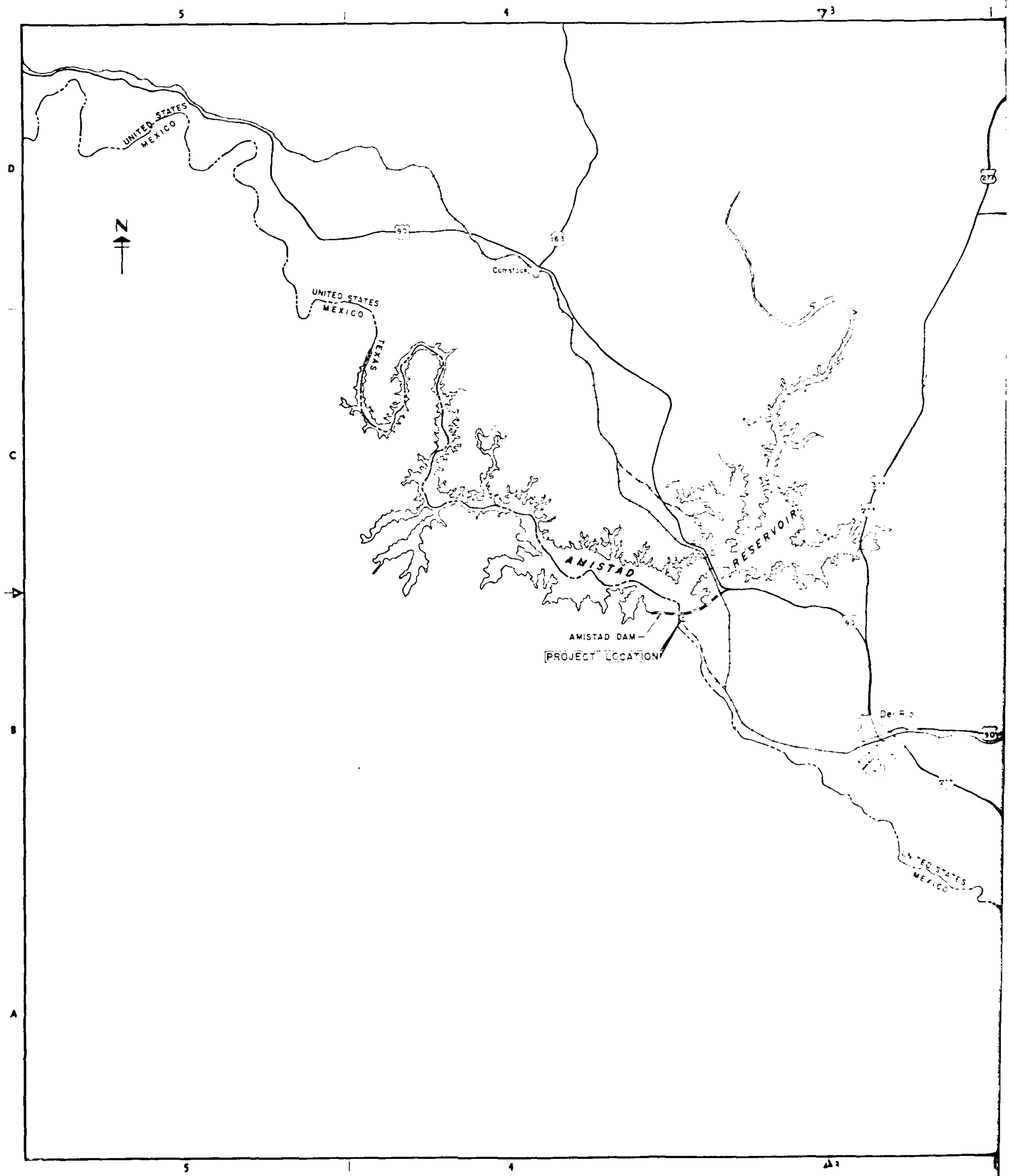
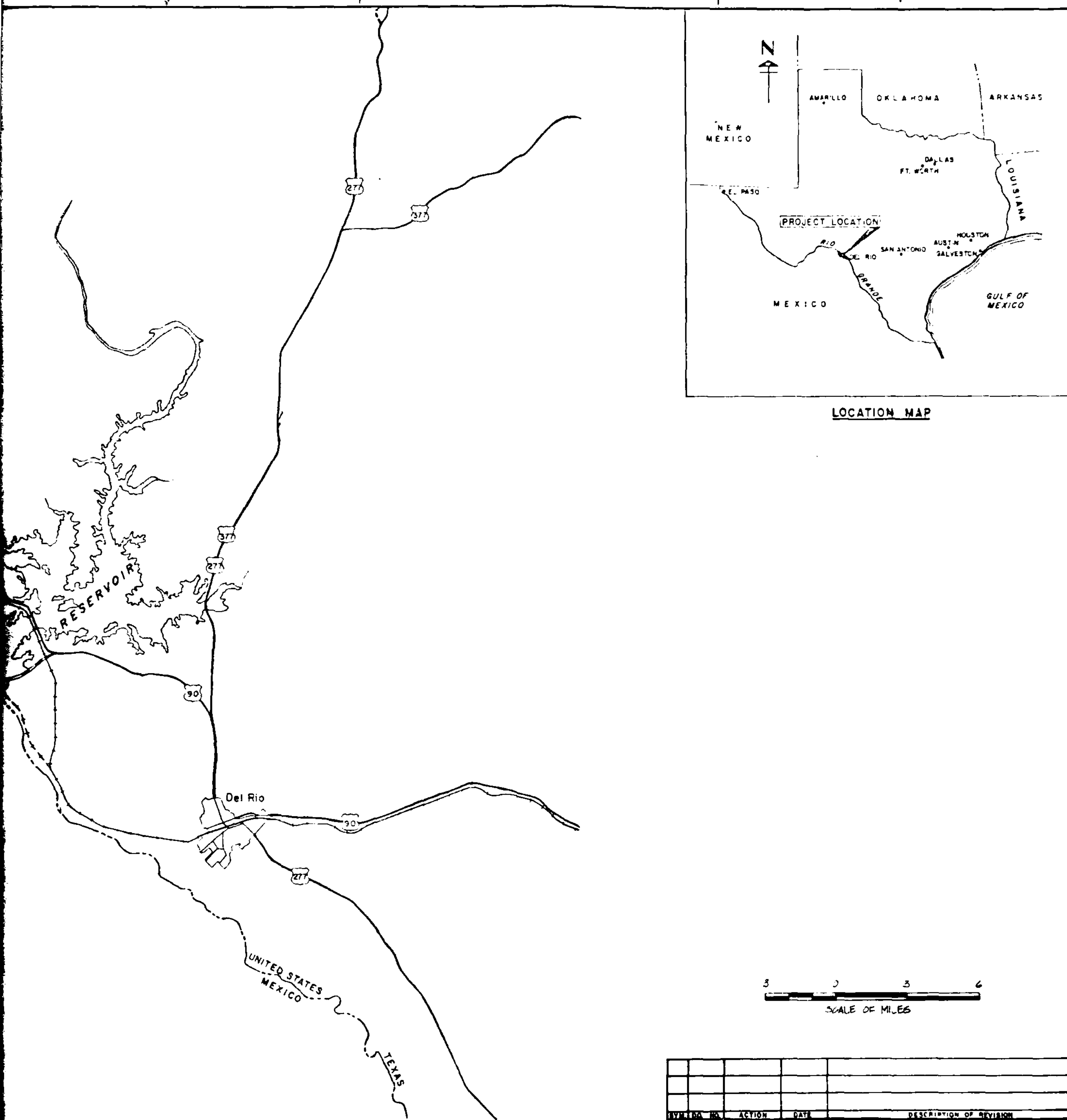


N
UNITED STATES
MEXICO
90
163
Comstock
TEXAS
AMISTAD
RESERVOIR
AMISTAD DAM
PROJECT LOCATION
Del Rio
90
UNITED STATES
MEXICO



SYMBOL	ACTION	DATE	DESCRIPTION OF REVISION

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

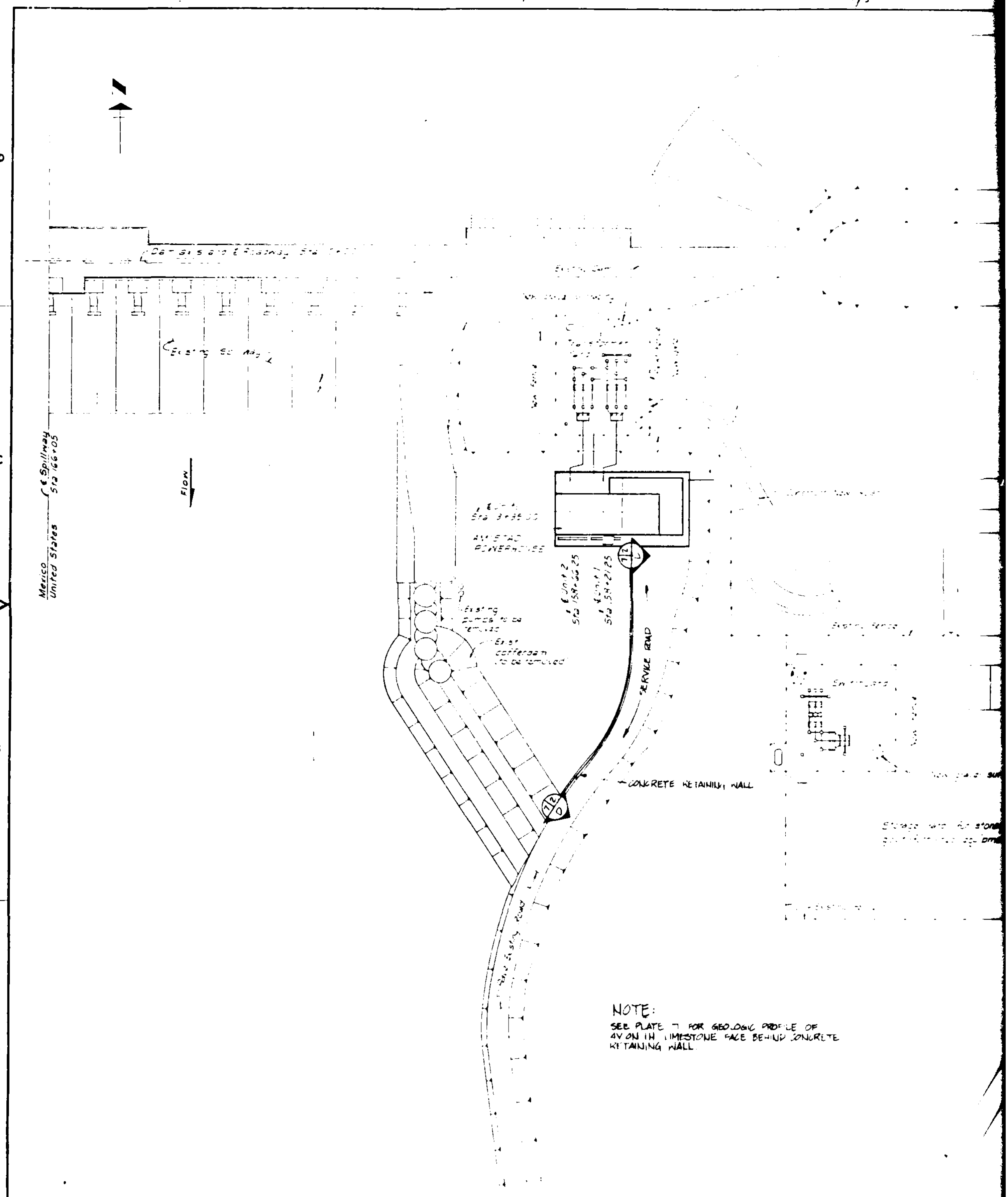
DESIGNED BY: A. MARR
DRAWN BY: L. GOSS
REVIEWED BY: M. GREEN
SUBMITTED BY: MEL GREEN

AMISTAD DAM
DEL RIO, TEXAS

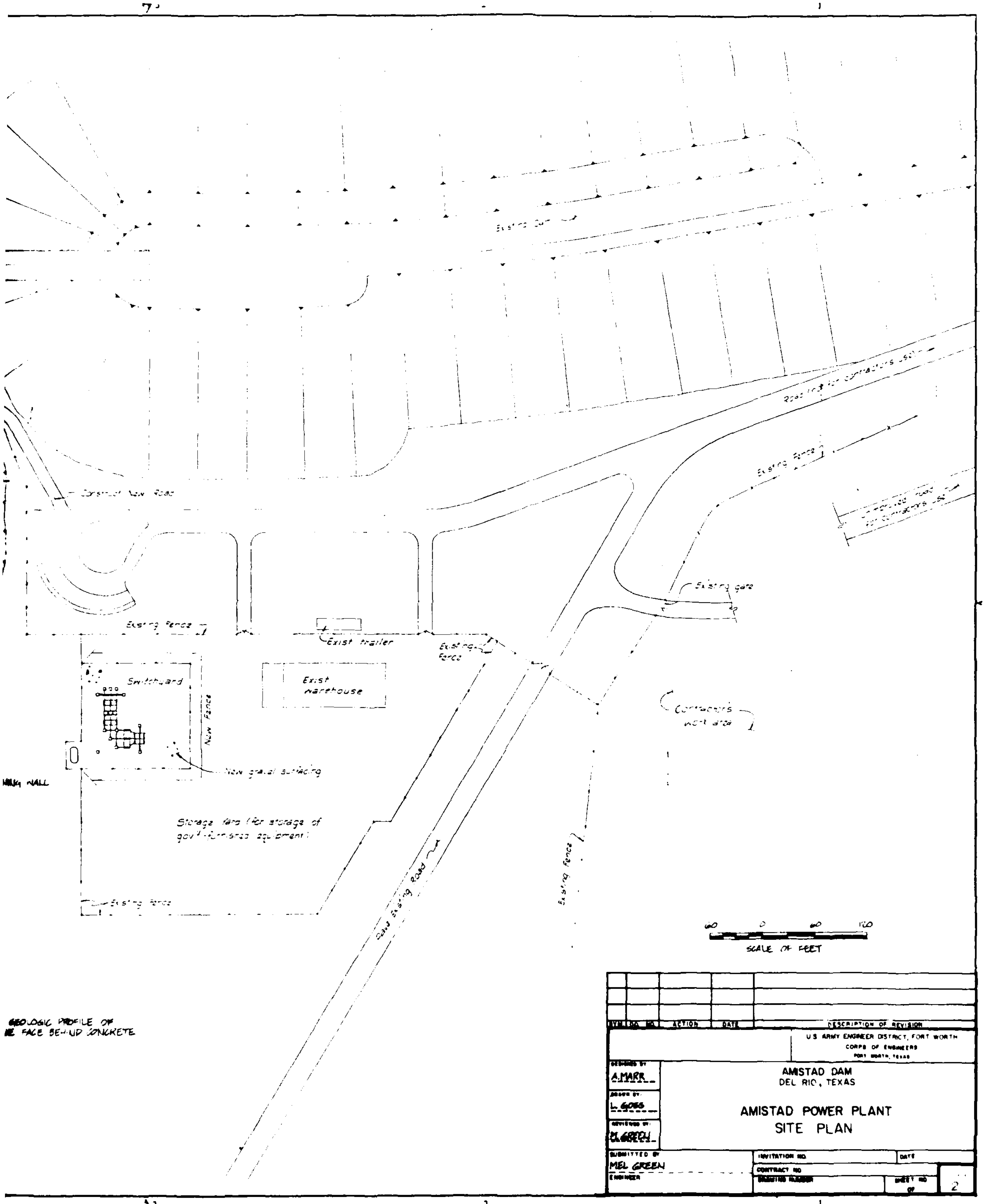
AMISTAD POWER PLANT
PROJECT LOCATION MAP

INVITATION NO. | DATE
CONTRACT NO.
DRAWING NUMBER | SHEET NO. | Plate 1

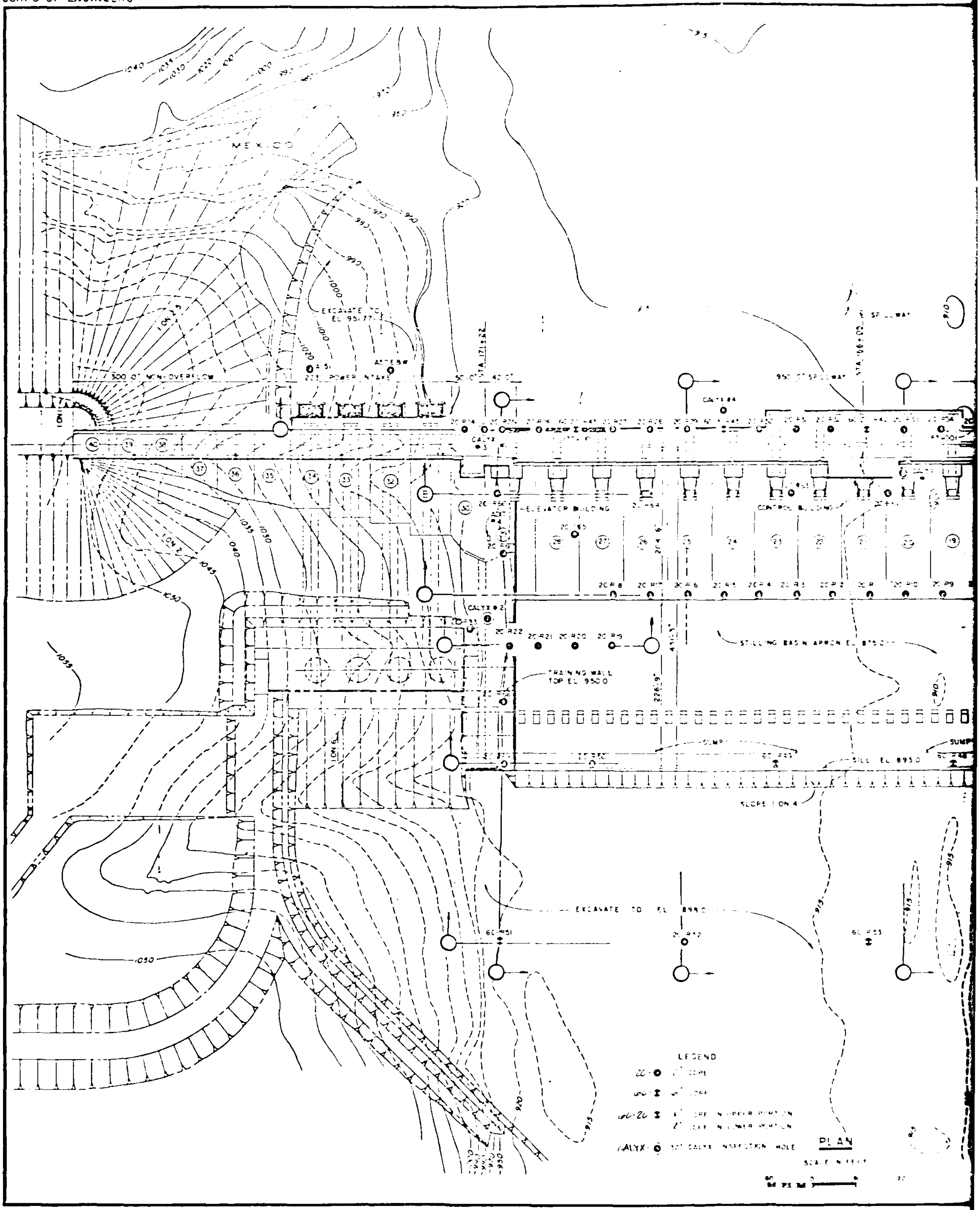
TO ACCOMPANY FINAL FOUNDATION REPORT

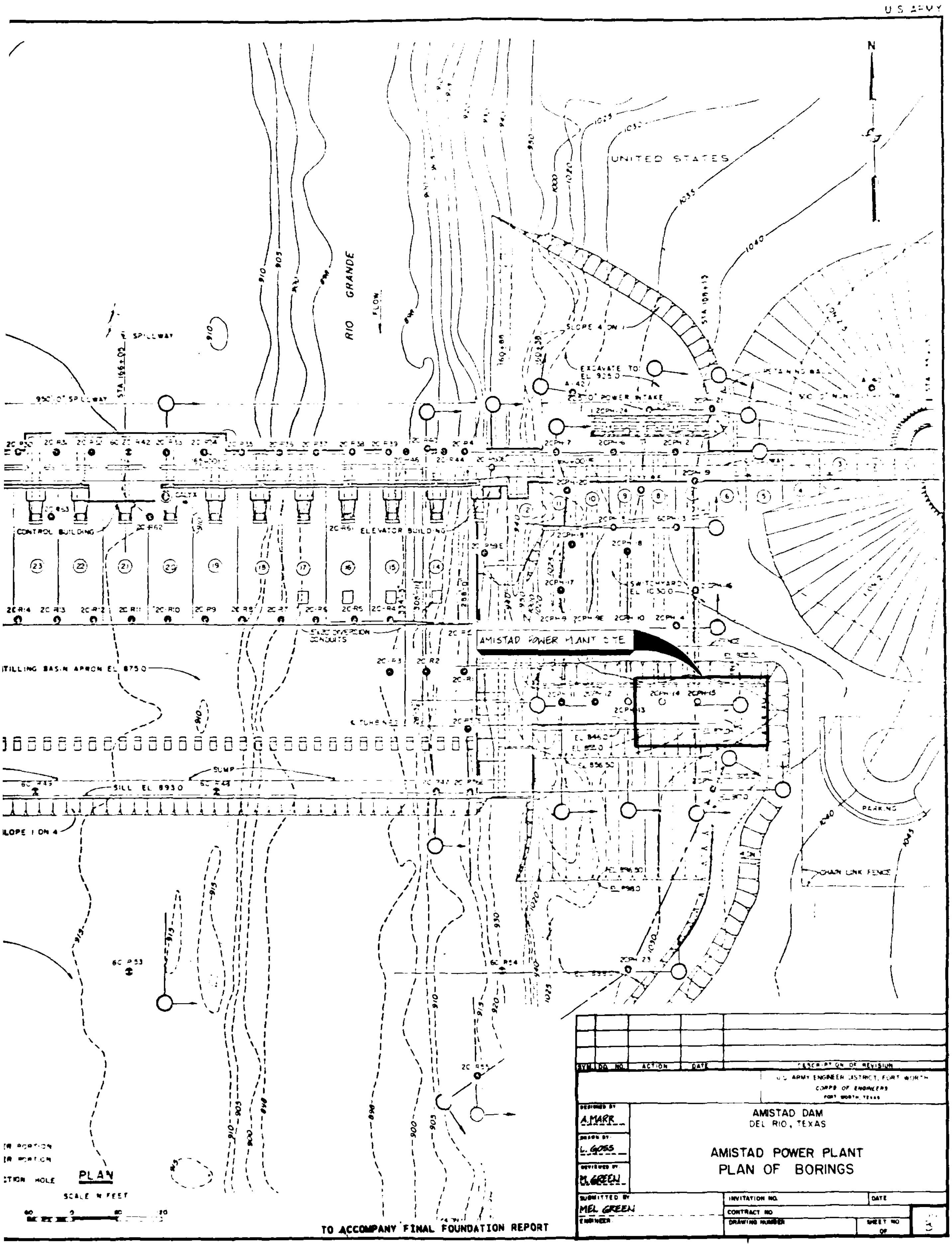


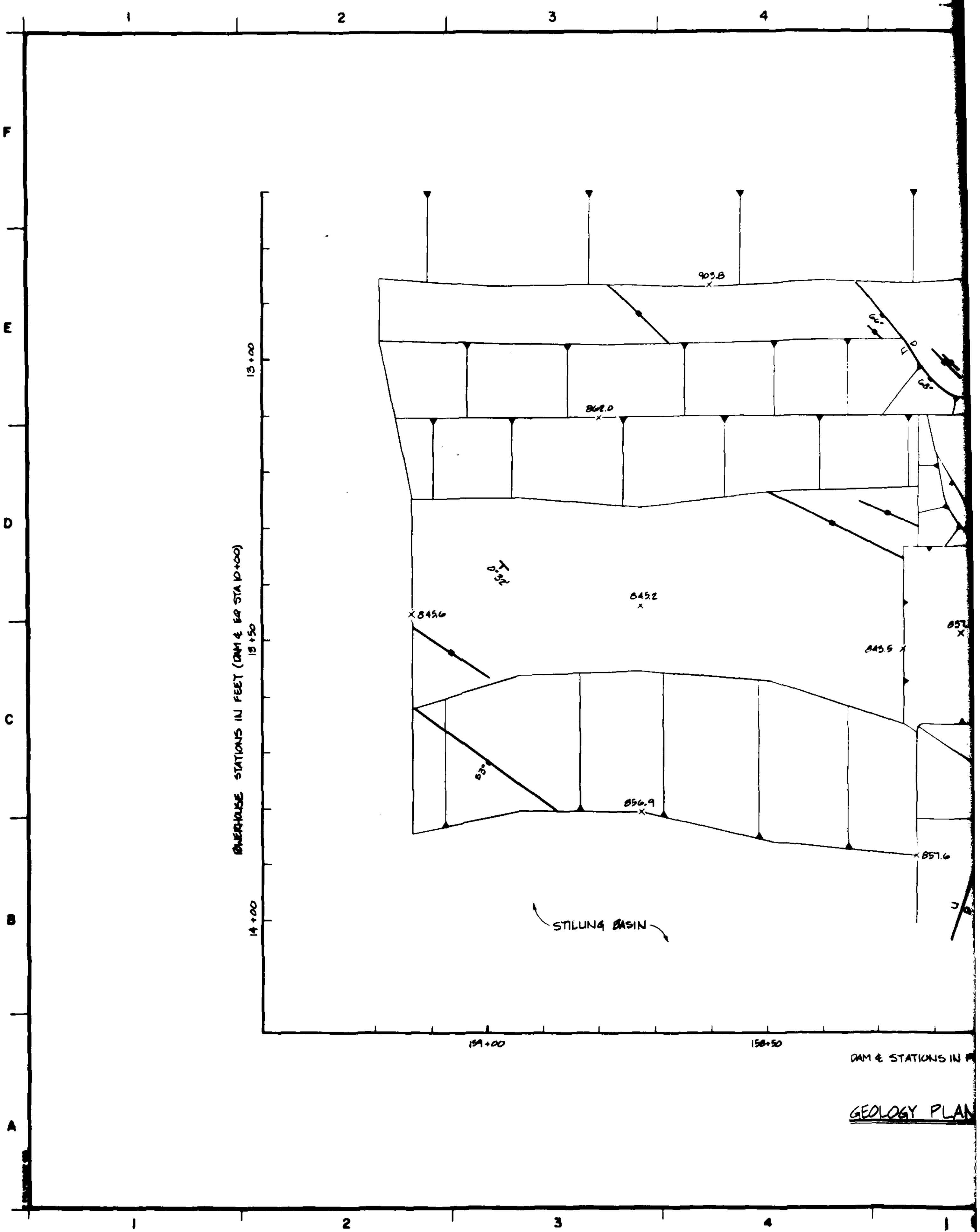
D
C
B
A
5
4
3
FLOW
Mexico
United States
℄ Spillway
Sta 166+05
AMISTAD
POWERHOUSE
Existing
pumps to be
removed
Exist
cofferdam
to be removed
SERVICE ROAD
CONCRETE RETAINING WALL
Existing Road
Switchyard
7-2
NOTE:
SEE PLATE 7 FOR GEOLOGIC PROFILE OF
4V ON 1H LIMESTONE FACE BEHIND CONCRETE
RETAINING WALL.



TO ACCOMPANY FINAL FOUNDATION REPORT

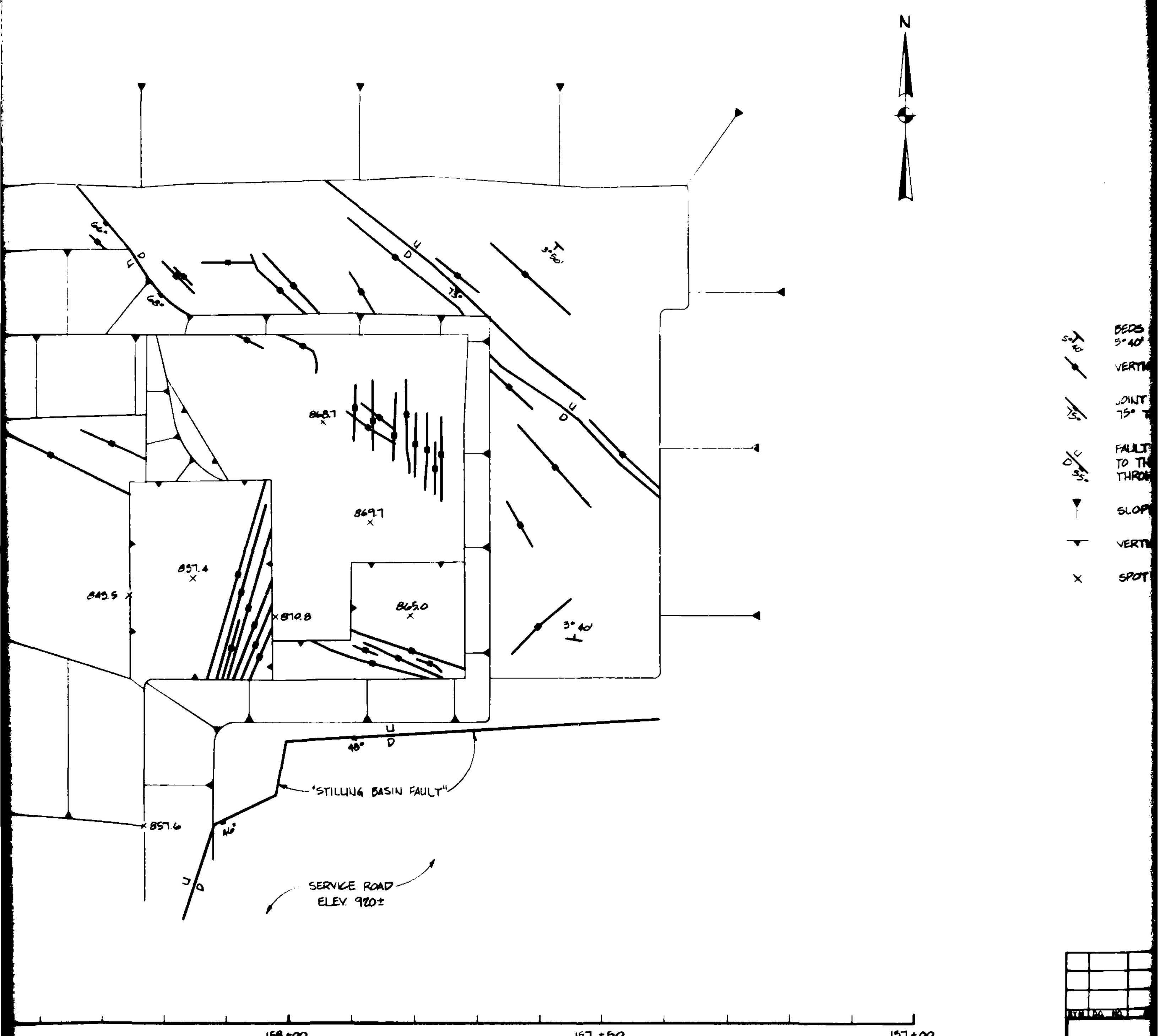

MEXICO
300 OT NON-OVERFLOW
POWER INTAKE
EXCAVATE TO EL 951.77
STA 171+62
STA 166+00
SPILLWAY
950 OT SPILLWAY
ELEVATOR BUILDING
CONTROL BUILDING
CALYX #2
CALYX #3
CALYX #4
STILLING BASIN APRON EL 875.0
TRAINING WALL TOP EL 950.0
SUMP
SILL EL 895.0
SLOPE 1 ON 4
EXCAVATE TO EL 889.0
LEGEND
PLAN
SCALE IN FEET


U.S. ARMY
N
UNITED STATES
RIO GRANDE
FLOW
SPILLWAY
STA 196+02
950.0' SPILLWAY
SLOPE 4 ON 1
EXCAVATE TO EL 925.0
POWER INTAKE
RETAINING WALL
CONTROL BUILDING
ELEVATOR BUILDING
SWITCHYARD EL 1030.0
AMISTAD POWER PLANT SITE
STILLING BASIN APRON EL 875.0
DIVERSION CONDUITS
TURBINES
SUMP
SILL EL 893.0
SLOPE 1 ON 4
PARKING
CHAIN LINK FENCE
PLAN
SCALE IN FEET
TO ACCOMPANY FINAL FOUNDATION REPORT
SYMBOL NO.
ACTION
DATE
DESCRIPTION OF REVISION
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS
DESIGNED BY
A. MARR
DRAWN BY
L. GOSS
REVIEWED BY
M. GREEN
SUBMITTED BY
MEL GREEN
ENGINEER
AMISTAD DAM
DEL RIO, TEXAS
AMISTAD POWER PLANT
PLAN OF BORINGS
INVITATION NO.
DATE
CONTRACT NO.
DRAWING NUMBER
SHEET NO.
OF
3



GEOLOGY PLAN

5 6 7 8



DAM ⊄ STATIONS IN FEET

GEOLOGY PLAN

NOTES:

1. POWERHOUSE FOUNDATION IS COMPOSED OF GEORGETOWN LIMESTONE FORMATION.
2. FOR GEOLOGIC SECTIONS SEE PLATE 6.
3. SOME FIELD MEASUREMENTS SHOWN WERE OBTAINED DURING CONSTRUCTION OF THE DAM BY IBWC PERSONNEL.

DESIGNED BY A. MARR
DRAWN BY L. ...
REVIEWED BY M. GREEN
SUBMITTED BY MEL GREEN, ENGINEER

5 6 2 7 8 TO ACCOMPANY FINAL FOUNDAT

8 | 9 | 10

N

LEGEND

- BEDS STRIKING NW-SE AND DIPPING 5°40' TO THE SOUTHWEST
- VERTICAL JOINT
- JOINT STRIKING NW-SE AND DIPPING 75° TO THE SOUTHWEST
- FAULT STRIKING NW-SE, DIPPING 55° TO THE SOUTHWEST, WITH THE DOWNTHROWN SIDE ON THE SOUTHWEST
- SLOPE
- VERTICAL SLOPE
- × SPOT ELEVATION

10' 0 10' 20'

SCALE OF FEET

157+00

...DATION IS COMPOSED
...LIMESTONE FORMATION.
...CTIONS SEE PLATE 6.
...UREMENTS SHOWN WERE
... CONSTRUCTION OF THE
...RSONNEL.

SYMBOL	DA. NO.	ACTION	DATE	DESCRIPTION OF REVISION

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: A. MAIR
DRAWN BY: L. GOSS
REVIEWED BY: M. GREEN

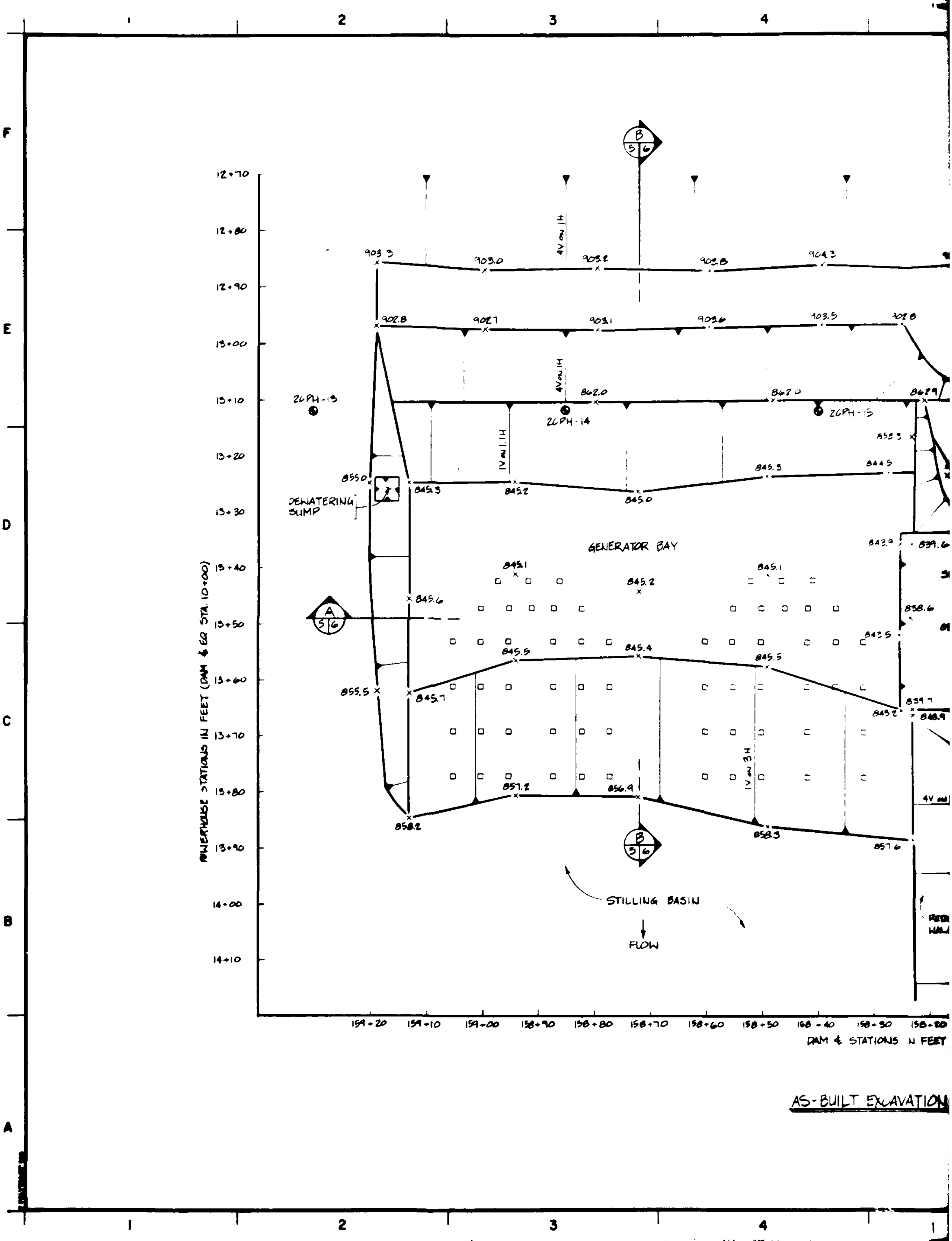
AMISTAD DAM
DEL RIO, TEXAS

AMISTAD POWER PLANT
AS-BUILT EXCAVATION PLAN
GEOLOGY

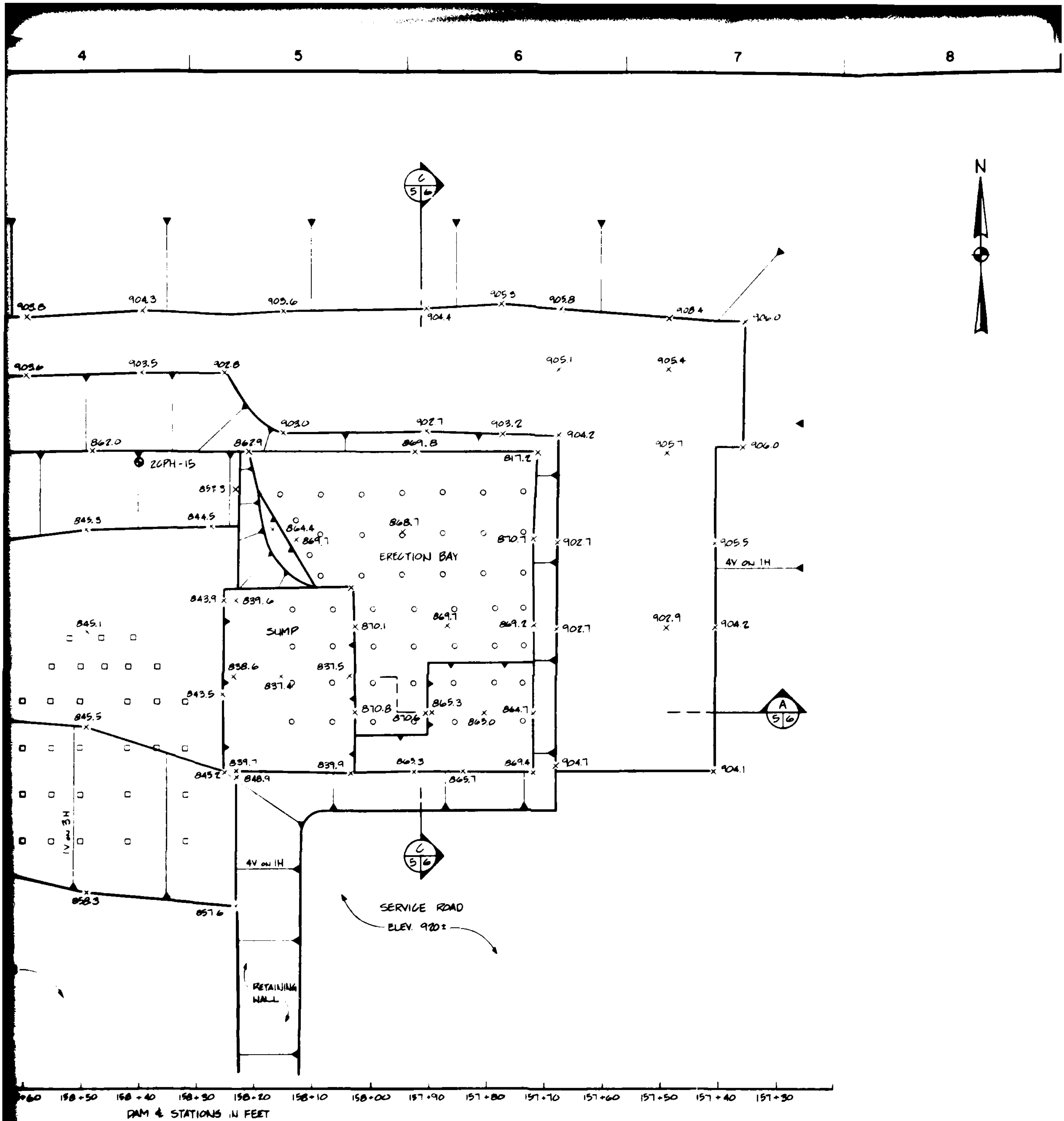
SUBMITTED BY: MEL GREEN, ENGINEER

INVITATION NO. | DATE
CONTRACT NO.
DRAWING NUMBER | SHEET NO. OF | PLATE 4

CONTRACT NO.

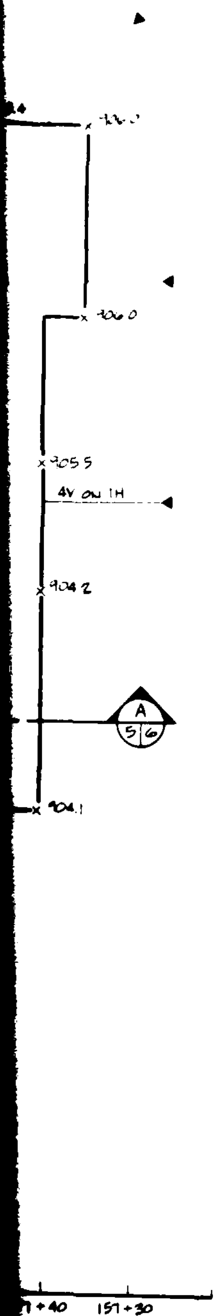


GENERATOR BAY
DEWATERING SUMP
STILLING BASIN
FLOW
POWERHOUSE STATIONS IN FEET (DAM & EQ STA. 10+00)
DAM & STATIONS IN FEET
2CPH-13
2CPH-14
2CPH-15
AS-BUILT EXCAVATION



AS-BUILT EXCAVATION PLAN

4 5 6 7 8 TO ACCOMPANY



NOTES:

1. FOR CROSS SECTIONS, SEE PLATE 6.
2. FOR LOGS OF BORINGS, SEE PLATES 8.
3. ALL ROCK ANCHORS WERE SET TO A DEPTH OF 30' INTO ROCK.

LEGEND

- □ ROCK ANCHOR PRESTRESSED TO 80K
- ○ ROCK ANCHOR PRESTRESSED TO 133K
- ● 2CPH - 2" Φ CORE HOLE LOCATED IN THE POWERHOUSE AREA
- x SPOT ELEVATION

10' 0 10' 20'
SCALE OF FEET

SYM	DO. NO.	ACTION	DATE	DESCRIPTION OF REVISION

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

DESIGNED BY: A. MARR
DRAWN BY: L. GOSS
REVIEWED BY: M. GREEN

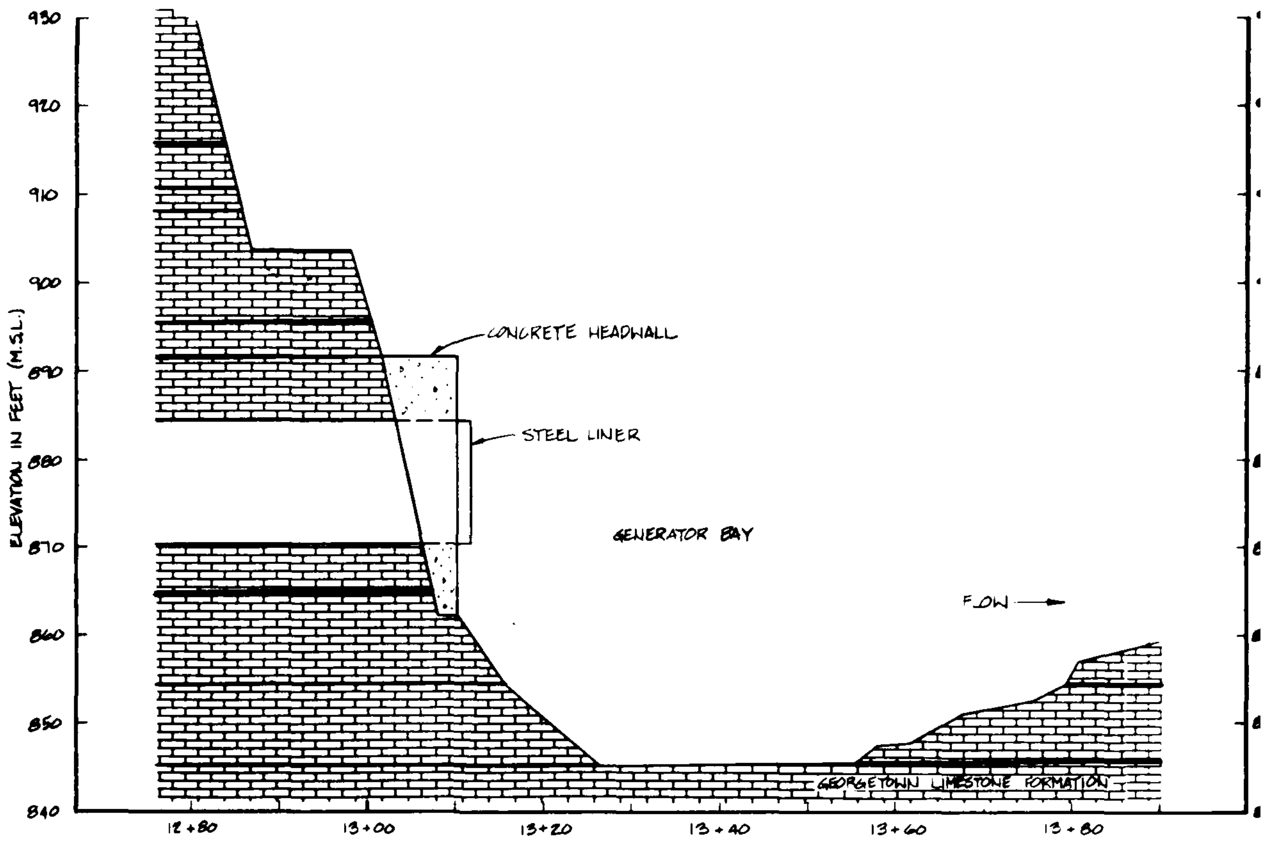
AMISTAD DAM
DEL RIO, TEXAS

AMISTAD POWER PLANT
AS-BUILT EXCAVATION PLAN
ELEVATIONS

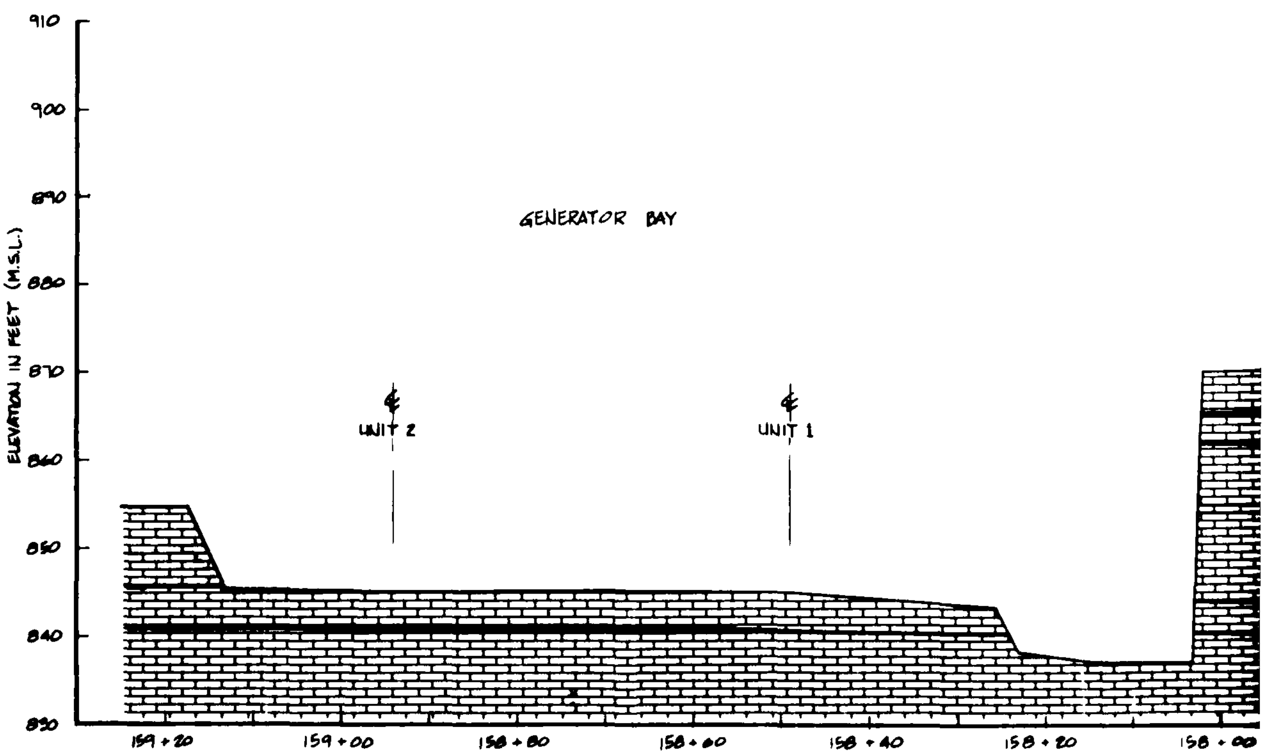
SUBMITTED BY: MEL GREEN
ENGINEER

INVITATION NO. | DATE
CONTRACT NO.
DRAWING NUMBER | SHEET NO. OF
PLATE 5

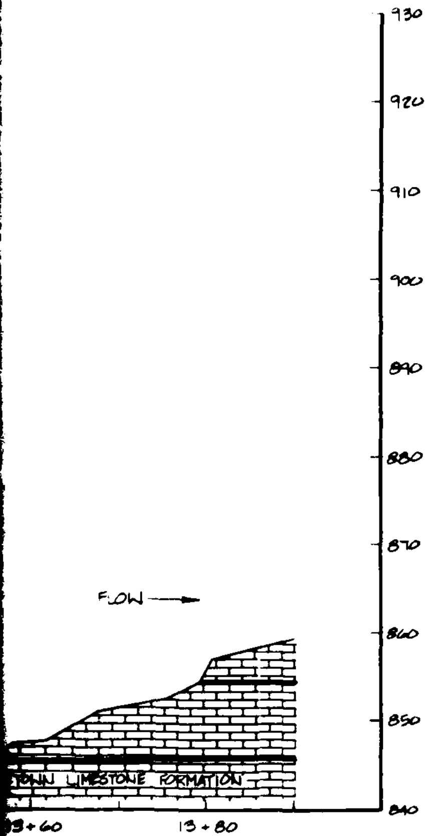
CONTRACT NO.

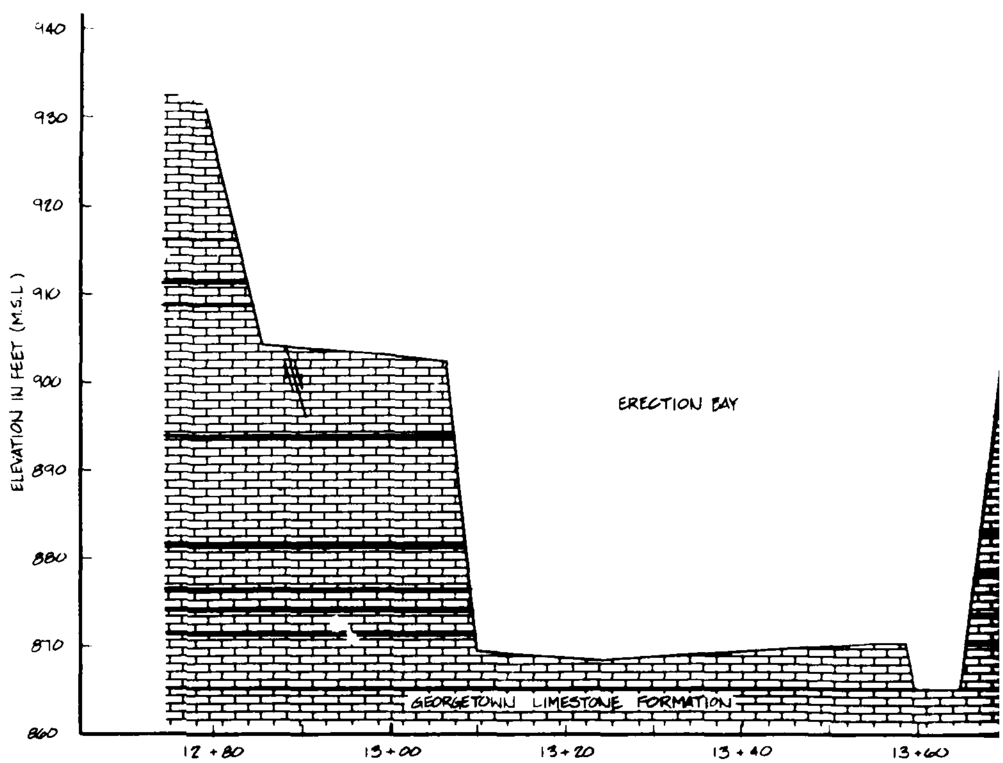


SECTION B 5 6

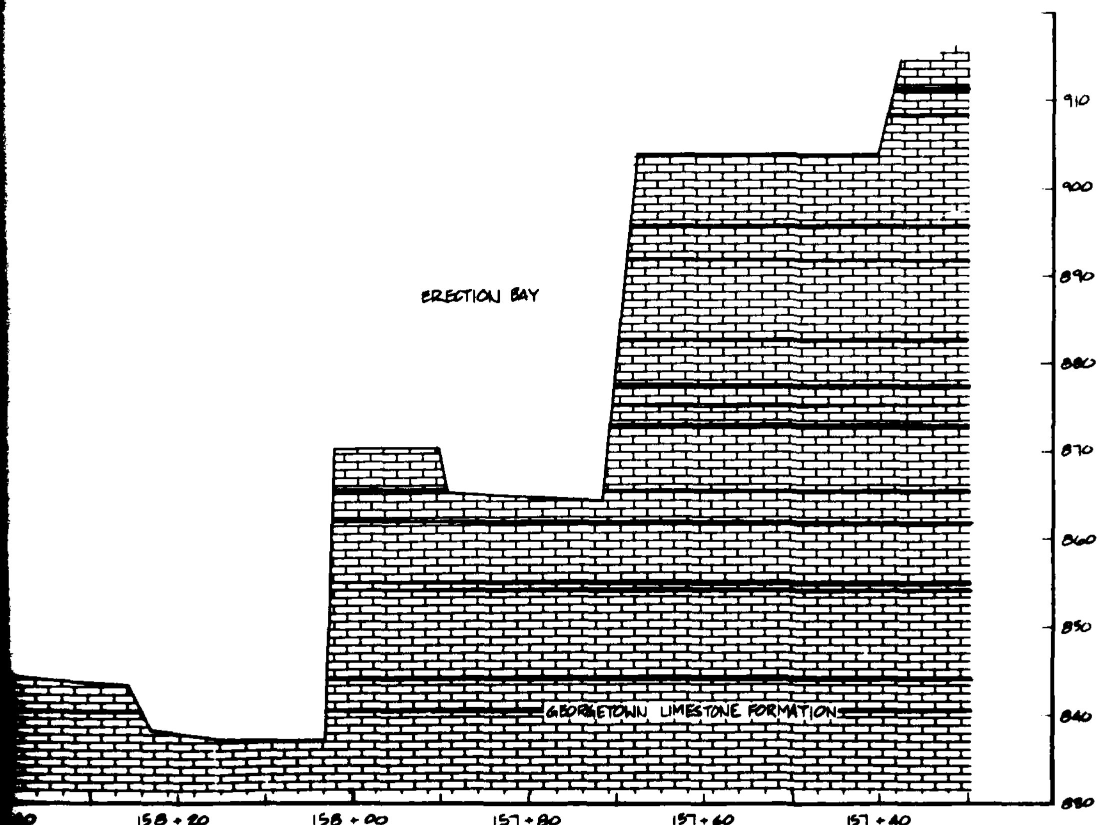


SECTION A 5 6





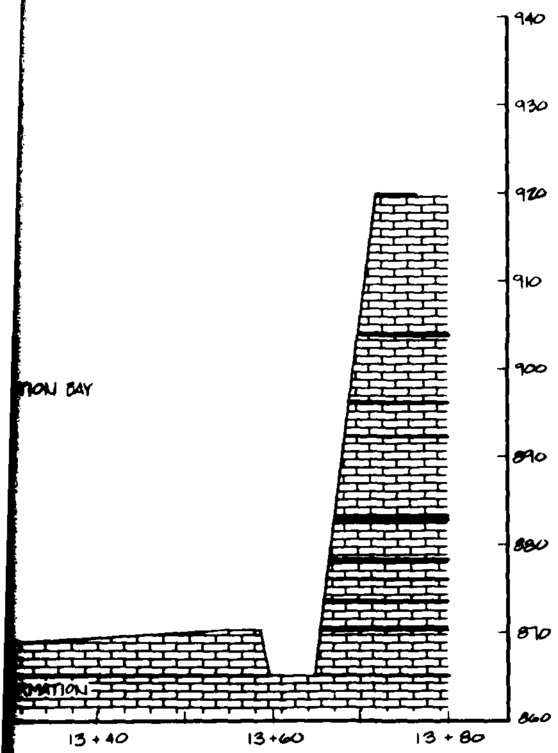
SECTION C 5|6



SECTION A 5|6

NOTE:
FOR LOCATION OF SECTIONS, SEE PLATE 5.

8 9 10



SECTION C 5|6

LEGEND

- LIMESTONE (GEORGETOWN FM) DARKER LINES WITHIN LIME-STONE DENOTE SHALE BANDS
- NORMAL FAULT EXPOSED AT SURFACE

...OTE:
...R LOCATION OF SECTIONS,
...E PLATE 5.

SYM	LTR NO.	ACTION	DATE	DESCRIPTION OF REVISION

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

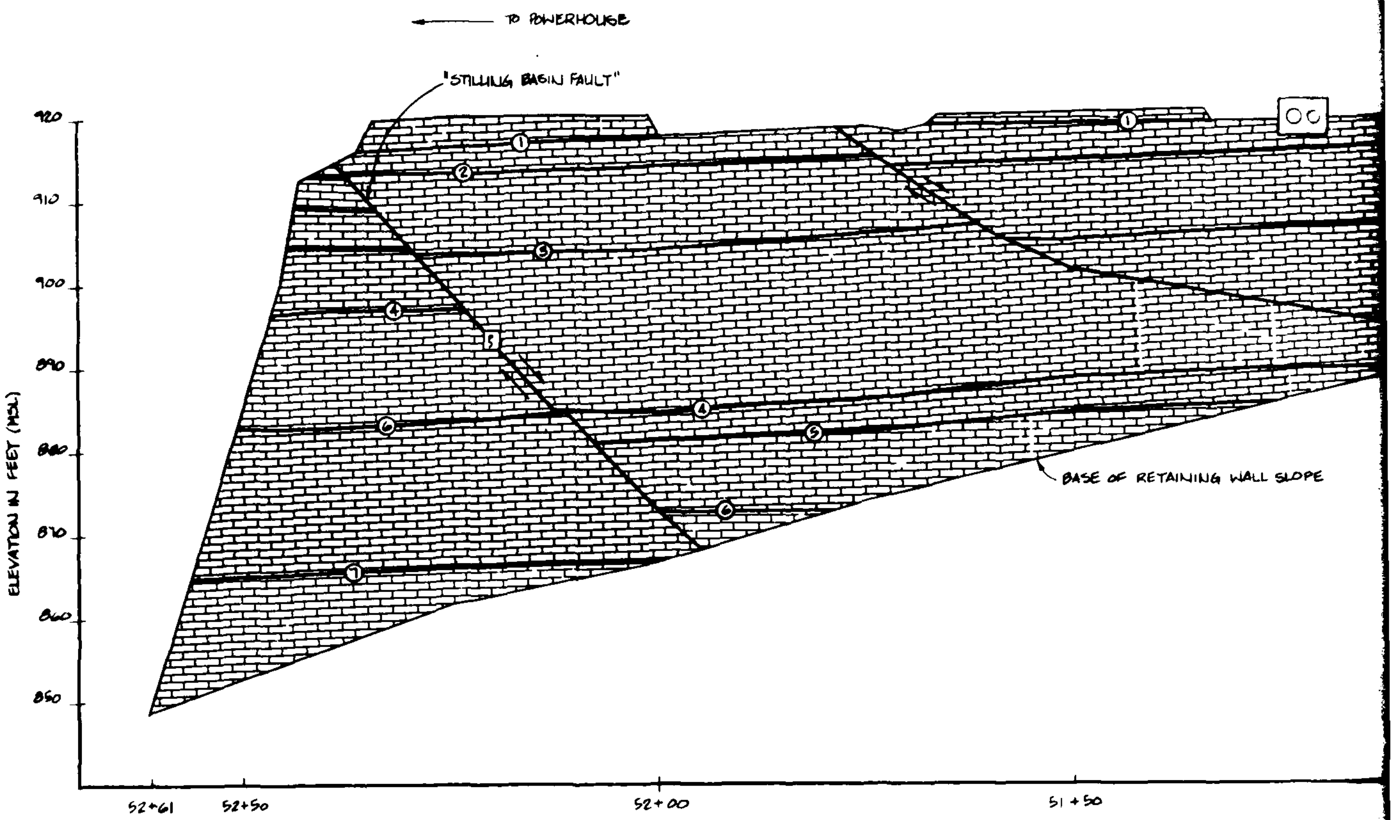
DESIGNED BY A. MARR
DRAWN BY L. GOSS
REVIEWED BY M. GREEN

AMISTAD DAM
DEL RIO, TEXAS

AMISTAD POWER PLANT
GEOLOGIC SECTIONS
A-A B-B C-C

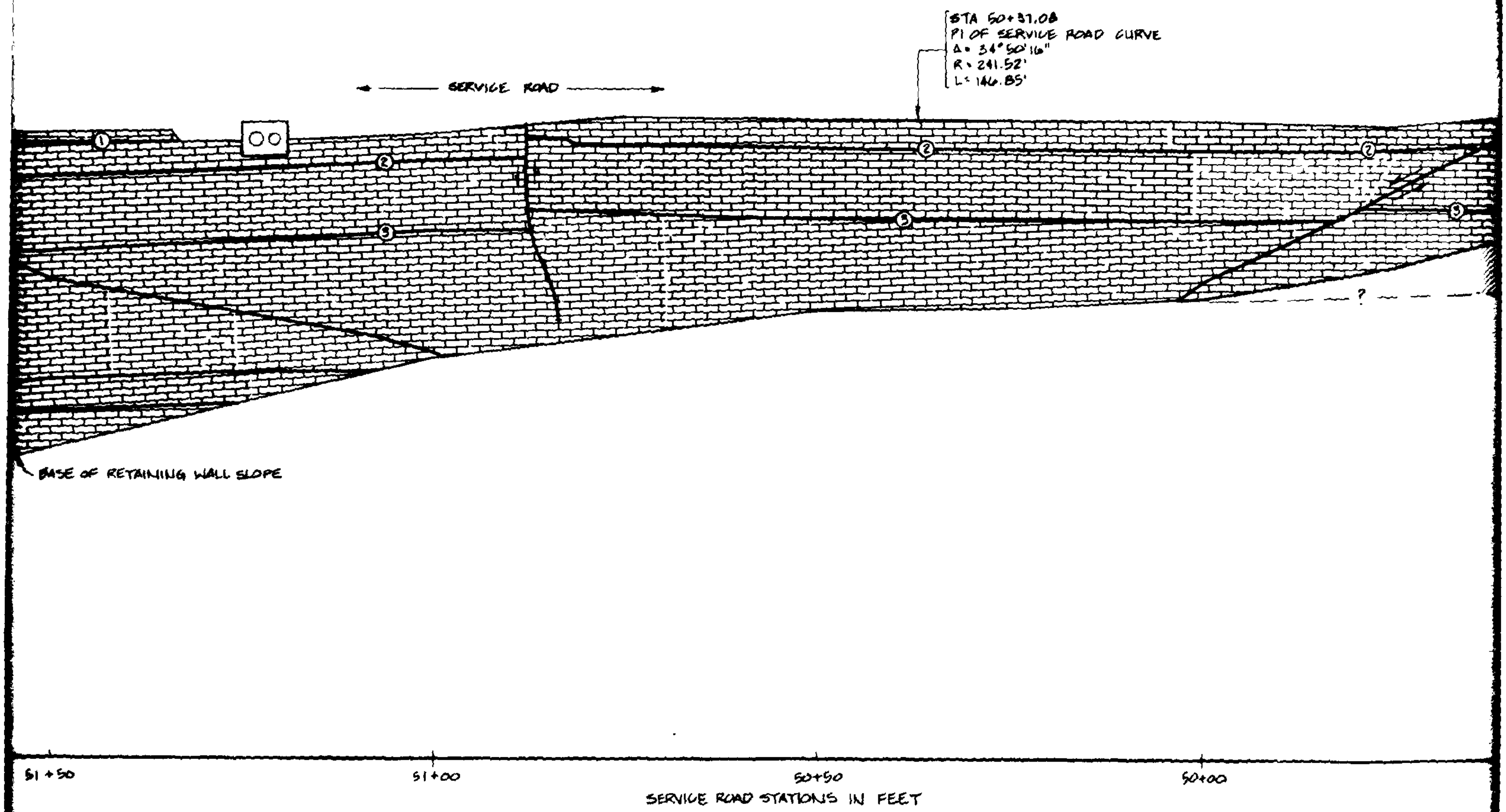
SUBMITTED BY MEL GREEN
ENGINEER

INVITATION NO. | DATE
CONTRACT NO.
DRAWING NUMBER | SHEET NO. OF
PLATE 6



OFFSET DISTANCES FROM SERVICE R

SERVICE ROAD STATION	DISTANC FROM TO
48+67	27.
48+90	27.
49+00	29.
49+25	27.
49+50	30.
49+75	29.
50+00	28.
50+25	[illegible]
50+50	27.
50+75	[illegible]
51+00	[illegible]
51+25	27.
51+50	27.
51+75	[illegible]
52+00	[illegible]
52+25	[illegible]
52+40	[illegible]



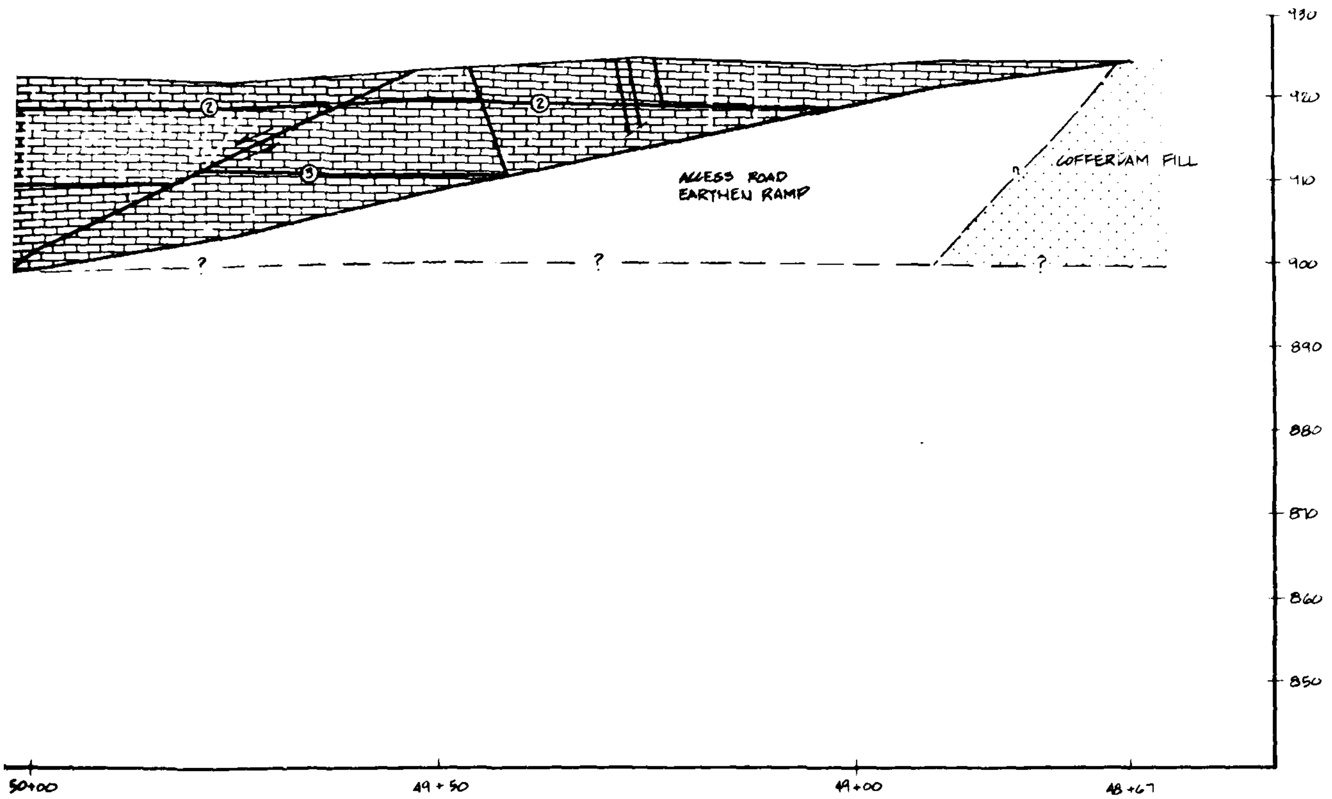
(OF)FSET DISTANCES FROM SERVICE ROAD ℄ TO RETAINING WALL FACE

SERVICE ROAD STATION	DISTANCE TO ℄ SERVICE ROAD (IN FEET)	
	FROM TOP OF SLOPE	FROM BASE OF SLOPE
48+67	27.0	27.0
48+90	27.2	30.0
49+00	25.0	30.4
49+25	27.6	32.2
49+50	30.0	33.8
49+75	29.6	34.9
50+00	28.0	33.2
50+25	28.6	34.6
50+50	27.2	33.1
50+75	24.9	31.1
51+00	26.8	33.1
51+25	27.8	34.7
51+50	27.5	36.9
51+75	28.6	38.9
52+00	28.8	41.5
52+25	29.2	41.5
52+40	31.0	-

LEGEND

- LIMESTONE (GEORGETOWN FM)
- ACCESS ROAD FILL
- COFFERDAM FILL
- ③ SHALE BANDS
- SEEPAGE
- EXPOSED NORMAL FAULT

NOT(ES)
1.
2.
3.
4.



NOTES:

1. SEE PLATE 2 FOR LOCATION OF PROFILE.
2. PROFILE USING SERVICE ROAD CENTERLINE STATIONS. SERVICE ROAD STA 52+67.16 FORWARD EQUALS POWERHOUSE STA 13+79.00 BACKWARD.
3. SHALE BANDS ARE NUMBERED FOR CORRELATION PURPOSES.
4. MATERIAL CHANGES DASHED WHERE INFERRED.

SYMBOL	DO. NO.	ACTION	DATE	DESCRIPTION OF REVISION

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

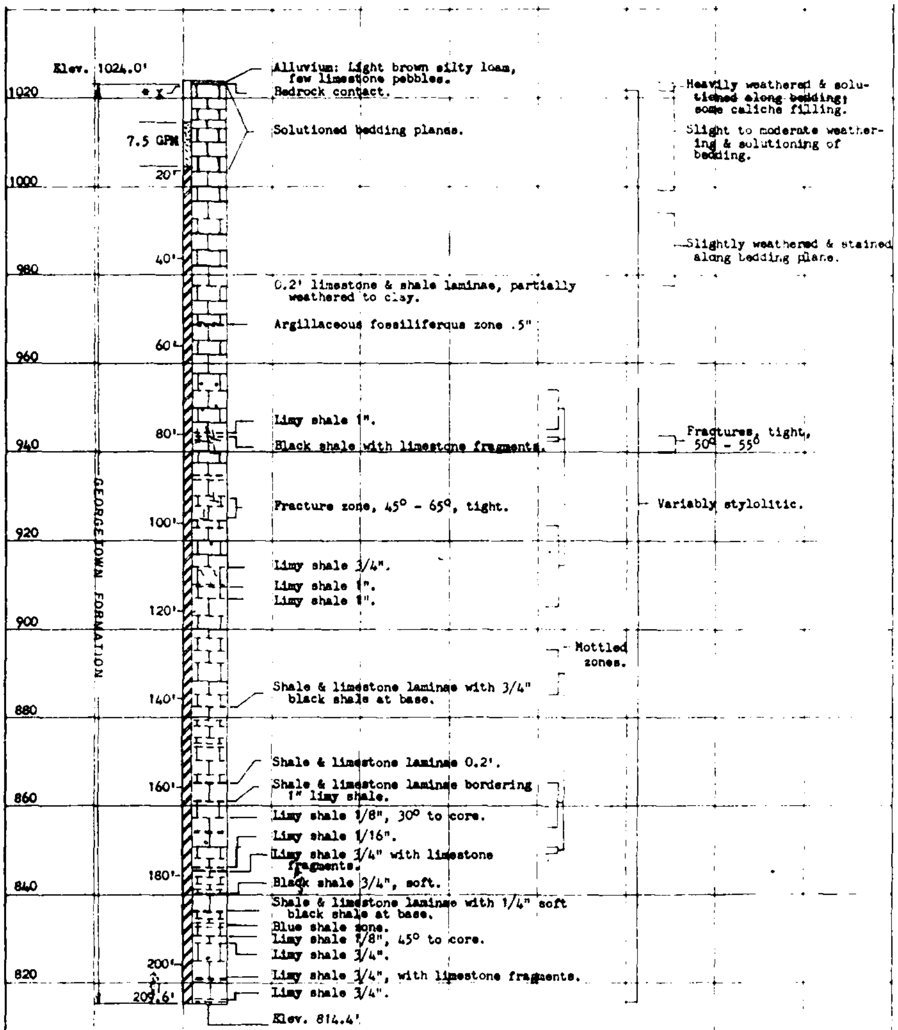
DESIGNED BY: A. MARR
DRAWN BY: L. GOBS
REVIEWED BY: M. GREEN

AMISTAD DAM
DEL RIO, TEXAS

AMISTAD POWER PLANT
RETAINING WALL GEOLOGIC PROFILE
D-D

SUBMITTED BY: MEL GREEN, ENGINEER
INVITATION NO. | DATE
CONTRACT NO.
DRAWING NUMBER | SHEET NO. OF | PLATE 7

TO ACCOMPANY FINAL FOUNDATION REPORT



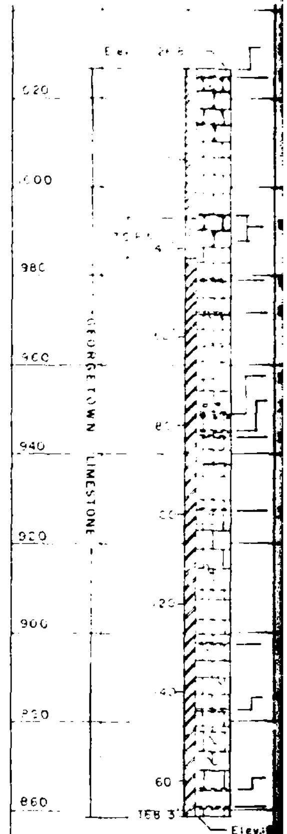
Note: 1. All shale seams are indicated by dashed lines.
2. To avoid congestion, only marker or persistent shale seams are shown in description.
* 3. Partial water loss 1.0' due to leakage around 4" casing.

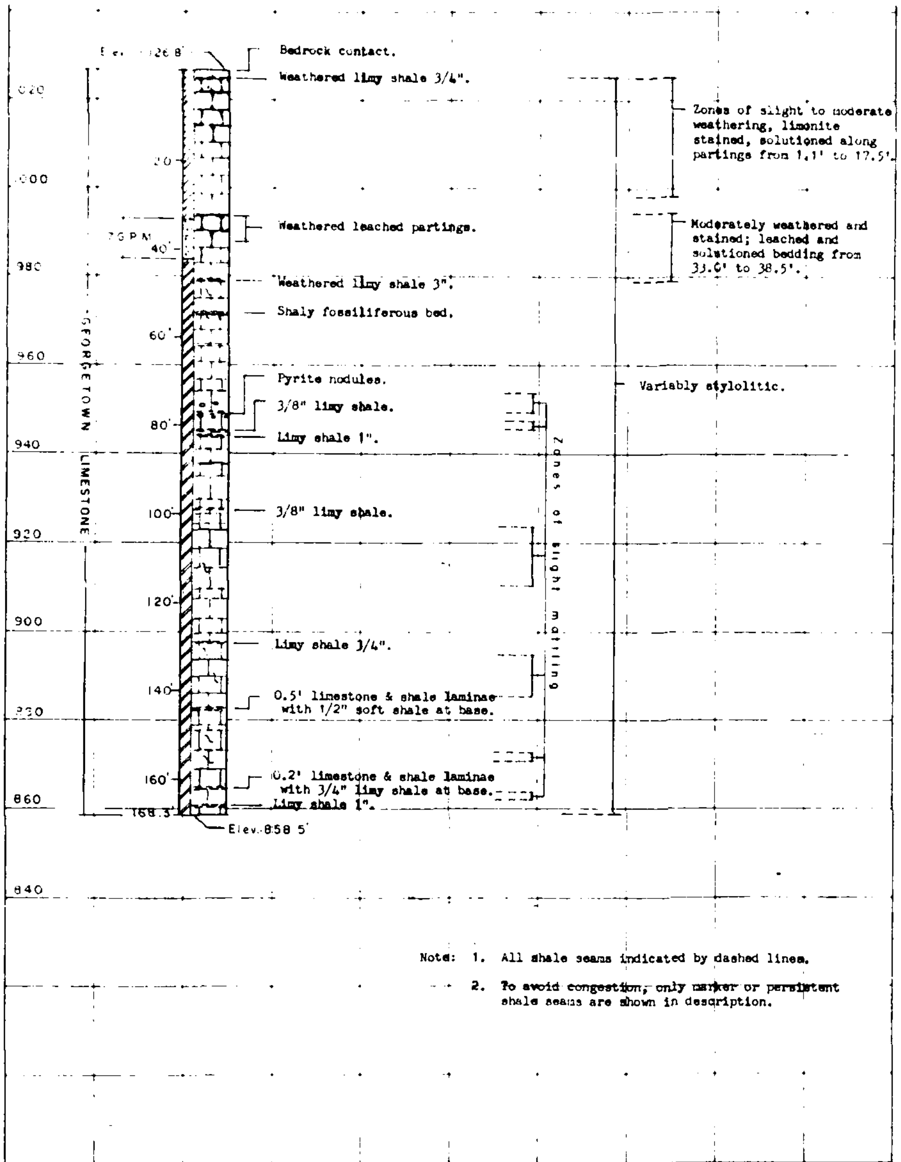
Attitude Vertical
Location Axis Sta 159+30
312' downstream Dam Axis

Total Depth 209.6
Total Core Bored 208.6
Total Core Recovered 206.2
% Total Core Recovered 98.8

Sheet 1 of 1 Sheets
N.G. Elevation 1024.0
Collar Elevation 1026.8
Water Table Elevation 1015.3 (5-7-62)
Driller DeArmond
Inspector Trevino, Thornton
Date Started April 7, 1962
Date of Completion May 8, 1962

GEOLOGIC LOG
CORE HOLE NO. PH 13





Note: 1. All shale seams indicated by dashed lines.

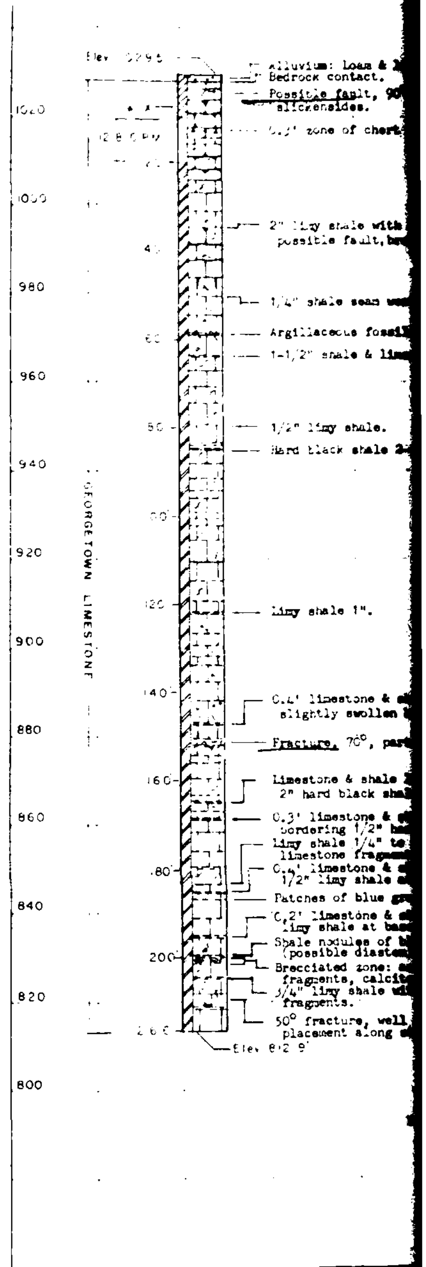
2. ~~To avoid congestion, only marker or persistent~~ shale seams are shown in description.

Attitude Vertical
Location Axis Sta 158+85
312' downstream Dam Axis

Total Depth 168.3
Total Core Bored 167.2
Total Core Recovered 164.8
% Total Core Recovered 98.6

Sheet 1 of 1 Sheets
N.G. Elevation 1026.8
Collar Elevation 1027.5
Water Table Elevation 1006.3 (4-11-62)
Driller Rumfield
Inspector Behm
Date Started April 6, 1962
Date of Completion April 11, 1962

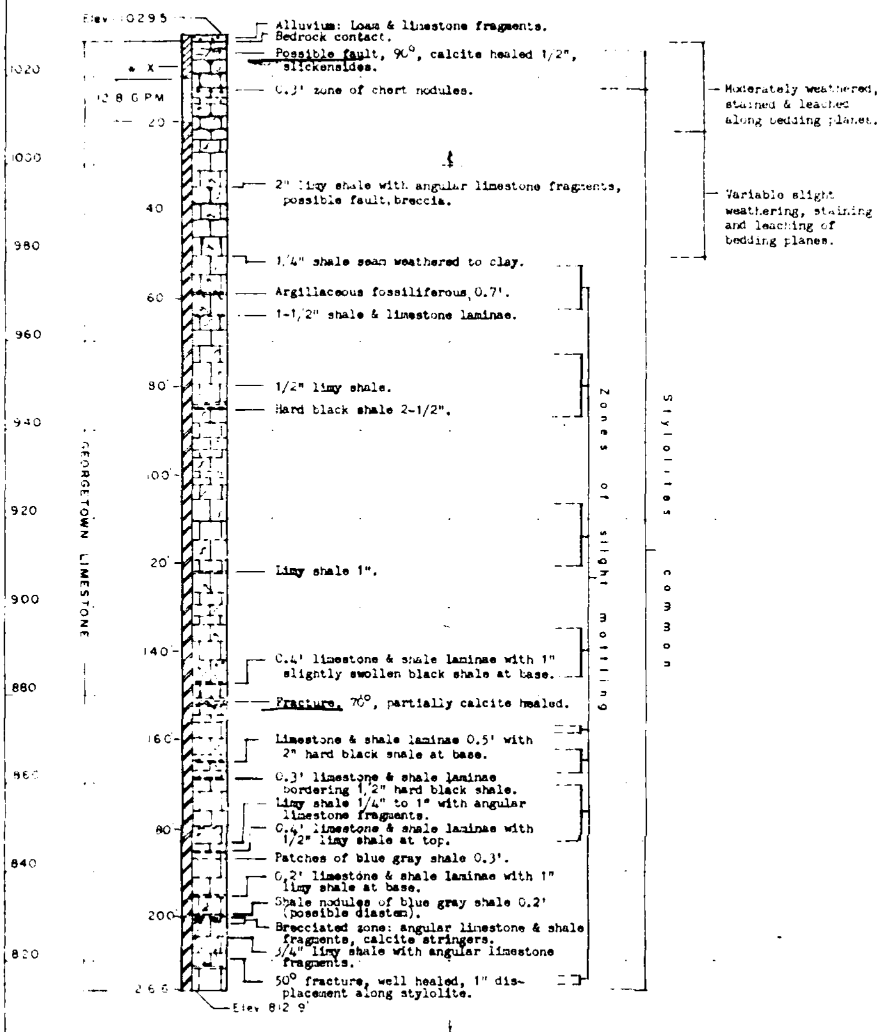
GEOLOGIC LOG
CORE HOLE NO. PH 14 V



Attitude Vertical
Location Axis Sta 158+40
312' downstream Dam Axis
216.6
214.5
212.5
99.1

LEGEND

x PARTIAL LOSS CIRCULATING DRILL WATER
xx TOTAL LOSS CIRCULATING DRILL WATER
PRESSURE TEST REFUSAL
PRESSURE TEST-WATER LOSS
CIRCULATING DRILL WATER RETURN



Note:
1. Shale seams indicated by dashed lines.
2. To avoid congestion only persistent or marker shale beds are shown in description.
* 3. Unable to set packers to test zone of partial drill water loss.

Vertical
Axis Sta 158+40
312' downstream Dam Axis

Total Depth 216.6
Total Core Bored 214.5
Total Core Recovered 212.5
% Total Core Recovered 99.1

Sheet 1 of 1 Sheets
1029.5
1029.9
Water Table Elevation 982.0 (4-16-62)
DeArmond, Rumfield
Trautwein, Thornton, Behm
Date Started April 4, 1962
Date Completed April 17, 1962

GEOLOGIC LOG
CORE HOLE NO PH 15 V

SYM	DC NO	ACTION	DATE	DESCRIPTION

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

AMISTAD DAM
DEL RIO, TEXAS

AMISTAD POWER PLANT
LOGS OF BORINGS

DESIGNED BY: A. MARR
DRAWN BY: L. GOSS
REVIEWED BY: M. GREEN
SUBMITTED BY: MEL GREEN
ENGINEER:

INVITATION NO.
DATE
CONTRACT NO.
DRAWING NUMBER
SHEET NO. OF
Plate 8

MED

8