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EJordan
Attorney, ELD
NPKadambi
ACRS (16)

Mr. J. H. Goldberg
Group Vice President - Nuclear
Houston Lighting and Power Company
Post Office Box 1700
Houston, Texas 77001

Dear Mr. Goldberg:

Subject: Draft Safety Evaluation Sections for the South Texas Project, Units 1 and 2

The NRC staff issued a Draft Safety Evaluation Report (DSER) on August 26, 1985 reflecting the status of the staff review. It was indicated that the DSER was not a complete document. In an effort to complete some of the missing sections of the DSER, enclosed are sections documenting the evaluation by the staff on the indicated portions of the FSAR. These sections are in addition to our transmittals of October 4, and October 18, 1985. The documentation could change as the review progresses; however, in its current form the evaluations should serve as the basis for discussion to resolve the remaining technical issues.

Please contact the Project Manager, N. Prasad Kadambi at (301) 492-7272 if you have any questions.

Sincerely,

Thomas M. Novak, Assistant Director
for Licensing
Division of Licensing

Enclosure:
As stated

cc: See next page

NPK
DL:LB#3
NPKadambi/yt
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GWKnighton
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DL:AD/L
TMNovak
11/21/85

8512050167 851122
PDR ADOCK 05000498
E PDR

Mr. J. H. Goldberg
Houston Lighting and Power Company

South Texas Project

cc:
Brian Berwick, Esq.
Assistant Attorney General
Environmental Protection Division
P. O. Box 12548
Capitol Station
Austin, Texas 78711

Mr. J. T. Westermeir
Manager, South Texas Project
Houston Lighting and Power Company
P. O. Box 1700
Houston, Texas 77001

Mr. H. L. Peterson
Mr. G. Pokorny
City of Austin
P. O. Box 1088
Austin, Texas 78767

Mr. J. B. Poston
Mr. A. Von Rosenberg
City Public Service Boad
P. O. Box 1771
San Antonio, Texas 78296

Jack R. Newman, Esq.
Newman & Holtzinger, P.C.
1615 L Street, NW
Washington, D.C. 20036

Melbert Schwartz, Jr., Esq.
Baker & Botts
One Shell Plaza
Houston, Texas 77002

Mrs. Peggy Buchorn
Executive Director
Citizens for Equitable Utilities, Inc.
Route 1, Box 1684
Brazoria, Texas 77422

Resident Inspector/South Texas
Project
c/o U.S. Nuclear Regulatory Commission
P. O. Box 910
Bay City, Texas 77414

Mr. Jonathan Davis
Assistant City Attorney
City of Austin
P. O. Box 1088
Austin, Texas 78767

Ms. Pat Coy
Citizens Concerned About Nuclear
Power
5106 Casa Oro
San Antonio, Texas 78233

Mr. Mark R. Wisenberg
Manager, Nuclear Licensing
Houston Lighting and Power Company
P. O. Box 1700
Houston, Texas 77001

Mr. Charles Halligan
Mr. Burton L. Lex
Bechtel Corporation
P. O. Box 2166
Houston, Texas 77001

Mr. E. R. Brooks
Mr. R. L. Range
Central Power and Light Company
P. O. Box 2122
Corpus Christi, Texas 78403

cc:
Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
Office of Executive Director
for Operations
611 Ryan Plaza Drive, Suite 1000
Arlington, Texas 76011

Mr. Lanny Sinkin
Citizens Concerned About Nuclear Power
3022 Porter Street, NW #304
Washington, D.C. 20008

Mr. S. Head, Representative
Houston Lighting and Power Company
Suite 1309
7910 Woodmont Avenue
Bethesda, Maryland 20814

South Texas Project (STP), Units 1 and 2

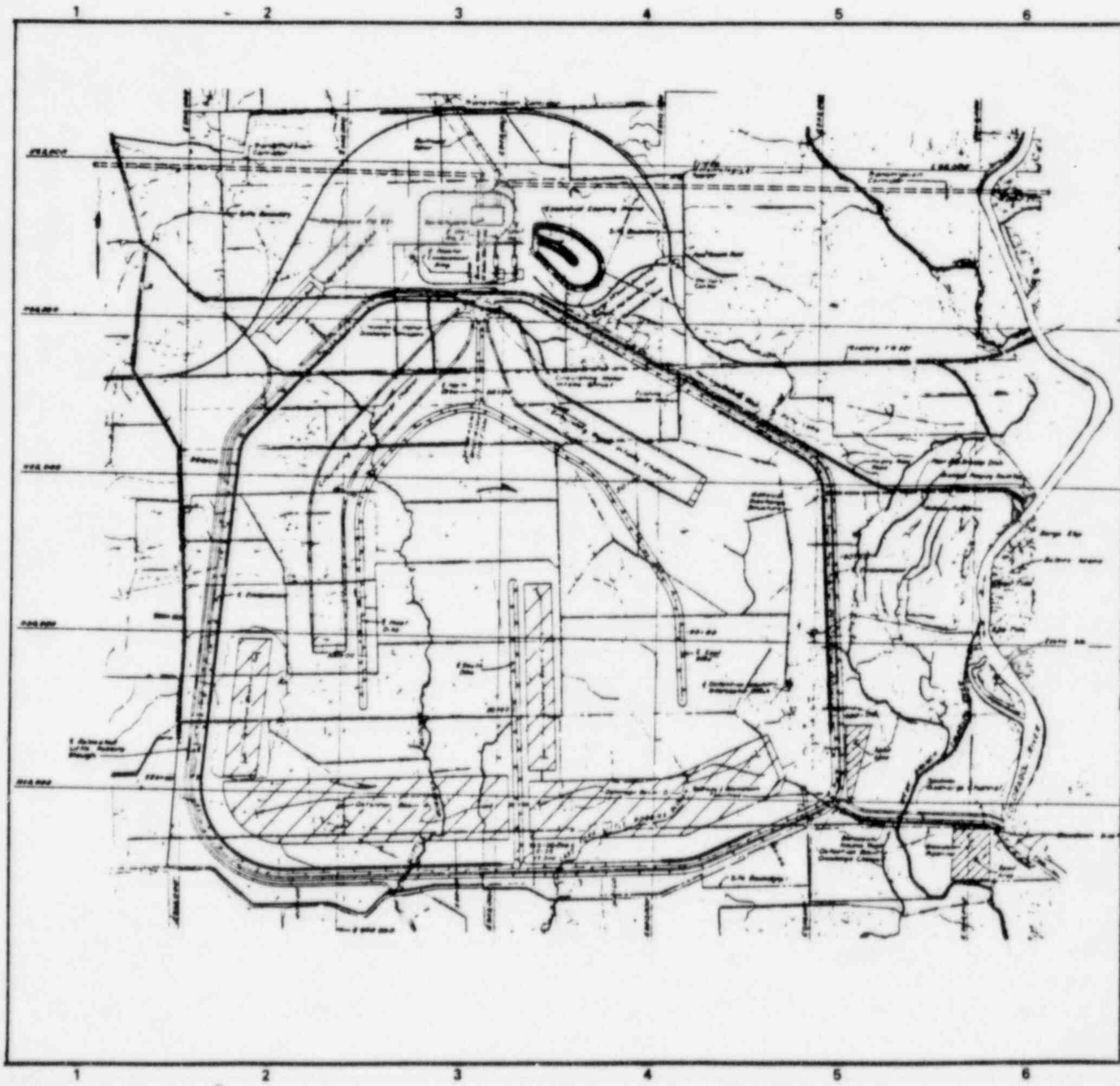
Docket No. 50-498/499

Draft SER Input: Geotechnical Engineering

Project Layout and Scope of Safety Evaluation. The South Texas Project (STP), Units 1 and 2, is located in south-central Matagorda County, west of the Colorado River, 8 miles north-northwest of the town of Matagorda and about 89 miles southwest of Houston, Texas. Figure 2.5.4.1 shows the general layout of the project. Hydrological considerations for the project are described in detail in SER section 2.4 and Geology and Seismology are evaluated in SER sections 2.5.1 thru 2.5.3. The maximum water level obtained during any postulated flooding phenomenon is EL. 50.8 feet. A maximum horizontal acceleration of 0.10g was selected for the Safe Shutdown Earthquake (SSE).

The Essential Cooling Pond (ECP) and appurtenant works and several buildings within the power plant complex are classified as Category I facilities which should be functional to accomplish a safe shutdown of the plant in the event of a Safe Shutdown Earthquake (SSE). Systems, structures and components important to safety are also protected against the effects of the maximum flood. The safety evaluations of the stability of Category I subsurface materials, slopes, foundations and embankments have been considered and are presented in the following sections. An evaluation of the Main Cooling Reservoir (non-Category I) embankment and foundation is also presented. Information utilized in these evaluations consisted of the South Texas Project

Final Safety Analysis Report (FSAR) through Amendment 48 and additional information from references cited and included at the end of this report. Section 2.5.4, 2.5.5 and 2.5.6 have been evaluated in accordance with the criteria outlined in Appendix A to 10 CFR Part 100, Reg. Guide 1.70, Rev. 3, (November 1978), and the current (July 1981) Standard Review Plan (SRP) NUREG-0800 Sections 2.5.4 and 2.5.5. Acceptance criteria include applicable General Design Criteria (GDC) outlined in Appendix A to 10 CFR Part 50.



GENERAL LAYOUT OF PROJECT

FROM FSAR FIGURE 2.5.6-2.

FIGURE 2.5.4.1

2.5.4 STABILITY OF SUBSURFACE MATERIALS AND FOUNDATIONS

2.5.4.1 SITE INVESTIGATIONS

2.5.4.1.1 General The STP site, located in a rural area, covers approximately 12,300 acres and borders the west bank of the Colorado River. Local relief of the area is characterized by fairly flat land varying in elevation from 15 feet to 28 feet mean sea level (MSL). Maximum open-cut excavation within the plant area extended to elevation - 41.50 feet MSL (approximately 68.5 feet deep) beneath the tendon galleries for the reactor containment building.

Geotechnical studies and investigations performed for design of the STP included:

(a) literature search on geology and seismology,

(b) geological explorations, including a deep exploratory boring, trenching, remote sensing, and field surface inspections,

(c) geophysical surveys, and

(d) geotechnical engineering explorations.

Items a and b were previously discussed and evaluated in SER Sections 2.5.1 and 2.5.3. Items c (from seismic analysis standpoint) and d are discussed in the following paragraphs. An evaluation of the Geology and Seismology basically resulted in the conclusion that

> "there are no identified geologic structures or other hazards at the site and near vicinity that represent a known safety hazard to the facility or that would localize an earthquake in the proposed area."

The stability of the plant site materials were, therefore, evaluated using soil test data and analyses. The stability of the rock was not considered because of the great depth (40,000 feet to basement rock. For geotechnical engineering purposes, the upper 300 feet beneath the plant site were considered of primary concern. These materials were divided into 13 generalized layers based on major soil types and physical characteristics as summarized in Table 2.5.4.1

TABLE 2.5.4.1

GENERALIZED FOUNDATION MATERIALS

LAYER DESIGNATION		APPROXIMATE DEPTH (FEET)	GENERAL DESCRIPTION
A	A_1	0 to 7	Dark gray to black, stiff to very stiff silty clay. Occasional roots and calcareous nodules.
	A_2	7 to 20	Reddish-brown and light gray, stiff to very stiff silty clay. Becomes more silty at approximately 16 feet.
B		20 to 36	Medium stiff to very stiff sandy silt with interbedded, noncontinuous layers of silty clay and clayey silt.
C		36 to 45	Dense to very dense silty sand.
D		45 to 60	Very stiff to hard silty clay.
E		60 to 82	Dense to very dense, slightly silty, fine sand. MAXIMUM DEPTH OF EXCAVATION AT 68.5 FEET (TENDON GALLERIES).
F		82 to 120	Very stiff to hard, silty clay. Gradational change to silt or sandy clay at 100 feet (Unit 2) and at 110 feet (Unit 1).
G		102 to 110	Dense brown silty sand. Exists only in eastern portion of plant site below Unit 1.
H		120 to 130	Very dense, brown, silty sand.
J		130 to 212	Hard silty clay.

K	212 to 230	Stiff to hard sandy clay and dense clayey or silty sand.
L	230 to 280	Very stiff to hard silty clay.
M	280 to 291	Very dense silty sand.
N	291 to 300	Very stiff to hard silty clay.
	300 to 2619.5	Alternating layers of very stiff to hard clay and very dense, fine to silty-fine sand.

2.5.4.1.2 Field Data Gathering Program. The field program to obtain data and soil samples for design consisted of soil test borings, static Dutch cone penetration testing, test pits, piezometer installations, pump tests and geophysical surveys. Field investigations for the Main Cooling Reservoir are discussed in paragraph 2.5.6

Test Borings. A total of 157 borings were drilled and sampled for design in the plant area and Essential Cooling Pond (ECP) utilizing thin-wall tube samplers (ASTM D 1587-67) in cohesive material and split-spoon penetration samplers (ASTM D 1586-67) in cohesionless or low-cohesion granular soils. Undisturbed samples of cohesionless soils were obtained using a Hvorslev-type stationary piston sampler (3-inch tubes) for cyclic triaxial and relative density tests. Sample recovery averaged 98.8 percent on accepted, undamaged tubes. Those samples subsequently selected for cyclic triaxial tests averaged 99.3 percent recovery. Locations of the test borings in the plant and ECP area are shown on PSAR Figures 2.5.1-35 and 2.5.1-53, respectively.

Static Dutch Cone Penetration Tests. A truck-mounted static Dutch cone sounding apparatus was used to evaluate various strata. Equipment and test procedures are described in FSAR Section 2.5.4.3.1.3. The tests were made 10 feet to 20 feet from previous test borings. Locations are shown on PSAR Figure 2.5.1-36 and test plots are presented in PSAR Section 2.5.7.

Test Pits. Sixteen test pits were excavated at the ECP site to depths corresponding to the 8-foot depth of the Pond below natural ground. Logs described the lithology and such features as cracks, fissures, slickensides, and water seepage. Test pit locations are shown on PSAR Figure 2.5.1-53 and the logs are on PSAR Figures 2.5.7-1008 thru 2.5.7-1023.

Piezometer Installation. The locations of piezometers installed and monitored within the site area during the safety and design studies are shown on FSAR Figures 2.5.4-50 and 2.5.4-51. Piezometer tips in the shallow aquifer zone consisted of slotted polyvinyl chloride (PVC) pipes. In the deep aquifer (below 300 feet), wrapped well screens were used. Many of these piezometers were abandoned during construction and replaced with permanent piezometric monitoring systems as described in FSAR Appendix 2.5.C. All abandoned piezometers were grouted up to the ground surface.

Geophysical Surveys. Geophysical explorations were performed at the site to evaluate site geology and to determine dynamic engineering properties of foundation materials. These explorations consisted of: (1) seismic crosshole measurements to determine insitu shear-wave velocities to depths of 300+ feet, (2) refraction profiles to determine compressional-wave velocities, (3) 105 miles of seismic reflection surveys used in the evaluation of the subsurface geologic structure, and (4) geophysical borehole logging consisting of electric resistivity, self (spontaneous) potential and gamma ray logs. Each of the geophysical methods are discussed in detail in FSAR Section 2.5.4.4.

Field Pumping Tests. Three pumping tests were performed at the plant site and an additional three tests were performed in wells located 1 to 3 miles from the site. Properties of the upper section of the shallow aquifer were determined from a test in layers B and C. Two tests in layer E were used to determine the properties of the lower section (layers E, G, and H). The permability, transmissibility, and storage coefficients computed from the tests are shown in FSAR table 2.5.4-33.

The scope and types of field investigations are considered by the staff to be reasonable and acceptable for the design of the various features of the project. Additional investigations, performed during or after construction, are described in subsequent paragraphs.

2.5.4.1.3 Laboratory Testing. The static and dynamic engineering properties of the materials beneath the site and the structural backfill, as determined by laboratory testing, are discussed in the following paragraphs. Materials were basically divided into three classifications - sands, clays and structural backfill.

Index Properties. Appropriate index properties for the materials were determined by ASTM standards for the following tests: particle size, specific gravity, moisture content and Atterburg limits. Unit weights for insitu soils were determined from undisturbed samples. Results are presented in FSAR Table

2.5.4-1. Grain size, relative density, and permability of the structural backfill are presented on FSAR Figure 2.5.4-1.

Shear-Strength and Stress-Strain Properties. The insitu shear strength of the clay layers was determined from unconfined compression tests, (ASTM D 2166-66), unconsolidated undrained (UU) triaxial (ASTM D 2850-70) tests, consolidated-isotropic-undrained (CIU) triaxial tests, (Reference 2.5.4.1), consolidated-isotropic-drained (CID) triaxial tests, direct-shear tests (ASTM-STP-479, Reference 2.5.4.2) and from the field Dutch cone penetration data. Unconfined compression, UU triaxial, and CIU triaxial tests were also performed on compacted remolded clay material. For the CIU triaxial tests, four special loading tests were conducted to simulate stress changes in the field due to dewatering, excavation, backfilling, building construction, and rewatering. Direct shear tests for samples from the plant site and ECP were also sheared on a predetermined failure surface or along a slickensided surface to measure the strength of such pre-existing surfaces.

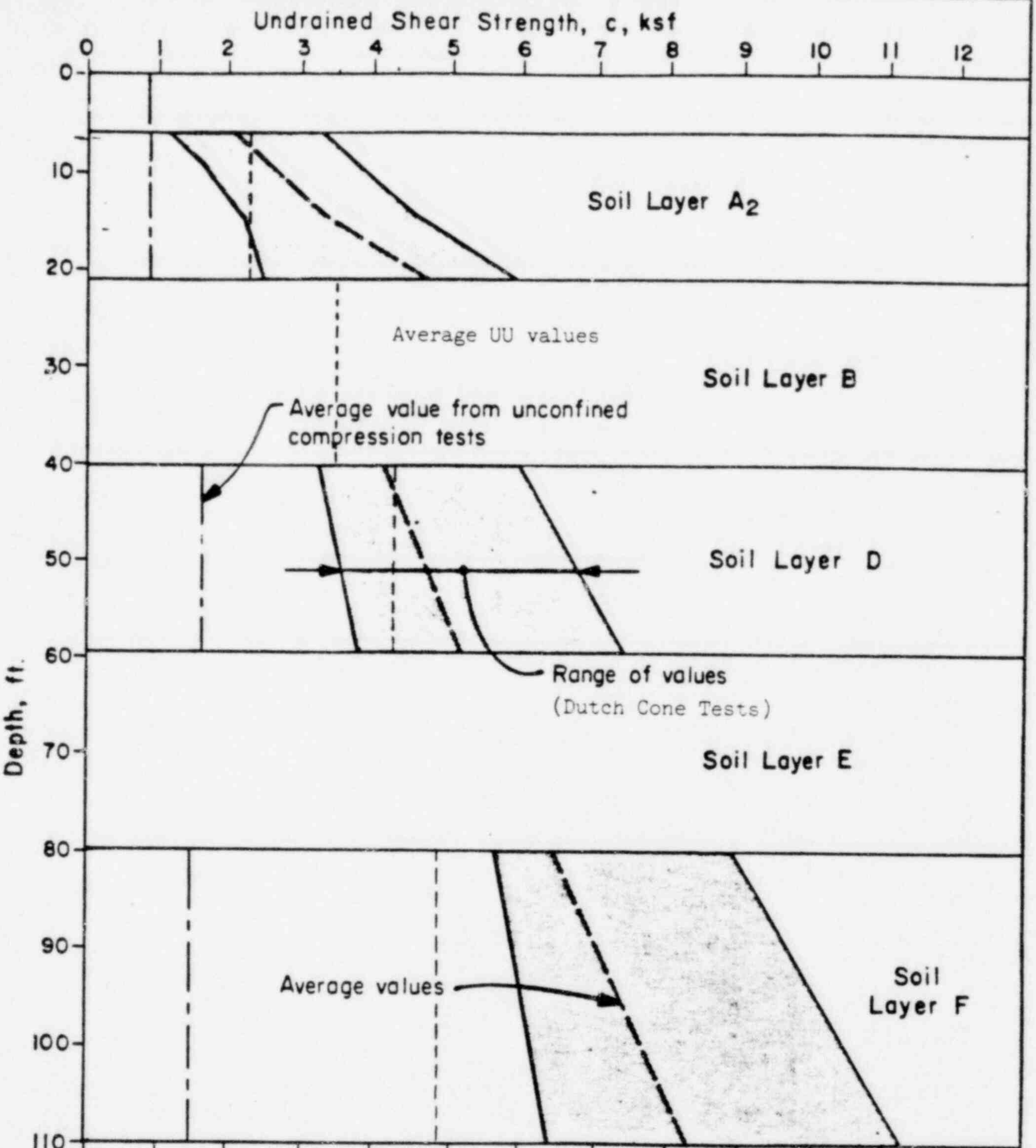
Results for the various tests are presented in FSAR Figures as shown on Table 2.5.4.2.

TABLE 2.5.4.2

SHEAR STRENGTH TEST RESULTS - CLAY

TYPE TEST	FSAR FIGURES
Unconfined Compression	2.5.4-2
Unconsolidated Undrained (insitu)	2.5.4-3
(Compacted)	2.5.4-4
Consolidated Isotropic Undrained	
(Plant Site)	2.5.4-5 through 2.5.4-13
(ECP)	PSAR 2.5.6-41 through 2.5.6-43
(fill)	2.5.4-14 through 2.5.4-17
Consolidated, Isotropic Drained	2.5.4-18 through 2.5.4-25
Direct Shear	2.5.4-26 and 2.5.4-27

Results of the Dutch cone penetration data indicated average shear-strength values significantly higher than those obtained from unconfined compression tests. This data, together with average UU strengths which were used in design for short-term undrained loading conditions for various analyses, are shown on Figure 2.5.4-2. Consolidated-undrained shear strengths used in analyses are presented in Table 2.5.4-3. Residual direct-shear tests indicated $\phi r = 9°$ for layer A and $\phi r = 5°$, C=0.46 Kg/cm^2 for the essential cooling pond (depth 8 feet). Comparisons of the shear strength of undisturbed and remolded samples from unconfined compression data indicated the clays are not sensitive to remolding with respect to axial stress required for failure.



From FSAR Figure 2.5.4-29
(With Additions)

SOUTH TEXAS PROJECT UNITS 1 & 2

UNDRAINED SHEAR STRENGTHS

FIGURE 2.5.4.2

TABLE 2.5.4-3

CIU TRIAXIAL COMPRESSION TESTS SHEAR-STRENGTH PARAMETERS

PLANT SITE

	Total Stress Parameters		Effective Stress Parameters	
	C	Ø	C'	Ø'
Clay Layer	(lb/ft^2)	(Degrees)	(lb/ft^2)	(Degrees)
A_2	140	14	140	20
B (Clay)	1,430	9	1,370	12
B(Silt)	220	27	0	34
D	1,040	16	940	23
F	450	18	360	29

ESSENTIAL COOLING POND

Clay Layer Depth (ft)				
0-5	-	-	140	20
0-5	370	11	350	15
5-20	-	-	0	27
10-15 (Silt)	-	-	0	34

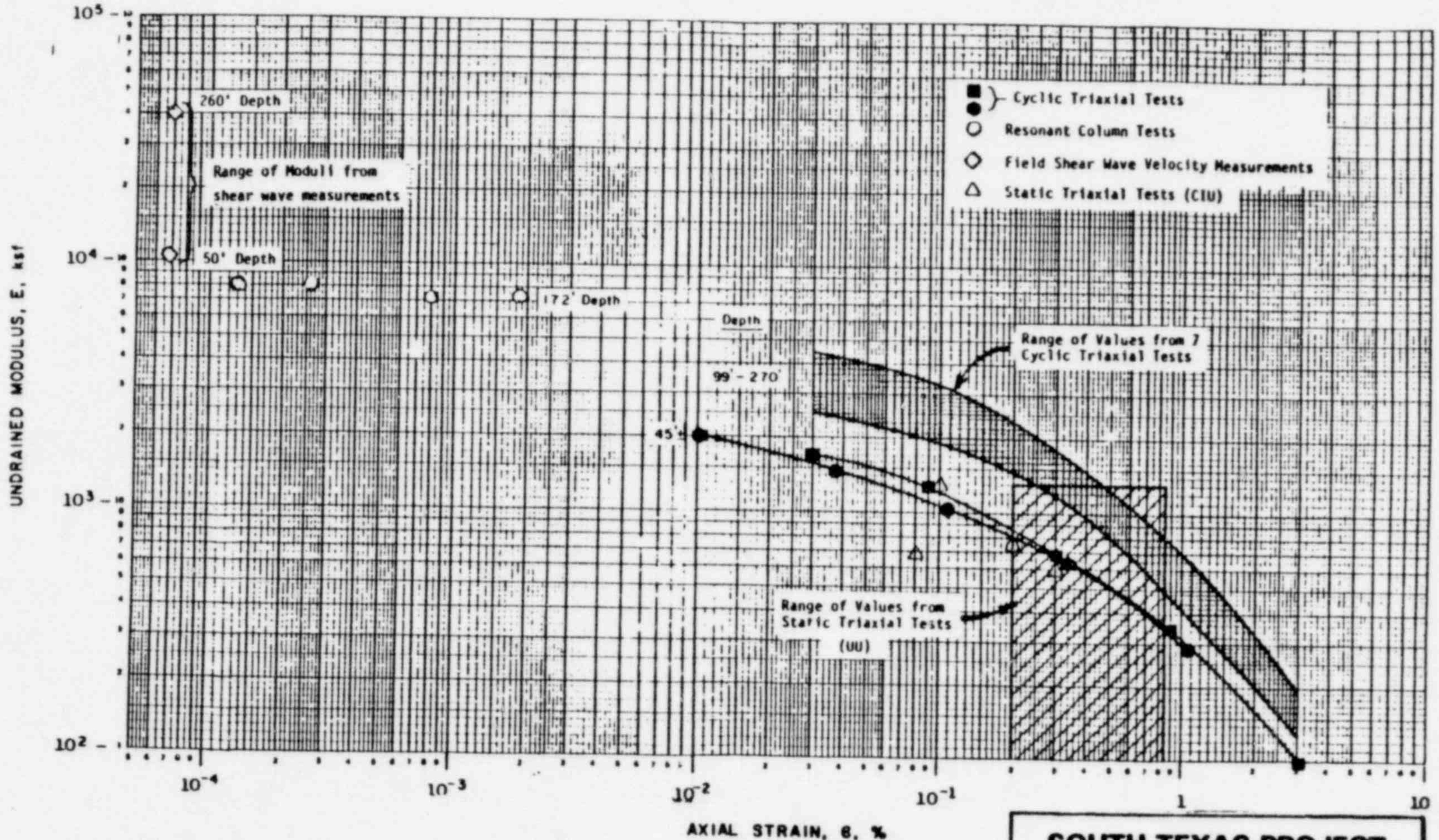
COMPACTED SAMPLES (90% MAX. DENSITY AND OPT. M.C.)

Soil Layer				
A_1	280	7	390	10
A_2	120	16	140	22
B (Clay)	80	17	140	22
B (Silt)	280	15	0	33

CID triaxial tests (References 2.5.4.1) were performed on selected thin-wall tube samples and on reconstituted samples of the sand layers (FSAR Figures 2.5.4-30 and 2.5.4-31). One unload-reload cycle was performed to simulate stress conditions occurring during excavation and structural loading. CID triaxial tests were also performed on samples of backfill material compacted to 80 percent relative density (FSAR Figure 2.5.4-32). For both short and long-term static loading conditions, ϕ'=36 degrees and 41 degrees were selected for reconstituted and undisturbed samples, respectively, for layer E. For compacted backfill material, ϕ'=43 degrees was selected.

<u>Deformation, Compressibility and Consolidation.</u> Consolidation tests (ASTM D 2435-70) were performed to determine compressibility indices and coefficients of consolidation and were also used to derive the drained modulus of elasticity of clay. The clays under the site are generally overconsolidated, therefore, the consolidation testing was concentrated in the stress range below preconsolidation pressures. Preconsolidation and existing effective overburden pressures, compressibility indices, and coefficients of consolidation are presented in FSAR Tables 2.5.4-7 and 2.5.4-10.

The Young's modulus values for clay were determined from static triaxial tests (UU and CIU), cyclic triaxial tests, resonant column tests and field shear-wave velocity measurements. Undrained modulus values computed from all sources are presented on Figure 2.5.4.-3 and discussed in FSAR Section 2.5.4.2.3.3.



From FSAR Figure 2.5.4-43

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UNDRAINED YOUNG'S MODULUS FOR CLAY

FIGURE 2.5.4.3

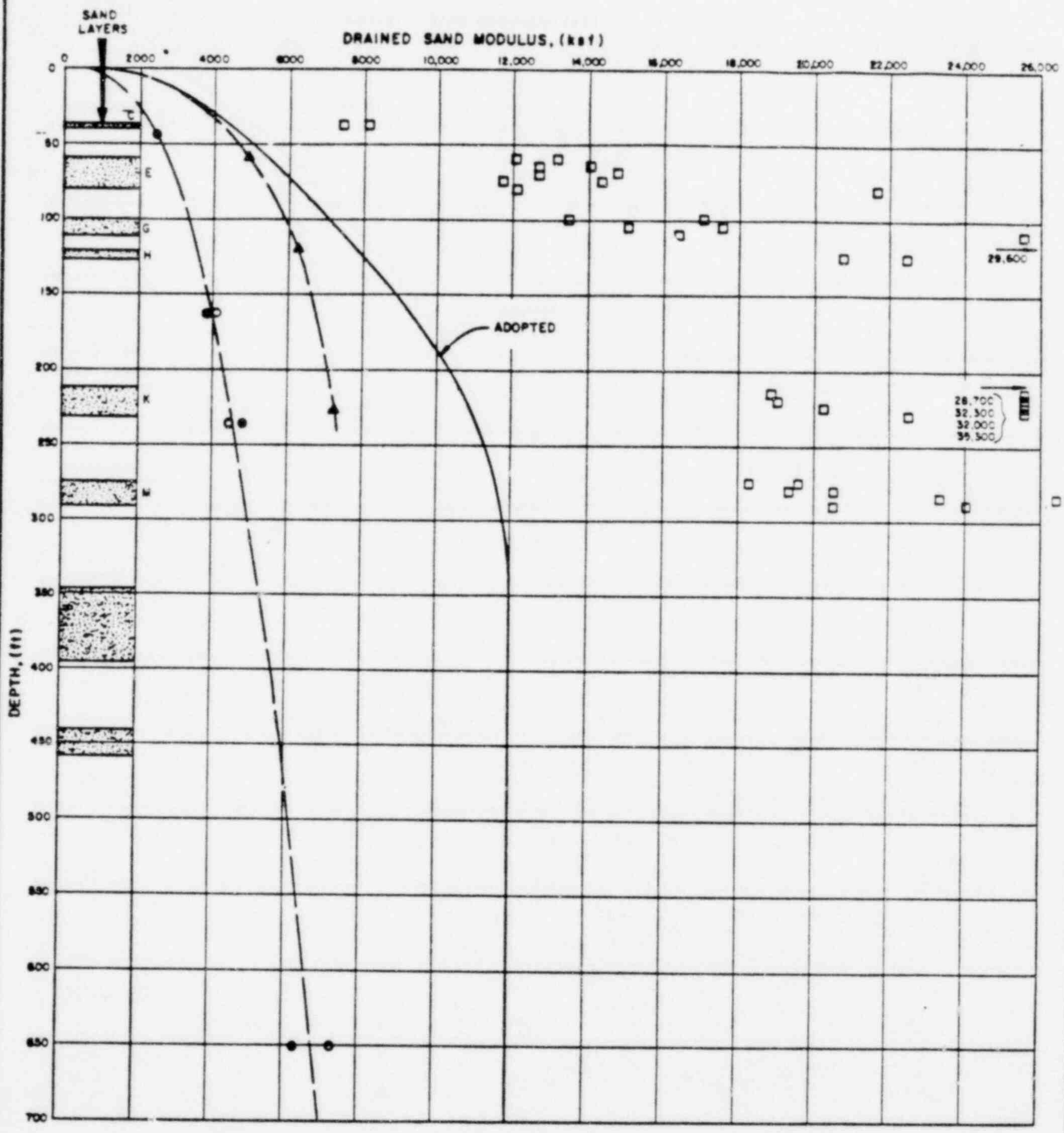
Strain levels associated with most of the deformation studies ranged between 10^{-1} and 10^{-3} percent. Using the upper bound from the cyclic test values and values slightly higher than resonant column tests, these strains correspond to modulus values of 3,000 to 10,000 kips/ft^2.

Drained Young's modulus, shown in FSAR Table 2.5.4-11, was developed from data of constrained modulus and Poisson's ratio according to the relationship in Ref. 2.5.4-3. A range of drained Poisson's ratio of 0.25 to 0.40 was assumed for each clay layer.

An average compression ratio of 0.006 for the sand layers was based on odometer tests on clayey sand from layer K and also computed using Young's modulus and Poisson's ratio for layer E. No values of consolidation coefficients were determined as the sand layers were assumed to rebound and recompress rapidly.

Young's modulus values for the sand layers were computed from field shear-wave velocity tests and from CID triaxial compression tests. The adopted average variation of modulus with depth used for settlement and subgrade reaction analyses is shown on Figure 2.5.4-4. Poisson's ratio varied from 0.25 to 0.30.

The average compressibility index (0.0014) of compacted structural backfill was



LEGEND:

- ○ E LAYER SAND – UNDISTURBED
- ● E LAYER SAND – RECONSTITUTED
- □ FIELD SHEAR WAVE VELOCITY
- ▲ GIFFORD HILL BACKFILL SAND

FROM FSAR FIGURE 2.5.4-45

SOUTH TEXAS PROJECT UNITS 1 & 2

DRAINED SAND-MODULUS VS. DEPTH

FIGURE 2.5.4-4

computed using values of Young's modulus, also shown on Figure 2.5.4.4, and Poisson's ratio with the modulus values computed from CID triaxial tests. Poisson's ratio of 0.25 for the backfill was determined from published data.

At-Rest Lateral Earth Pressure. At-rest lateral earth pressure was estimated to determine lateral soil pressures acting against buried structures and to assist in selecting stress levels for laboratory soil testing. Three methods were used to determine insitu lateral pressure in the clay: (a) work of Brooker and Ireland (Reference 2.5.4.4) relating K_o to the plasticity index and overconsolidation ratio (average K_o = 0.92), (b) consolidation tests (average K_o =0.93) and triaxial compression tests (Reference 2.5.4.1). An insitu K_o value of 1.0 was used for design.

For insitu sand, K_o = 0.35 was computed using CID triaxial test results (0^1 = 41 degrees). For clean insitu sands, the theoretical at-rest earth pressure coefficient varies from about 0.35 for dense sands to about 0.5 for loose sands. The at-rest pressure used for compacted backfill (K_o=0.5) took into consideration the lateral pressure in the upper few feet of the wall due to compaction.

Unit Weight. Unit weight for insitu soils, shown on FSAR Figure 2.5.4-49, was determined from undisturbed samples by dividing the wet weight by the measured volume.

Compaction tests (ASTM D 1557-70) were performed on samples of clay to establish maximum dry density and optimum moisture. Maximum and minimum density tests were used to establish the unit weight for structural backfill. These results are summarized in Table 2.5.4.4.

TABLE 2.5.4-4

LABORATORY DENSITY TEST RESULTS

PLANT SITE AREA

LAYER	DEPTH (FT)	Classification	MAX. DRY Density (lb/ft³)	OPT. WATER Content (%)
A_1	0-6	CH	103	19
A_2	6-21	CH	112	16
B	21-37	CL	117	14
B	21-37	ML	117	11

ESSENTIAL COOLING POND AREA

0.5-5.0	CH	108	16
6.5-10.0	CH	116	13

COMPACTED STRUCTURAL BACKFILL

Average minimum dry density (lb/ft^3)	95
Average maximum dry density (lb/ft^3)	124
80-percent relative density (lb/ft^3)	117

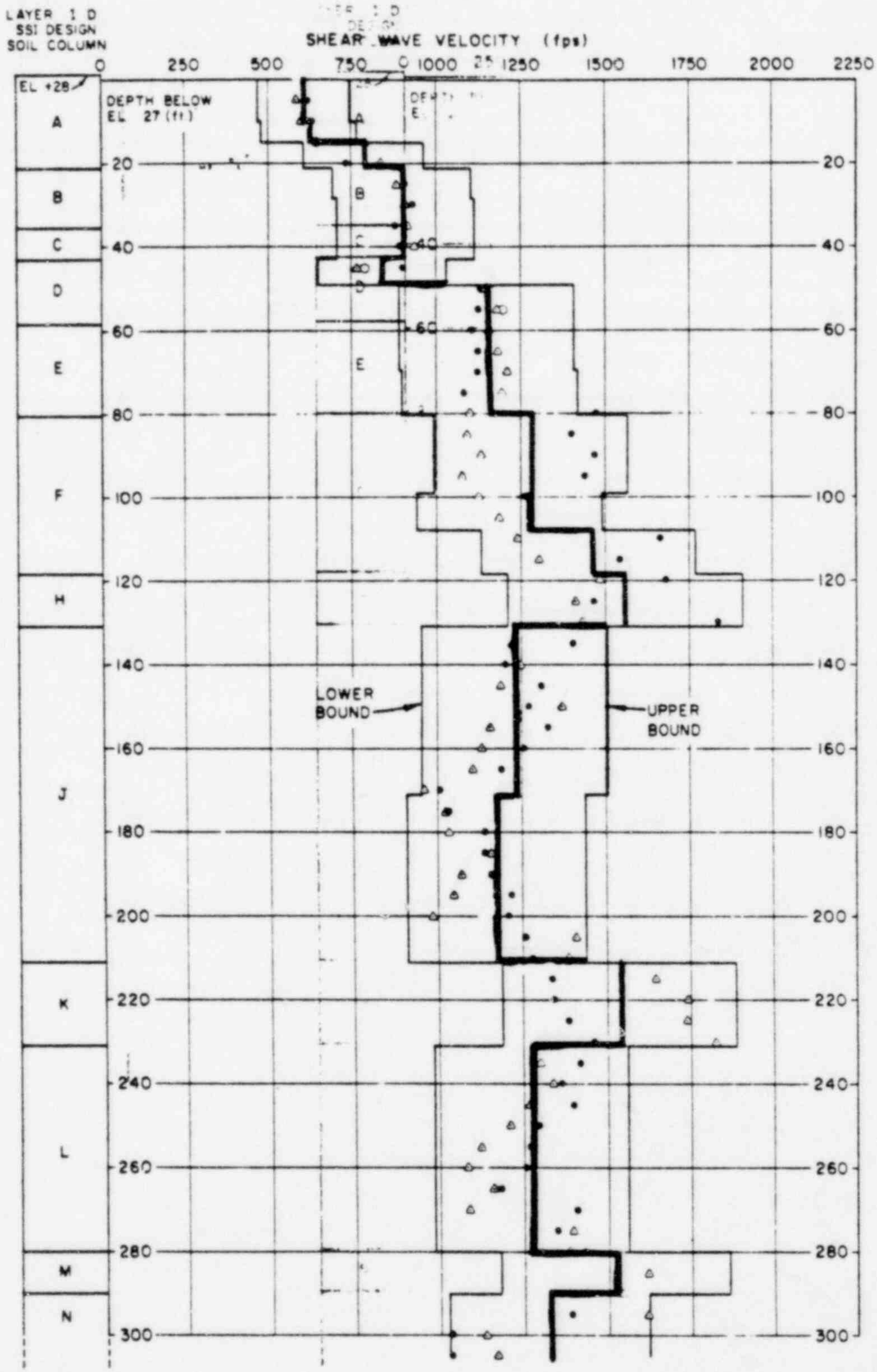
Permeability. Laboratory permeability tests were performed on undisturbed samples of clay from the site, on compacted clay samples from the ECP, and on compacted structural backfill material. Field pumping tests were used to determine the permeability of the insitu sand layers. Coefficients of permability ranged from 10^{-6} to 10^{-8} cm/sec for insitu clay, 10^{-5} for compacted clay, 10^{-4} for insitu sand and 10^{-3} for structural backfill.

Dynamic Soil Properties. Dynamic soil properties were determined from dynamic laboratory tests and from field geophysical measurements of shear-wave velocity. Dynamic laboratory tests included stress-controlled and strain-controlled cyclic triaxial tests on undisturbed cohesive and cohesionless samples and resonant column tests on reconstituted samples of backfill material.

Results of the stress-controlled cyclic tests are presented in PSAR Tables 2.5.4-6 through 2.5.4-11, strain-controlled test results are in FSAR Tables 2.5.4-16 (insitu soils) and 2.5.4-17 (backfill), and resonant-column results are in FSAR Table 2.5.4-18. Measured and design (SSI analyses) shear-wave velocities are shown on Figure 2.5.4.5.

Staff Conclusions

Laboratory procedures utilized for the various tests for design were in accordance with ASTM standards or other generally accepted practices. The scope and results of the laboratory testing program and the recommended design



LEGEND

- • Shear wave velocity at Reactor No. 1
- Δ Shear wave velocity at Reactor No. 2
- ○ Shear wave velocity at Reactor No. 2 measured in uncased holes
- ▬ Shear wave velocity used in SSI analyses for average soil properties

NOTES

1. Shear wave data are from July, 1984 measurements (Reference 12)

FROM FSAR FIGURE 2.5.4-71.

SOUTH TEXAS PROJECT UNITS 1 & 2

MEASURED SHEAR WAVE VELOCITIES AND VELOCITY VALUES USED IN SSI ANALYSES

FIGURE 2.5.4.5

parameters are considered reasonable and acceptable. Additional testing, performed either during or after construction, are described in subsequent paragraphs.

2.5.4.2 GROUNDWATER CONDITIONS

2.5.4.2.1 General. Site and regional groundwater conditions are discussed in FSAR Sections 2.4.13 and 2.5.1.2.10. Results of groundwater investigations in Matagorda County by the Texas Department of Water Resources and subsequent project investigations, including the installation and monitoring of piezometers, were used to determine the groundwater conditions at the site. The Beaumont Formation supplies most of the usable groundwater in the county and extends from the ground surface to a depth of approximately 1,400 feet in the site area. Groundwater in the formation is confined under artesian pressure. The main producing aquifer zone lies below depths of 200 to 300 feet in the site area and is the only source for high-capacity water well supplies. Prior to significant groundwater withdrawals, which began in the 1940's, deep aquifer piezometric levels were slightly above the ground surface in the vicinity of the STP. Since that time, piezometric levels have declined uniformly throughout the deep aquifer. Present static ground water levels range from about 20 feet to 60 feet beneath the site. Elevations are estimated to be lowered an additional 87 feet between 1973 and 2020. Groundwater movements are westward. The deep aquifer zone is well below the influence of any construction activities.

A shallow aquifer zone occurs above depths ranging from 90 feet to 150 feet in the site area and is segmented into lower and upper units over most of the site. This zone has been shown by several site pumping tests also to be confined with somewhat different piezometric heads in the two units. The shallow aquifer is limited in production capability; only stock and, occasionally, domestic wells pump from it. Piezometric levels are generally within 15 feet of the ground surface. Piezometers were designed and installed to monitor either the upper or lower portion of the shallow aquifer zone exclusively. The shallow aquifer zone was temporarily affected by plant construction dewatering but is being allowed to return to the natural elevations upon completion of the plant area subsurface construction and backfill. Flow in the shallow aquifer is in a southeasterly direction.

2.5.4.2.2 Foundation Stability Considerations. The influence of piezometric pressures on the foundations and supporting soil was considered for the periods of excavation, backfill, construction, and plant operation. The groundwater level in the shallow aquifer will return to between Els. 17 feet and 26 feet MSL after construction is completed. The applied foundation pressures used in the bearing-capacity evaluation were conservatively based on the lower level. Derivations of coefficients of subgrade reaction were based on the highest postulated piezometric pressure as this will cause the lowest effective confining pressure thereby reducing the stiffness of the soil. Also, the highest groundwater table assumption (El. 26 feet MSL) results in

conservatively increasing the estimated settlement by reducing the foundation modulus. Regional subsidence from long term groundwater withdrawal of the deep aquifer will be uniform across the plant site and should not affect the stability or performance of the facilities (See FSAR Section 2.5.1.2.9.6.5).

During construction, the piezometric elevation was maintained at least 5 feet below the excavation bottom within all permeable strata supporting Category I structures. During substructure construction, a calculated factor of safety of at least 1.3 against uplift of the partially completed structures was maintained. These criteria were met by use of a construction dewatering system as described in paragraph 2.5.4.4.2.

Piezometers were installed in the C, E, G, and H layers to monitor drawdown and performance of the Dewatering System. Time plots of the piezometer data are shown on FSAR Figures 2.5.4-65 through 2.5.4-66A. Pore pressure cells were installed at selected piezometer locations in the building areas and also in the backfill to allow monitoring after construction. The piezometric levels in the shallow and deep aquifer zones will be monitored throughout the life of the plant.

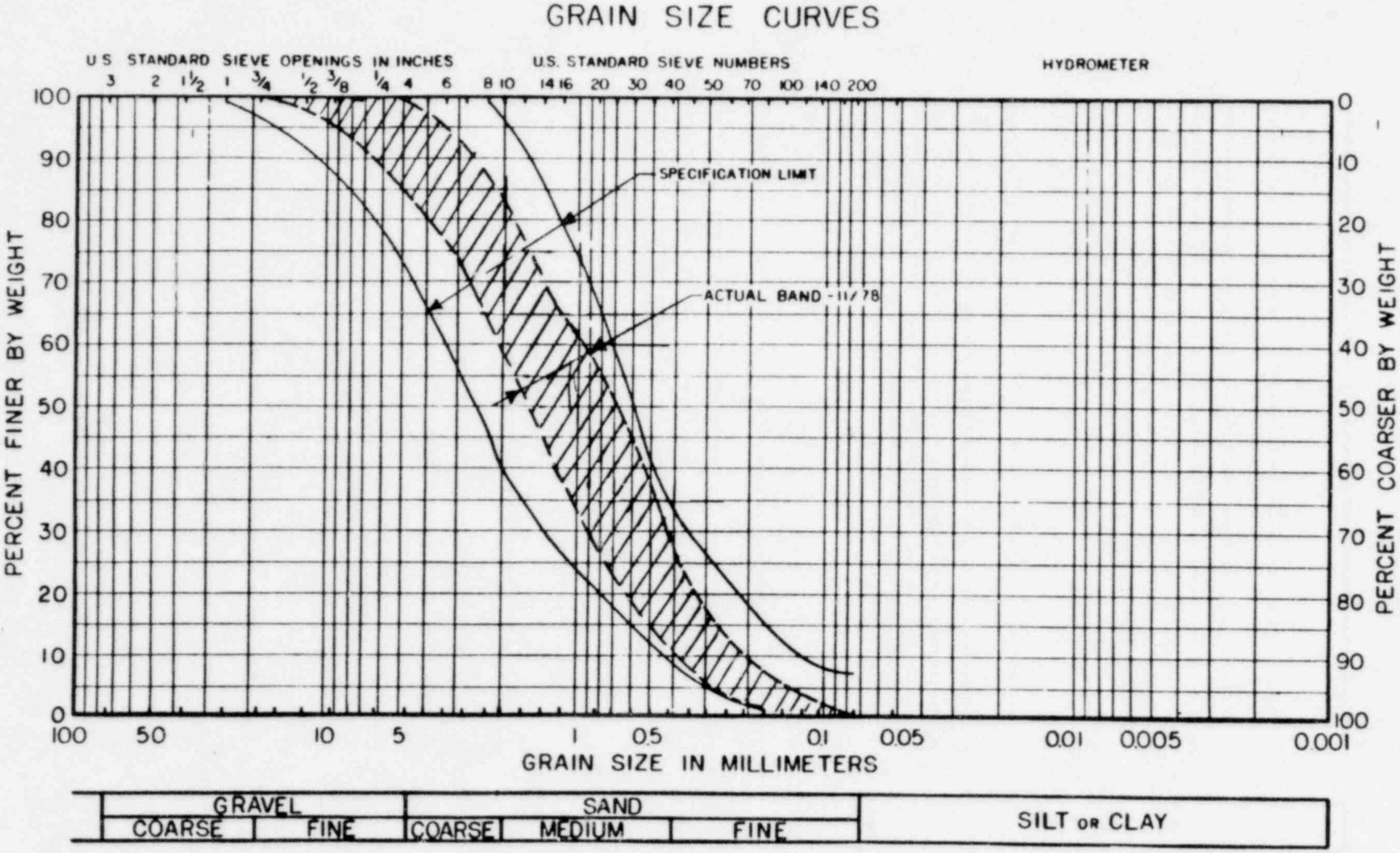
Groundwater from the deep artesian zone will be used for certain project operational water requirements. Three wells, each with a design capacity of 500 gal/min., will be located a minimum distance of 4,000 feet from the power station to minimize effects on local groundwater heads. A system of isolation

valves are utilized to assure the well system is available as a secondary makeup system for the ECP (FSAR Section 2.4.13.1.4). Two types of potential radioactive releases from the plant and the associated Main Cooling Reservoir to the groundwater were identified and are discussed in FSAR Section 2.14.13.3.

2.5.4.3 BACKFILL MATERIALS

The backfill materials used at the STP site, for the most part, were noncohesive granular fill. The plant area excavation, including the Turbine Generator Building (TGB) area, was backfilled to the foundation elevations and to within 18 inches of grade adjacent to the structures with clean, well graded, medium to coarse sand imported from sources in the Eagle Lake area (55 miles north of the plant site within the Colorado River allevium). The same material was used for backfill to support ECW piping in yard areas outside of the main excavations for Category I structures. Actual gradation of the Category I structural backfill after placement is shown on Figure 2.5.4-6. Some minor amounts of layer E granular soils were used as backfill immediately adjacent to the interior walls of Unit 1 and 2 tendon galleries and beneath Containment mats. This material was compacted to obtain strength and compressibility characteristics commensurate with or greater than the underlying layer E material.

A minimum 6-inch concrete mud slab was poured to provide a work surface free from potential deterioration beneath all Category I structures. The slab was



FROM FSAR FIGURES 2.5.4-59
AND 2.5.4-60 (COMBINED)

SOUTH TEXAS PROJECT
UNITS 1 & 2

GRADATION - BACKFILL
AS PLACED
FIGURE 2.5.4.6

constructed immediately on top of the prepared subgrade for structures founded on insitu soils or structural backfill. For structures founded above excavation grade, the concrete mud slab typically had a 3-inch concrete base with waterproofing. This, in turn, was covered with a 3-inch concrete slab. Certain areas of the ECP bottom were backfilled with compacted clay as described in section 2.5.6.

2.5.4.4 EXCAVATION AND BACKFILL FOR SAFETY-RELATED STRUCTURES

2.5.4.4.1 General. The extent and depth of the excavation for the Category I plant area facilities and Turbine-Generator Buildings are shown in plan on FSAR Figure 2.5.4-52 and in profiles on FSAR Figures 2.5.4-53 through 2.5.4-54A. Excavations for the Essential Cooling Water (ECW) structures are shown on FSAR Figure 2.5.A.4-3. The vertical and horizontal extent of the plant area excavation was established from considerations of soil strength and compressibility, plant layout and foundation depth requirements, and construction needs. Soil layers with unsuitable strength and compressibility characteristics for the applied foundation loads were removed to limit total and differential settlement of the plant facility to acceptable amounts.

2.5.4.4.2 Power Plant Buildings.

Excavation. The plant area consisted essentially of a large open-cut excavation to accommodate both units to a depth of approximately 40 feet (EL. -13 feet MSL). Additional open-cut excavations at each of the Reactor

Containment Buildings and Fuel-Handling Buildings (RCB and FHB) extended to a depth of 60 feet and to a depth of 67 feet (El. - 40 feet MSL) at the bottom of the tendon gallery. The foundation of the RCB is on dense native soil (Layer E). At elevation - 33 feet MSL, the foundation mat in the "pedestal" area bears on compacted structural backfill and insitu dense to very dense sand (layer E) underlain by very stiff clay interbedded with layers of very dense sand. The tendon gallery is founded on the layer E soil at EL. - 40 feet MSL. Except for the northern end of the FHB, the other major power plant building foundations were founded closer to plant grade. The gross bearing pressures for these buildings are significantly less than that of the RCB.

The general site grading and open-cut excavation were done with conventional earth-moving equipment. Scrapers were used to remove near-surface material to a depth of about 7 feet, and deeper materials were typically excavated by draglines and loaded out on trucks. Gradealls and dozers were used to shape the final slopes and for fine grading. Side slopes of 1-1/2 horizontal to 1 vertical with benches were used. The excavation was extended beyond the perimeter of the structures supported on structural backfill to provide uniform foundation support under the entire building. The minimum horizontal distance between the edge of the structure and the toe of the slope for this criterion was 12 feet. Additional distance was provided as required to accommodate construction requirements.

The excavation penetrated into the shallow aquifer requiring groundwater control by deep-well dewatering installations. The system consisted of one perimeter circuit of deep wells penetrating layer E, supplemented by sand drains for control of layer C and local well circuits for the RCB-FHB excavations penetrating to layer H. The configuration of the excavation and dewatering system is shown on FSAR Figure 2.5.4-64. The construction specification required the piezometric elevation be maintained at least 5 feet below the excavation bottom within all permeable strata in the shallow aquifer zone that subsequently would be supporting Category I structures, i.e., the E, G and H layers. This requirement was met during all construction operations as shown on FSAR Figures 2.5.4-65 through 2.5.4-66A.

Torpdeo inclinometer monitoring of the RCB-FHB local excavations indicated lateral movements of insitu soil of approximately 0.1 inch for Unit 1 and 0.4 inch for Unit 2 as compared to the allowable deformations of 6 inches (See Figures 2.5.4-7 and 2.5.4-8). These observations documented that all slopes had satisfactory stability against mass movement during construction and that slopes within soil that would support Category I structures performed better than expected. There were no adverse events during the excavation work. The excavation work was carried out as unclassified, non-safety-related work.

Foundation Preparation and Acceptance. The final excavation bottom was inspected and verified to assure satisfactory conditions for support of Category I structures as described in FSAR Appendix 2.5A. Geologic mapping, described in FSAR Appendix 2.5.8, was also performed.

The subgrade was prepared in order to obtain a suitable surface for placement of structural backfill. Criteria established and complied with during subgrade preparation consisted of the following:

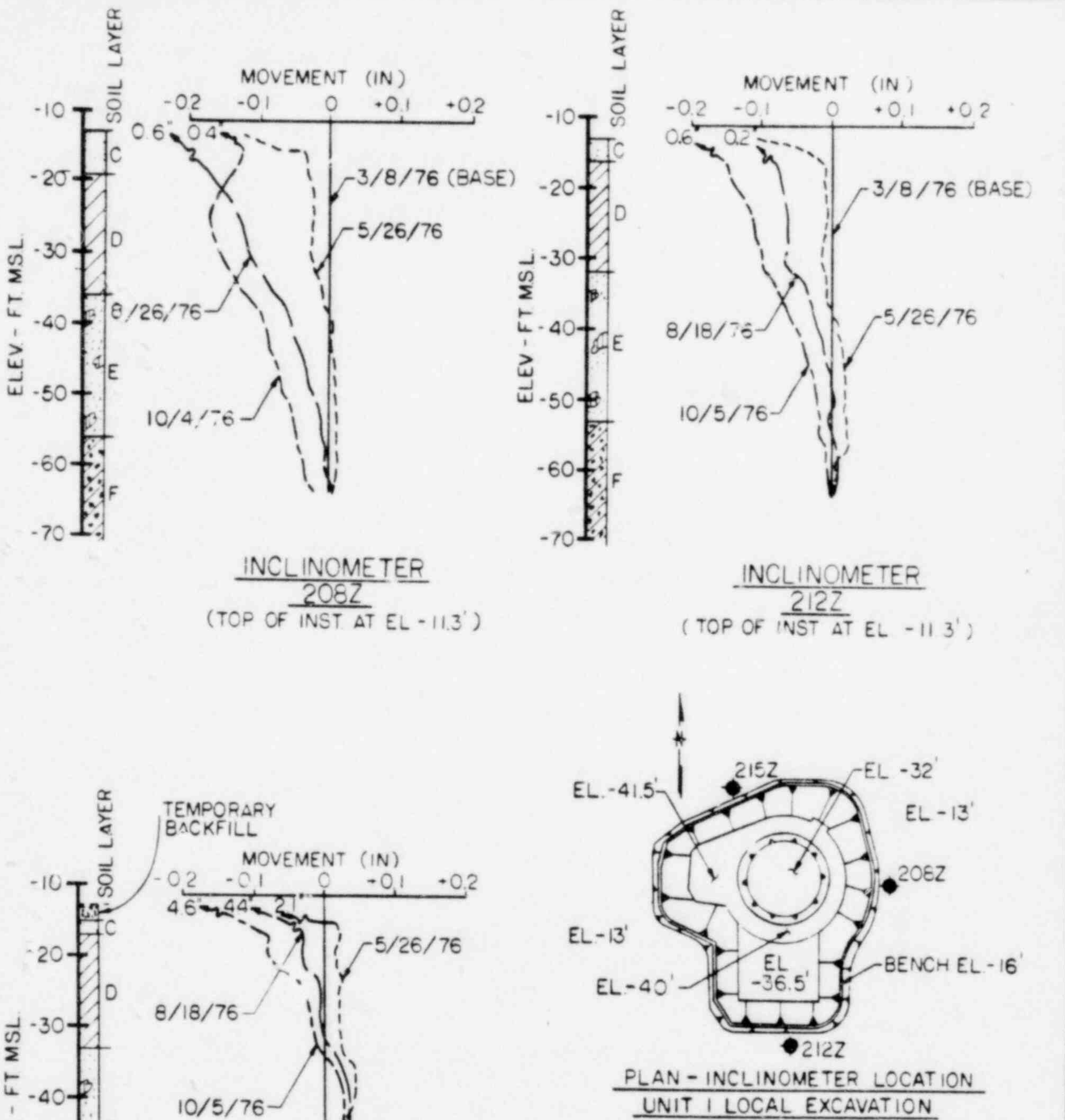
1. Natural soil subgrade was prepared immediately prior to placing fill or backfill.

2. Subgrade composed of cohesionless soil was compacted to a minimum of 80 percent relative density (ASTM D 2049-60). The E layer was compacted to a minimum dry unit weight of 98 lb/ft^3.

3. Subgrade composed of cohesive soil was compacted to 90 percent maximum dry density (ASTM D 1557-Method D - Modified Proctor).

4. Where fill was placed adjacent to a sloping natural subgrade, the surface was excavated to firm, undisturbed natural soil immediately prior to placing fill or backfill. Average and range of in-place density tests from subgrade preparation are tabulated in Table 2.5.4-5.

In some locations, as shown on FSAR Figure 2.5.4-116, a concrete mud seal was employed in lieu of subgrade preparation by compaction. A minimum of 6-inches of insitu soil was carefully removed to provide an even, undisturbed surface, the exposed soil was inspected as part of the foundation verification program, and the mud seal was placed immediately upon acceptance. The foundation verification program (FSAR Appendix 2.5A) was implemented during construction



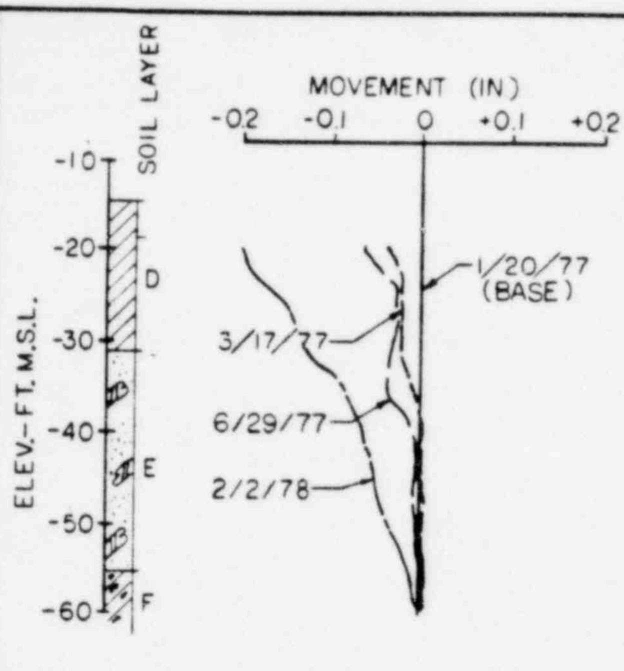
NOTES

1. NEGATIVE READING INDICATES MOVEMENT AWAY FROM THE SLOPE.
2. DETAILED DESCRIPTION OF SOIL LAYERS REFER TO SUBSECTION 2.5.4.1
3. INSTRUMENTS WERE DECOMMISSIONED AFTER BACKFILL TO EL.-20' M.S.L. ON 10-5-76.

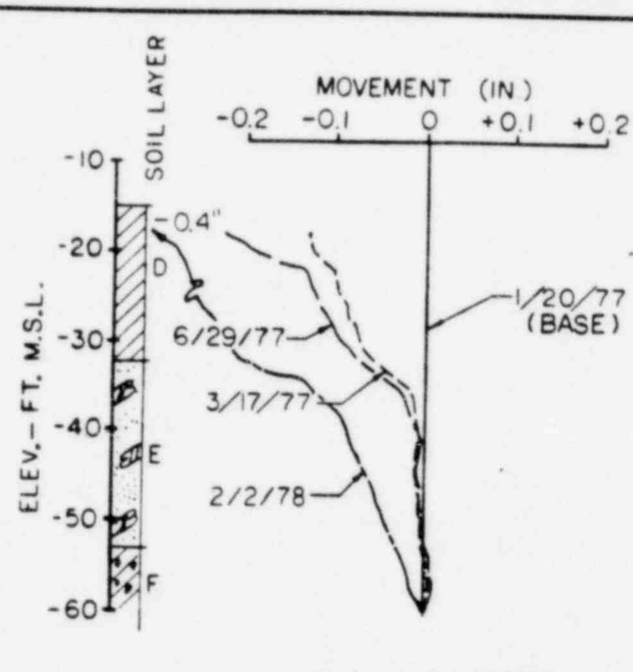
FROM FSAR FIGURE 2.5.4-55.

SOUTH TEXAS PROJECT
UNITS 1 & 2

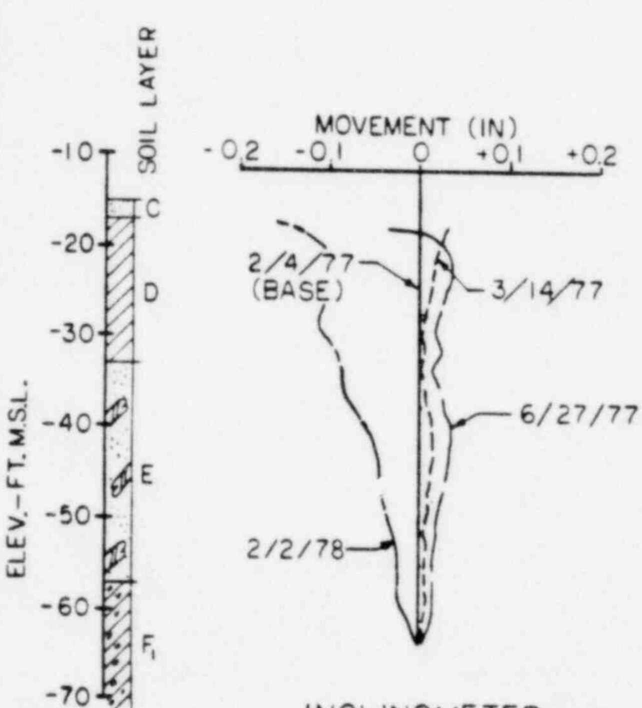
SLOPE STABILITY
UNIT 1
FIGURE 2.5.4.7



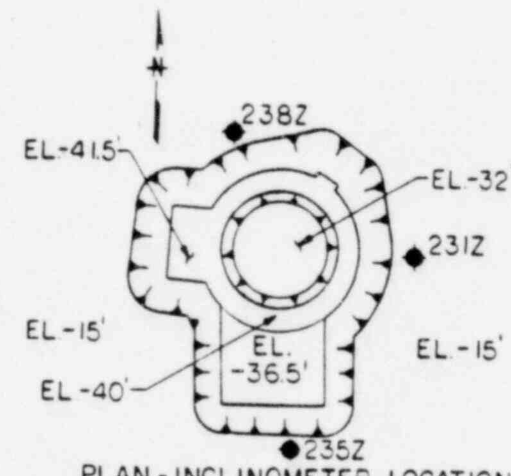
INCLINOMETER
231Z
(TOP OF INST. AT EL.-7.6')



INCLINOMETER
235Z
(TOP OF INST. AT EL.-7.7')



INCLINOMETER
238Z
(TOP OF INST. AT EL.- 11.2')



PLAN - INCLINOMETER LOCATION
UNIT 2 LOCAL EXCAVATION

NOTES:

1. NEGATIVE READING INDICATES MOVEMENT AWAY FROM THE SLOPE.
2. DETAILED DESCRIPTION OF SOIL LAYERS REFER TO SUBSECTION 2.5.4.1
3. INSTRUMENTS WERE DECOMMISSIONED AFTER BACKFILL TO EL.-20' M.S.L. ON 2-2-78.

FROM FSAR FIGURE 2.5.4-56

SOUTH TEXAS PROJECT
UNITS 1 & 2

SLOPE STABILITY
UNIT 2
FIGURE 2.5.4.8

TABLE 2.5.4 .5

SUBGRADE PREPARATION - DENSITY RESULTS

Unit	Building	Soil Type	Required Dry Densities (lb/ft^3) Avg	Min	Max	Field Results (γd, lb/ft^3) Avg	Min	Max
1	Reactor Containment	Non-Cohesive	98.0	-	-	105.5	98.2	111.4
		Cohesive						
	Fuel-Handling	Non-Cohesive	98.0	-	-	101.5	98.2	105.6
		Cohesive	104.2	-	-	107.0	-	-
	Mech.-Elec. Aux.	Non-Cohesive						
		Cohesive						
	Turbine Generator	Non-Cohesive	104.6	98.0	117.9	106.7	99.1	121.0
		Cohesive	103.5	93.6	108.6	107.4	95.8	119.4
2	Reactor Containment	Non-Cohesive						
		Cohesive						
	Fuel-Handling	Non-Cohesive						
	Mech.-Elec. Aux.	Non-Cohesive						
		Cohesive	104.2	-	-	107.4	104.2	109.0
	Turbine Generator	Non-Cohesive						
		Cohesive	110.0	-	-	114.6	110.8	119.3

(From FSAR Table 2.5.4.23)

to demonstrate and document that the naturally deposited soils at final excavation grade were the types anticipated and of a quality equal to or better than those anticipated during the design phase. Implementation of the foundation verification field work followed the event diagram shown on Figure 2.5.4.9.

The strength and compressibility characteristics of the layer-A soils were considered inadequate for direct support of large and/or heavy buildings and this layer was removed beneath the major power plant structures. Soil characteristics and foundation verification results for final conditions are summarized in FSAR Table 2.5.A.5-1 for layers B, C, D and E.

During initial foundation verification of the E layer of Unit 1, it was determined that some soils had less-than-anticipated dry density. Results of subsequent standard penetration tests (15-1/2 feet to 26 feet below excavation levels) showed that the E-layer soils had lower-than-anticipated relative density. Low densities to a depth of approximately 2 feet below excavation levels in the area of the RCB and to depths in excess of 2 feet in the northern portion of the FHB were discovered. The lower density in the RCB area was attributed to excavation disturbance. Loosenings of soils in the northern portion of the FHB was attributed to installation of casings by vibratory driving. Remedial action in the RCB areas consisted of compacting the exposed silty sand with a vibratory roller in combination with removing the loosened 2 feet and then proof rolling the exposed foundation soil. Remedial action at the north end of the FHB, (FSAR Section 2.5.4.12) consisted

of vibroflotation of the area. Procedures for this remedial work are presented in Reference 2.5.4.5. Field density tests following the remedial actions resulted in dry densities exceeding verification criteria. FSAR Figure 2.5.4-119 shows Standard Penetration Test Data before and after the vibroflotation remedial action.

The dewatering excavation and foundation verification program are considered by the staff to be reasonable and acceptable. Based on results presented in the FSAR, conditions are equal to or better than foundation conditions anticipated for the foundation engineering analyses and design.

Backfill. As indicated in paragraph 2.5.4.3, the plant area excavation, including the TGB area, was backfilled to the foundation elevations and to within 18 inches of grade adjacent to the structures with clean, well-graded, medium to coarse sand imported from sources in the Eagle Lake area (55 miles north of the plant site). The density criteria for Category I structural backfill were developed considering the dynamic modulus and damping characteristics, cyclic strength and liquefaction potential, bearing capacity, and lateral earth pressures. To meet or exceed this criteria, field construction acceptance criteria required a minimum 80 percent relative density and at least 84 percent average relative density. The maximum loose lift thickness was 18 inches in unrestricted placement areas and 4 to 6-inch lifts were used within restricted placement areas. Tests (ASTM standards)

which were performed during construction included relative density, grain size, organic matter, particle shape, and field density. The material was free from organic matter, was subrounded to angular, and had a coefficient of uniformity greater than 4. Actual gradation of the Category I structural backfill from samples in the placement areas are shown on Figure 2.5.4-6. In-place density test results (statistical) for Units 1 and 2 are shown on Figures 2.5.4-10 and 2.5.4-11, respectively. The mean of the in-place density distribution exceeded 94 percent relative density (July 1980).

In response to a Show Cause Order issued on April 30, 1980 by the NRC, an Expert Committee was retained by the applicant to perform an in-depth study of the structural backfill. Nine tasks were originally outlined for review covering the following generalized subjects: (a) structural backfill design, (2) compaction criteria, (3) construction specifications and procedures, (4) inspection and testing procedures, (5) compaction qualify control results, (6) special investigations of placed backfill, (7) potential remedial action, (8) inspection of on-site laboratory, and (9) evaluation of test fill. In addition, special studies undertaken by the Committee included: (1) supplemental testing of soils for maximum-minimum densities, (2) review of settlement measurements, (3) analysis of liquefaction potential based on Standard Penetration Test data, (4) analysis

of liquefaction resistance of structrual backfill underlying mat foundations, (5) maximum density by wet method, (6) statistical analysis, (7) comparison of SPT results with backfill placement and density test results, (8) locations and sequence of Category 1 backfill placement and density test distribution, (9) review of Earthwork Inspection Reports, and (10) review of evaluations and audit findings. Each of these 19 items are discussed in detail in the Committee's final report, Reference 2.5.4.6. In summary, the committee's overall conclusion was that "the condition of the fill as it now exists is entirely adequate for the design requirements of this project."

The field acceptance criteria, placement and compaction procedures, and testing procedures and results are considered by the staff to be reasonable and acceptable. Based upon test results presented in the FSAR and the very detailed review and analyses performed by the Expert Committee, the staff concludes that the Category I structural backfill for the power plant buildings is adequate for the design conditions.

2.5.4.4.3 Essential Cooling Water (ECW) Intake and Discharge Structures. Excavation. Excavation for these structures began in May 1978 and was completed in June 1978. Open-cut excavation, similar to that described for the main plant, extended to elevation +3.0 MSL (Layer B) for the intake structure and to elevation +11.0 MSL (Layer A_2) for the discharge structure. The excavations were extended beyond the perimeter of the structure to

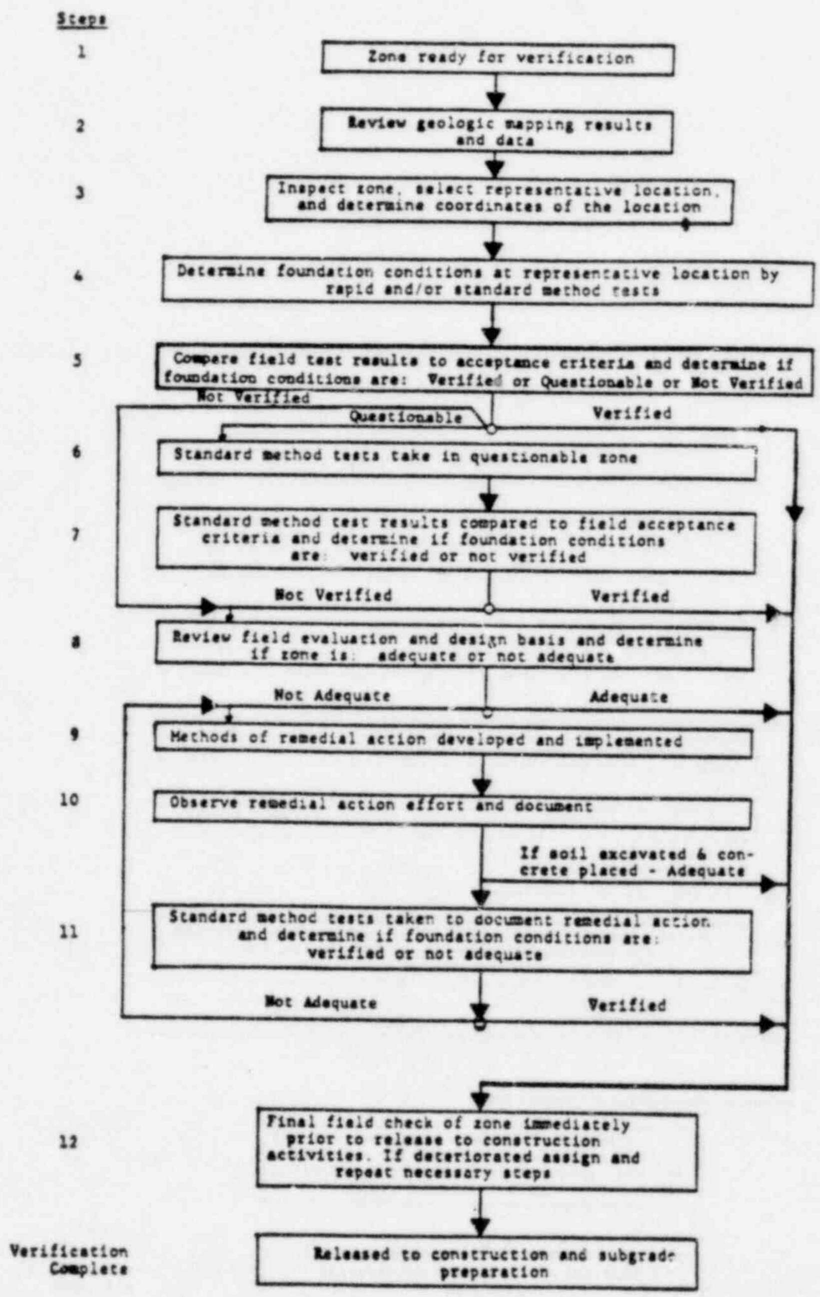
provide uniform foundation support on the structural backfill. Geologic mapping and foundation verification, as described for the main plant, were performed (FSAR Appendix 2.5.A and 2.5.B). Dewatering was not needed and the slopes were stable during construction. Foundation verification zones are shown on FSAR Figure 2.5.4-117B and test results are presented in FSAR Table 2.5.A.6-1.

Backfill. The Intake Structure (79 feet by 136 feet in plan) was founded at elevation 6 feet MSL on three feet of compacted structural backfill. The trapezoidal shaped Discharge Structure (maximum plan dimensions of 54 feet by 53 feet) was founded at elevation 15 feet MSL on 4 feet of compacted structural backfill. Material types, placement and compaction procedures and requirements, and field testing procedures were basically the same as described for the main plant area.

Excavation procedures, foundation verification procedures and results, and backfill procedures and test results are considered by the staff to be reasonable and acceptable.

2.5.4.4.4 Essential Cooling Water Piping System.

Excavation. The ECW piping consists of 30-inch diameter pipe with the inverts varying between 17.5 feet MSL and 10 feet MSL in Layer A_2 as shown in profile on FSAR Figures 2.5.A.3-1 through 2.5.A.3.3. A silty zone of clay interbedded



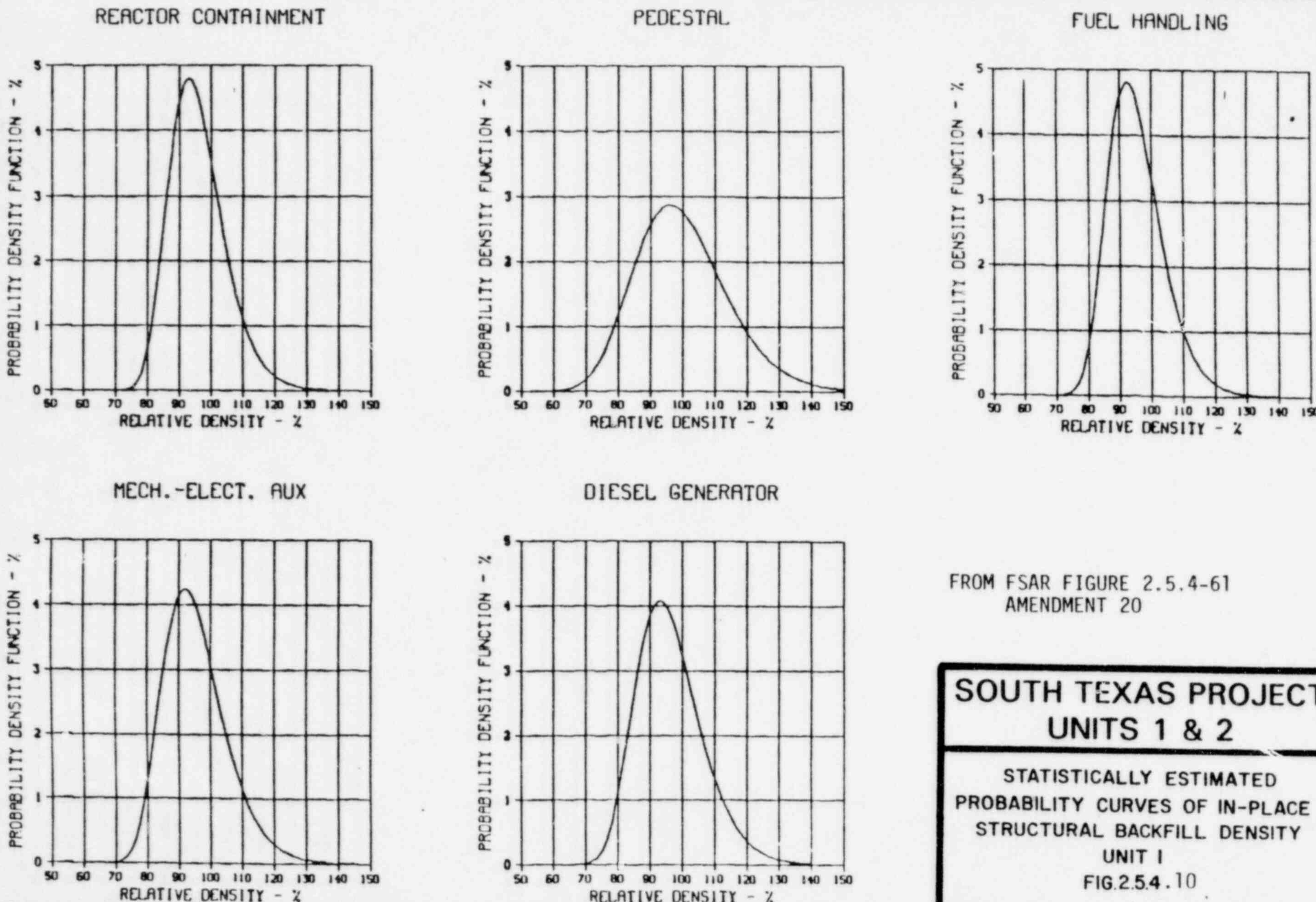
FROM FSAR FIGURE 2.5.A.4-6
AMENDMENT 35

SOUTH TEXAS PROJECT UNITS 1 & 2

VERIFICATION EVENT DIAGRAM

FIGURE 2.5.4.9

41

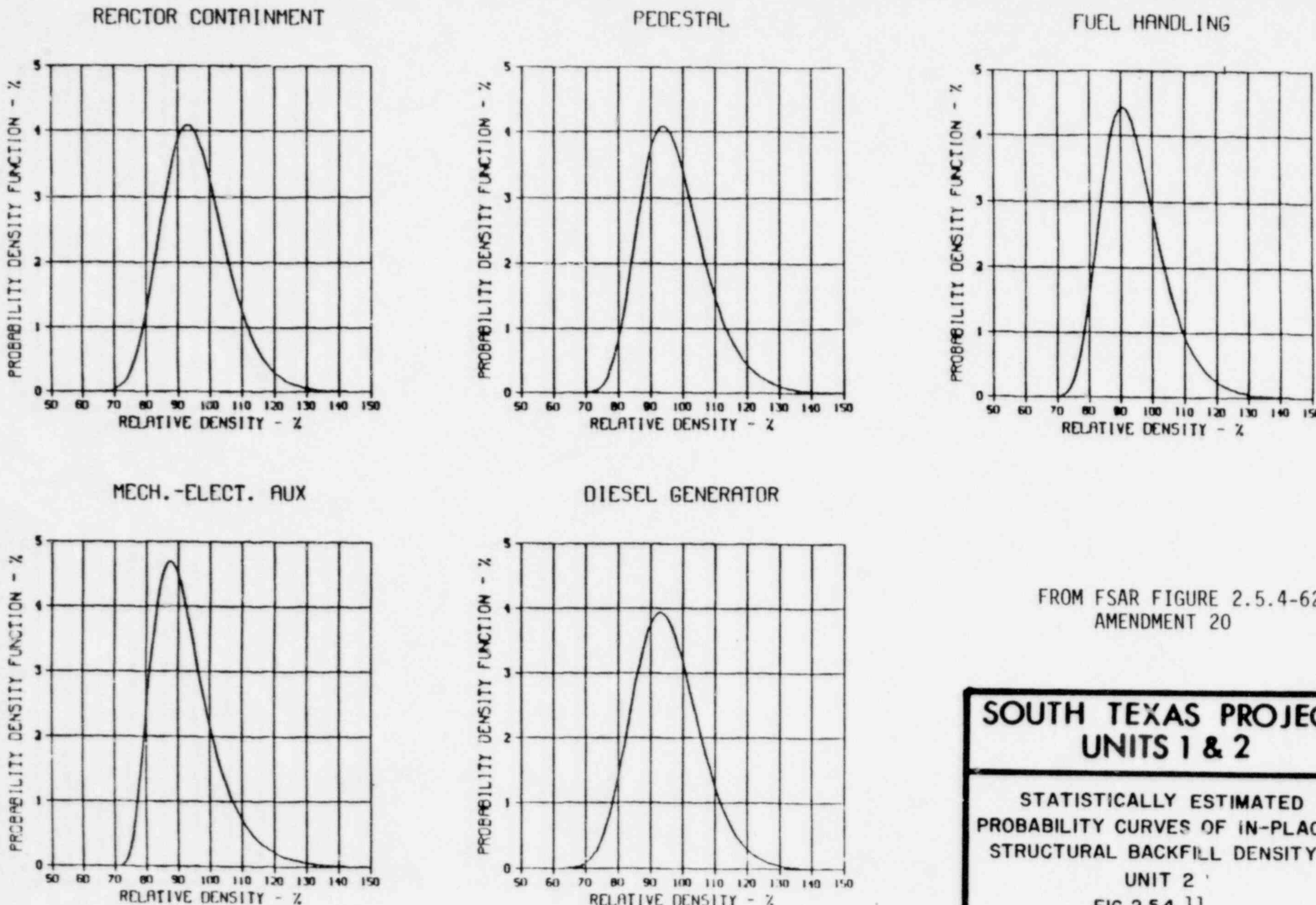


FROM FSAR FIGURE 2.5.4-61
AMENDMENT 20

SOUTH TEXAS PROJECT UNITS 1 & 2

STATISTICALLY ESTIMATED PROBABILITY CURVES OF IN-PLACE STRUCTURAL BACKFILL DENSITY UNIT I

FIG.2.5.4.10



FROM FSAR FIGURE 2.5.4-62
AMENDMENT 20

SOUTH TEXAS PROJECT UNITS 1 & 2

STATISTICALLY ESTIMATED PROBABILITY CURVES OF IN-PLACE STRUCTURAL BACKFILL DENSITY UNIT 2

FIG. 2.5.4-11

with silt lenses was found during design phase and when encountered in the bottom of the ECW piping trench, it was excavated and replaced by structural backfill. Dewatering was not needed and the excavation slopes were stable. Foundation criteria and verification procedures were established and complied with during construction. Foundation verification zones are shown on FSAR Figure 2.5.A.4-4 and test results are presented in FSAR Table 2.5.A.6-1.

Backfill. The ECW pipes were embedded in structural backfill and were supported either on compacted structural backfill or on a lean concrete bedding placed individually in narrow strips under the pipeline. Where necessary, the concrete bedding was provided in lieu of compacted backfill to assure competent contact between the pipe and the backfill underneath. The Category I material in which the ECW pipes were embedded outside of the structural excavation limits was compacted to a minimum 70 percent relative density although design studies indicated material at only 45 percent relative density would have a factor of safety of 1.3 against liquefaction. Category I structural backfill supporting the pipes was placed to the horizontal limits of the trench excavation and to a depth of at least 18 inches below the pipes and a height of at least 6 feet above the pipes.

Excavation and backfill for the ECW piping are considered by the staff to be reasonable and acceptable.

2.5.4.4.5 Essential Cooling Pond (ECP).

Excavation. The water surface of the ECP covers an area of 45.6 acres at El. 25 feet and 40.0 acres at pond bottom, EL. 17 feet. The natural ground surface outside the ECP is approximately at El. 25 feet. Foundation verification zones are shown on FSAR Figure 2.5.4-117B and test results are presented in FSAR Table 2.5.A.6-1. The ECP soil investigation during construction also included both geologic mapping and the excavation and logging of 59 test pits in the pond bottom (FSAR Figure 2.5.8.5.3-9). The excavation exposed only soils of the A layer with the pond bottom located within sublayer A_2. The excavation was accomplished utilizing conventional earth moving equipment. Dewatering was not needed and the slopes were stable during construction.

Backfill. The geologic mapping and logging of test pits in the pond bottom indicated that toward the eastern one-third of the pond area, soils of the A_2 layer became chiefly clayey silt (ML) with silty sand lenses (See FSAR Figure 2.5.B.5.3-10). The silty soils were excavated to a two feet depth below pond bottom and the area was backfilled with compacted clay. No other backfill was required for the pond.

The excavation, foundation verification, and backfill procedures for the ECP are considered reasonable and acceptable by the staff.

2.5.4.5 FOUNDATION STABILITY

2.5.4.5.1 Stability Criteria. The stability of the plant site soils was evaluated using geologic and soil test data and analyses. The foundation soils were evaluated for mineralogy, consolidation, bearing capacity and seismic response behavior characteristics including liquefication potential.

2.5.4.5.2 Mineralogy. The mineralogy study (FSAR Section 2.5.1.2.9.5) included particle-size analyses and qualitative and quantitative mineral classifications. The soils range from clay with essentially no sand to nearly clean sands. Most of the sand-fraction samples were composed predominantly of hard silicate grains. The silt fraction was primarily quartz with very minor amounts of feldspar, calcite, and mica.

The clay fraction was almost entirely composed of true clay minerals; only traces of calcite were encountered. The clay fraction was composed of 40 to 90 percent kaolinite and illite - the remainder was composed of montmorillonite with a small amount of mixed-layer material. All montmorillonite appeared to be of the calcium variety except for one sample which contained about 3 percent clay mineral of which one-tenth appeared to be sodium montmorillonite.

The clays underlying the site are subject to volume change due to changes in effective stress, however, all of the soils are saturated. Thus, high swelling tendencies associated with saturation of dried expansive clay will not be experienced.

The staff concurs with the applicant's conclusions that the clay minerals and other minerals will not adversely influence the static or dynamic behavior of the plant and that the long-term stability of the clay mineral composition will not affect plant operation under the present and anticipated groundwater regime.

2.5.4.5.3 Bearing Capacity. The design of mat foundations was governed by soil-structure interaction effects (as reflected by subgrade reaction values and deflected shapes) and not by bearing-capacity considerations. The soil layers and extent of structural backfill of significance to the bearing capacity are shown on Figures 2.5.4-53 through 2.5.4-54A of the FSAR. The plant layout is shown on Figure 2.5.4-12 and a generalized description of the various structures is presented in Table 2.5.4.6.

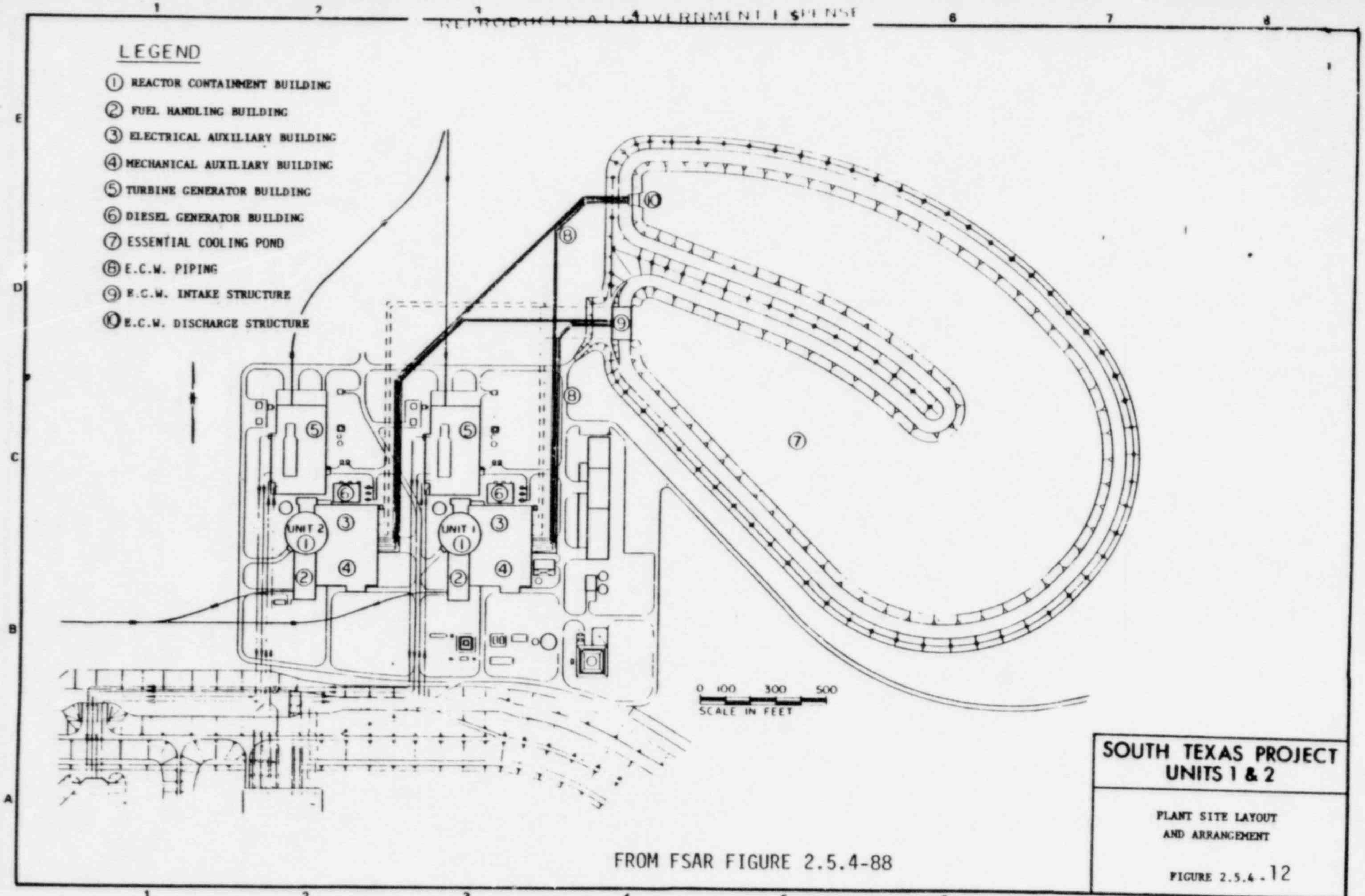


FIGURE 2.5.4-12

TABLE 2.5.4.6

DESCRIPTION OF STRUCTURES

Structure *	General Description
RCB	Prestressed, post-tensioned, reinforced concrete structure with 166 ft. diameter mat foundation. Founded at El. - 32 ft. MSL on undisturbed sand and compacted structural backfill.
FHB	Approximately 88 ft. x 190 ft. in plan. Reinforced concrete structure. Deeper section (El. - 36 ft.) on natural soil and shallower portions (-1 to 14 ft. MSL on structural backfill.
MEAB	250 ft. x 32 ft. in plan, founded at El. 4 ft. MSL on structural backfill.
DGB	82 ft. x 107 ft. in plan, founded at El. 20 ft. MSL on structural backfill.
AFST	50-ft diameter tank on mat at El. 19 ft. MSL on structural backfill.
ECW Intake	79 ft. x 136 ft. in plan, founded at El. 6 ft. MSL on structural backfill.
ECW Discharge	54 ft. x 53 in plan, founded at El. 25 ft. MSL on structural backfill.

*Reactor Containment Building (RCB); Fuel Handling Building (FHB); Mechanical and Electrical Auxiliaries Building (MEAB); Diesel Generator Building (DGB); Auxiliary Feedwater Storage Tank (AFST); Essential Cooling Water (ECW).

Effective stress parameters were used for long term normal service loading conditions and total stress parameters were used for short term, non-service (extreme environmental) loading conditions. Soil parameters used in the analyses are included in Table 2.5.4.7.

TABLE 2.5.4.7

SOIL DESIGN PARAMETERS

	Total Unit Weight (PCF)	Buoyant Unit Weight (PCF)	Total Stress C (PSF)	Total Stress 0 (DEG)	Effective Stress C (PSF)	Effective Stress 0 (DEG)
Structural Backfill	134	72	-	-	0	43
Layer B	125	63	1,430	9	1,370	12
Layer D	125	63	1,040	16	940	23
Layer E	122	63	-	-	0	41
Layer F	125	63	450	18	360	29

Bearing capacity for normal service conditions was based on dead plus live load whereas non-service conditions considered dead plus live load in combination with seismic loads (SSE). Groundwater level was assumed near the ground surface.

The ultimate bearing capacity of the mat foundations was computed by the Meyerhof method as presented in Reference 2.5.4.7. The capacity of the upper level of the Fuel Handling Building (FHB) was computed by the Terzaghi's method presented in Reference 2.5.4.8. Computed safety factors, tabulated in FSAR Section 2.5.4.10.2.3, for the normal service conditions ranged from 4.6 (ECP Intake Structure) to 31.3 (FHB-upper level). Safety factors for the extreme non-service conditions ranged from 2.3 (ECP Intake Structure) to 12.7 (FHB-upper level).

The design parameters, analyses and results are considered by the staff to be reasonable and acceptable. The strength of the compacted structural backfill and underlying stiff clays and dense sands are considered adequate for support of the imposed structural loads.

2.5.4.5.4 Settlement.

Design Phase. The structures are affected both by short term elastic deformation of insitu cohesionless soils and backfill and long term consolidation settlement of cohesive material. Short term deformations were considered in determining subgrade reaction coefficients for design of mat foundations and allowable bearing pressures of footings. Long term consolidation affects the deformation of the mat foundations, tilt of the various structures, and differential movements between structures. Conditions considered which would affect heave and/or settlement were (1) changes in groundwater levels due to groundwater control, (2) excavation, and (3) construction loads of various buildings and backfill. Ultimate heave values resulting from excavation were calculated by evaluating stresses from elastic half-space theory using the computer program H-SPACE (Reference 2.5.4.9.) and then computing the heave using Terzaghi's theory of one-dimensional consolidation. Ultimate heave, as calculated, did not occur because the excavation did not remain open long.

Ultimate settlement values at various points within the powerplant complex were analyzed using the building layout, foundation elevations, net bearing pressures (plant load and backfill minus excavation) and with the groundwater level at the natural condition after termination of dewatering.

After the ultimate heave and ultimate settlement were computed, estimates of ground movement with time were made by adding together the time-movement histories of all the long term compressible layers considering the combined effects of both heave and settlement. The degree of consolidation or swell for clay layers was assumed to follow the Terzaghi theory of one-dimensional consolidation. For the sand layers, it was assumed that the settlement or heave occurred simultaneously with the load application.

From the design phase settlement studies and from structural design studies, settlement criteria were prepared for the plant. A comprehensive geotechnical instrumentation monitoring system was implemented during construction to measure the movement of the structures. The program consisted of an array of borehole heave points, extensometers, and structural bench marks together with piezometers and pore pressure cells for groundwater observations in the plant areas. The location, description, installation, and monitoring procedures for these instruments are described in FSAR Appendix 2.5.C. Plots of active heave/settlement are shown on FSAR Figures 2.5.C-9 through 2.5.C-10A for the time from start of construction until 1983. Results are summarized in Table 2.5.4.8.

TABLE 2.5.4.8

MEASURED MOVEMENTS - 1975 to 1983

(FROM FSAR FIGURES 2.5.C-9 THRU 2.5.C-10A)

Structure*	Heave (In.)	Recompression (In.)	Settlement (In.)
UNIT 1			
RCB	4.7	4.7	0.85
FHB	4.7	4.7	0.75
DGB	3.9	3.9	1.1
MEAB	3.8	3.8	1.5
UNIT 2			
RCB	5.5	4.3	-
FHB	5.3	4.3	-
DGB	4.3	3.6	-
MEAB	5.0	4.0	-

*Reactor Containment Building (RCB); Fuel Handling Building (FHB); Diesel Generator Building (DGB); Mechanical and Electrical Auxiliaries Building (MEAB).

Differential movements between buildings, as determined from the instrumentation system, are shown on FSAR Figures 2.5.C-11 through 2.5.C-12A and are summarized in Table 2.5.4.9. The values in Table 2.5.4.9 are maximum values which were measured from the start of monitoring. As shown on the plots, however, the differential movement between buildings as of the day of the last data (1983) is generally considerably less than the previously experienced maximum values.

TABLE 2.5.4.9

DIFFERENTIAL MOVEMENT BETWEEN BUILDINGS - To 1983

(FROM FSAR FIGURES 2.5.C-11 THROUGH 2.5.C-12A)

Buildings*	Design Criteria (in.)	Measured in. Unit 1	Unit 2
FHB vs. RCB	1.0	0.5	0.6
MEAB vs. RCB	1.0	0.4	0.4
IVC vs. RCB	1.0	0.6	0.3
MEAB vs. FHB	1.0	0.6	0.45
MEAB vs. DGB	1.0	0.35	-
IVC vs. TGB	1.5	1.0	0.15

*Reactor Containment Building (RCB); Fuel Handling Building (FHB); Mechanical and Electrical Auxiliaries Building (MEAB); Isolation Valve Cubical (IVC); Turbine Generator Building (TGB).

The measured differential movement profiles within buildings are shown on FSAR Figures 2.5.C-13A through 2.5.C-14A and are summarized in Table 2.5.4.10.

TABLE 2.5.4.10

MEASURED DIFFERENTIAL MOVEMENT as of 1983

(FROM FSAR FIGURES 2.5.C-13A THROUGH 2.5.C-14A)

Building*	Design Criteria (in.)	Measured (in.) Unit 1	Measured (in.) Unit 2
RCB	0.5	0.3	0.2
MEAB			
E-W Direction	1.0	0.6	0.4
N-S Direction	0.5	0.6	0.2
FHB			
E-W Direction	0.5	0.3	0.1
N-S Direction	1.0	0.5	0.5
DGB	0.5	0.15	-
AFST	0.75	-	-
ECW			
Intake	0.75	0.1	N-S in 1985
Discharge	0.75	0.3	N-S in 1985

*See previous tables for building identification.

As indicated in the above Tables, measured differential movements between buildings of Units 1 and 2 have been relatively small and are within the design limits established. Differential movements within the buildings are within design limits.

Reevaluation. Various construction phase re-analyses were performed between 1977 and 1983 which are discussed in detail in Appendix 2.5.C of the FSAR. These re-analyses considered the actual construction load schedule, the effect of the main cooling reservoir embankment load and water load to be applied, and results of the field monitoring program. Projections of future settlement were made using these analyses and instrument data and were checked using a consolidation model based on a compression/tension spring analogy. Results of the analyses are presented in Tables 2.5.4.11 and 2.5.4.12, and shown in FSAR Figures 2.5.C-9 through 2.5.C-10A and 2.5.4-93.

TABLE 2.5.4.11

PROJECTED MAXIMUM ANTICIPATED DIFFERENTIAL SETTLEMENTS
FROM CONSTRUCTION DAY 3400 (END OF 1984)

STRUCTURE*	ANTICIPATED SETTLEMENT - IN. Unit 1	ANTICIPATED SETTLEMENT - IN. Unit 2	DESIGN CRITERIA
RCB-FHB	LESS THAN 1/2	LESS THAN 1/2	1.0
RCB-MEAB	LESS THAN 3/4 (10A-6A)	LESS THAN 3/8 (60-59)	1.0
RCB-MEAB	LESS THAN 1/4 (11-12)	LESS THAN 1/4 (61-62)	1.0
DGB-MEAB	LESS THAN 1/4	LESS THAN 1/4	1.0

*See previous tables for building identification

TABLE 2.5.4.12
PROJECTED MAXIMUM ANTICIPATED TILT FROM CONSTRUCTION
DAY 3400 (END OF 1984)

	Unit 1		Unit 2		
STRUCTURE*	DIRECTION	MAXIMUM ANTICIPATED TILT IN.	DIRECTION	MAXIMUM ANTICIPATED TILT IN.	DESIGN CRITERIA (IN.)
RCB	N-S	LESS THAN 1/4	N-S	LESS THAN 1/4	0.5
	E-W	LESS THAN 1/4	E-W	LESS THAN 1/4	0.5
MEAB	N-S	LESS THAN 1/4	N-S	1/2	0.5
	E-W	LESS THAN 1/4	E-W	LESS THAN 1/4	1.0
FHB	N-S	LESS THAN 3/4	N-S	1"	1.0
	E-W	LESS THAN 1/2	E-W	LESS THAN 1/4	0.5
DGB	N-S	LESS THAN 1/4	N-S	LESS THAN 1/4	0.5
	E-W	LESS THAN 1/4	E-W	LESS THAN 1/4	0.5

*See previous tables for building identification

TABLE 2.5.4.11

PROJECTED MAXIMUM ANTICIPATED DIFFERENTIAL SETTLEMENTS
FROM CONSTRUCTION DAY 3400 (END OF 1984)

STRUCTURE	ANTICIPATED SETTLEMENT - IN. Unit 1	ANTICIPATED SETTLEMENT - IN. Unit 2	DESIGN CRITERIA
RCB-FHB	LESS THAN 1/2	LESS THAN 1/2	1.0
RCB-MEAB	LESS THAN 3/4 (10A-6A)	LESS THAN 3/8 (60-59)	1.0
RCB-MEAB	LESS THAN 1/4 (11-12)	LESS THAN 1/4 (61-62)	1.0
DGB-MEAB	LESS THAN 1/4	LESS THAN 1/4	1.0

TABLE 2.5.4.12 ← Differential Mat Movement
PROJECTED MAXIMUM ANTICIPATED TILT FROM CONSTRUCTION
DAY 3400 (END OF 1984)

STRUCTURE	Unit 1 DIRECTION	Unit 1 MAXIMUM ANTICIPATED ~~TILT~~ IN.	Unit 2 DIRECTION	Unit 2 MAXIMUM ANTICIPATED ~~TILT~~ IN.	DESIGN CRITERIA (IN.)
RCB	N-S	LESS THAN 1/4	N-S	LESS THAN 1/4	0.5
	E-W	LESS THAN 1/4	E-W	LESS THAN 1/4	0.5
MEAB	N-S	LESS THAN 1/4	N-S	1/2	0.5
	E-W	LESS THAN 1/4	E-W	LESS THAN 1/4	1.0
FHB	N-S	LESS THAN 3/4	N-S	1*	1.0
	E-W	LESS THAN 1/2	E-W	LESS THAN 1/4	0.5
DGB	N-S	LESS THAN 1/4	N-S	LESS THAN 1/4	0.5
	E-W	LESS THAN 1/4	E-W	LESS THAN 1/4	0.5

The design criteria for differential movement affecting piping systems are applicable after pipe connections between buildings have been made. The applicant estimated that no pipe connections would be made prior to the end of 1984 (day 3400). In the event maximum design movement is approached during plant lifetime, ample time would be available to take corrective action such as adjustment of piping and equipment supports. The applicant indicates that the NRC will be advised should differential settlement values approach the design criteria limits shown on Tables 2.5.4.11 and 2.5.4.12.

The design soil parameters, assumptions, analyses procedures and results are considered reasonable and acceptable by the staff. Results of the monitoring program for measuring actual movements indicate the structures are performing within established limits. Actual movements are beginning to stabilize and, generally, small amounts of additional movements are anticipated throughout the operational life of the structures. The buildings should be capable of functioning properly without any adverse effects from settlement or differential movement.

2.5.4.5.5 Subgrade Reaction. The coefficient of subgrade reaction, K_s, or foundation modulus, was used for structural design of mat foundations as described in FSAR Section 2.5.4.10.4. Deformation produced by contact stresses instead of displacements caused by soil consolidation were used to derive the K_s values. For evaluating contact pressures and deflected shape of the RCB's foundation mat, four load groups (vertical, internal pressures, environmental lateral, and seismic lateral) which produced the maximum overall

foundation stresses were selected for analysis. For the vertical loading and internal pressure cases, contact pressures along the soil-structure interfaces were evaluated by the three-dimensional axisymmetric analysis using the AZI-5 finite element program (Reference 2.5.4.10). For the lateral loading cases, a two-dimensional plane strain analysis using SAP IV finite element program (Reference 2.5.4.11) was performed. The finite element mesh used to represent the foundation soils is shown on FSAR Figure 2.5.4-106. Elastic moduli were determined from laboratory tests and field shear-wave velocity measurements. Static soil properties used in the analysis are provided in FSAR Table 2.5.4-32. Values of coefficients of subgrade reaction for the RCB for the various loading conditions are shown on Figures 2.5.4-109, 110, 113 and 114 of FSAR.

Coefficients of subgrade reaction of 150 $Kips/ft^3$, governed by properties of backfill, were established for short term vertical loading for the MEAB, DGB, and FHB. For long term vertical loading, predicted differential settlement values were used to determine the deflected shape of the mats.

2.5.4.5.6 Lateral Earth Pressure. Imported granular materials were used for backfill around Category I buildings. Compacted onsite soil was used for backfill at the ECP hydraulic structures. Both static and dynamic lateral earth pressures were considered.

Static. An active earth pressure coefficient, K_a, as defined from the Rankine theory (Reference 2.5.4.3), of 0.21 was used. This value was based on an effective angle of internal friction of 41 degrees for a well-graded sand backfill compacted to a relative density of 80 percent. A coefficient of at-rest earth pressure, K_0 of 0.5 was used for the granular backfill for design. (See paragraph 2.5.4.1.3). Neglecting wall friction and using an effective angle of internal friction of 41 degrees, a passive pressure coefficient, K_p, of 4.8 was computed (Rankine theory) for the compacted structural backfill. Pressures in addition to those exerted by the retained soil as a result of external loading from adjacent facilities at higher elevations were also considered. Horizontal pressure from large-area loads was considered to be uniform pressure equal to 0.35 times the vertical pressure for compacted sand backfill and 0.60 times for compacted clay backfill. A uniform area-wide surcharge load of 200 lb./sq.ft.was applied to all walls in addition to the specific, defined loads from buildings. Design curves for surcharge lateral pressures resulting from small-area and line-load sources are presented on FSAR Figure 2.5.4-115.

Dynamic. Dynamic lateral earth pressures are discussed in FSAR Appendix 3.7.A. Two methods were used to determine the dynamic lateral earth pressures, i.e., pseudostatic method (Reference 2.5.4.12 and finite element, soil-structure interaction method. The higher computed pressures by either method were used in design of the structures. Calculated dynamic earth pressures are shown on Figures in Appendix 3.7A for the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE).

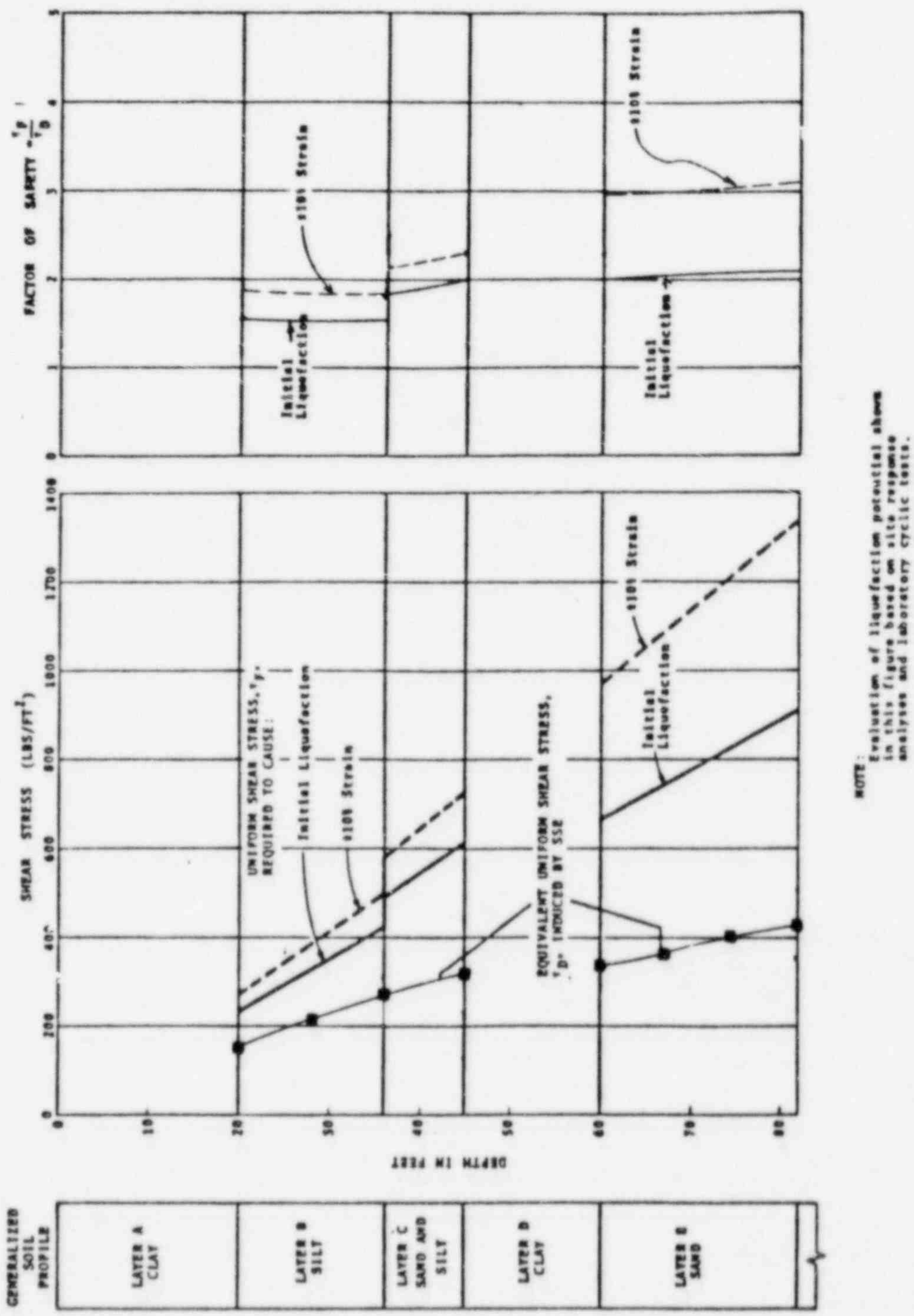
2.5.4.5.7 Seismic Considerations.

Dynamic Soil Design Parameters. The dynamic soil properties were determined from field shear-wave velocity measurements (FSAR Section 2.5.4.4) and dynamic laboratory tests (FSAR Section 2.5.4.2.8). Results of the soil-structure interaction (SSI) analyses for the Category I structures are presented in FSAR Section 3.7.2.4. Material properties utilized for horizontal earthquake excitation cases for the insitu design soil column are presented in FSAR Table 2.5.4-27. Laboratory strain-controlled, cyclic triaxial tests (FSAR Table 2.5.4-17) and resonant-column tests (FSAR Table 2.5.4-18) were performed to define the dynamic properties of the backfill material which are summarized in FSAR Table 2.5.4-26. FSAR Figure 2.5.4-87 summarizes the modulus reduction curve and the damping ratio curve for the backfill. The predominant motion for vertical excitation is due to vertically propagating compression waves. Refraction profiles showed compression-wave velocities of 5,500 ft./sec (5 to 80-ft depth) to 6,000 ft./sec (80 to 400-ft. depth).

2.5.4.5.7 Liquefaction Potential. A horizontal maximum acceleration of 0.10g was assigned for the SSE and was subsequently used for the evaluation of liquefaction potential. Within the upper 100 feet, cohesionless layers B, C, and E were evaluated using two methods: (1) simplified procedures using standard penetration test (SPT) data (Reference 2.5.4-13) and (2) direct comparison of earthquake induced stresses with cyclic strength characteristics from laboratory tests. The induced stresses were obtained from site response analyses using a computer program called SHAKE (Reference 2.5.4.14).

All SPT samples taken in the plant area to a depth of 150 feet were examined. Average relative densities (Gibbs and Holtz Method, Reference 2.5.4.15) were 85 percent in layer B, 94 percent in layer C, and 83 percent in layer E. Liquefaction potential utilizing SPT values was assessed using the recent (1983) method proposed by Seed, Idriss and Arango (Reference 2.5.4.13). Factors of safety against liquefaction, a ratio of critical cyclic stress ratio to induced cyclic stress ratio, for the insitu plant area soils are shown in FSAR Table 2.5.4-35 and ranged from 1.4 to greater than 3.8.

Site response analyses were made using seven accelerograms recorded during past earthquakes and an artificial accelerogram. The accelerograms, from recording stations with relatively deep soil profiles for earthquakes of low to moderate magnitude, produced peak accelerations close to 0.1g. The ordinates were adjusted to provide peak values equal to 0.10g. Values of maximum shear modulus used in the analyses, shown on Figure 2.5.4.5, were determined from shear-wave velocity measurements. Variation of shear modulus with strain and of damping ratio with strain were determined using field shear-wave data and laboratory cyclic test data. The response computations for the time-history of shear stresses throughout the soil profile were converted to an equivalent series of uniform stress applications by the Lee and Chan procedure (Reference 2.5.4.15). The cyclic strength characteristics of the soils in layers B, C, and E were determined from a series of 54 cyclic triaxial tests. The evaluation of liquefaction potential, shown on Figure 2.5.4.13, was based on the cyclic stress ratio (corrected by Seed procedure) required to cause initial liquefaction and 10 percent strain in five cycles.



FROM FSAR FIGURE 2.5.4-123
AMENDMENT 36.

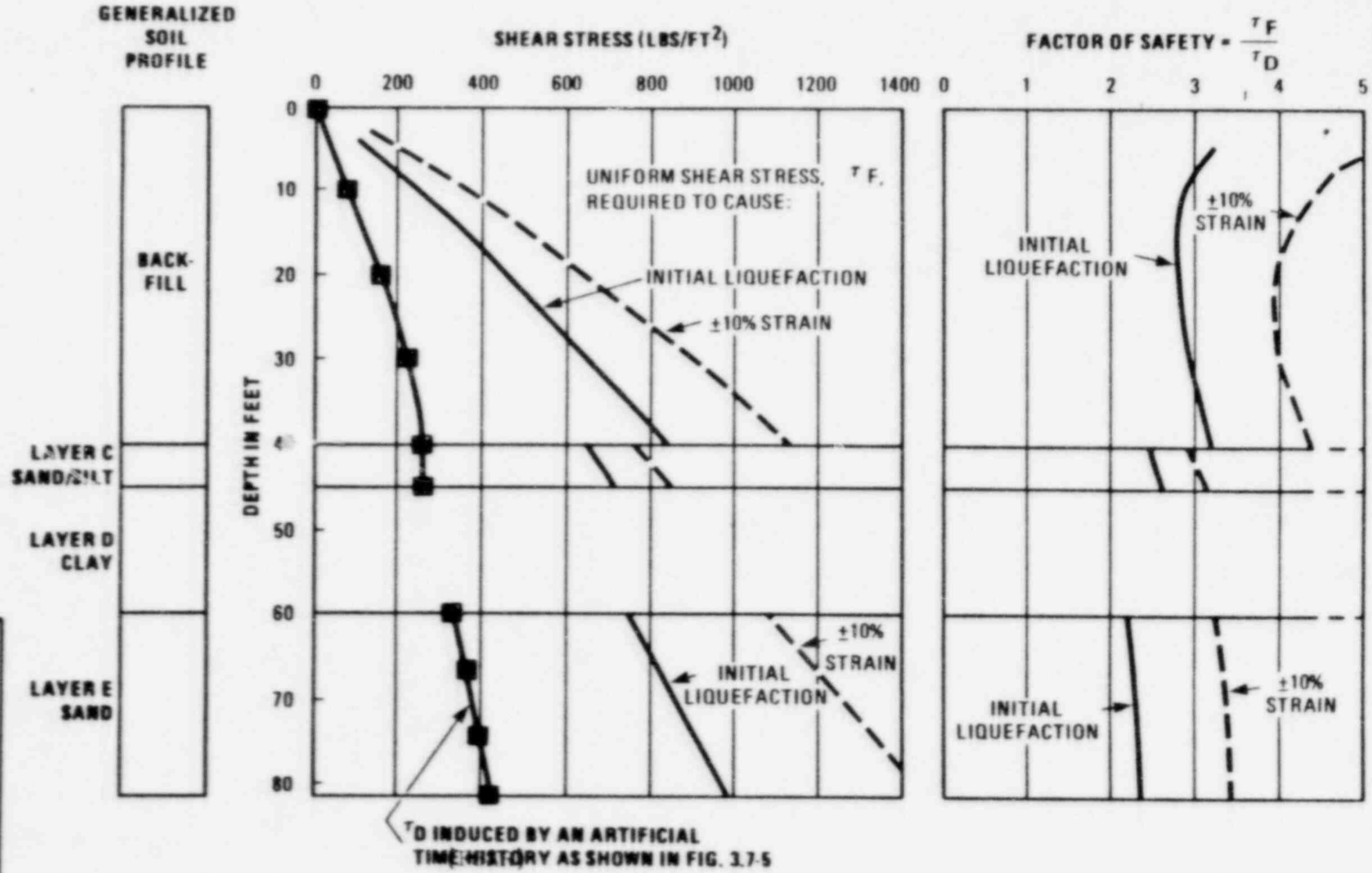
SOUTH TEXAS PROJECT
UNITS 1 & 2

LIQUEFACTION POTENTIAL IN PLANT AREA

FIGURE 2.5.4.13

FROM FSAR FIGURE 2.5.4-126
AMENDMENT 36

65



NOTE:
EVALUATION OF LIQUEFACTION POTENTIAL SHOWN IN THIS FIGURE BASED ON SITE RESPONSE ANALYSIS AND LABORATORY CYCLIC TESTS.

SOUTH TEXAS PROJECT UNITS 1 & 2

LIQUEFACTION POTENTIAL IN PLANT AREA (IN-SITU SOIL WITH TOP 40ft REPLACED BY COMPACTED STRUCTURAL BACKFILL)

FIGURE 2.5.4.14

Minimum factors of safety in the respective layers are as follows:

Layer	Typical Depth Range (ft.)	Minimum Factor of Safety: Initial Liquefaction	Minimum Factor of Safety: 10 Percent Strain
B	20 to 36	1.5	1.8
C	36 to 45	1.8	2.2
E	60 to 82	2.1	3.0

The liquefaction potential of the structural backfill was evaluated by the same two methods. SPT data on the structural backfill at the plant site are plotted versus depth on FSAR Figure 2.5.4-125. Results of the analyses are shown in FSAR Table 2.5.4-35 with a minimum factor of safety in excess of 3.0. The liquefaction potential of the backfill at a relative density of 80 percent was also evaluated by comparing the stresses induced by the SSE (response analyses) with the stresses required to cause initial liquefaction and 10 percent strain as shown on Figure 2.5.4.14.

The liquefaction potential of the structural backfill used for embedment of the ECW pipes evaluated (Seed Method Reference 2.5.4.16) at 70 percent relative density resulted in a computed factor of safety of 2.1 or greater. The factor of safety at 45 percent relative density was found to be 1.3. Construction specifications required at least 70 percent relative density.

The evaluation of liquefaction potential for the plant area insitu soils, structural backfill, and ECW pipe embedment material are considered by the staff to be in accordance with the state-of-the-art. The staff concurs with the applicant's conclusion that these materials are sufficiently resistant to liquefaction under SSE conditions.

2.5.4.5.8 Conclusions. Based on the applicant's field investigations, field and laboratory tests, design criteria, design analyses, construction data, and field monitoring data, it is concluded by the staff that the foundations for the power block structures, ECW structures and pipelines, and electrical duct banks will provide adequate support for these structures under both static and dynamic (SSE) loading conditions.

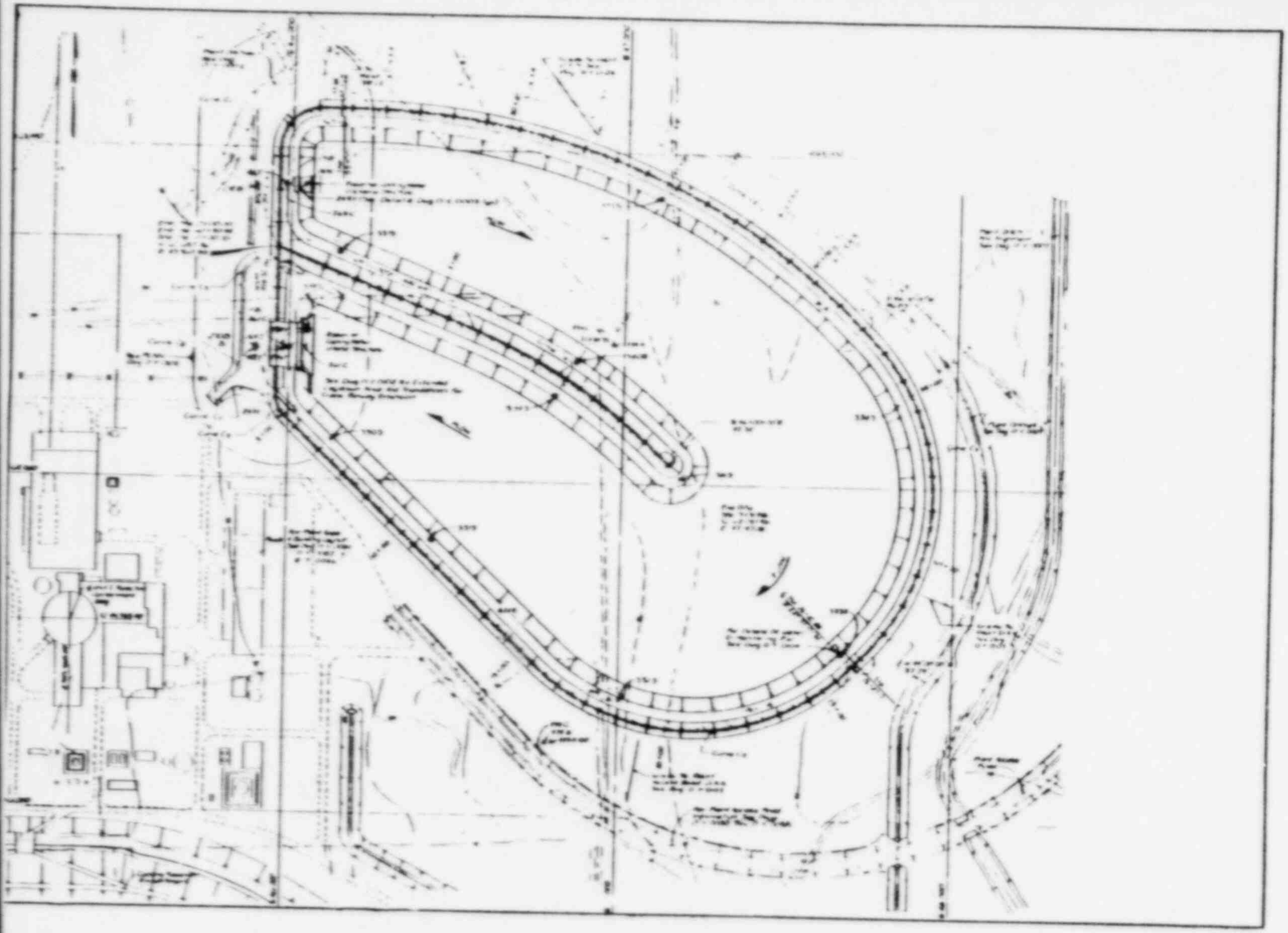
2.5.5 STABILITY OF SLOPES

2.5.5.1 Scope of Safety Evaluation. The shallow excavation slopes and low dikes for the Essential Cooling Pond (ECP) are the only permanent earthen slopes for Category I nuclear plant facilities. The safety evaluation of the ECP dikes and excavation slopes are presented in this section. The safety evaluation of the Main Cooling Reservoir (MCR) and ECP embankments are presented in Section 2.5.6 of this SER.

2.5.5.2 Slope and Soil Characteristics (Essential Cooling Pond). The 1 vertical on 5 horizontal excavation slopes for the pond are 9 feet high (elevation +26 to elevation +17) and are protected by a 1.25 foot thick soil-cement facing. An earth embankment totaling 6,200 feet in length was constructed around the pond perimeter to provide an 8 foot high freeboard for wave runup and to retain water during periods in which heavy precipitation would raise the water level. Normal operating level, is elevation +26.0. The Category I portion of the embankment was protected with a concrete facing as shown in Plan on Figure 2.5.5.1 and in Section on Figure 2.5.5.2.

The field investigation for the slopes of the ECP, obtained during the design phase, consisted of 43 borings. For slope stability studies, the soils in the upper 20 feet were of primary interest. These soils are predominantly overconsolidated clays with random slickensides and partly healed desiccation cracks. In the upper 5 feet, the clays are medium stiff to very stiff and of high plasticity. Below 5 feet, the clays are stiff to very stiff and of medium to high plasticity.

2.5.5.3 Stability Analyses. Slope stability analyses were made for static, earthquake and rapid drawdown conditions for the perimeter dike, the center dike, the excavated pond slope, and the combined dike and pond slope. For both static and pseudostatic analyses, the slopes were analyzed by the modified Bishop circular-arc method. Checks of wedge and other noncircular surfaces were also made with the Morgenstern-Price method and the lowest factor



LEGEND:

- △ PIEZOMETER RISER PIPE
- BORE HOLE HEAVE POINT
- BENCH MARK VERTICAL CONTROL ONLY
- BENCH MARK VERTICAL CONTROL AND RANGE MARKER
- SAFETY-RELATED EMBANKMENT

NOTES:

1 FOR EMBANKMENT SECTIONS SEE FIGURE 2.5.5.2

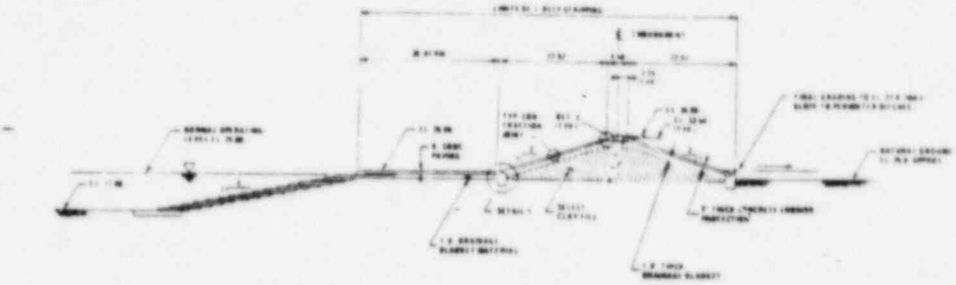
FROM FSAR FIGURE 2.5.6-12
AMENDMENT 20

500 400 300 200 100 0 500 1000
SCALE IN FEET

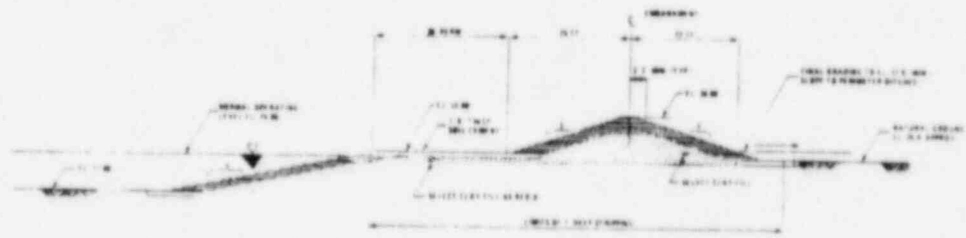
SOUTH TEXAS PROJECT
UNITS 1 & 2

ESSENTIAL COOLING POND LAYOUT

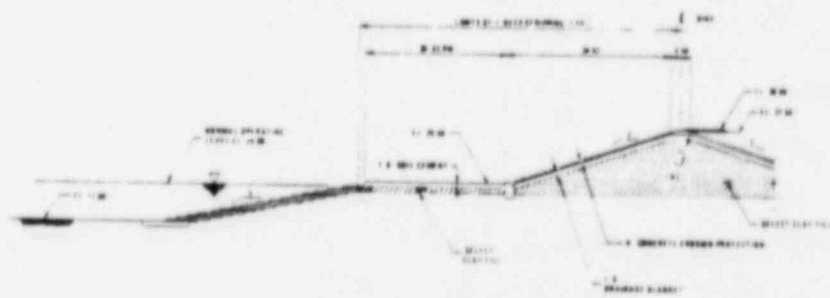
FIGURE 2.5.5.1



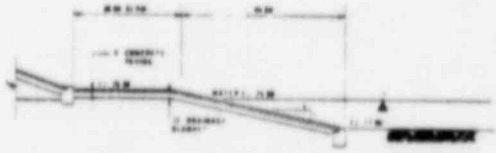
TYPICAL SAFETY-RELATED EMBANKMENT SECTION



TYPICAL NON-SAFETY RELATED EMBANKMENT SECTION



TYPICAL DIKE SECTION



TYPICAL 5:1 SLOPE WITH CONCRETE PAVING PROTECTION AT INTAKE & DISCHARGE STRUCTURES

FROM FSAR FIGURE 2.5.6-13
AMENDMENT 26

SOUTH TEXAS PROJECT
UNITS 1 & 2

ESSENTIAL COOLING POND

SECTIONS AND DETAILS

FIGURE 2.5.5.2

of safety was found. Soil strength parameters used in the analyses are summarized in Table 2.5.5-1 of the FSAR. The strength parameters were determined from consolidated-undrained (CU) triaxial tests from undisturbed insitu samples and undisturbed samples from the ECP embankment. The computed factors of safety are compared to the acceptable factors of safety for the conditions analyzed and tabulated in Table 2.5.5-2 of the FSAR. In all cases the computed factors of safety equaled or exceeded acceptable values.

An analysis was also made of the pore water pressures that might develop in cohesionless soil layers at the ECP during an SSE and of the effect of the pore pressures on the post-earthquake stability of the dikes and slopes. The analysis indicated that excess pore pressures would be very small and any tendency for strain in the cohesionless layers following an SSE would be accompanied by a tendency for dilation which would immediately dissipate the excess pore pressure. In addition, a static slope stability analysis was made for the assumption of an increase in pore water pressure equal to 0.25 in cohesionless soil layers. Results showed that potential sliding surfaces were in clay layers above a depth of 5 feet and did not pass through the cohesionless layers. Therefore, the minimum factors of safety for the dikes and slopes were unaffected by the assumed increase in pore pressure.

2.5.5.4 Conclusions. The design parameters and methods of analyses are considered by the staff to be reasonable and acceptable. The ECP slopes will remain stable under both static and seismic loading conditions. Liquefaction potential at the ECP site is discussed in Section 2.5.6 of this SER.

2.5.6 EMBANKMENTS AND DAMS

2.5.6.1 General Description.

Main Cooling Reservoir (MCR): The MCR, shown on Figure 2.5.6.1, will be used to dissipate the excess heat from the circulating cooling water. Principal features consist of the reservoir embankment, interior dikes, a spillway and discharge channel, blowdown system, makeup pump station, and circulating water intake and discharge system. Although designed to withstand the Safe Shutdown Earthquake (SSE) and Probable Maximum Flood (PMF), the MCR is not a Category I structure. The MCR embankment is approximately 65,500 feet long and totally encloses an area of 7,000 acres. The 38-to 50-foot high embankment had a design crest elevation which varied between El. 65.75 feet and 67 feet MSL. Minimum water surface operating level is El. 25.5 MSL and normal maximum operating level is El. 49 MSL. Probable maximum flood level within the MCR is El. 52.1 MSL. The spillway system basically consists of a ogee-type spillway, slide gates, a stilling basin and a discharge channel. The blowdown system consists of an intake, a 7,370-foot long, prestressed concrete pipe and seven blowdown discharge ports. The makeup system consists of a pump station on the Colorado River, associated pipes and an energy dissipator in the MCR.

Essential Cooling Pond (ECP): The ECP is utilized as a source of cooling water for safe plant shutdown and as the normal heat sink for plant auxiliaries. The ECP covers 45.6 acres at natural ground EL.25 feet and 40 acres at EL. 17 feet. The embankment surrounding the ECP is 6,050 feet long with crest elevation of 34 feet. The ECP is normally supplied with water from the MCR but also has an emergency backup from wells. Location and

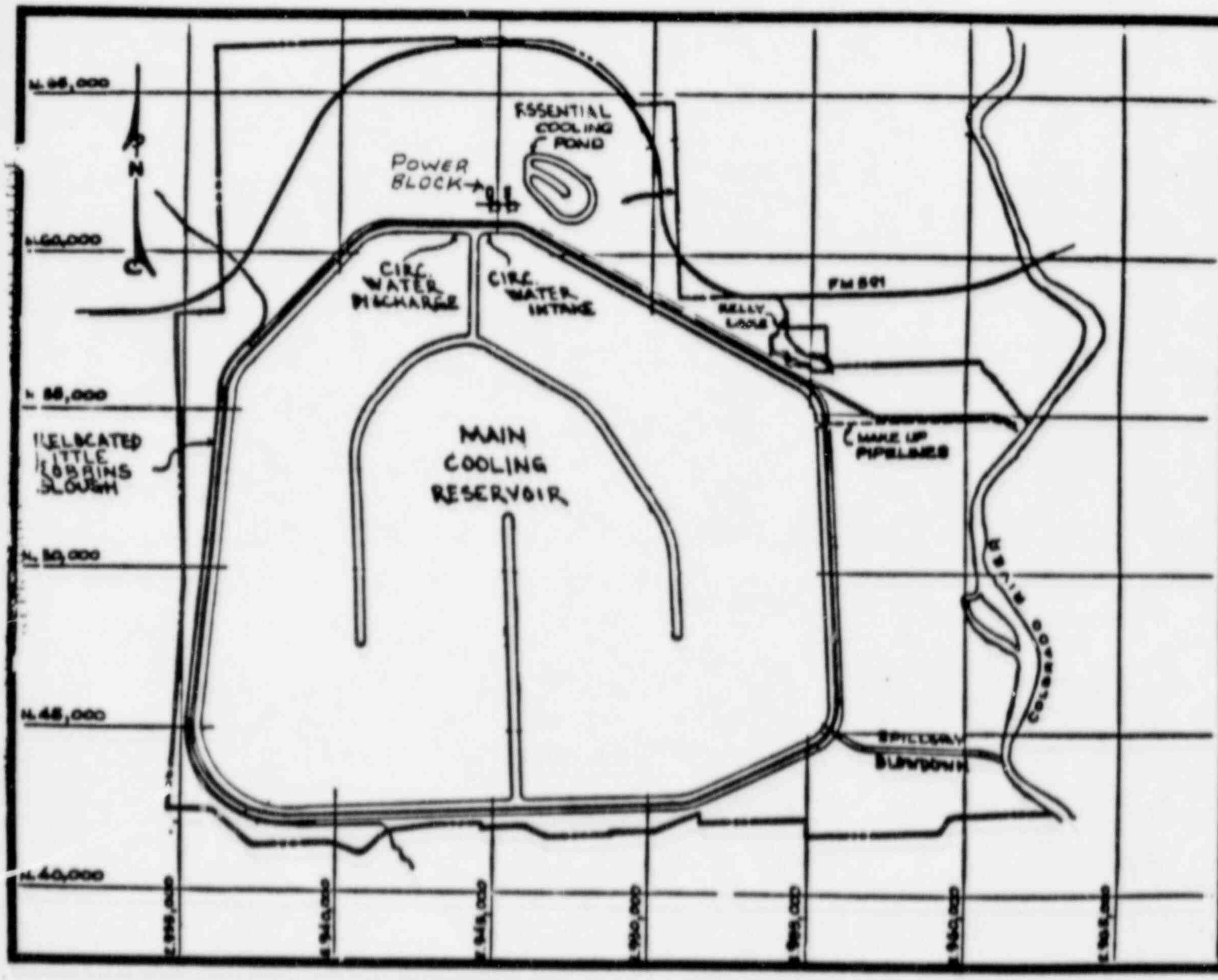
configuration of the ECP and MCR are shown on Figure 2.5.6.1.

2.5.6.2 Explorations. Geologic and seismologic conditions are described in FSAR Section 2.5. Results of the foundation verification and geologic mapping of the ECP are presented in FSAR Appendix 2.5.A and 2.5.B.

Main Cooling Reservoir. Subsurface conditions along the MCR embankment centerline were determined from borings 30 to 80 feet deep at 500-foot intervals and at 1,000-foot intervals along the interior dikes. Three-inch diameter, thin-wall tube samples (ASTM D 1587-67) were obtained in the clay soils and samples of granular soils were obtained with a 2-inch split-barrel sampler (ASTM D 1586-67). An additional 52 undisturbed sample borings were made at the sites of appurtenant facilities. A total of 91 undisturbed borings, supplemented by 34 auger borings, were drilled for borrow area studies and 40 undisturbed sample borings were obtained in the reservoir area.

Laboratory tests conducted for design included unconfined compression, triaxial compression, direct shear, consolidation, compaction, dispersion, constant volume swell, permeability, water content, density, Atterburg limits, and grain size. Results of the field and laboratory data show the foundation soils to be predominantly stiff to hard clays and medium-dense to dense sands. The soils to 80-foot depth were divided into 5 generalized strata as shown on Figure 2.5.6.2.

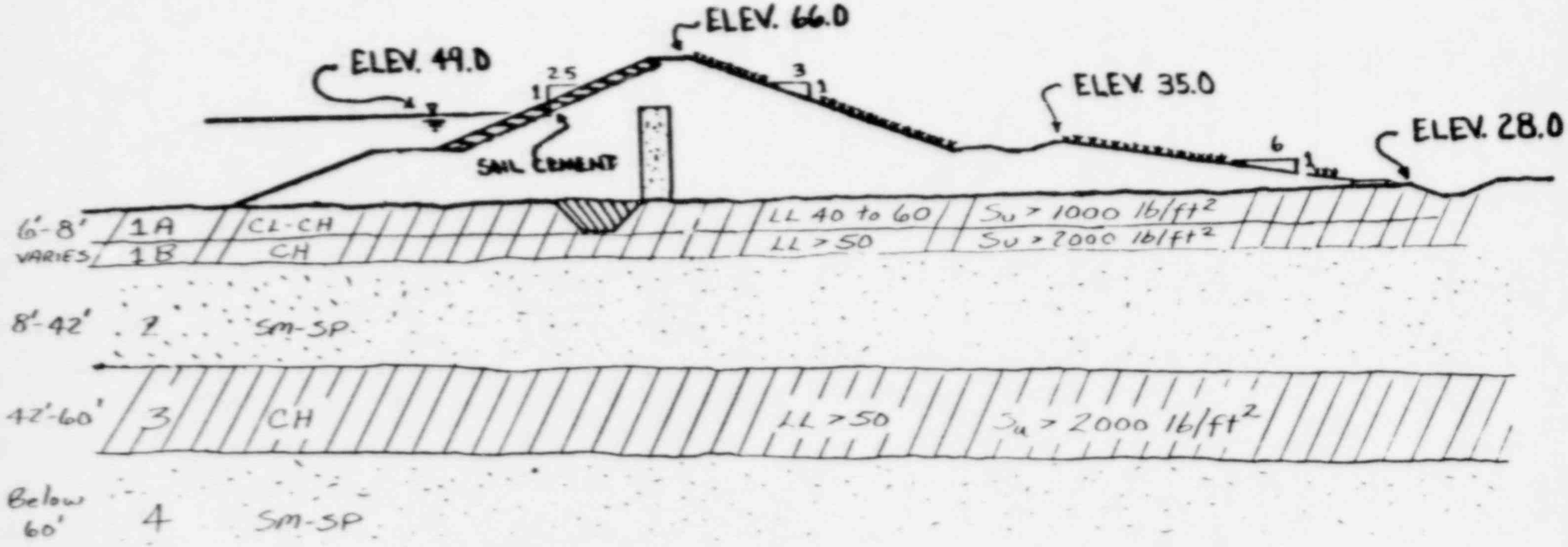
STP SITE



SOUTH TEXAS PROJECT
UNITS 1 & 2

MCR AND ECP
SITE LAYOUT

FIGURE 2.5.6.1



FOUNDATION SOILS (MCR)

FIGURE 2.5.6.2

Essential Cooling Pond. Forty-three borings, to a maximum depth of 110 feet, were made in the ECP area to obtain thin-wall tube samples (ASTM D 1587-67) and standard penetration tests (ASTM D 1586-67). Electric logs were obtained for all but two of these borings. Sixteen test pits were also excavated to depths ranging from 6 to 13 feet. Some undisturbed samples of cohesionless soils were obtained with a Hvorslev-type stationary piston sampler for cyclic triaxial and relative density tests. Laboratory tests consisted of grain size analysis, specific gravity, moisture content, unit weight, Atterburg limits, and static and cyclic triaxial tests. Results of the field and laboratory data indicate the soils to be alternating layers of cohesive and cohesionless deposits similar to the plant area. Conditions encountered during construction are described in FSAR Appendix 2.5.A and Appendix 2.5.B.

The field exploration and laboratory testing program are considered by the staff to be reasonable and acceptable for defining the foundation conditions at the MCR and ECP and the engineering properties of embankment materials. Foundation verification and geologic mapping during construction for the ECP basically verified the design conditions. Subsequent drilling and testing, described in paragraph 2.5.6.4.3 of this SER, likewise, tended to verify the design conditions for the MCR.

2.5.6.3 Foundation Treatment.

Main Cooling Reservoir. After clearing of all trees, stumps, and brush, the surface soils were scarified to a depth of at least 9 inches and compacted to at least 95 percent maximum density (ASTM D 698-70). Excluding the areas beneath the berms, cohesive foundation soils with shear strengths less than

1,000 lb/ft^2 were removed and replaced with compacted CL-CH clays. A 10-foot wide inspection trench, 5 to 10 feet deep, was excavated to permit continuous examination of soil conditions beneath the embankment. Construction specifications for the MCR earthwork are in Reference 2.5.6.1.

Essential Cooling Pond. Stripping to a depth of 1-foot was accomplished to remove all topsoil, organic matter and similar deposits along the embankment alignment. Any silty or sandy soil within 2 feet below design subgrade elevation was excavated and replaced with compacted (CH, CL) as described in FSAR Appendix 2.5.A. Insitu soil subgrade was scarified to a depth of 6 in. and compacted. Earthwork design and construction for the ECP are described in Reference 2.5.6.2.

2.5.6.4 Embankments and Dikes

2.5.6.4.1 Essential Cooling Pond.

Source and Characteristics of Borrow Material. The embankment and dike were constructed of soils from the pond excavation within the clay layer located about 5 feet below the ground surface. The surface soils at the site are predominantly high plasticity clays (CH) that extend to an average depth of 20 feet. The upper 5 feet of clay are generally dark gray to black - below 5 feet, the clay changes to reddish-brown in color. Sand for soil-cement was obtained from Borrow sources A and B as described for the main cooling reservoir embankment.

Embankment and Interior Dike Cross-Sections. Typical cross-sections for the embankment and dike are shown on Figure 2.5.5.2. The embankment and interior dike have a crest height of approximately 9 and 13 feet, respectively, above the original ground surface. The select clay fill has a minimum liquid of 30 and a plasticity index of at least 10. Sand for the drainage blanket conformed to the requirements of Category I structural backfill as described in paragraph 2.5.4.3 of this SER. Slope protection for the south and west Category I embankment sections and interior berm, the interior dike and berms, and local areas of the slope of the pond excavation adjacent to intake and discharge structures is provided by 6 inches of reinforced concrete. Slope protection for the interior berm of the embankment and pond excavation consists of a 1.25-foot thick layer of soil-cement. Soil-cement consisted of sand excavated from stratum 2 mixed with approximately 12 percent cement by weight. Gradation of the sand was as follows:

Sieve Size	Percent Passing
1"	100
No. 4	80-100
No. 200	5-35

Placement. The select clay fill was placed and spread in layers not more than 6 inches thick after compaction and compacted with sheepsfoot rollers to a density of at least 80 percent but not more than 95 percent of Modified Proctor Compaction (ASTM D 1557). Moisture content was established as +3 percent to +8 percent of optimum. The density and moisture criteria were

established to minimize swell potential that could possibly affect the concrete slope protection. Placement and testing data are presented in Reference 2.5.6.2. A geotechnical verification program of the compacted embankment soils is presented in Reference 2.5.6.3.

Settlement. Ultimate settlement for the ECP embankment and dike was estimated to be within the range of 1 to 2 inches.

Slope Stability. The embankment, dike, and cut slopes were analyzed by the circular-arc method. Wedge and other noncircular sliding surfaces were evaluated to verify the lowest factor of safety obtained from a circular failure mode. Strength parameters selected for the embankments and foundation are presented in Section 2.5.5. Specific conditions that were analyzed were: (1) Static, (2) Earthquake using pseudostatic coefficient of 0.1g, (3) postearthquake assuming 25 percent increase in pore pressure in the sandy and silty layers, (4) flood conditions assuming an equivalent static lateral force of 7.0 kips/linear foot, and (5) sudden drawdown. For slopes of the embankment and central dike, drawdown was assumed from El. 34 feet MSL to normal operating pool level El. 26 feet MSL which assumes occurrence of flooding from the postulated main cooling reservoir embankment breach. Analysis for the flood condition was based on the lateral force acting on the southern face of the embankment above the final adjacent grade at El. 26.0. The critical failure surfaces for the various conditions analyzed are shown on Figures 2.5.5-1 thru 2.5.5.1-B of FSAR Section 2.5. Computed safety factors,

are shown in FSAR Table 2.5.5-2.

Seepage Control. A shallow aquifer zone generally extends from the ground surface to a depth of 90 to 150 feet. Pervious layers are separated by a clay layer into an upper and lower section with the ECP extending into the upper section. Any silty or sandy soil encountered in the ECP excavation or below berms or dikes was removed to a depth of at least 2 feet below design grade and replaced with compacted clay (CH,CL) material to separate the sand from the aquifer.

Sealed standpipe piezometers were installed at three depths before construction started. Tips are located in clayey silt at 15 foot depth, in fine sand at 33 feet, and in fine and medium sand at 70 feet. Silt layers within the surface clays and the fine sand layer have a piezometric level varying between 0 and 4 feet below ground surface. The deeper sand layer has an artesian head and piezometric levels varying from 6 to 11 feet below ground surface.

On the basis of a normal pond level at El. 25 feet MSL and a low groundwater table outside the pond at El. 17 feet, MSL seepage through the bottom of the ECP was estimated to be approximately 1.2 ft^3/sec.

Liquefaction Potential. Soil conditions at the ECP are generally similar to conditions encountered at the plant.

The applicant's procedures for evaluating liquefaction potential of the ECP were the same as those used in the evaluation of the plant power block area. Analysis were performed based on the free field condition-of the insitu soil profile with the removal of the upper 8 feet of soil within the pond. The average relative density of sand between depths of 20 feet and 46 feet at the ECP was 91 percent (compared to 85 percent in layer B and 94 percent in layer C at the plant). At a depth of 55 feet to 91 feet, the average relative density was 88 percent at the ECP compared to 83 percent in layer E at the plant.

Results of the liquefaction potential analysis based on the use of standard penetration tests are presented in FSAR Table 2.5.4-35 indicating a minimum factor of safety of 1.4.

The variation of induced shear stress with depth within the ECP, obtained from response analysis using artificial accelerogram, is shown on FSAR Figure 2.5.4-124. The cyclic strength characteristics of cohesionless soils were determined from 28 cyclic triaxial tests. The shear stress to cause initial liquefaction and 10 percent strain are also plotted on FSAR Figure 2.5.4-124. The minimum factor of safety for initial liquefaction was 1.6 and the minimum for 10 percent strain was 2.2.

The analysis performed was for free field conditions that exist within and adjacent to the ECP. The overall effect of the dikes and slopes will be to increase to some degree the factors of safety against liquefaction as compared to free field values.

Conclusions. The staff concludes that the ECP embankment and dike are low earthen structures founded on competent foundations as indicated in the design investigations and later verified during construction. Studies were performed to evaluate slope stability under static and dynamic loading conditions, liquefaction potential, and seepage conditions. Adequate margins of safety were obtained for stability and potential liquefaction and adequate measures were included for control of seepage for the heads which are expected. Slope and embankment protection, in the form of reinforced concrete or soil-cement, is considered to provide adequate protection. Instrumentation consisting of piezometers and benchmarks are available for monitoring conditions throughout the life of the facilities. Design, construction and planned operational aspects of the ECP embankment and dike are also considered adequate. With proper inspection, monitoring and maintenance, the embankment and dikes should perform satisfactorily without developing any adverse conditions which would affect the safety or safe operation of the plant facilities. If problems develop, a system of deep wells is available as a secondary makeup system for the ECP.

2.5.6.4.2 Main Cooling Reservoir

Source and Characteristics of Borrow Material. The embankment and dikes were constructed of onsite clay soils from strata 1a, 1b and 3 and of onsite sand from stratum 2 (sand sources A and B). Locations of these borrow sources are shown on FSAR Figure 2.5.6.-14. Sand source A, generally at a depth of 8 to 25 feet below ground surface, contained between 10 and 25 percent (average 11 to 12 percent) material passing the no. 200 sieve. Sand source B, 8 to 35

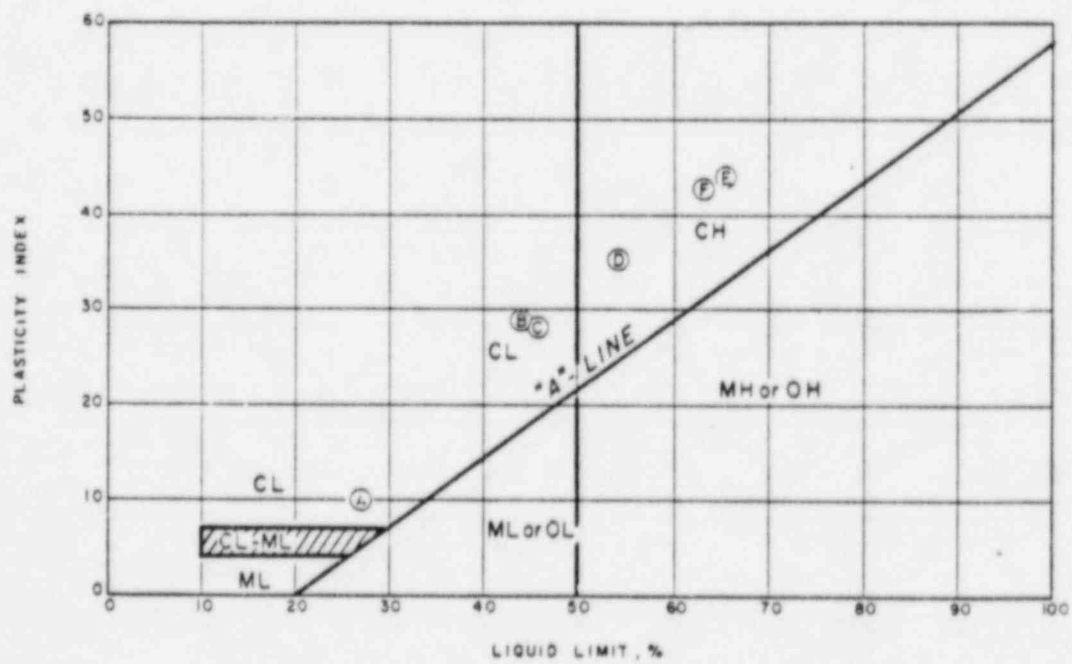
feet below ground surface, contained 10 to 40 percent passing the no. 200 sieve (average 14 to 15 percent). Permeability of the sand for the sand core and blanket varied from 8.2×10^{4} cm/sec to 4.1×10^{-3} cm/sec. Borrow characteristics, determined from lab tests, are presented in Reference 2.5.6.4 and shown on Figure 2.5.6.3.

Embankment and Interior Dike Cross-Section. Typical cross-sections for the main embankment and interior dikes are shown on Figure 2.5.6.4. Three embankment sections (type A, B, and C) were utilized depending upon pore pressures developed in the underlying soils and fill as the embankment was raised. Type A and C embankment sections have an interior berm 20 feet wide where pore pressure increase is less than 25 percent of the embankment loading. For type A and C sections the width was 35 and 45 feet, respectively, for pore pressures in excess of 25 percent. All type embankments have an exterior berm varying in width from 33 to 48 feet.

The clays used in the embankment were assumed to be dispersive and a vertical silty sand core (filter) was constructed to provide material to granular interrupt any potential pinhole seepage paths. The 10-foot wide sand core extended the full length of the embankment from ground surface to El. 50 feet MSL.

A horizontal sand drainage blanket and collector pipe were included in the type A embankment where the granular soils of stratum 2 are either nonexistent or irregular. The horizontal blanket was provided to prevent a potential

				Composite Laboratory Compaction Sample						
SAMPLE	Auger Boring No.	Depth, Ft. From	To	General Description	Liquid Limit	Plastic Limit	Plasticity Index	USC Class	Optimum Water Content %	Maximum Dry Density Pcf
	1475	10	20							
-	1483	6	9							
	1485	6	10							
A	1487	9	14	Tan Very Silty Clay	27	17	10	CL	13	116.4
	1490	6	12							
	1495	14	20							
	1498	8	12							
	1467	0	6	Yellowish Red Sandy Clay	44	15	29	CL	16	110.0
B	1491	5	9							
	1464	4	8.5							
	1466	0	5							
	1466	5	10							
	1467	0	5	Tan Silty Clay	45	17	28	CL	16	109.3
	1468	0	6							
C	1463	0	8							
	1475	6	10							
	1484	0	8							
	1495	0	20							
	1465	0	11							
	1486	0	6							
	1487	0	9							
D	1488	0	20	Tan Clay	54	19	35	CH	19	106.0
	1490	0	6							
	1496	0	20							
	1497	0	20							
	1464	0	4							
	1469	8	20							
	1479	0	14							
E	1480	0	14	Tan Clay	65	21	44	CH	22	102.0
	1492	0	20							
	1494	0	20							
	1493	0	20							
	1465	11	18							
F	1437	9	20	Red Clay with Shell Fragments	63	20	43	CH	22	99.4
	1471	0	20							
	1481	0	20							
	1498	0	14							

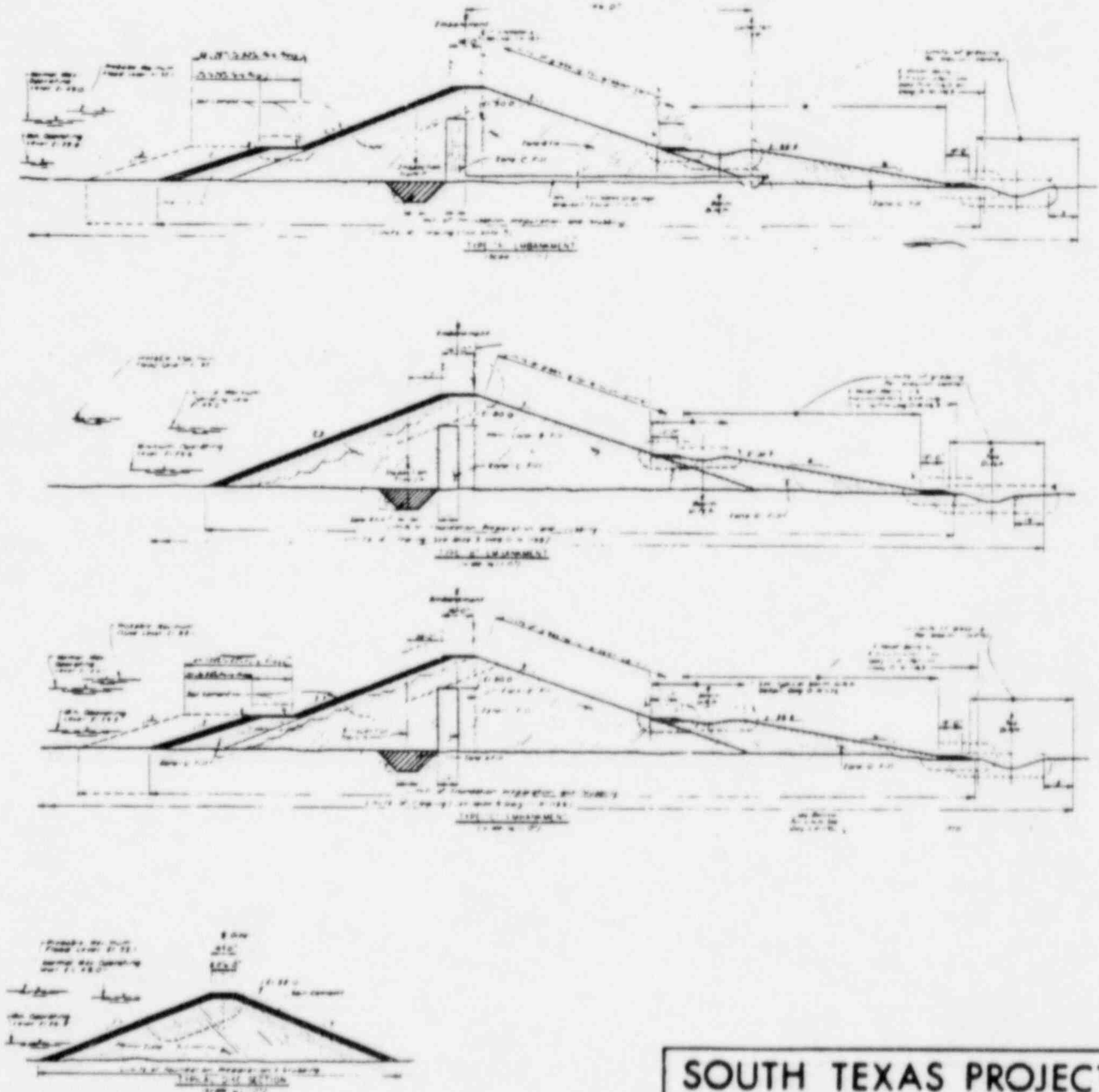


SUMMARY OF LABORATORY COMPACTION TESTS

FROM REFERENCE 2.5.6.4, VOL III

BORROW MATERIALS - DESIGN (MCR)

Figure 2.5.6.3



FROM FSAR FIGURES 2.5.6-15
AND 2.5.6-16

SOUTH TEXAS PROJECT
UNITS 1 & 2

TYPICAL CROSS SECTIONS

MCR

FIGURE NO. 2.5.6-4

"blocked exit" condition for seepage water from the reservoir.

The interior slope of the main embankment is covered with a 2.5-foot thick layer of soil cement to prevent wave erosion. Exterior slopes are grass covered. The interior dikes have side slopes of 2.5:1 and are protected with soil cement. The soil cement consisted of sand from stratum 2 mixed with approximately 12 percent cement. Gradation requirements for the sand were as follows:

Sieve Size	Percent Passing
4. in.	100
1. in	95-100
No. 4	70-100
No. 200	10-35

Six types of fill were specified for constructing the MCR embankment and interior dikes, as follows:

Type	Material	Location
Zone A	Clay, LL 40	Inspection Trench, Areas where former streams cross embankments, and at spillway
Zone B	Clay, LL 30	Embankment fill.

Zone C	Granular, % passing No. 200 sieve ≤ 35	Sand core and drainage blanket
Zone D	Zone A, B, or C material or any combination thereof	Interior dikes and all berms
Type I	ASTM C33-74 fine aggregate	Filters around collector pipes and structures.
Type II	ASTM C33-74 coarse aggregate	Filters around collector pipes and structures

Placement and Compaction. Construction specifications for MCR fill placement and compaction are in Reference 2.5.6.1. Cohesive embankment fill materials were compacted to a density which, when averaged by the moving average method, was at least 95 percent of the maximum dry density determined by the Standard Proctor Compaction Test (ASTM D 698-70). Moisture content was established at 1.5 percent below optimum to 4.5 percent above optimum (ASTM D 698-70). These materials were placed by scrapers, spread by bulldozers in layers not more than 9 inches thick after compaction and compacted by sheepsfoot rollers. The sands were compacted to an average relative density (ASTM D 2049-69) of 80 percent.

Settlement. Settlement of the embankment is due to a combination of consolidation of the foundation clays and settlement within the embankment

soils. The results of settlement studies indicated an ultimate settlement during and after construction of 1 to 2 feet. The postconstruction settlement of the embankment crest is expected to be less than 1 foot and to occur gradually over a 10-to 20-year period.

Slope Stability. Stability analysis for the main embankment and interior dikes were based on the simplified Bishop method for circular-arc failure surfaces and the Morgenstern and Price method for noncircular failure surfaces. Design conditions generally critical to the stability of an embankment and its foundation are: (1) end of construction, (2) long-term steady seepage, (3) sudden drawdown, and (4) earthquake. Minimum factors of safety adopted by the applicant were 1.3 for end of construction and 1.5 for steady seepage. Conditions 3 and 4 are discussed in Section 2.5.6.4.3.

Design Parameters. Drained-direct shear tests and triaxial compression tests were performed to determine long term strength parameters for the foundation clays. Triaxial tests on undisturbed samples, conducted with pore pressure measurements, indicated an effective angle of internal friction, ϕ, of at least 22 degrees. Peak strengths from drained direct shear tests resulted in ϕ values from approximately 15 to 43 degrees. A statistical evaluation of direct-shear results indicated a ϕ of 20.5 degrees and cohesive strength, c, of 320 lb/ft^2. Embankment clays and stratum 1a clays were analyzed for end of construction conditions on the basis of cohesive strength with no angle of

internal friction. Stratum lb and 3, however, tend to be fissured and slickensided, therefore, a conservative value of 0 was used and cohesion was neglected. Strength parameters selected for design are given in Table 2.5.6-1.

Stability at End of Construction. The total shear resistance of the slickensided clays of strata lb and 3 is a function of pore pressure response as the embankment is constructed and the piezometric level established by underseepage. The size of the interior berm was determined by assuming (1) a 0 to 25 percent pore pressure response or (2) a 50 percent pore pressure response for both the interior and exterior berms. Instrumentation was provided in the embankment and dikes during construction to measure pore pressure response. The construction plans showed an interior berm width as determined in (1) above with the provision to increase the berm width to that determined in (2) depending upon results from the instrumentation. The exterior berm width was the larger required for either end of construction or steady seepage condition. Computed factors of safety for end of construction varied from 1.3 (dike section, no berm, 50 percent pore pressure) to 1.6.

Long Term Stabilty. The critical condition for the exterior slopes is the long term stability condition. Factors of safety computed during the design phase are shown in Table 2.5.6.2 for the various berm widths.

TABLE 2.5.6-1

COOLING RESERVOIR SOIL STRENGTH PARAMETERS

			Strength			
Stratum	Material	Wet Density lb/ft3	End of Construction c, lb/ft2	, degrees	Long Term c, lb/ft2	, degrees
Embankment	Compacted Clay (CL-CH)	125	1,100	5	150	20
1a	Stiff Clay and Sandy Clay (CL-CH)	125	1,000	0	0	20
1b	Very Stiff Slickensided (CL-CH)	125	0	20	0	20
2	Sand (SM-SP)	125	0	30	0	30
3	Very Stiff Slickensided Clay (CH)	125	0	20	0	20
4	Sand (SM-SP)	125	0	30	0	30

TABLE 2.5.6.2

MAIN COOLING RESERVOIR

FACTOR OF SAFETY FOR LONG TERM STEADY SEEPAGE CONDITIONS

OF EMBANKMENT EXTERIOR SLOPES

PRE-CONSTRUCTION ANALYSES

Foundation Model	Initial Design Berm Width, ft	Computer Factor of Safety for Initial Design of Berm	Berm Width Constructed, ft
1	45	1.5	48
2	30	1.5	33
3	30	1.5	33
4	45	1.5	48
5	45	1.5	48
6	30	1.5	33

Upon commencement of the filling of the MCR, uplift pressure in sand stratum 2 will be observed and corrective measures taken if required. Such measures could consist of increasing the size of the exterior berm, adding additional relief wells, or increasing the size of the toe ditch.

Seepage Control. Surface layers, strata 1a and 1b, are clay which are underlain by a zone of granular material (stratum 2) over most of the length of the embankment. Measures to ensure that underseepage does not endanger embankment stability consisted of:

1. Restrictions on excavation near the embankment which could expose the sands of stratum 2 to the reservoir head.

2. Installation of relief wells to control seepage pressures.

3. Provision of a drainage blanket to intercept seepage in areas where stratum 2 does not occur as a thick, continuous zone causing the relief wells to be ineffective.

Restrictions on Excavation. The methods and results of seepage entrance and seepage exit studies were published in Reference 2.5.6-14. The designated borrow areas within the MCR area had boundaries such that clay borrow was not permitted within 800 feet of the toe of the embankment slope nor sand borrow within 1,200 feet. Similar limitations were placed on excavation for the sedimentation basins. For the circulating water intake and discharge channel

where no such limitations could be placed, the portion of channel within 500 feet of the embankment toe was overexcavated 10 feet (where normal excavation extended to within 10 feet or less of the top of stratum 2) and replaced with a 10-foot thick compacted clay blanket.

Relief Wells. A relative measure of safety against uplift or piping at the toe of an embankment underlain by a pervious substratum is the exit gradient. An exit gradient of 0.8 to 1.0 could result in heave of the top stratum or sand boils with possible piping. Criteria established for relief well design were as follows: (1) reduce computed exit gradient to 0.5 or less, (2) install piezometers to monitor pressures in stratum 2, (3) intercept at least 50 percent of ground seepage and (4) lower piezometric elevation at midpoint between relief wells opposite plant area structures below El. 27.0 feet MSL. Based on these criteria, 669 wells were installed with a minimum and maximum spacing of 40 feet and 200 feet, respectively. Well locations are shown on FSAR Figure 2.5.6-19,.

Drainage Blankets. The granular soils of stratum 2 are either nonexistent or irregular along some reaches of the embankment, indicating a potential "blocked exit" condition could occur. This condition could allow the reservoir head to occur in fingers of confined sand near the toe of the slope which could result in unexpected heave of the toe or piping. Where this potential condition exists, a horizontal sand blanket was provided, as shown on Figure 2.5.6.4, to relieve pore water pressures.

2.5.6.4.3. Reevaluation of Completed Main Cooling Reservoir.

General. To satisfy the provisions of Regulatory Guide 1.59, Rev. 0, in effect at the time the STP Construction Permit was docketed, an instantaneous non-mechanistic breach of the embankment was postulated to determine flood levels due to the MCR. This postulated breach, discussed in FSAR Section 2.4, consisted of the instantaneous removal, or breach, of a 2,000-foot long section of the embankment. Flood protection design of the south, west, and east sides of safety-related structures and components, including the ECP, were based on the most critical effects of this breach. Issuance of Rev. 2 of Regulatory Guide 1.59 changed Appendix A of the guide to ANSI N170 for guidelines on postulation of events producing the Design Basis Flood. ANSI N170 suggested evaluation of the effects of scour and erosion caused by a postulated breach. The applicant chose to make an evaluation of the integrity of the segment of the MCR embankment facing the safety-related plant structures rather than an assessment of scour effects on the plant.

After Bechtel assumed Architect/Engineer responsibilities for the STP, the following items were studied in a review of the condition of the completed MCR.

(1) Stability of the as-built embankment under design loading conditions.

(2) Dispersive potential of embankment clays and the effect of the sand core and drainage blanket on embankment stability.

(3) Pipe and structural penetrations through the embankment.

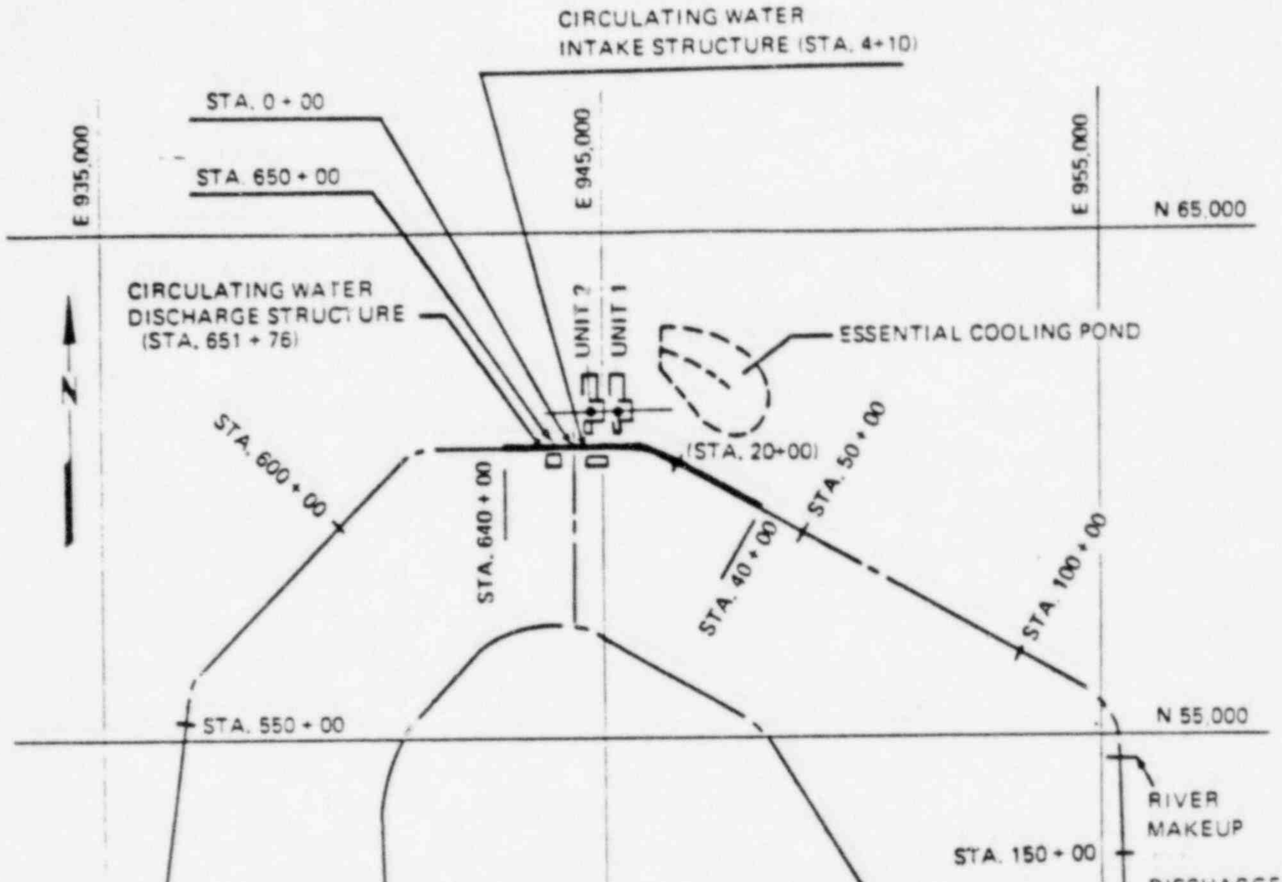
(4) Underseepage monitoring and control measures.

(5) Potential for embankment overtopping during the Probable Maximum Flood (PMF) and erosion potential during a flood external to the MCR.

(6) Construction quality of the as-built embankment.

To assist in the reevaluation of the completed MCR embankment and resolution of several of these items, Bechtel retained a Consulting Review Board (CRB). Emphasis was placed on the embankment section between stations 640+00 to 655+00 and 0+00 to 40+00 (See Figure 2.5.6.5) due to its proximity to the STP safety-related structures. During a meeting (Reference 2.5.6.5), it was indicated that an embankment breach outside this section would not effect the safety-related structures. Each of the 6 above mentioned review items are discussed in the following paragraphs.

Stability of As-Built Embankment. Stability analyses were performed based on strength parameters established for the initial design. Additional field investigations (See Figure 2.5.6.6) and soil testing were performed to verify



OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5)

MAIN COOLING
RESERVOIR
KEY PLAN
FIGURE 2.5.6.5

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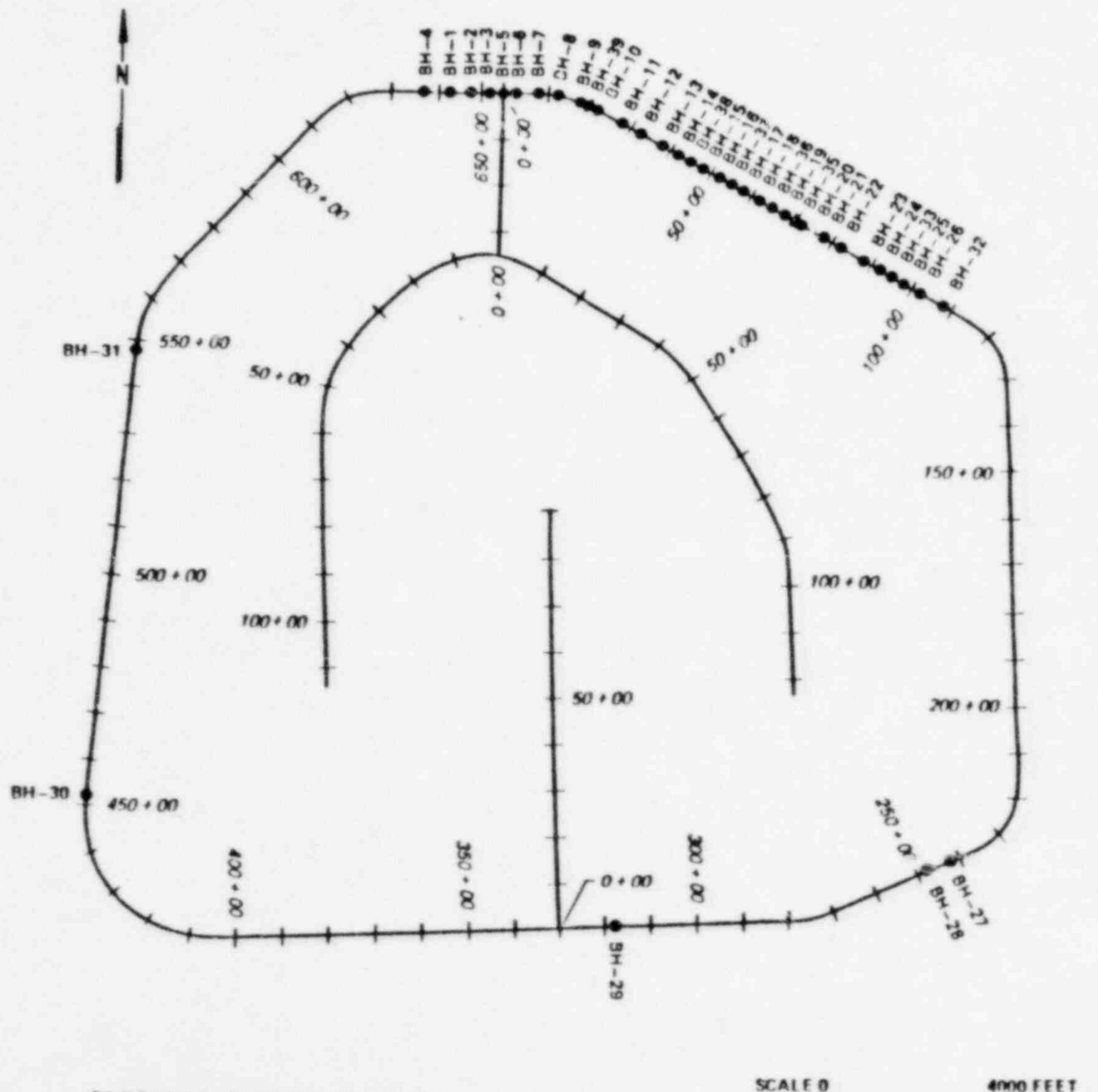


BOREHOLE No.	STATION	LOCATION
BH-1	642 + 50	D/S
BH-2	647 + 50	CREST
BH-3	652 + 50	U/S
BH-4	637 + 50	D/S
BH-5	0 + 00	D/S
BH-6	2 + 50	U/S
BH-7	7 + 50	CREST
BH-8	12 + 50	D/S
BH-9	17 + 50	U/S
BH-10	22 + 50	D/S
BH-11	27 + 50	CREST
BH-12	32 + 50	U/S
BH-13	37 + 50	D/S
BH-14	42 + 50	U/S
BH-15	47 + 50	D/S
BH-16	52 + 50	U/S
BH-17	57 + 50	D/S
BH-18	62 + 50	U/S
BH-19	67 + 50	D/S
BH-20	72 + 50	U/S
BH-21	77 + 50	D/S
BH-22	82 + 50	U/S
BH-23	87 + 50	D/S
BH-24	92 + 50	U/S
BH-25	97 + 50	D/S
BH-26	102 + 50	U/S
BH-27	242 + 50	CREST
BH-28	247 + 50	D/S
BH-29	317 + 50	D/S
BH-30	452 + 50	D/S
BH-31	547 + 50	CREST
BH-32	107 + 50	U/S
BH-33	96 + 25	D/S
BH-35	71 + 25	U/S
BH-36	66 + 25	D/S
BH-37	56 + 25	U/S
BH-38	46 + 75	D/S
BH-39	20 + 00	CREST

OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5

CONFIRMATORY PROGRAM BOREHOLE LOCATION PLAN

FIGURE 2.5.6.6

the original design parameters. A total of 48 borings were drilled to obtain undisturbed samples and to perform standard penetration tests. Laboratory testing included consolidation tests and triaxial and direct shear-strength tests. These tests confirmed that strength parameters used in the stability analyses are conservative. Results of the field and laboratory programs are presented in References 2.5.6.6 and 2.5.6.7. The stability of the embankment was studied for steady state seepage, rapid drawdown, and seismic conditions. These analyses are presented in detail in Reference 2.5.6.8 and summarized in Table 2.5.6.3. A typical embankment cross-section with selected material strengths is shown on Figure 2.5.6.7.

Table 2.5.6.3

Stability Analyses Results Station 20+00

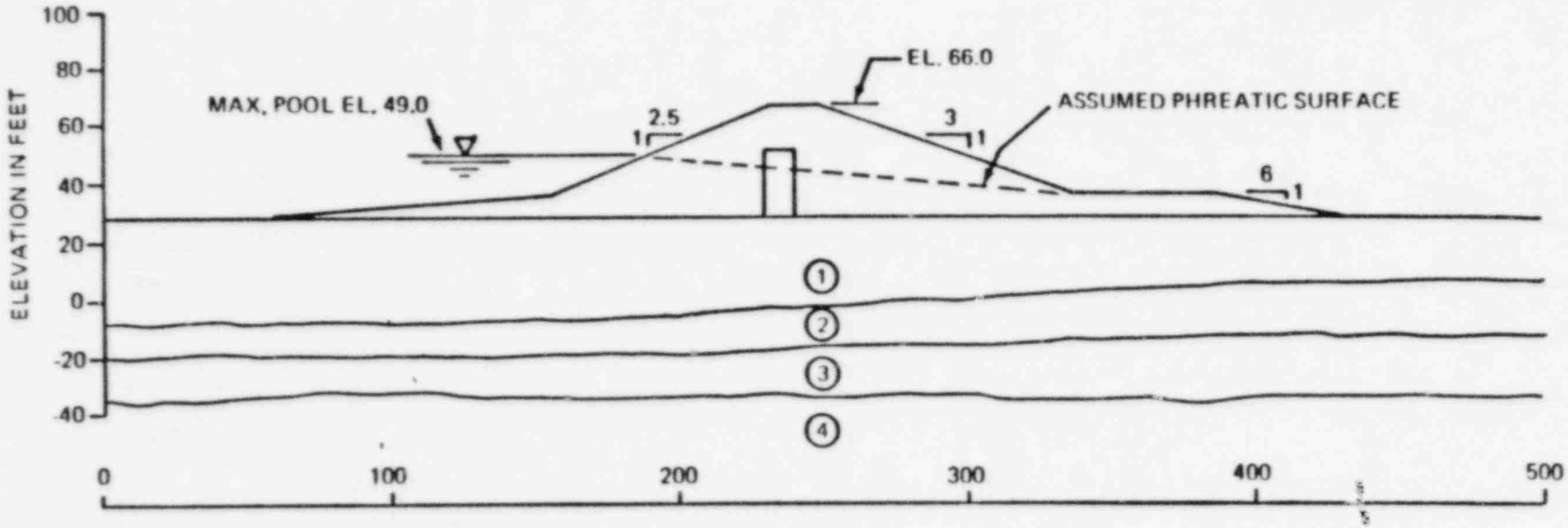
Case	Computed Factor of Safety
Steady Seepage	
Upstream	1.82
Downstream	1.72
Rapid Drawdown	
(El. 49 to 39)	1.50
Pseudostatic	
(Seismic)	1.30

Analyses were also performed at stations 105+00, 250+00, and 365+00. These analyses indicated adequate safety factors.

Because the project is located in a very low seismicity zone with the clay embankment founded on clays and medium dense to dense sands, a Newmark-type displacement analysis was performed. Also, a liquefaction potential analysis was performed for the embankment between stations 42+50 and 72+50 where low blow count sandy material was encountered. Results of the displacement analyses are presented on Figure 2.5.6.8 and show that permanent deformations will not occur as the yield accelerations are much greater than the SSE induced accelerations. Also, clay embankments on clay or dense sand have successfully withstood earthquake accelerations much higher than the SSE for the STP plant with no significant effects (Reference 2.5.6.9). Results of the liquefaction potential analysis are shown on Figure 2.5.6.9 with the cyclic strength determined for average corrected standard penetration values and the cyclic stress determined from a response spectrum analysis corrected for confinement pressures (depth) estimated for non-level ground near the embankment.

In early 1985, a surface or "skin" slide occurred on the downstream face of the embankment. The approximate location and configuration of the slide is shown on Figure 2.5.6.10. The embankment soils are highly plastic and such soils tend to shrink and swell with alternating drying and wetting cycles. Surface slides are to be expected in these type materials, however, they do not affect the overall stability of the embankment. The staff concurs with this assessment of the effect of surface slides.

MATERIAL	Ø	C psf
EMBANKMENT	20°	300
SAND CORE	35°	0
TYPE 1	17°	350
TYPE 2	35°	0
TYPE 3	17°	350
TYPE 4	35°	0



OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5

TYPICAL CROSS-SECTION FOR ANALYSIS

FIGURE 2.5.6.7

SEISMIC STABILITY EVALUATION

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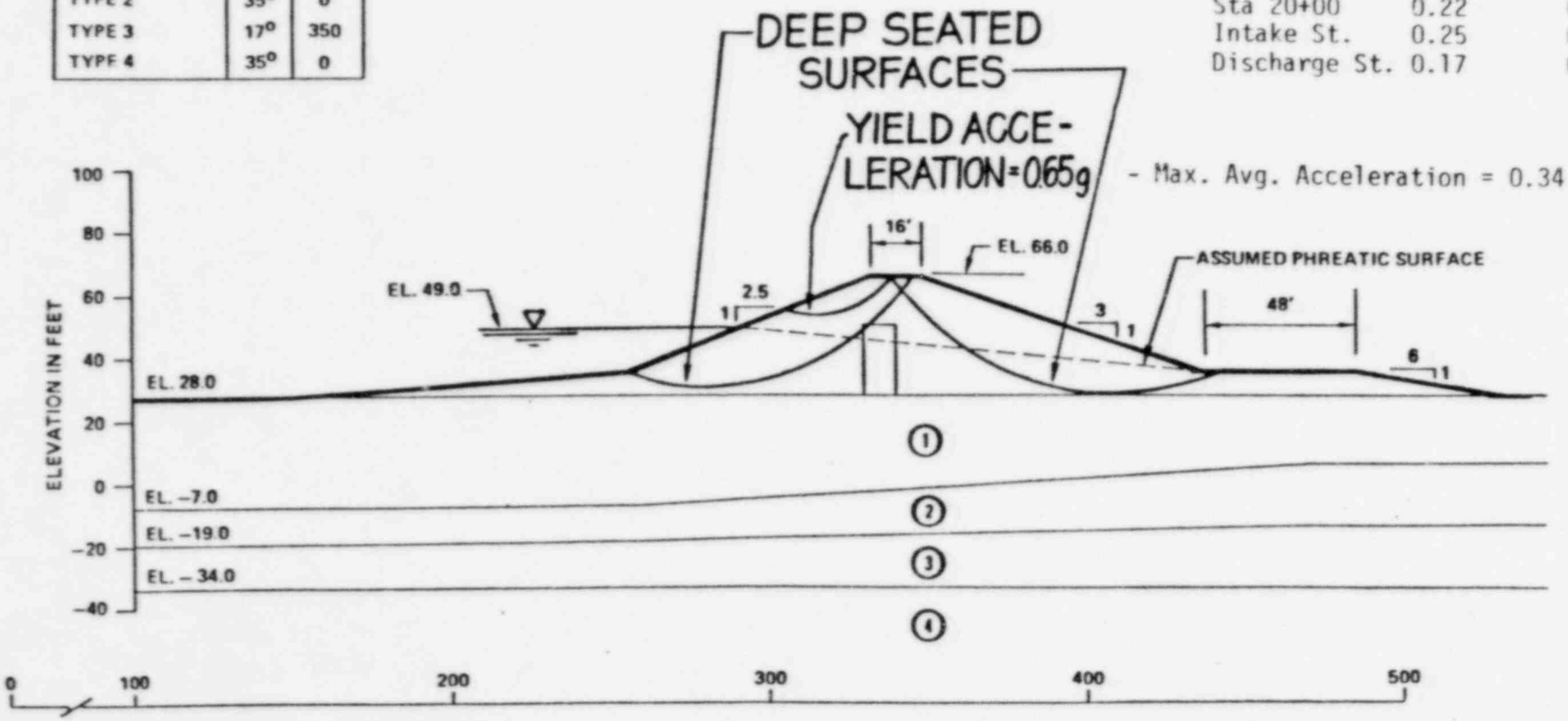
MATERIAL	$\bar{\phi}$	$\bar{C}$, psf
EMBANKMENT	20°	300
SAND CORE	35°	0
TYPE 1	17°	350
TYPE 2	35°	0
TYPE 3	17°	350
TYPE 4	35°	0

Yield Acceleration, g

Section	Upstream	Downstream
Sta 20+00	0.22	0.25
Intake St.	0.25	0.25
Discharge St.	0.17	0.11



OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5

FIGURE 2.5.6.8

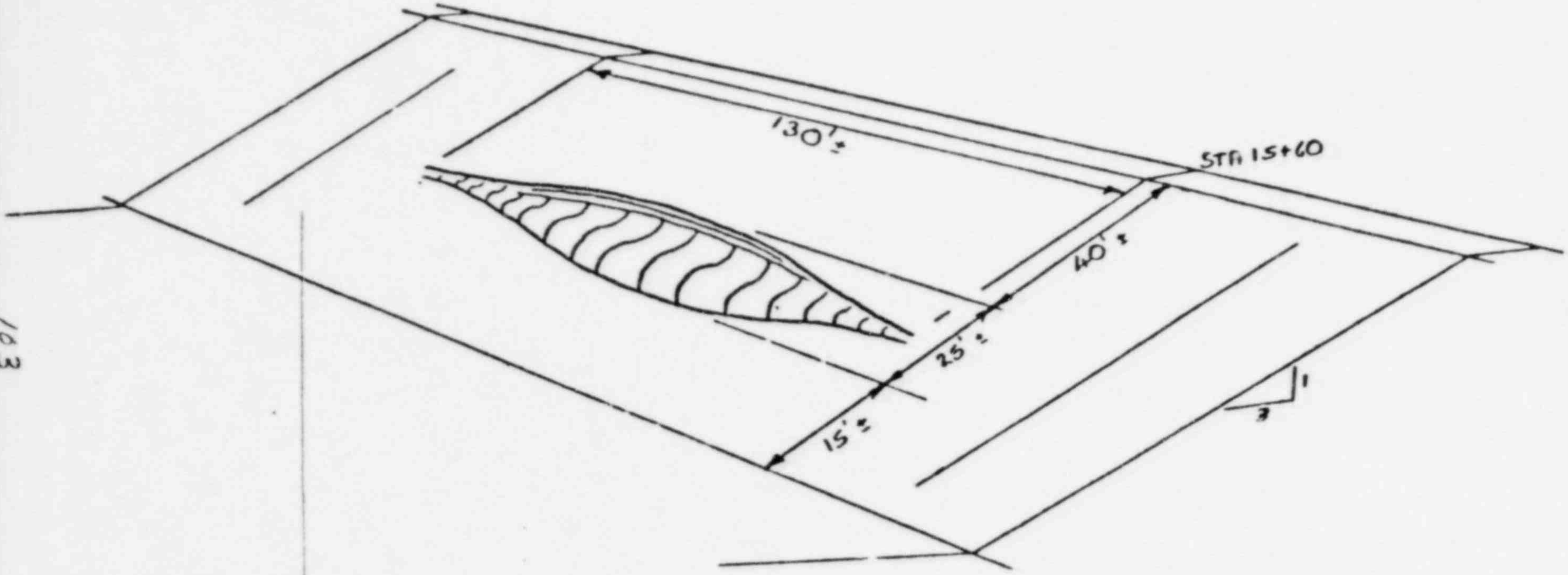
FACTOR OF SAFETY AGAINST LIQUEFACTION

Station	Elevation	$F.S. = \frac{\text{Cyclic Strength}}{\text{Cyclic Stress}}$		
		Crest	D/S Berm	Free Field
		Fines 15% - 35%	Fines 15% - 35%	Fines 15% - 35%
637± to 10±	-13 to -3	3.0 - 3.6	1.8 - 2.1	1.8 - 2.1
637± to 10±	+5 to +10	2.9 - 3.4	1.4 - 1.7	1.5 - 1.8
16± to 40±	+2 to +10	3.7 - 4.6	1.9 - 2.3	2.0 - 2.5
30± to 45±	+13 to +16	2.6 - 3.1	1.2 - 1.5	1.4 - 1.7

OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5

RESULTS OF LIQUEFACTION
POTENTIAL ANALYSIS

FIGURE 2.5.6.9



SLIDE ON MCR EMBANKMENT DOWNSTREAM SLOPE
AT APPROX STA. 16+00.

FURNISHED BY HL&P

SURFACE SLIDE

FIGURE 2.5.6.10

Dispersive Potential of Embankment Clays.

Laboratory tests were conducted to further evaluate the dispersive potential of the embankment clays into the sand core. The tests, described in References 2.5.6.10 and 2.5.6.11, lasted about five months and involved hydraulic gradients in the range of 150 to 200 - values more than two orders of magnitude above any anticipated in the field. There was no tendency for the hydraulic conductivity to increase with time and no cloudy effluent. When the test was dismantled, there was no sign of intrusion of clay into the sand. The test confirmed earlier judgements that erosion of the clay embankment into the central sand core should not occur.

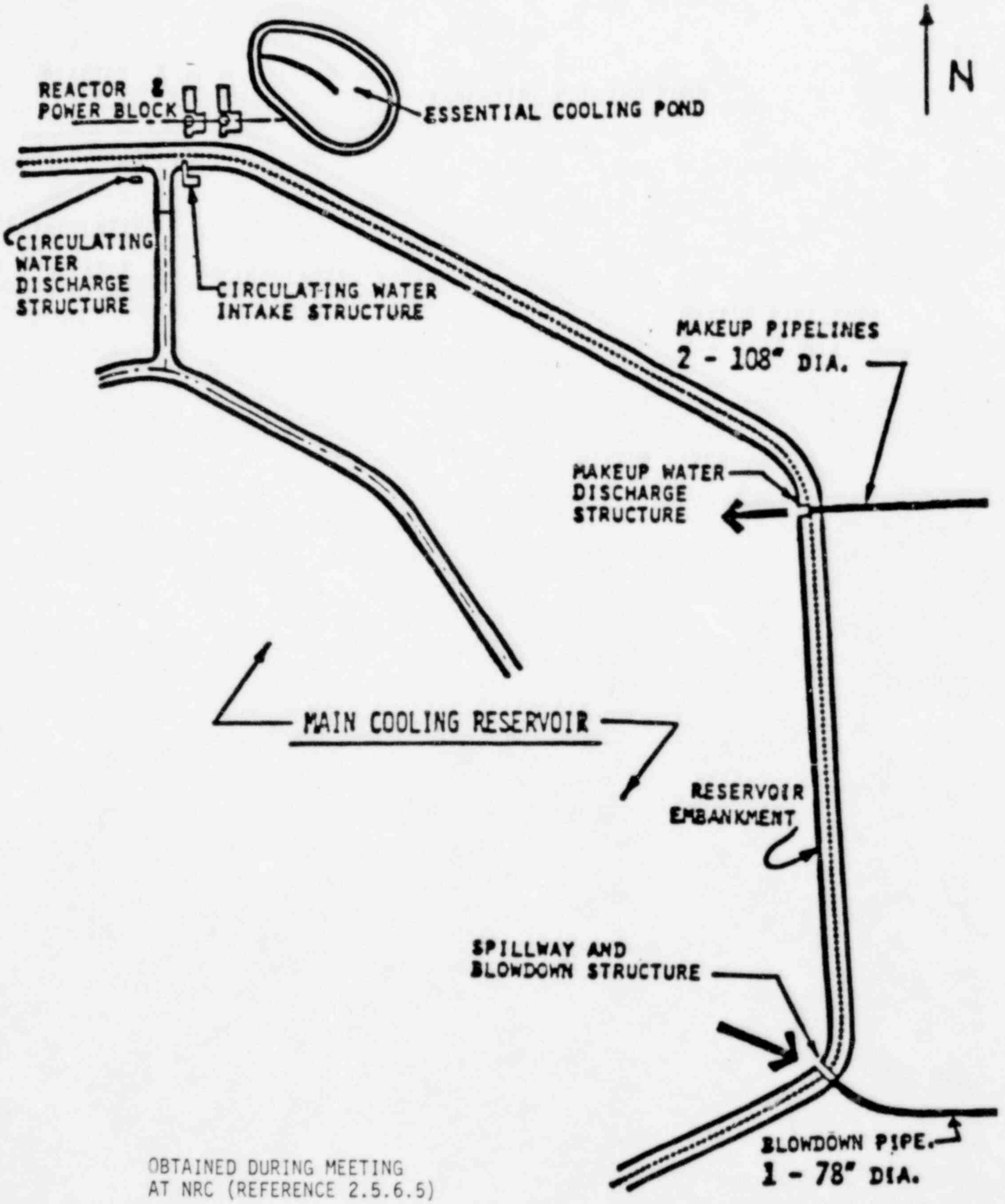
Pipe and Structure Penetrations Through Embankment.

There are a number of pipe and structural penetrations through the existing embankment as shown on Figure 2.5.6.11. Only the Circulating Water Intake and Discharge Pipes are located in the section of the embankment opposite the power block. These pipes, shown on Figure 2.5.6.12, consist of eight 96-inch diameter pipes for the intake which tap into four 138-inch diameter pipes near the toe berm, and four 138-inch diameter pipes of the same type for the discharge. The pipes that penetrate the embankment have bell and spigot joints with rubber gaskets and are embedded in sand and surrounded by embankment material. Some joints were welded at bends to provide thrust restraint and some were harnessed to permit joint rotation. Major

concerns related to these pipes included a lack of inspectability and lack of watertightness of joints which could open causing leakage and subsequent embankment failure. Remedial measures to alleviate these concerns are currently in progress (See Figure 2.5.6.13). Measures consist of removing the existing pipes, installing new concrete pipes at the crest and slopes in concrete chutes to provide erosion protection and inspectability of joints, and installing additional piezometers along the existing pipes at the berm to detect any leakage that might develop.

In addition to the above modifications, individual joint liners for makeup and blowdown pipes and chemical grout barriers for the makeup structure and spillway are being implemented to improve the reliability of the reservoir embankment.

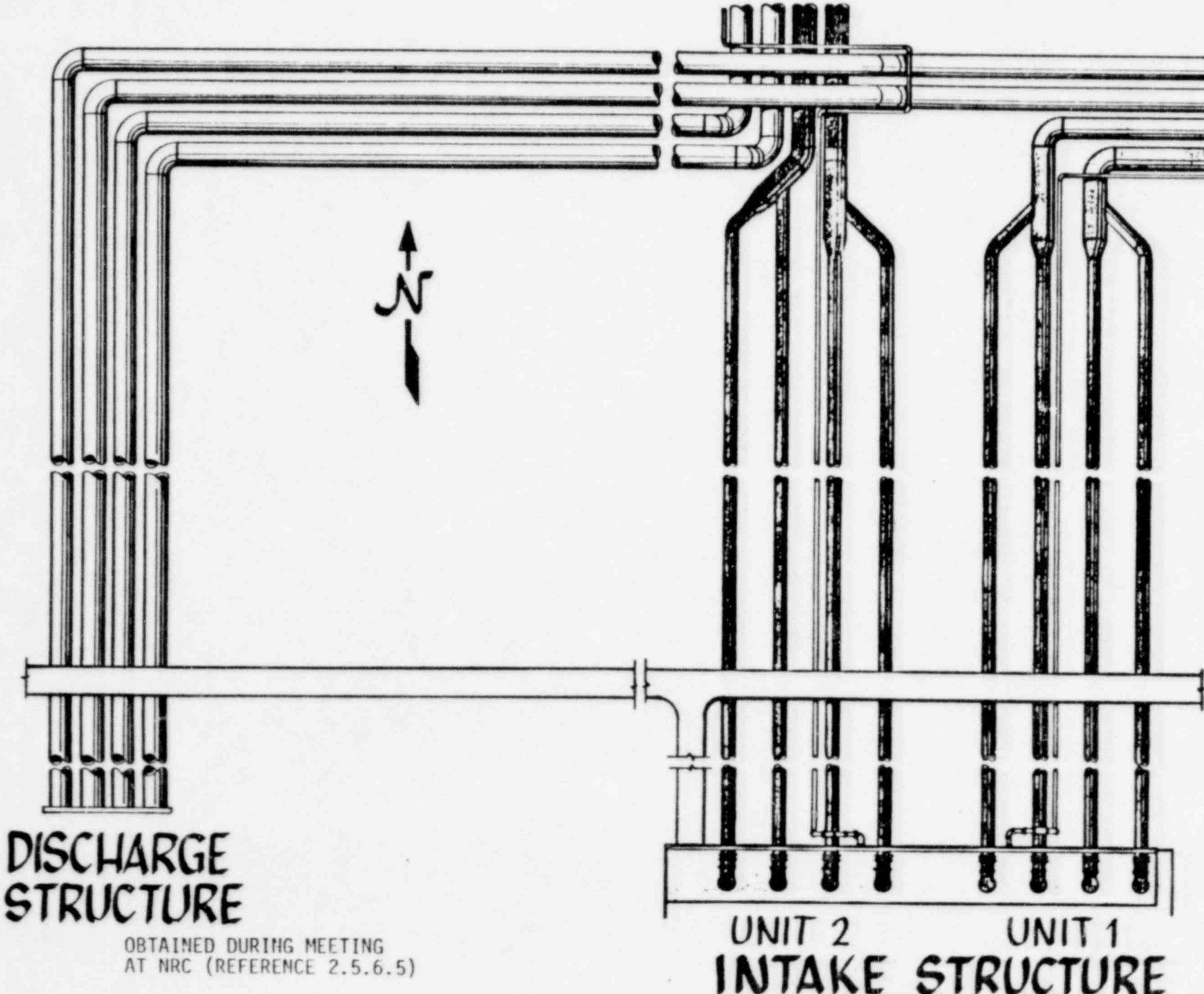
During excavation of the intake and discharge pipes, a testing program was initiated to investigate existing embankment materials in the excavation. Testing consisted of in-place densities, soil classification, Atterburg limits, gradation, moisture content and standard Proctor compaction. Results, shown in References 2.5.6.12 and 2.5.6.13, indicated the material to be high plasticity clay (CH) compacted to at least 95 percent of Standard Proctor maximum density. During a site visit, reference 2.5.6.14, there was no visual evidence of heave in the bottom of the excavation after removal of the discharge pipes. Field observations (Reference 2.5.6.15) during removal of



OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5)

PENETRATION THROUGH THE EMBANKMENT

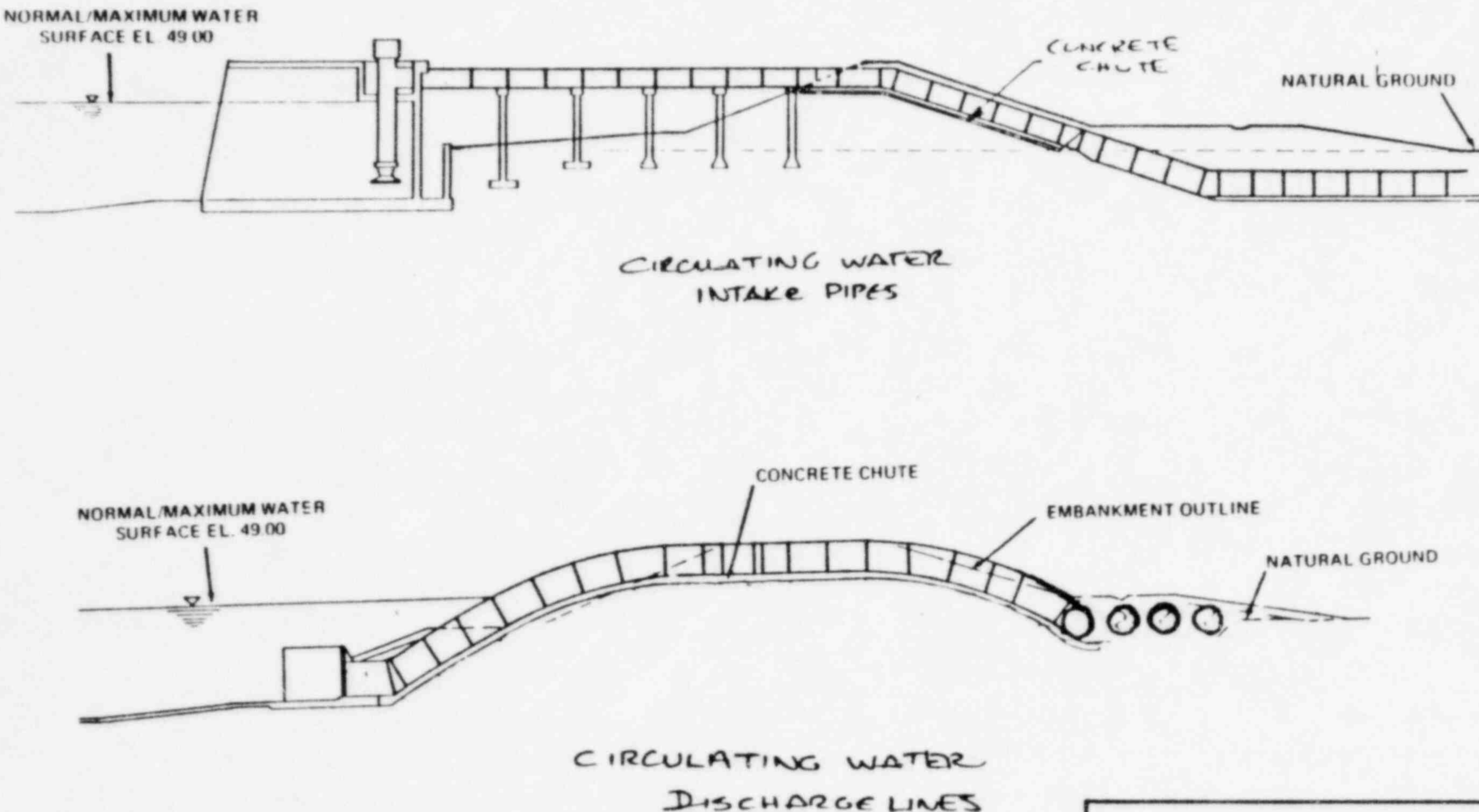
FIGURE 2.5.6.11



OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5)

FIGURE 2.5.6.12

108



OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5)

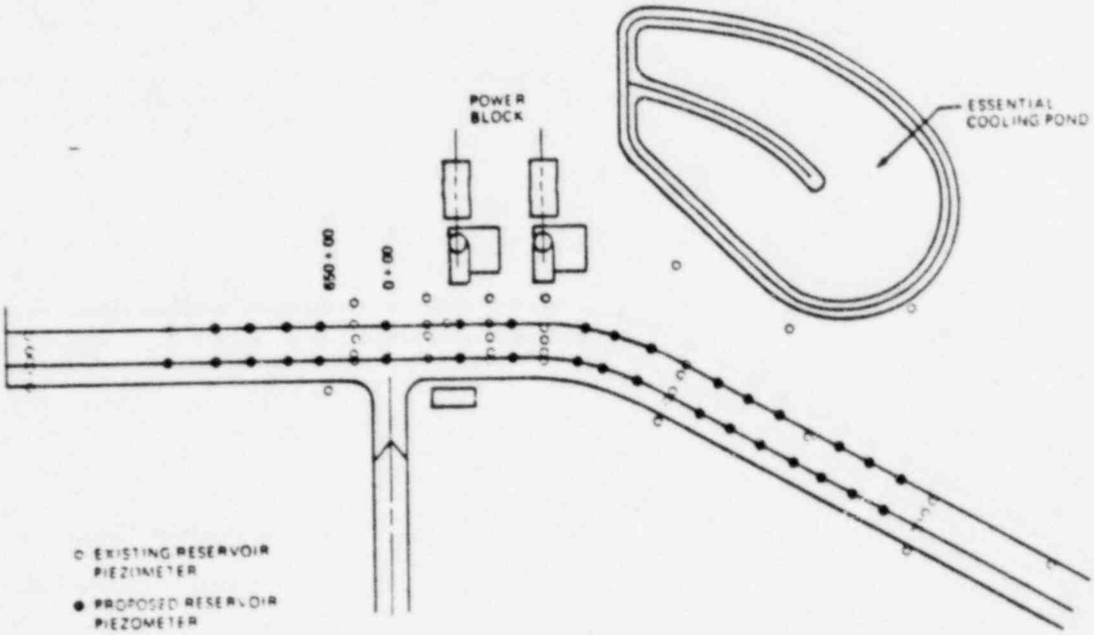
CIRCULATING WATER INTAKE & DISCHARGE PIPES BEFORE MODIFICATIONS

FIGURE 2.5.6.13

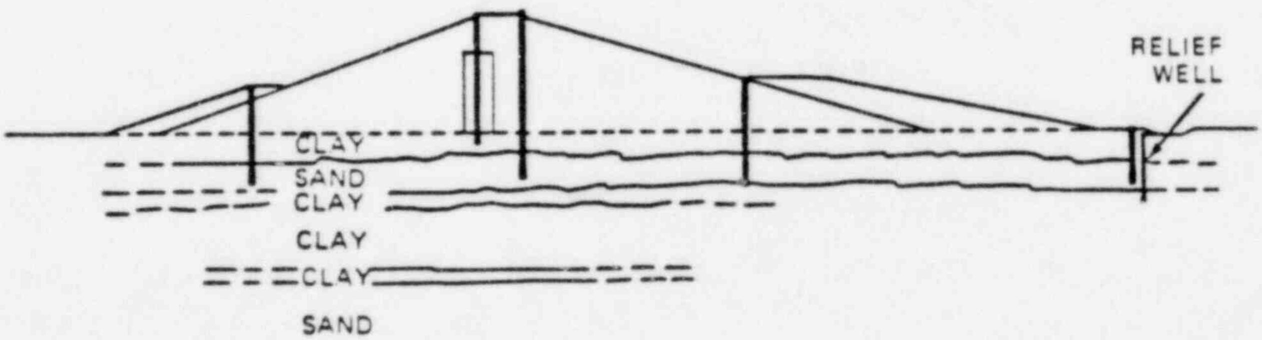
the 138-inch discharge pipes revealed that some joints had been tack-welded. An inspection program has been implemented by the applicant to insure other joints in the embankment toe berm are welded. Corrective actions, if required, will be determined based upon the investigation.

Underseepage Control Measures. Underseepage control is provided by over 650 relief wells extending into sand layer 2 near the toe of the downstream berm. McClelland Engineers, Inc. (MEI) was retained by the applicant to address underseepage control. MEI cleaned and refurbished the wells not affected by power block dewatering and developed recommendations for further renovation of that portion of the relief well system. Proper functioning of the underseepage control measures will be checked by periodic monitoring of piezometers Figure 2.5.6.14 shows the plans for these instruments. The embankment will be closely monitored during filling and the data will be used to evaluate uplift pressures in the foundation. Additional relief wells, if required, will be installed to ensure satisfactory embankment performance. The monitoring program during reservoir filling will provide the basis for long term monitoring during normal plant operation. See Table 2.5.6.4 for present monitoring plans.

Embankment Overtopping. The as-built embankment crest, corrected for settlement, ranges from El. 65 feet to over El. 66 feet. The normal maximum operating water level is El. 49.0 feet. The estimated total rise in water



PLAN
(NEAR POWER BLOCK)



TYPICAL PIEZOMETER ARRAY

OBTAINED DURING MEETING
AT NRC (REFERENCE 2.5.6.5)

INSTRUMENT LOCATIONS

FIGURE 2.5.6.14

level from a PMF event in combination with a wind setup and wave runup on the north section of the embankment is approximately 13 feet or 3 feet below the top of the embankment. The wind setup and wave runup associated with a Probable Maximum Hurricane (PMH) was approximately 1.4 feet below the top of dam.

External Erorsion Potential. Possible erosion of the exterior slope of the embankment near the power block was considered for calculated velocities past the embankment and for sustained wave action. Water levels above plant grade only occur for PMF or failure of upstream dams in the Colorado River Basin. Although the discharge at the site is large for either event, the area of the flooded section is sufficiently large to prevent flow velocities required for erosion of compacted soils. Considering the limited duration of these events, the well compacted clay and the protective grass cover, wave erosion potential is negligible.

Construction Quality of As-Built Embankment. In addition to design aspects, construction quality was also addressed by the applicant. Reviews by Harza and Bechtel (Reference 2.5.6.5) of construction records for the embankment section opposite the power block revealed that 33 standard Proctor compaction tests were conducted. In-place density tests (average one per 1,000 cubic yards of fill) averaged 98 percent maximum compaction. Five percent of the construction reports were sampled to determine disposition and action taken if a field test did not meet specifications. On the basis of this sampling, 7.5

percent of the field tests failed to meet specification requirements, however, in all cases reviewed, the fill was reworked and retested until acceptable results were achieved.

The staff's reviewer who prepared this SER conducted a cursory review of construction quality by reviewing construction records during a site visit (Reference 2.5.6.14). He concluded that specifications for the Main Cooling Reservoir earthwork (Reference 2.5.6.1) included adequate provisions for the following items:

(1) Dewatering.

(2) Clearing and grubbing of foundation areas.

(3) Embankment material classifications.

(4) Foundation preparation.

(5) Fill placement and

(6) Compaction (moisture-density) requirements.

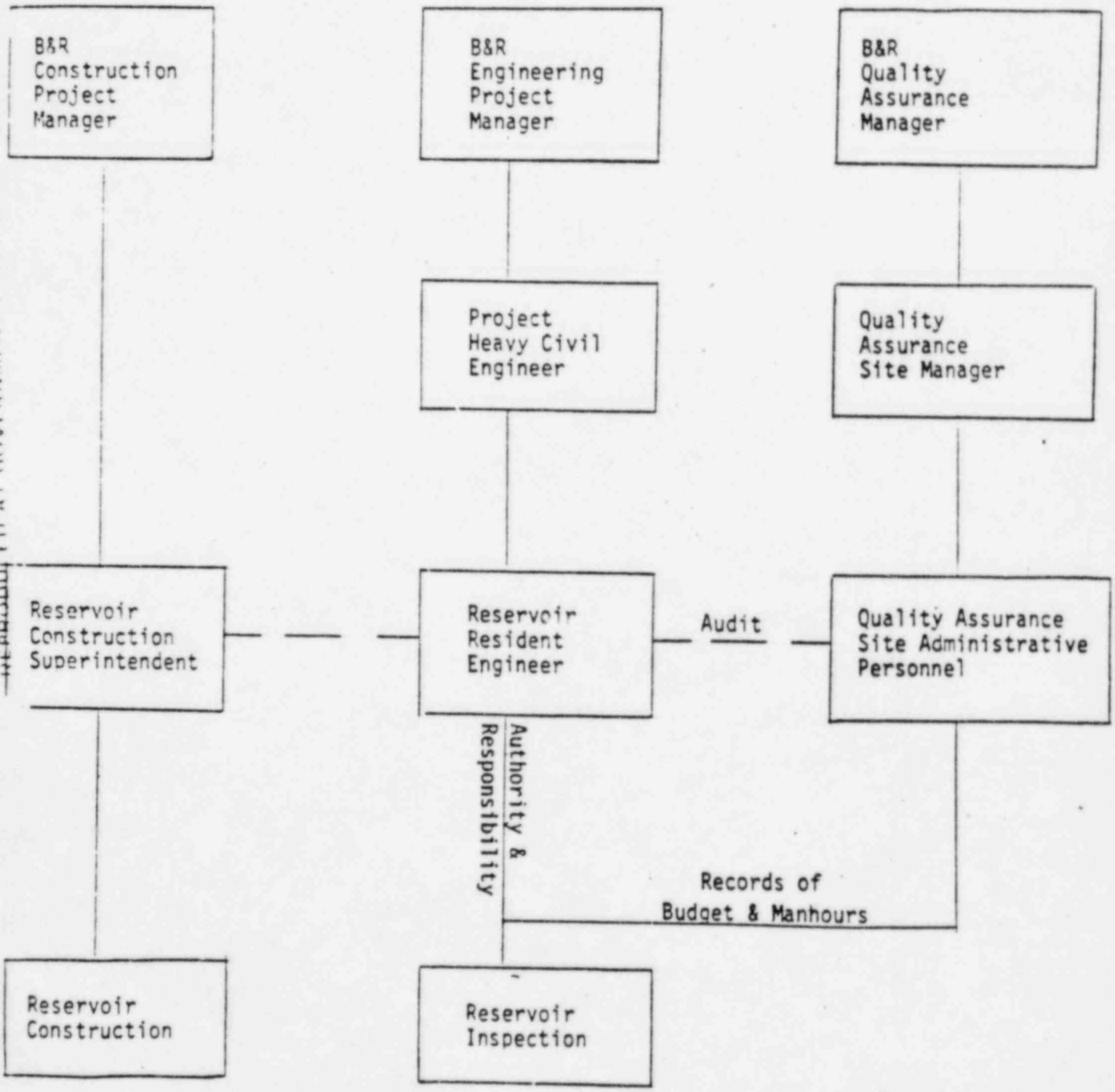
The Basic Project Organization is shown on Figure 2.5.6.15 which indicates that the Resident Engineer developed and technically administered the quality control program for reservoir construction. The quality control program, in turn, was subject to inspection and audit by Brown and Root quality assurance personnel and by HL&P personnel. Figure 2.5.6.16 shows the Reservoir Inspection and Testing Organization. Typical examples of reports prepared included earthworks placement inspectors (Figure 2.5.6.17), field test results (Figure 2.5.6.18), senior inspector (Figure 2.5.6.19), Brown and Root Quality Assurance (Figure 2.5.6.20), and HL&P surveillance (Figure 2.5.6.21). In all cases checked by the reviewer, it appeared that proper materials, equipment and procedures were utilized, adequate inspection was performed, and corrective measures were taken, when required.

Throughout construction of the embankment, periodic inspections were also performed by personnel of the Texas Department of Water Resources (TDWR) to ensure compliance with approved plans and specifications (Reference 2.5.6.16). These inspections were generally performed on a monthly basis. Construction records or documentation were provided to the TDWR periodically. At completion of construction, a completion certificate was furnished which certified that the dam "was constructed in accordance with and includes all items in plans and specifications filed with and approved by the Texas Water Commission."

FIGURE 2

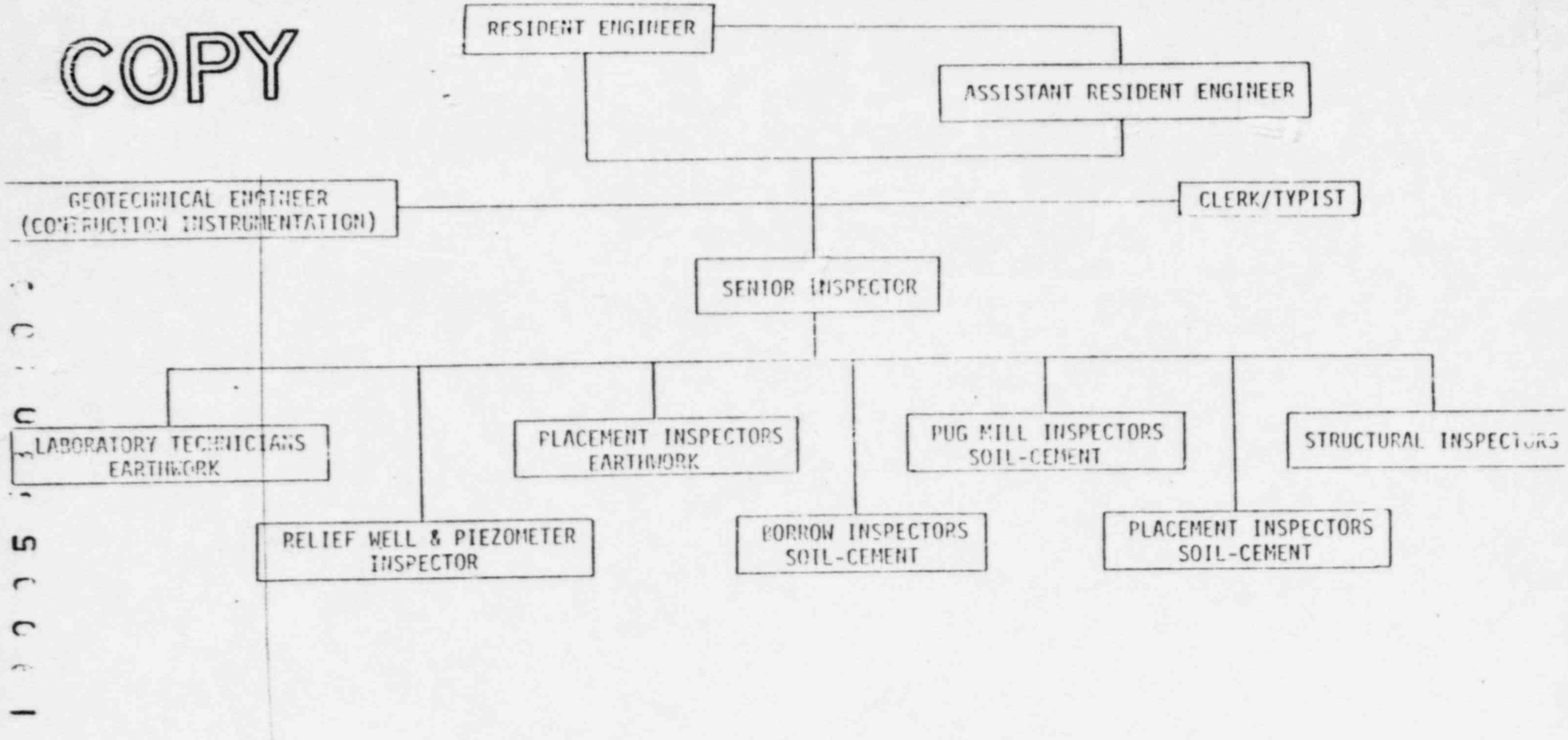
BASIC PROJECT ORGANIZATION

COPY



Obtained during site visit 3-19-85

Figure 2.5.6.15



RESERVOIR INSPECTION AND TESTING ORGANIZATION

Attachment 6-A

Obtained during site
visit 3-19-85

Figure 2.5.6.16

SOUTH TEXAS PROJECT
COOLING RESERVOIR INSPECTION & TESTING

FORM NO.: 03DR

0210717I496

EARTHWORK PLACEMENT INSPECTOR'S DAILY REPORT

NAME: Goza

HOURS WORKED: 5:30 - 4:30 DATE: 8/24/76

CONSTRUCTION EQUIPMENT:

6 scrapers
8 D-8 dozers
4 sheepsfoot rollers
2 Hysters
3 cat rollers
3 disk plows
2 water trucks
7 light plants
4 maintainers

CONSTRUCTION ACTIVITIES:

Processed area 238 - 285 L ℄ and area 262 - 285

Placed fill area 244 - 250+50

TESTING EQUIPMENT: rings
torvane

TESTING & INSPECTION ACTIVITIES:

Tested areas 250 - 262 R ℄ and 238 - 250 L ℄

Inspected various Processing and Fill placeing activities.

COMMENTS: Was informed by Don Deacon that fill placement was to be stoped untill area L ℄ at same stations was processed. Processing equiptment was brought in and processing done.

Obtained during site visit 3-19-85

Figure 2.5.6.17

Attach all test results and all forms completed during day

SUMMARY OF EARTHWORK COMPACTION TESTS

REPORT NO. [illegible]
PAGE 1 OF 1
DATE: 9-26-76

TEST NO.	LOCATION					MATERIAL DESCRIPTION	LL	PI	PROCTOR		FIELD TEST		% OF ASTM D-698	SHEAR STRENGTH (psf)	PASS/ FAIL
	ITEM	ZONE	STA.	OFFSET	ELEV.				MC	UDW	MC	UDW			
GN 0097	Embankment	B	34+00	20' Lt	27	Foundation	60	42	20.4	103.0	22.3	104.3	101.3	5000	PASS
GN 0098	Embankment	D	18+50	170 Lt	26.0	R & LCI, s/s	64	46	19.9	105.1	22.2	97.5	92.8	1650	FAIL
GN 0099	Embankment	D	24+75	175 Lt	25.5	Foundation	60	42	20.4	103.0	23.0	103.3	100.3	[illegible]	PASS
GN 0098A	Embankment	D	19+00	170 Lt	26.0	R & LCI, s/s	64	46	19.9	105.1	24.4	102.7	97.7	4000	PASS

REMARKS: Test GN 0098 Failed due to low compaction. Retested GN 0098A after more compaction. This Test passed.

ENGINEER: A R Stubb[illegible]

INSPECTOR: [illegible signature]

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Obtained during site visit 3-19-85

Figure 2.5.6.18

SOUTH TEXAS PROJECT
COOLING RESERVOIR INSPECTION & TESTING

COPY

SENIOR INSPECTOR'S DAILY REPORT

NAME: R. A. Day HOURS WORKED: [illegible] –1330 DATE: [illegible]

NO. & TYPE OF INSPECTION PERSONNEL		CHANGES IN TESTING EQUIPMENT
Lab Technicians (Erthwk)	—	—
Placement Inspectors (Erthwk)	3	
Borrow Inspectors (S-C)	1	
Pug Mill Inspectors (S-C)	2	
Placement Inspectors (S-C)	2	
Structural Inspectors	—	
Relief Well & Piez. Inspector	—	

CONSTRUCTION ACTIVITIES:

[illegible]

... Fill Placed 15000 ... 4900 ...

COMMENTS:

[illegible]

Obtained during site visit 3-19-85

Figure 2.5.6.19

Attach all Inspector's and Technician's daily reports complete with all test reports

Brown & Root, Inc.
QUALITY ASSURANCE DEPARTMENT

SYSTEM INSPECTION REPORT

PROJECT: SOUTH TEXAS JOB NO. 35-1197 UNIT: 1 & 2 PAGE 1 OF 1

SYSTEM: M.E.I. Surveillance	DRAWING NO(s): P.O. #35-1197-0113	PLAN NO: YS1-1	REV: 1	REPORT NO: 8
LOCATION: Cooling Reservoir	ITEM(s): Subcontract Surveillance		ITEM NO(s): 300 Series	
Date(s) of Inspection: 3/9/77	Type of Inspection: ☐ INITIAL ☐ IN PROCESS ☒ WITNESS TEST ☐ FINAL ☐			

No.	Inspection Characteristic	Sat.	Unsat.	N/A	Inspection Results
300	Performance				
	Test Methods and Proceedures	X			
314					
		x			Observed field density determining test performed by M.E.I. technician R. Mosley at approximately STA 244 on the reservoir embankment.

Supplemental Details

WAS Accompanied by R.A. Day on field trip to observe McClelland Engineers testing proceedures of field Density tests. Able only to observe one technician performing tests.

Personnel Contacted: R.A. Day	Next Inspection Due: ~~[illegible]~~	PERFORMED BY: Richard Ashley	DATE: 3/9/77
DISTRIBUTION		REVIEWED BY:	DATE: / /

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Obtained during site visit 3-19-85

Figure 2.5.6.20

1077100009

Organization B&R	Checklist No. C6.5- 001	Date(s) 10-15-79	Activity COOLING RESERVOIR CONSTRUCTION
Unit No. I & II	By Robert Schreiner	Code Explanation S=Satisfactory	N=Not Audited U=Unsatisfactory NA=Not Applicab.

No.	Item Characteristic & Description	Code	Remarks
	INSPECTOR'S REPORTS		
1	The Senior Inspector's daily report is in order. (Y510HM034, Sec. 4.1.3)	S	
2	The Senior Inspector is keeping a diary of all construction, testing, inspection activities and pertinent QC discussions with the Constructor. (Y510HM034, Sec. 4.1.3)	S	
3	Tests by the Earthwork Placement Inspector reports in-place density, in-place moisture and in-place shear strength on Form 15TR. (Y510HM034, Sec. 4.1.5)	S	
4	The Relief Well and Piezometer Inspector submits a daily report on Form 08DR to the Senior Inspector at the end of each day. (Y510HM034, Sec. 4.1.10)	S	
	FILL MATERIAL		
5	The initial frequency of moisture content and field density testing is once every 2000 cubic yards but may be reduced to once every 5000 cubic yards as a sufficient level of confidence is established. (Y510HM034, Sec. 5.1.4)	S	
	GRAVEL ROADS		
6	The gradation of the base material and aggregate is tested as required by the Resident Engineer to ensure that it complies with specifications. (Y510HM034, Sec. 5.1.8.2)	S	
7	A one point Proctor is performed on the base material as required by the Resident Engineer and is recorded on Form 05TR. (Y510HM034, Sec. 5.1.8.2)	~~N/A~~ S RTS 10-15-79	
8	The in-place density, moisture content and thickness of the compacted layer of base will be tested as required by the Resident Engineer and is recorded on Form 15TR. (Y510HM034, Sec. 5.1.8.2)	S	
	Obtained during site visit 3-19-85 Figure 2.5.6.21		

120 Approval Signature Logan D. Wilson | Rev. No. 0 | Approval Date 9-26-7?

Instrumentation Monitoring and Inspection. Instruments have been installed to monitor the performance of the Main Cooling Reservoir during initial filling and operational stage. The types, number and monitoring frequency are presented in Table 2.5.6.4.

Table 2.5.6.4

MAIN COOLING RESERVOIR INSTRUMENTATION

Frequency of Monitoring

		During Filling	After Filling		
Type	Number		0-1 yr.	1-15 yrs	After 5 yrs
Benchmarks and Settlement Plates	75	Monthly	Bimonthly	Quarterly	Semiannually
Piezometers	230	Biweekly	Monthly	Bimonthly	Quarterly
Relief Wells	669	Biweekly	Monthly	Bimonthly	Quarterly
Inclinometers	12	Biweekly	Monthly	Bimonthly	Quarterly

Instrument locations and specific instructions pertaining to maintenance, monitoring procedures, standards, reports, etc. are presented in Reference 2.5.6.17.

In addition to monitoring of instruments, an inspection program has been implemented by the applicant. The objective of this program is to evaluate the performance of the reservoir, embankment and appurtenant structures to identify existing or potential conditions that could affect their function or cause a safety hazard. Two types of inspections will be conducted - a general or periodic inspection conducted at a prescribed frequency and special inspections to address specific conditions or features. A detailed discussion of these planned inspections is presented in Reference 2.5.6.17.

Staff Conclusions. Considering the applicants original and post-construction studies, an adequate number and type of field investigations and laboratory tests were performed to define the engineering properties of the foundation and embankment materials for the various conditions which are expected to exist in the MCR. Selected geotechnical design parameters are considered reasonable. Detailed studies were performed to evaluate all reasonable modes of failure or potential problems which could lead to failure of the MCR. These studies included analyses of settlement, slope stability (static and dynamic), liquefaction potential, through and underseepage, dispersion, overtopping, and erosion from an external flood. In all cases, adequate safety factors were obtained or measures were incorporated into the design and construction to control potential problem areas. Investigations and design of the MCR embankment, dikes and appurtenant structures are considered reasonable and acceptable from a geotechnical standpoint.

Specifications for construction of the embankment and dikes were in accordance with commonly accepted practices for earthfill embankments. Records indicate that adequate equipment (number and type) and construction procedures were utilized, the work was sufficiently inspected and tested, and corrective work was accomplished, when required, to conform with the approved plans and specifications. Construction procedures used for the MCR embankment and dikes, certified to have been completed on February 18, 1981, are considered to be reasonable and acceptable.

Deliberate impoundment of the Main Cooling Reservoir began on January 23, 1980. As of the summer of 1985, the maximum sustained impoundment level has been approximate El. 25 feet MSL. The project has been monitored since construction began with no unexpected conditions encountered. The reservoir will be filled in stages and closely monitored, which is considered good practice. A detailed inspection and monitoring program has been implemented for the operational life of the project. This program is considered to be in agreement with State and Federal recommendations for periodic inspections and monitoring of dams. With the intended inspection and monitoring program and by performing remedial measures or maintenance, as required, the MCR embankment, dikes and appurtenant works should perform satisfactorily for the design life of the project. Design, construction, and operational procedures and plans are considered reasonable and acceptable. The staff therefore has concluded that there is reasonable assurance that the MCR dike in the vicinity

of plant structures is capable of containing the reservoir under all anticipated operational conditions. The postulated, instantaneous breach of 2,000 feet of the section embankment is not considered necessary. Measures to protect the plant from scour and erosion from such a non-mechanistic breach are also unnecessary.

Because initial filling of the reservoir to El. 49 ft MSL and the period immediately following filling is most critical to the stability and safety of the MCR dike, the staff's final judgement of the MCR must await the results of the applicant's future work. A later supplement to this SER will report the results of the staff's evaluation.

2.5.6.5 REFERENCES

NUMBER	TITLE
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2.5.4.2	American Society for Testing Materials, ASTM-STP-479, "Proposed Method of Test for Consolidated, Drained Direct-Shear Test of Soils, "Committee D-18, Subcommittee D-5 (1970).
2.5.4.3	Lambe, T. W., and R. V. Whitman, Soil Mechanics, Wiley and Sons (New York, 1969), 553 pp.
2.5.4.4	Brooker, E. W., and H. O. Ireland, "Earth Pressures At-Rest Related to Stress History, "Canadian Geotechnical Journal, Vol. II, No. 1 (1965).
2.5.4.5	South Texas Project, Job 35-1197, "VIBROFLOTATION", May 3, 1976 (Revision 1, Nov. 21, 1978), Brown & Root, Inc., Houston, Texas.
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2.5.4.7	Meyerhof, G. G., "Ultimate Bearing Capacity of Footings on a Sand Layer Overlying Clay, "Canadian Geotechnical Journal, Vol. II, No. 2 (1974).
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2.5.4.13 Seed, H. B., I. M. Idriss and I. Arango, "Evaluation of Liquefaction Potential Using Field Performance Data," Journal of Geotechnical Engineering Division, American Society of Civil Engineers, Vol. 109, No. 3 (March 1983), Proc. Paper No. 17785.

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9.0 AUXILIARY SYSTEMS

9.5.2 Communication Systems

The function of the communication system is to provide reliable intraplant and interplant (or plant-to-offsite) communications under both normal plant operation and accident conditions.

9.5.2.2 System Description

9.5.2.2.1 Intraplant Systems

The intraplant communication systems provide sufficient equipment of various types so that the plant has adequate communications to start up, continue safe operation, or safely shut down. The intraplant systems include:

1. telephone system
2. public address paging/alarm system
3. maintenance jack system
4. refueling communication system
5. two-way radio system
6. radio paging system
7. distributed command control consoles

9.5.2.2.1.1 Telephones System

The telephone system consists of an onsite PBX (private branch exchange) telephone system, private business lines and trunk connections with the local telephone utility central office, and multiplexed telephone circuits through the HL&P private regional microwave system.

The onsite PBX system consists of two (2) separate EPBX (electronic private branch exchange) switches, located in separated areas of the South Texas Plant and interconnected with each other and the trunk connected to the local telephone utility.

PBX telephone instruments are distributed throughout the plant. This arrangement permits telephone communications in the event of failure of either switch. Each switch is powered by the plant 120 volt ac system with an 8 hour battery system backup. Loss of normal 120 volts ac and low battery voltages are annunciated to the control room. Telephones located in some high noise areas (90 db ambient and above) are installed with wrap around noise reducing telephone booths. Also, noise cancelling handsets and headsets are provided where required.

9.5.2.2.1.2 Public Address Paging/Alarm System

A centralized public address (PA) system is provided for South Texas which may be accessed from any plant telephone or the distributed command control consoles with the control room having priority access. PA speakers are located in all areas of the plant where operating and maintenance personnel may be working. Sufficient amplifier power, which is automatically adjusted, is provided to assure audibility over anticipated maximum plant noise levels. Power to the public address system is from the plant 120 volt ac system with a non-Class 1E diesel generator as a backup.

Plant emergency and fire alarm signals are routed through the PA system. These alarms have priority over other paging. In areas where noise levels are too high for audible alarms, flashing lights are supplied in addition to audible alarms for emergency warning.

9.5.2.2.1.3 Maintenance Jack Communication System

Maintenance jacks are provided throughout the plant. Each jack station consists of three jacks. Two are powered by 8 volts dc for use with electrosound telephones. The third jack is reserved for sound powered telephones. In high noise areas (greater than 90 db ambient), noise cancelling headsets are provided for use with the maintenance jack system.

9.5.2.2.1.4 Refueling Communication System

This system is similar in design to the maintenance jack system described above, and connects the control room with designated stations in the fuel handling building and the reactor containment building.

9.5.2.2.1.5 Two-Way Radio System

The two-way radio system consists of repeater base stations, control base stations, mobile units, hand-held portable units and lossy loop antenna systems within the power block structure. Power for the system is provided by the plant 120 volt ac system backed-up by a non-Class 1E diesel generator. Mobile radios are powered by vehicular batteries. Hand held portables are powered with self contained batteries backed-up with spare batteries. Portables that must be used in high noise level areas (90 dB ambient) are provided with a jack, plug, and noise cancelling headsets. Solid state panels will be tested during startup for possible interference with other control circuits using hand held UHF transceivers.

9.5.2.2.1.6 UHF Radio Paging System

The UHF radio paging system is used to page individuals carrying portable receivers, groups of individuals, or all personnel simultaneously. In addition, a paging terminal telephone interface allows designated individuals with specified telephone instruments the capability to select and call any pocket pager unit. The radio paging is powered by the plant 120 volts ac system backed up by a non-Class 1E diesel generator. The pocket pager units are supplied with a self contained battery backed-up with spare batteries.

9.5.2.2.1.7 Distributed Command Control Console

Independent command control consoles provide plant operators with access to onsite/offsite telephone systems, two-way radio channels, radio paging system, activation of the plant emergency and fire alarm signals, and the public address paging system. Consoles are powered from the normal plant 120 volts ac system and backed up on the non-Class 1E diesel generator. Consoles are located in control rooms 1 and 2, technical support centers 1 and 2, operational support centers 1 and 2, EOF, central/secondary alarm stations, east/west gate houses, fire brigade house, and the training facility.

9.5.2.2.2 Interplant (Plant-to-Offsite) Communication System

The function of the interplant communications is to provide dependable communication for reliable operation. The interplant communication systems include:

1. telephone system
2. two-way radio
3. HL&P microware system

9.5.2.2.2.1 Telephone System

The offsite telephone system access is provided through the local telephone

utility central office. Private business lines from the central office terminate at designated plant instruments which bypass the onsite PBX system. Additional instruments which bypass the onsite PBX system and the local utility central office. These telephones are also provided with access to the HL&P private microwave network.

9.5.2.2.2.2 Two-Way Radio

Radio set-up facilities for outside agencies are provided at the EOF. Outside agencies providing their own HF/VHF/UFH radio systems are provided with work station counter top and desk space, normal facility 120 volt ac power backed up by a non-Class 1E diesel generator, and a self supporting tower, for mounted antennas.

9.5.2.2.2.3 HL&P Microwave System

This network provides PBX gateways distributed through the HL&P regional private telephone system. This includes the HL&P headquarters and energy control center in Houston.

9.5.2.2.3

Special communication system requirements for fire protection are addressed in Section 9.5.1 of this SER.

9.5.2.3 Scope of Review

The scope of review of the plant communication systems included the assessment of the number and types of communication systems provided, assessment of the adequacy of the power sources, and verification of the functional capability of the communications systems under all conditions of operation.

9.5.2.4 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design criteria and bases and design of the installed communication systems to the acceptance criteria and guidance of SRP 9.5.2. Other bases for acceptance was conformance to industry standards, and the ability of the systems to provide effective communications from diverse means within the units of South Texas under maximum potential noise levels.

9.5.2.5 Conclusion

Based on its review, the staff concludes that the installed communications systems at South Texas conform to the above-cited standards, criteria, and design bases, they can perform their design functions, and, therefore, are acceptable.

Procedures covering preventive maintenance activities and operability checks necessary to assure reliable operation of site emergency communications will be available prior to fuel load and will be verified by the Region IV staff.

9.5.3 Lighting System

9.5.3.1 System Function

The function of the lighting system is to provide adequate station lighting for all modes of plant operating and accident conditions.

9.5.3.2 System Design

The lighting system for South Texas is designed to provide adequate lighting in all areas of the station and consists of a normal, and essential ac lighting systems, and an emergency dc lighting system. During normal plant operation the normal ac and essential ac lighting systems operate together to provide

sufficient lighting for plant operation. The design is based on illumination levels that equal or exceed those recommended by the Illuminating Engineering Society for central stations, and NUREG-0700 "Guidelines for Control Room Design Review."

9.5.3.2.1 Normal AC Lighting System

The normal ac lighting system provides general illumination for the station. It is powered from the non-Class 1E power system.

9.5.3.2.2 Essential AC Lighting System

The essential ac lighting system supplements the normal lighting system and provides illumination for the safe shutdown areas, other operating areas, and access/egress routes. The system is supplied power from two Class 1E and one non-Class 1E power systems. Upon loss of the normal power supply, the Class 1E powered portions of the system are automatically connected to the Train A and C Class 1E emergency diesel generators; the non-Class 1E power portions of the system are automatically connected to the non-Class 1E diesel generator.

9.5.3.2.3 Emergency DC Lighting System

The dc lighting system consists of 90 minute and eight-hour, self-contained, sealed beam battery packs. The dc lighting system operates upon loss of the normal ac essential lighting system depending on area. The dc lighting system provides lighting for the control room, auxiliary shutdown panel, transfer switch panels, emergency diesel generator control panels, chiller control panels, boric acid and tank room, component cooling water surge tank, essential cooling water traveling screen rooms, technical support center, emergency operations facility, and in access and egress paths for personnel evacuation throughout the station.

9.5.3.2.4 Inservice Inspection of Lighting System

The plant ac lighting systems are tested at installation and procedures are developed for testing the dc emergency system. The applicant in a letter dated April 24, 1985 committed to the following inservice inspection and testing program of the dc emergency lighting system.

1. At least once every 12 months the installed emergency dc lighting packs shall be verified as operable and shown to provide rated illumination and inspect the battery leads and wiring connections as recommended by the manufacturer.

2. At five year intervals, a representative sample of batteries will be load tested or replaced as necessary.

The staff finds the above program for testing the dc emergency lighting system acceptable. Verification that the above test program is included in the plant operating procedures, which will be available prior to fuel load, will be performed by the Region IV staff.

9.5.3.3 Scope of Review

The scope of the review of the lighting system for South Texas included assessment of all components necessary to provide adequate lighting during both normal and emergency operating conditions, the adequacy of the power sources for the normal and emergency lighting systems, and verification of functional capability of the lighting system under all conditions of operation.

9.5.3.4 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design bases and criteria and conformance of the design of the lighting systems and necessary auxiliary supporting systems to the acceptance criteria and guidance

of SRP 9.5.3. Other bases for acceptance were conformance to industry standards, NUREG-0700, and the ability to provide effective lighting in all conditions of operation.

9.5.3.5 Conclusion

Based on its review, the staff concludes that the various lighting systems provided at South Texas are in conformance with the above-cited standards and design basis criteria, they can perform their design function, and, therefore, are acceptable.

9.5.4 Emergency Diesel Engine Fuel Oil Storage and Transfer System

9.5.4.1 Emergency Diesel Engine Auxiliary Support Systems (General)

9.5.4.1.1 System Function

The design function of the emergency diesel generator is to provide a separate and independent source of power for each of the Class 1E electric power trains in order to permit the functioning of structures, systems, and components important to safety. There are three emergency diesel generators for each unit at South Texas, and each diesel engine has the auxiliary systems listed below. These systems are discussed in detail in the SER sections indicated in parentheses after the system name.

(1) fuel oil storage and transfer system (9.5.4.2)
(2) cooling water system (9.5.5)
(3) starting system (9.5.5)
(4) lubrication system (9.5.7)
(5) combustion air intake and exhaust system (9.5.8)

The diesel generator is designed to meet the requirements of GDC 2, 4, 5, 17, 21, 44, 45, and 46. The meeting of the requirements of the above GDCs for the

various DG auxiliary systems is discussed in the above referenced SER sections and in this section of the SER (9.5.4.1) which applies to all of the above systems.

9.5.4.1.2 System Description

With two exceptions, the diesel generator and its auxiliary support systems including the fuel oil storage tanks are housed in a seismic Category I diesel generator building that provides protection from the effects of tornadoes, tornado missiles, and floods. The exceptions are: portions of the diesel generator exhaust stacks and the fuel oil fill and vent lines. Therefore, the requirements of GDC 2 and 4 with regard to missiles, and the recommendations and guidance of RGs 1.115 and 1.117 are met. Protection from the effects of tornadoes, tornado missiles, and floods is evaluated in Section 3.0 of this report. Tornado-missile protection of the diesel generator fuel oil fill and vent lines and exhaust stacks is discussed in Sections 9.5.4.2.3.6.1, 9.5.4.2.3.4 and 9.5.8.3.7 respectively.

The diesel generators and their auxiliary systems for South Texas Units 1 and 2 are independent of each other, and are located in separate buildings. However, the diesel fuel oil storage tanks for each units are replenished with fuel oil during all normal, accident and transient conditions from a yard auxiliary fuel oil storage tank (AFOST). Thus, the two units do share the tank and are connected by the AFOST system transfer line. There is proper isolation between the units in this transfer system and each unit has an independent means of replenishing the fuel oil in the unit's emergency diesel fuel oil storage tanks, if the yard tank and its transfer system is available. Each diesel generator fuel oil storage tank includes a common truck fill and an emergency truck fill connection. Thus, the requirements of GDC 5 are met.

The diesel engine and its engine-mounted and separately skid-mounted portions of the auxiliary support systems piping and components normally furnished with the diesel generator package are designed to seismic Category I requirements

and follow the guidelines of the Diesel Engine Manufacturers Association (DEMA) standards. The diesel engine and its mounted auxiliary support systems piping and components conform to the requirements of IEEE Standard 387-1977, "Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," which endorses the Diesel Engine Manufacturers Association (DEMA) standard and the guidelines of RG 1.9, "Selection, Design and Qualification of Diesel-Generator Units Used as Onsite Electric Power Systems at Nuclear Plants." The diesel engine and its auxiliary support systems meet the quality control requirements of 10 CFR 50, Appendix B. The quality assurance program is evaluated in Section 17.0 of this report.

The applicant will perform preoperational and startup tests of the diesel engine auxiliary support systems in accordance with recommendations and guidelines of RG 1.68, "Initial Test Programs for Water Cooled Reactor Power Plants." The adequacy of the test program is evaluated in Section 14.1 of this report.

The design of the diesel engine auxiliary support systems has been fully evaluated with respect to the recommendations and guidelines of BTP ASB 3-1, "Prevention Against Postulated Piping Failures in Fluid System Piping Outside Containment," and MEB 3-1, "Postulated Break and Leakage Locations in Fluid System Piping Outside Containment." Therefore, the systems are in conformance with GDC 4. Protection against dynamic effects associated with the postulated pipe system failures is evaluated in Section 3.6 of this report.

The adequacy of the fire protection for the emergency diesel generator and associated auxiliary support systems with respect to the recommendations and guidelines of BTP CMEB 9.5.1, "Guidelines for Fire Protection for Nuclear Power Plants," is evaluated in Section 9.5.1 of this report.

The applicant discussed the procedures for no-load and light-load operation of the diesel generator and committed to implement the following procedures for testing, troubleshooting, and no-load/light-load operation before startup:

During extended no-load and light-load operation (less then 50% full load), the diesel generators will be loaded to a minimum of 75% of full load for 15-30 minutes following each six hours of continuous no-load or light-load operation.

The design of the diesel generator auxiliary support systems also has been evaluated with respect to the recommendations of NUREG/CR-0660, "Enhancement of Onsite Emergency Diesel Generator Reliability." This report made specific recommendations on increasing the reliability of nuclear plant emergency diesel generators. Information requests concerning these recommendations were transmitted to the applicant during the review process. The applicant responded in the amendments to the FSAR stating how the recommendations of NUREG/CR-0660 have been or will be met. The staff has reviewed these responses and determined that the applicant's conformance to the recommendations is as shown in the following Table.

Table 9.1 Conformance to NUREG/CR-0660

Recommendation	Conformance	SER Section
(1) Moisture in air starting system	Yes	9.5.6.2
(2) Dust and dirt in diesel generator room	Yes	9.5.4.1.2
(3) Turbocharger gear drive problem	N/A	
(4) Personnel training	Yes	9.5.4.1.2
(5) Automatic prelube	Yes	9.5.7.2
(6) Testing, test loading, and no-load operation	Yes	9.5.4.1.2
(7) Preventive maintenance and improve identification of root cause of failures	Yes	9.5.4.1.2
(8) Diesel generator ventilation and combustion air systems	Yes	9.5.8.1
(9) Fuel storage and handling	Yes	9.5.4.2.1
(10) High temperature insulation	*	9.5.4.1.2
(11) Engine cooling water	Yes	9.5.5.2
(12) Concrete dust control	Yes	9.5.4.1.2
(13) Vibration of instruments	Yes	9.5.4.1.2

*Explicit conformance is considered unnecessary by the staff in view of the equivalent reliability provided by the design, margin, and qualification testing requirements that are normally applied to emergency standby diesel generators.

On the basis of its review, the staff has concluded that there is sufficient assurance of diesel generator reliability.

9.5.4.1.4 Scope of Review

The scope of review of the diesel generator system included layout drawings, piping and instrumentation diagrams and descriptive information in FSAR sections 8.3 and 9.5.4 through 9.5.8 for the system and auxiliary support systems essential to the operation of the diesel generator.

9.5.4.1.5 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design criteria and bases and the design of the diesel generator to the requirements of GDCs 2 and 4 with respect to tornado and missile protection, GDC 5 with respect to sharing of systems between units, GDC 17 and 18 with respect to testability and GDC 21 with respect to system reliability, to the guidance of the cited RGs, to the recommendations of NUREG/CR-0660 and to industry codes and standards.

9.5.4.1.6 Conclusion

The present diesel generator design meets the requirements of GDC 2 and 4 with regard to tornado- and turbine-missile protection GDC 5, 17, 18, and 21 and the guidelines of the cited RG and industry codes and standards. The design of the diesel generator and its auxiliary systems also is in conformance with recommendations of NUREG/CR-0660 for enhancement of diesel generator reliability and the related NRC guidelines and criteria. The staff concludes that there is reasonable assurance of diesel generator reliability throughout the design life of the plant.

9.5.4.2 Emergency Diesel Fuel Oil Storage and Transfer System

9.5.4.2.1 System Function

The design function of the emergency diesel engine fuel oil storage and transfer system is to provide a separate and independent fuel oil supply train for each diesel generator and to permit operation of the diesel generator at ESF load requirements for a minimum of seven days without replenishment of fuel. The system is designed to meet the requirements of GDC 2, 4, 5 and 17. The meeting of the requirements of GDC 2, 4, and 5 is discussed in Section 9.4.5.1.2 of this SER.

9.5.4.2.2 System Description

There are three emergency diesel generators for each unit at South Texas. Each diesel engine fuel oil storage and transfer system consists of a 67,000 gallon diesel fuel oil storage tank sufficient to power the diesel engine based on the continuous rated load for seven days, an engine driven fuel oil booster pump, a dc motor-driven fuel oil booster pump, a fuel oil cooler, a fuel oil drain tank, a motor driven fuel oil transfer pump to transfer fuel oil from the drain tank to the seven day storage tank and associated piping, valves, instrumentation, and controls.

Except for the sharing noted in Section 9.5.4.1.2 above between the plant fuel systems, each diesel engine fuel oil storage and transfer system is independent and physically separated from the other system supplying the redundant diesel generator. Thus, a single failure within any one of the systems will affect only the associated diesel generator. Therefore, the requirements for GDC 17, as related to the capability of the fuel oil system to meet independence and redundancy criteria, are met.

Except for the fuel oil tank fill lines, the fuel oil drain tank, and fuel oil transfer pump and its associated piping, the diesel engine fuel oil storage and

transfer system piping and components up to the diesel engine interface, including skid-mounted piping, are designed to seismic Category I, ASME Section III, Class 3 (Quality Group C) requirements. They meet the recommendations of RG 1.26, "Quality Group Classifications and Standards for Water-, Steam, and Radioactive Waste Containing Components of Nuclear Power Plants," and RG 1.29, "Seismic Design Classification." The engine-mounted piping and components, from the engine block to the engine interface, are considered part of the engine assembly and are seismically qualified to seismic Category I requirements as part of the diesel engine package. The fuel oil drain tank, fuel oil transfer pump, and its associated piping is seismically supported. This piping and the engine mounted piping, and the associated components, such as valves, fabricated headers, fabricated special fittings, and the like are designed, manufactured, and inspected in accordance with the guidelines and requirements of ANSI Standard B31.1 "Code for Pressure Piping," ANSI N45.2 "Quality Assurance Program Requirements for Nuclear Facilities" and 10 CFR 50 Appendix B. This fuel oil system piping and associated components are intentionally over designed (subjected to low working stresses) for the application, and thereby resulting in high operational reliability. The design of the fuel oil piping and components to the cited design philosophy and standards is considered equivalent to a system designed to ASME Section III Class 3 requirements with regard to system functional operability and inservice reliability.

The fuel oil fill line - truck fill connection and connections to the yard storage tank - are designed nonseismic Quality Group D. Since each fuel oil storage tank is being provided with its own seismic Category I ASME Section III Class 3 emergency fill connection located on the roof of the diesel generator building, the design is acceptable.

The design of the emergency diesel fuel oil storage and transfer system conforms to ANSI-N195 with the following exceptions:

a) Section 6.1 and 8.0 - Tanks and Instrumentation and Control

The design of the South Texas emergency diesel generator fuel oil storage and transfer system does not include a day tank and its associated instrumentation. Each seven day storage tank is located in a room above its respective diesel generator and serves as the diesel generator day tank. It is located at a sufficient elevation to provide a net positive suction head to the engine fuel oil booster pumps. Because of the design, the instrumentation required for the day tank is not required. The staff finds the design acceptable.

b) Section 6.2 - Pumps

Because of the fuel oil storage and transfer system design described above a fuel oil transfer pump to transfer fuel from the seven day storage tank to the day tank is not required.

In addition the diesel fuel oil storage system conforms with the guidelines of RG 1.137 positions C.2.a through C.2.g with the following exceptions. The fuel oil quality tests will be in conformance to the McGuire technical specification for fuel oil quality, as modified by the applicant's letter of September 19, 1985.

The emergency fuel oil fill line is protected from tornado missiles by virtue of the D/G roof design. The fuel oil storage tank vent line will shear off upon impact of a tornado missile. The staff finds this acceptable.

9.5.4.2.3 <u>Scope of Review</u>

The scope of review of the diesel engine fuel oil storage and transfer sysem included layout drawings, piping, and instrumentation diagrams, and descriptive information in FSAR Section 9.5.4 for the system and auxiliary support sysems essential to its operation.

9.5.4.2.4 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design criteria and bases and design of the diesel engine fuel oil storage and transfer sysem to the requirements of GDC 17 with respect to redundancy and physical independence, to the guidance of the cited RGs, to the recommendations of NUREG/CR-0660, and to industry codes and standards.

9.5.4.2.5 Conclusion

Based on its review, the staff concludes that the emergency diesel engine fuel oil storage and transfer sysetm meets the requirements of GDC 2, 4, 5 and 17, meets the recommendations of NUREG/CR-0660, the guidance of the cited RGs and SRP 9.5.4, and industry codes and standards; thus, it can perform its design safety function and, therefore, is acceptable.

9.5.5 Emergency Diesel Engine Cooling Water System

9.5.5.1 System Function

The design function of the emergency diesel engine cooling water system is to maintain the temperature of the diesel engine within a safe operating range under all load conditions and to maintain the engine coolant preheated during standby conditions to improve starting reliability. The system is designed to meet the requirements of GDC 2, 4, 5, 17, 44, 45, and 46. Conformance with requirements of GDC 2, 4, and 5 is discussed in section 9.5.4.1.2 of this SER.

9.5.5.2 System Description

The emergency diesel engine cooling water sysem provides cooling to the engine jacket, lube oil cooler, governor oil cooler, fuel oil cooler, and air heaters/intercoolers, and is composed of two subsystems: the closed-LOOP cooling water system and the open-loop cooling water system.

9.5.5.2.1 Closed-LOOP Cooling Water System

The major components of the closed-LOOP cooling water system for each standby emergency diesel engine include an engine-driven jacket coolant water pump, jacket water heat exchanger, an expansion tank (standpipe), an ac motor driven circulation pump, combustion air heaters/intercoolers (one for each cylinder bank), an ac motor-driven jacket coolant standby pump, an electric heater, and thermost-tic three-way valves, as well as the required instrumentation, controls, and alarms, and the associated piping and valves to connect the equipment. When the diesel engines are operating, the heat generated is rejected to the essential cooling water system by means of the jacket cooling water heat exchanger.

During operation of the standby diesel engine, the temperature of the diesel engine coolant is regulated automatically through the action of a temperature-sensing three-way thermostatic valve. When the standby diesel engine is idle, the engine coolant is heated by an electric heater and continuously circulated through the engine. The temperature is controlled by a thermostat to keep the engine warm and ready to accept loads within the prescribed time interval.

The diesel generator is capable of operating fully loaded without secondary cooling for approximately two minutes. The engine and expansion tank contain enough water to absorb the heat generated during this period. This time interval is greater than the time needed to restore essential cooling water to the diesels in the event of a loss of offsite power.

9.5.5.2.2 Open-Loop Cooling Water System

The open-loop cooling water system is a subsystem of the essential cooling water system. Each diesel generator has its own open-loop cooling water by separate trains of the essential cooling water system. This system provides cooling water for the diesel generator closed cooling water system, the lube

oil cooler, the fuel oil cooler, the governor oil cooler and the combustion air intercoolers (one cooler per cylinder bank).

9.5.5.2.3 System Description (Common Areas)

Alarms have been provided to enable the control room operator to monitor the diesel generator cooling while the unit is in the standby mode or in operation.

There are three emergency diesel generators for each unit at South Texas and, each diesel generator has a physically separate independent cooling water system. Therefore, the requirements of GDC 17 and 44 as related to redundancy and single failure criterion are met.

The design engine cooling water system piping and components up to the diesel engine interface, including auxiliary skid-mounted piping, are designed to seismic Category I, ASME Section III, Class 3 (Quality Group C) requirements and meet the recommendations of RGs 1.26 and 1.29. The engine-mounted piping and components, from the engine block to the engine interface, are considered part of the engine assembly and are seismically qualified to seismic Category I requirements as part of the diesel engine package. This piping and associated components, such as valves, fabricated headers, fabricated special fittings, and the like are designed, manufactured, and inspected in accordance with the guidelines and requirements of ANSI Standard B31.1 "Code for Pressure Piping," ANSI N45.2 "Quality ASsurance Program Requirements for Nuclear Facilities" and 10 CFR 50 Appendix B. The engine mounted cooling water piping and associated components are intentionally over designed (subjected to low working stresses) for the application, thereby resulting in high operational reliability. The design of the engine mounted cooling water piping and components to the cited design philosophy and standards is considered equivalent to a system designed to ASME Section III Class 3 requirements with regard to sysem functional operability and inservice reliability.

The diesel engine cooling water system conforms with RG 1.9, position C.7, as it relates to engine cooling water protective interlocks. The diesel generator system protective interlocks are discussed in Section 8.3 of this report.

The diesel engine cooling water system has provisions to permit periodic inspection and functional testing during standby and normal modes of power plant operation as required by GDC 45 and 46.

9.5.5.3 Scope of Review

The scope of the review of the emergency diesel engine cooling water system included layout drawings, piping and instrumentation diagrams, and descriptive information in FSAR Section 9.5.5 for the systems and the auxiliary support systems essential to its operation.

9.5.5.4 Basis For Acceptance

The bases for the acceptance in the staff review were (1) conformance of the design criteria and bases and design of the diesel engine cooling water system to GDC 17 and 44 with respect to redundancy and physical independence, to GDC 45 and 46 with respect to inspection and testability of the system, to the guidance of the cited regulatory guides, and to the recommendations of NUREG/CR-0660 and industry codes and standards, and (2) the ability of the system to maintain stable diesel engine cooling water temperature under all load conditions.

9.5.5.6 Conclusions

Based on its review, the staff concludes that the emergency diesel engine cooling water system meets the requirements of GDC 2, 4, 5, 17, 44, 45, and 46; meets the guidance of the cited regulatory guides, and SRP 9.5.5, meets the recommendations of NUREG/CR-0660 and industry codes and standards; thus it can perform its design function and is, therefore, acceptable.

9.5.6 Emergency Diesel Engine Starting System

9.5.6.1 System Function

The design function of the emergency diesel engine starting system is to provide a reliable method for automatically starting each diesel generator so that the rated frequency and voltage are achieved and the unit is ready to accept required loads within 10 seconds. The system is designed to meet the requirements of GDC 2, 4, 5, and 17. The meeting of the requirements of GDC 2, 4, and 5 is discussed in Section 9.5.4.1 of this SER.

9.5.6.2 System Description

The air starting system for each diesel includes two ac motor drive air compressors, two receiver tanks, two desiccant air dryers, intake air filters, injection lines and valves, air-to-cylinder control and starting valves, instrumentation, controls, alarms, and the associated piping to connect the equipment. Alarms annunciate on the local panel and in the main control room to enable the operator to monitor the air pressure of the diesel generator starting air system. Automatic controls are provided to automatically start and stop each air compressor when the pressure in its respective air receivers decreases or increases respectively to predetermined levels.

There are three emergency diesel generators for each unit at South Texas. Each diesel generator has an independent and redundant air starting system consisting of two separate full-capacity air starting subsystems, each with sufficient air capacity to provide a minimum of five consecutive cold engine starts from the low pressure alarm setpoint. Redundancy in the starting system is provided by the three emergency diesel generators so that a malfunction or failure in one DG system does not impair the capability of any other air start system to start its respective diesel engine. This meets the requirements of GDC 17.

The diesel engine air starting system piping and components from the valve upstream of the air receiver up to the diesel engine interface, including auxiliary skid-mounted piping, are designed to seismic Category I, ASME Section III, Class 3, (Quality Group C) requirements and meet the recommendations of RGs 1.26 and 1.29. The engine-mounted piping and components, from the engine block to the engine interface, are considered part of the engine assembly and are seismically qualified to seismic Category I requirements as part of the diesel engine package.

This piping and the associated components, such as valves, fabricated headers, fabricated special fittings, and the like are designed, manufactured, and inspected in accordance with the guidelines and requirements of ANSI Standard B31.1 "Code for Pressure Piping," ANSI N45.2 "Quality Assurance Program Requirements for Nuclear Facilities" and 10 CFR 50 Appendix B. The engine mounted air starting piping and associated components are intentionally over designed (subjected to low working stresses) for the application, and thereby resulting in high operational reliability. The design of the engine mounted air starting piping and components to the cited design philosophy and standards is considered equivalent to a system designed to ASME Section III Class 3 requirements with regard to system functional operability and inservice reliability.

The diesel generator air starting system conforms with RG 1.9, position C.7, as it relates to diesel engine air starting system protective interlocks. The diesel generator system protective interlocks are discussed in Section 8.3 of this report.

9.5.6.3 Scope of Review

The scope of review of the emergency diesel engine starting system included layout drawings, piping and instrumentation diagrams, and descriptive information in FSAR Section 9.5.6 for the system and auxiliary support systems essential to its operation.

9.5.6.4 Basis for Acceptance

The bases for acceptance in the staff review were (1) conformance of the design criteria and bases and design of the diesel engine air starting system to the recommendations of NUREG/CR-0660, and industry codes and standards, and (2) the ability of the system to start the diesel generator within a specified time period.

9.5.6.5 Conclusion

Based on its review, the staff concludes that, the emergency diesel engine air starting system meets the requirements of GDC 4, 5, and 17 and meets the guidance of the cited regulatory guides and SRP 9.5.6, the recommendations of NUREG/CR-0660, and industry codes and standards; thus, it can perform its design safety function and is, therefore, acceptable.

9.5.7 Emergency Diesel Engine Lubricating Oil System

9.5.7.1 System Description

Major components of the emergency diesel engine lubricating oil system include an engine-driven lube oil pump; an ac motor-driven lube oil standby pump; a motor-driven circulation pump; a lube oil collection sump, strainers, and filters; a lube oil cooler; an electric heater and thermostatic three-way valve; instrumentation, controls and alarms; and associated piping and valves to connect the equipment. The diesel engine is equipped with relief ports, as well as a crankcase breather system composed of piping from the crankcase to the outside of the diesel generator building. This system provides protection from crankcase explosion. Alarms and protective devices are provided to alert the control room operator to abnormal conditions in the diesel generator lube oil system during standby, startup, or operating status.

The emergency diesel engine lubrication oil system is an integral part of the diesel engine and thus meets the requirements of GDC 17 with regard to system independence and single failure criterion. The engine lube oil heat is rejected to the essential cooling water system.

During engine operation or when the engine is on standby, the main engine lube oil system supplies oil to all main bearings, the camshaft bearings, cam followers, engine wearing parts, and turbocharger. The prelubrication portion of this system is operated only when the engine is on standby, at which time the lube oil is heated by an electric heater and circulated through the engine continuously by an ac motor-driven pump to improve the first-try starting reliability.

Except for the crankcase breather system, the diesel engine lubrication oil system piping and components up to the diesel engine interface, including auxiliary skid-mounted piping, are designed to seismic Category I, ASME Code Section III, Class 3 (Quality Group C) requirements and meet the recommendations of RGs 1.26 and 1.29. The crankcase breather system up to the diesel engine interface is not necessary for proper diesel operation; therefore, it is designed to Quality Group D requirements. The engine-mounted piping and components, from the engine block to the engine interface, are considered part of the engine assembly and are seismically qualified to seismic Category I requirements as part of the diesel engine package. This piping and the associated components, such as valves, fabricated headers, fabricated special fittings, and the like are designed, manufactured, and inspected in accordance with the guidelines and requirements of ANSI Standard B31.1 "Code for Pressure Piping," ANSI N45.2 "Quality Assurance Program Requirements for Nuclear Facilities" and 10 CFR 50 Appendix B. The engine mounted lube oil piping and associated components are intentionally over designed (subjected to low working stresses) for the application, and thereby resulting in high operational reliability. The design of the engine mounted lube oil piping and components to the cited design philosophy and standards is considered equivalent to a

system designed to ASME Section III Class 3 requirements with regard to system functional operability and inservice reliability.

The diesel generator lubricating oil system conforms with RG 1.9, position C.7, as it relates to diesel engine lubrication system protective interlocks. The diesel generator system protective interlocks are discussed in Section 8.3 of this report.

The applicant in a letter dated April 24, 1985 stated that the lube oil sump has a capacity of 1260 gallons and that the normal lube oil consumption rate during engine operation is 12 gallons per 24 hours. The lube oil sump capacity between the minimum oil levels (low level alarm) and the minimum operating level is 549 gallons. This is a sufficient quantity of oil to operate the diesel generator in excess of seven days at a normal consumption rate.

9.5.7.3 Scope of Review

The scope of review of the diesel generator lubricating oil system included piping and instrumentation diagrams and descriptive information in FSAR Sections 9.5.7 for the system and auxiliary support systems essential to its operation.

9.5.7.4 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design criteria and bases and design of the diesel engine lubricating oil system to the requirements of GDC 17 with respect to redundancy and physical independence, to the guidance and additional acceptance criteria of SRP 9.5.7, to the recommendations of NUREG/CR-0660, and to industry codes and standards.

9.5.7.5 Conclusion

Based on its review, the staff concludes that the emergency diesel engine lubricating oil system meets the requirements of GDC 2, 4, 5, and 17, and meets the guidance of the cited RGs and SRP 9.5.7, and meets the recommendations of NUREG/CR-0660 and industry codes and standards; thus, it can perform its design safety function and is, therefore, acceptable.

9.5.8 Emergency Diesel Engine Combustion Air Intake and Exhaust System

9.5.8.1 System Function

The function of the emergency diesel engine combustion air intake and exhaust system is to supply filtered air for combustion to the engine and to dispose of the engine exhaust to atmosphere. The system is designed to meet the requirements of GDC 2, 4, 5, and 17. The meeting of the requirements of GDC 2, 4, and 5 is discussed in Section 9.5.4.1 of this SER.

9.5.8.2 System Description

A separate source of combustion air for each diesel engine is taken from the associated diesel generator air intake structure through an air filter, turbocharger compressor, and combustion air coolers. The path of the exhaust gas discharge is through the turbocharger, exhaust silencer, and exhaust ducting to the outside of the building. This meets the requirements of GDC 17 with regard to system independence, redundance, and single failure criterion.

The location of the air intake and exhaust structures and design precludes or minimizes the blockage of the structures due to rain, snow, ice, freezing rain, dust and precludes the failure of the diesel due to fire and other deleterious materials that would affect diesel generator operation.

The diesel generator combustion air intake and exhaust system conforms with RG 1.9, position C.7, as it relates to diesel engine combustion air intake and exhaust system protective interlocks. The diesel generator system protective interlocks are discussed in Section 8.3 of this report.

The diesel engine combustion air intake and exhaust system piping and components such as fabricated headers, fabricated special fittings, and the like, up to the diesel engine interface, are designed to seismic Category I, ASME Section III, Class 3 (Quality Group C) requirements, and meet the recommendations of RGs 1.26 and 1.29. The engine mounted piping and components, from the engine block to the engine interface, are considered part of the engine assembly and are seismically qualified to seismic Category I requirements as part of the diesel engine package. The piping and the associated components, such as valves, fabricated special fittings, and the like are designed, manufactured, and inspected in accordance with the guidelines and requirements of ANSI Standard B31.1 "Code for Pressure Piping," ANSI N45.2 "Quality Assurance Program Requirements for Nuclear Facilities" and 10 CFR 50 Appendix B. The engine mounted air intake and exhaust piping and associated components are intentionally over designed (subjected to low working stresses) for the application, and thereby resulting in high operational reliability. The design of the engine mounted air intake and exhaust piping and components to the cited design philosophy and standards is considered equivalent to a system designed to ASME Section III Class 3 requirements with regard to system functional operability and inservice reliability.

The combustion air intake structure is adequately projected from tornado missiles. The combustion exhaust stack is not protected from tornado missiles; however, it is designed to break-off if impacted by a tornado missile. The staff finds this acceptable.

9.5.8.3 Scope of Review

The scope of review of the diesel generator intake and exhaust system included layout drawings, piping and instrumentation diagrams, and descriptive information in FSAR Section 9.5.8 for the system and auxiliary support systems essential to its operation.

9.5.8.4 Basis for Acceptance

The bases for the acceptance in the staff review was conformance of the design criteria and design of the diesel engine air intake and exhaust system to GDC 17 with respect to redundancy and physical independence, to the guidance of the cited RGs, to the guidance and additional acceptance criteria of SRP 9.5.8, to the recommendations of NRC/CR-0660, and to industry codes and standards and the ability of the system to provide sufficient combustion air and release of exhaust gases to enable the emergency diesel generator to perform on demand.

9.5.8.5 Conclusion

Based on its review, the staff concludes that the emergency diesel engine intake and exhaust system meets the requirements of GDC 12, 4, 5 and 17 and meets the requirements of NUREG/CR-0660, the guidance of the cited RGs and SRP 9.5.8, and industry codes and standards; thus, it can perform its design safety function and is, therefore, acceptable.

10 STEAM AND POWER CONVERSION SYSTEM

10.1 System Description

The steam and power conversion system is designed to remove heat energy from the primary reactor coolant loop via three steam generators and to generate electrical power in the turbine generator. After the steam passes through the high- and low-pressure turbines, the main condensers deaerate the condensate and transfer the rejected heat to the closed-cycle circulating water system, which uses a reservoir to dissipate the rejected heat. The condensate is reheated, further deaerated in a deaerating heater, and returned as feedwater to the steam generator. The entire system is designed for the maximum expected energy from the nuclear steam supply system.

A turbine steam dump (bypass) system is provided to discharge directly to the condenser up to 40% of the main steam flow around the turbine during transient conditions. This bypass capacity together with a 10% reactor automatic step load-reduction capability is sufficient to withstand a 50% generator load loss without tripping the turbine or lifting the main steam safety valves or tripping the reactor.

10.2 Turbine Generator

10.2.1 System Function

The turbine generator converts steam power into electrical power and has a turbine control and overspeed protection system. The design function of the turbine control and overspeed protection system is to control turbine action under all normal or abnormal conditions, to assure that a full-load turbine trip will not cause the turbine to overspeed beyond acceptable limits, and to minimize the probability of generation of turbine missiles in accordance with the requirements of General Design Criterion (GDC) 4, "Environmental and

Missile Design Bases." The turbine control system and overspeed protection system is, therefore, essential to the overall safe operation of the plant.

10.2.2 System Description

10.2.2.1 General Description

The turbine generator is manufactured by the Westinghouse Electric Company and is a tandem-compound type (single shaft) with one double-flow high-pressure turbine and two double-flow low-pressure turbines. The rotational speed is 1800 rpm and is designed for a net generator output of 1,312 MWe at a nominal plant exhaust pressure of 3.5 inches mercury (absolute).

The turbine generator is equipped with an digital electrohydraulic control (EHC) system. The EHC system consists of an electronic governor using solid-state control techniques in combination with a high-pressure hydraulic actuating system. The system includes electrical control circuits for steam pressure control, speed control, load control, and steam control valve positioning.

The applicant will include preoperational and startup tests of the turbine generator in accordance with RG 1.68, "Initial Test Programs for Water Cooled Power Plants." The adequacy of the test program is evaluated in Section 14 of this SER.

The turbine generator system meets the recommendations of Branch Technical Positions (BTPs) ASB 3-1, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," and MEB 3-1. "Postulated Break and Leakage Locations in Fluid Systems Outside Containment". Evaluation of protection against dynamic effects associated with the postulated pipe system failure is covered in Section 3.6 of this report.

10.2.2.2 Overspeed Protection Systems

Overspeed protection is accomplished by five independent systems. These systems are the following:

10.2.2.2.1 Main Speed Control Loop

The main speed control loop modulates the turbine governor (control) valves to maintain desired speed load characteristics and will start to close the governor valves when the turbine speed exceeds 100%.

10.2.2.2.2 Overspeed Protection Controller (Breaker Status)

If the unit is carrying more than 30 percent load and the generator breaker opens, the governor and interceptor valves are closed rapidly. The interceptor valves are oscillated between closed and partially open by the acceleration responsive auxiliary governor until the reheater steam is dissipated. After turbine speed has decreased, the auxiliary governor releases control to the normal speed control governor, which either maintains rated speed if the system is in automatic or brings the turbine down to turning gear operation if the system is in manual.

10.2.2.2.3 Overspeed Protection Controller (103% of Rated Speed)

The governor and interceptor valves are closed rapidly when the unit exceeds 103 percent of rated speed and remain closed until the speed drops below 103 percent. Thereafter, the valves function as described above in 10.2.2.2.2.

10.2.2.2.4 Mechanical Overspeed Trip

The mechanical overspeed trips the turbine throttle, governor, reheat stop, and interceptor valves by independently deenergizing the hydraulic fluid system when 111 percent of rated speed is reached. The unit then coasts down to turning gear operation.

10.2.2.2.5 Electrical Overspeed Trip

The electrical overspeed trip is a backup to the mechanical overspeed system and will trip these same valves when 111 percent of rated speed is reached by independently deenergizing the hydraulic fluid system when 111 percent of rated speed is reached. The unit then coasts down to turning gear operation.

10.2.2.2.6 Valve Closure Time

After an overspeed condition is detected, the turbine steam valves close in 150 milliseconds or less and the extraction steam valves within one second. These valves are designed to fail closed on loss of hydraulic system pressures. The overspeed trip system can be tested while the unit is on-line. Therefore, the requirements of GDC 4 are met.

10.2.2.3 Other Protective Trips

In order to protect the turbine generator, the following signals will also shutdown the turbine: (1) manual emergency trip from control room, (2) low bearing lubricating oil pressure, (3) low condenser vacuum, (4) manual trip at the turbine, (5) loss of stator cooling, (6) electrical equipment protection trip, (7) low hydraulic fluid pressure, (8) remote generator trip, (9) reactor trip, and (10) excessive thrust bearing wear.

10.2.2.4 Inservice Inspection

An inservice inspection program for the main steam throttle, governor reheat stop and interceptor valves is provided and includes: (a) dismantling and inspection of one of each type of turbine steam valves, at approximately 3 1/3 year intervals during refueling or maintenance shutdowns coinciding with the inservice inspection schedule, and (b) exercising and observing at least once a week the main steam stop and control, reheat stop, and intercept valves. This will be included in the plant technical specifications. The applicant is also

providing a monthly inservice inspection program for the extraction steam valves. The inspection will check that the extraction check valve closing mechanism travels in the closing direction in a free and positive manner.

10.2.3 Scope of Review

The scope of review of the turbine generator included descriptive information in Section 10.2 of the FSAR, flow charts and diagrams.

10.2.4 Basis for Acceptance

The basis for acceptance in our review was conformance of the design criteria and bases and design of the turbine generator system to GDC 4 with respect to the prevention of the generation of turbine missiles, the additional guidance of Standard Review Plan 10.2 and industry codes and standards.

10.2.5 Conclusion

Based on our review, we conclude that the turbine generator overspeed protection system meets the requirements of GDC 4, the guidance of Standard Review Plan 10.2, it can perform its design safety functions, and is, therefore, acceptable.

10.3 Main Steam Supply System

The function of the main steam supply system is to convey steam from the steam generators to the high-pressure turbine and other auxiliary equipment for power generation. Section 10.3.1 evaluates the safety-related portion of the main steam system including the main steam isolation valves (MSIVs). Section 10.3.2 evaluates the non-safety-related portion of the main steam system downstream of the MSIVs up to and including the turbine stop valves.

10.3.2 Main Steam Supply System Downstream of the Main Steam Isolation Valves

10.3.2.1 System Description

This portion of the main steam system is not required to effect or support safe shutdown of the reactor. This portion of the main steam and turbine steam systems provide steam to the feedwater pump turbine, pegging steam to the deaerator, auxiliary steam system, turbine gland seal systems, turbine steam dump (bypass) system and steam supply to the moisture separator reheaters. The main steam system from the MSIV to the first restraints outside the valve cubicle and connected piping up to and including the first valve that is either normally closed or capable of automatic closure during all modes of normal reactor operation are designed seismic Category I ASME Section III Class 2 (Quality Group B). The piping from the first restraint outside the valve cubicle to the turbine stop valves and all branch lines are designed to the requirements of ANSI B31.1 and are acceptable.

10.3.2.2 Scope of Review

The scope of review of the main steam supply system (between the MSIVs and up to and including the turbine stop valves) included descriptive information in FSAR Section 10.3, and flow charts and diagrams.

10.3.2.3 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design criteria and bases and design of main steam supply system to the acceptance criteria of Standard Review Plan 10.3.

10.3.2.4 Conclusion

Based on our review, we conclude the main steam supply system between the MSIVs and up to and including the turbine stop valves is in conformance with the above cited criteria and design bases, it can perform its designed functions, and is, therefore, acceptable.

10.4.1 Main Condenser

10.4.1.1 System Function

The main condenser functions as a heat sink for the turbine exhaust steam, turbine bypass steam, and other turbine cycle flows and to receive and collect condensate flows for return to the steam generators.

10.4.1.2 System Description

The main condenser transfers heat to the circulating water system which uses a reservoir to dissipate the rejected heat. The main condenser is not required to effect or support safe shutdown of the reactor or to perform in the operation of reactor safety features. The main condenser has three shells and is designed to produce a turbine back pressure of 3.5 inches mercury absolute when operating at rated turbine output. The main condenser design includes provisions for condensate deaeration and hotwell surge storage of condensate for approximately five minutes supply at design conditions. Offgas from the main condenser is processed in the condenser air removal system, which is described and evaluated in Section 10.4.2 of this report.

The main condenser is designed to accept full load exhaust steam from the main turbine, and reactor feedwater pump turbines, up to 40% of the main steam flow from the turbine steam bypass system, and other cycle steam flows. The main condenser is also designed to deaerate the condensate to the required water

quality. Titanium tubes have been used to minimize corrosion and erosion of condenser tubes. In addition, an impressed current cathodic protection system is provided to protect the titanium tube ends, and the aluminum bronze tube sheets. Condenser tube leakage could result in degradation of the feedwater quality with potential for corrosion of secondary system components. The applicant monitors condensate sodium content by means of an automatic hotwell sampling system to give an indication of tube leakage. The adequacy of the secondary sampling system for leak detection is evaluated in Section 9.3.2 of this report. Radiation monitors are provided in the steam lines and in the steam generator blowdown system which dump into the main condenser and in the condenser vacuum pump discharge.

The applicant will include preoperational and startup tests of the main condenser in accordance with RG 1.68, "Initial Test Programs for Water Cooled Reactor Power Plants." The adequacy of the test program is evaluated in Section 14.1 of this SER.

The effects of flooding resulting from condenser failure is evaluated in Section 3.4 of this SER.

10.4.1.3 Scope of Review

The scope of review of the main condenser included layout drawings and descriptive information of the condenser in Section 10.4.1 of the FSAR.

10.4.1.4 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design criteria and bases and design of the condenser to the acceptance criteria and guidance of Standard Review Plan 10.4.1 and industry codes and standards.

10.4.1.5 Conclusion

Based on our review, we conclude that the main condenser is in conformance with the above cited criteria and design bases, it can perform its designed function and is, therefore, acceptable.

10.4.4 Turbine Bypass System

10.4.4.1 System Function

The turbine bypass system's (TBS) function is to control coolant temperature as follows: (a) during the reactor heatup to rated pressure, (b) while the turbine generator is being brought up to speed and synchronized, (c) during power operation when the reactor steam generation exceeds the transient turbine steam requirements, and (d) during cooldown.

10.4.4.2 System Description

The turbine bypass system is designed to bypass up to 40% of main steam flow to the main condenser. This capacity together with a 10% reactor automatic step load capability is sufficient to withstand a 50% generator load loss without tripping the turbine or causing control rod movement. This system is not required to perform during accident conditions.

The turbine bypass system's (TBS) function to control coolant temperature as follows: a) during the reactor heatup to rated pressure; b) while the turbine generator is being brought up to speed and synchronized; c) during power operation when the reactor steam generation exceeds the transient turbine steam requirements; and d) during reactor cooldown.

10.4.4.2 System Description

The turbine bypass system is designed to bypass up to 40% of main steam flow to the main condenser. This capacity together with a 10% reactor automatic step load capability is sufficient to withstand a 50% generator load loss without tripping the turbine or causing control rod movement. This system is not required to perform during accident conditions.

The bypass system is composed of the following: (1) 12 air operated valves, (2) associated instruments and controls, and (3) piping. Each valve is rated for a capacity of approximately 3.3 percent of the main steam flow at full load pressure and temperature. The 12 bypass valves are connected to the main steam header downstream of the main steam isolation valves and discharge the steam directly to the main condenser (six valves to each condenser side). The turbine bypass valves are designed to fail closed upon loss of electric power or air system pressure to the valve control system. The turbine bypass valves are designed to close on loss of main condenser vacuum.

The applicant will include preoperational and startup tests of the turbine bypass system in accordance with recommendations of Regulatory Guide 1.68, "Initial Test Programs for Water Cooled Reactor Power Plants." The adequacy of the test program is evaluated in Section 12.1 of this report. The turbine bypass system will be covered by an inservice inspection program and will be tested on an 18 month frequency.

The turbine bypass system meets the recommendations of Branch Technical Positions SB 3-1, "Protection Against Postulated Piping Failures in Fluid System Piping Outside Containment and MEB 3-1, "Postulated Break and Leakage Locations in Fluid System Piping Outside Containment." Evaluation of protection against dynamic effects associated with the postulated pipe system failure is covered in Section 3.6 of this report.

10.4.4.3 Scope of Review

The scope of review of the turbine bypass system included drawings, piping and instrumentation diagrams and descriptive information of the system in Section 10.4.4. of the FSAR.

10.4.4.4 Basis for Acceptance

The basis for acceptance in the staff review was conformance of the design criteria and bases and design of the turbine bypass system to the acceptance criteria and guidance of Standard Review Plan 10.4.4 and industry codes and standards.

10.4.4.5 Conclusion

Based on our review, the staff concludes that the turbine bypass system is in conformance with the above cited criteria and design bases, it can perform its designed function, and is, therefore, acceptable.

APPENDIX C
NUCLEAR REGULATORY COMMISSION (NRC)
UNRESOLVED SAFETY ISSUES

C.1 Introduction

The NRC staff evaluates the safety requirements used in its reviews against new information as it becomes available. Information related to the safety of nuclear power plants comes from a variety of sources including experience from operating reactors; research results; NRC staff and Advisory Committee on Reactor Safeguards (ACRS) safety reviews; and vendor, architect/engineer, and utility design reviews. After the Accident at TMI the Office for Analysis and Evaluation of Operational Data was established to provide a systematic and continuing review of operating experience. Each time a new concern or safety issue is identified from one or more of these sources, the need for immediate action to ensure safe operation is assessed. This assessment includes consideration of the generic implications of the issue.

In some cases, immediate action is taken to assure safety, e.g., the derating of boiling water reactors as a result of the channel box wear problems in 1975. In other cases, interim measures, such as modifications to operating procedures, may be sufficient to allow further study of the issue prior to making licensing decisions. In most cases, however, the initial assessment indicates that immediate licensing actions or changes in licensing criteria are not necessary. If the issue applies to several or a class of plants the issue is evaluated further as a "generic safety issue". This evaluation considers the safety significance of the issues, the cost to implement any changes in plant design or operation and other significant and relevant factors to establish a priority ranking of the issue. Based on this ranking, resolution of the issue is scheduled for near term resolution, deferred until resources become available or dropped from further consideration.

Issues with the highest priority ranking are reviewed to determine whether they should be designated as "unresolved safety issues" (NUREG-0410, "NRC Program for the Resolution of Generic Issues Related to Nuclear Power Plants", dated January 1, 1978). However, as discussed above, such issues are considered on a generic basis only after the staff has made an initial determination that the safety significance of the issue does not prohibit continued operation or require licensing actions while the longer term generic review is underway.

These longer term generic studies were the subject of a Decision by the Atomic Safety and Licensing Appeal Board of the Nuclear Regulatory Commission. The Decision was issued on November 23, 1977 (ALAB-444) in connection with the Appeal Board's consideration of the Gulf States Utility Company application for the River Bend Station, Unit Nos. 1 and 2. These issues were also considered in the operating license proceeding, "Virginia Electric and Power Company (North Anna Nuclear Power Station, Unit Nos. 1 and 2)", ALAB-491, issued August 25, 1978. A further discussion of these issues is contained in a decision by the Atomic Safety and Licensing Appeal Board in connection with its considerations of the Pacific Gas and Electric Company operating license application for the Diablo Canyon Nuclear Power Plant, Units 1 and 2

(ALAB-728, issued May 18, 1983). In the ALAB-728 Decision, the Board stated with regard to an operating license proceeding that: "it would be helpful to us if the staff would include in an SER supplement an explanation of the unresolved safety issues affecting the facility under review and the reasons the facility could nonetheless safely operate pending resolution of those issues." This appendix is provided in response to the Board's request.

C.2 Unresolved Safety Issues

In a related matter, as a result of Congressional action on the Nuclear Regulatory Commission budget for the Fiscal Year 1978, the Energy Reorganization Act of 1974 was amended (PL 95-209) on December 13, 1977, to include, among other things, a new Section 210 as follows:

UNRESOLVED SAFETY ISSUES PLAN

> SEC. 210. The Commission shall develop a plan for providing for specification and analysis of unresolved safety issues relating to nuclear reactors and shall take such action as may be necessary to implement corrective measures with respect to such issues. Such plan shall be submitted to the Congress on or before January 1, 1978, and progress reports shall be included in the annual report of the Commission thereafter.

The Joint Explanatory Statement of the House-Senate Conference Committee for the Fiscal Year 1978 Appropriations Bill (Bill S. 1131) provided the following additional information regarding the Committee's deliberations on this portion of the bill:

SECTION 3 - UNRESOLVED SAFETY ISSUES

> The House amendment required development of a plan to resolve generic safety issues. The conferees agreed to a requirement that the plan be submitted to the Congress on or before January 1, 1978. The conferees also expressed the intent that this plan should identify and describe those safety issues, relating to nuclear power reactors, which are unresolved on the date of enactment. It should set forth: (1) Commission actions taken directly or indirectly to develop and implement corrective measures; (2) further actions planned concerning such measures; and (3) timetables and cost estimates of such actions. The Commission should indicate the priority it has assigned to each issue, and the basis on which priorities have been assigned.

In response to the reporting requirements of the new Section 210, the NRC staff submitted NUREG-0410 to Congress on January 1, 1978. This NUREG describes the NRC generic issues program. The NRC program was already in place when PL 95-209 was enacted and is of considerably broader scope than the unresolved safety issues plan required by Section 210. In the letter transmitting NUREG-0410 to the Congress on December 30, 1977, the Commission indicated: "the progress reports, which are required by Section 210 to be included in future NRC annual reports, may be more useful to Congress if they focus on the specific Section 210 safety items."

It is the NRC's view that the intent of Section 210 was to ensure that plans were devloped and implemented on issues with potentially significant public safety implications. In 1978, the NRC undertook a review of more than 130 generic issues addressed in the NRC program to determine which issues fit this description and qualify as unresolved safety issues for reporting to the Congress. The NRC review included the development of proposals by the NRC staff and review and final approval by the NRC Commissioners.

The review is described in a report, NUREG-0510, "Identification of Unresolved Safety Issues Relating to Nuclear Power Plants - A Report to Congress", dated January 1979. The report provides the following definition of an unresolved safety issue:

> An Unresolved Safety Issue is a matter affecting a number of nuclear power plants that poses important questions concerning the adequacy of existing safety requirements for which a final resolution has not yet been developed that involves conditions not likely to be acceptable over the lifetime of the plants it affects.

Further, the report indicates that in applying this definiton, matters that pose "important questions concerning the adequacy of existing safety requirements" were judged to be those for which resolution is necessary to (1) compensate for a possible major reduction in the degree of protection of the public health and safety, or (2) provide a potentially significant decrease in the risk to the public health and safety. Quite simply, an unresolved safety issue is potentially significant from a public safety standpoint and its resolution is likely to result in NRC action on the affected plants.

All of the issues addressed in the NRC program were systematically evaluated against this definition as described in NUREG-0510. As a result, 17 unresolved safety issues addressed by 22 tasks in the NRC program were identified.

An in-depth and systematic review of generic safety concerns identified between January 1979 and March 1981 was performed by the staff to determine if any of these issues should be designated as Unresolved Safety Issues. The candidate issues originated from concerns identified in NUREG-0660, "NRC Action Plan as a Result of the TMI-2 Accident"; from ACRS recommendations; from abnormal occurrence reports; and from other operating experience. The staff's proposed list was reviewed and commented on by the ACRS, the Office of Analysis and Evaluation of Operational Data (AEOD), and the Office of Policy Evaluation. The ACRS and AEOD also proposed that several additional Unresolved Safety Issues be considered by the Commission. The Commission considered the above information and approved the four Unresolved Safety Issues A-45 through A-48. A description of the review process for candidate issues, together with a list of the issues considered, is presented in NUREG-0705, dated March 1981. An expanded discussion of each of the new Unresolved Safety Issues is also in NUREG-0705. In addition to the four issues identified above, in December 1982 the Commission approved another issue, A-49, Pressurized Thermal Shock, as an Unresolved Safety Issue.

A further review of generic issues was performed in 1984 to determine if any new issues should be designated Unresolved Safety Issues (SECY-84-458, dated December 3, 1984). No new USIs were approved by the Commission as a result of that review.

The issues are listed below. The number(s) of the generic task(s) (for example, A-1) in the NRC program addressing each issue is indicated in parentheses following the title.

Unresolved Safety Issues (Applicable Task Nos.)

(1) Waterhammer (A-1)
(2) Asymmetric blowdown loads on the reactor coolant system (A-2)
(3) Pressurized water reactor steam generator tube integrity (A-3, A-4, A-5)
(4) BWR Mark I and Mark II pressure suppression containments (A-6, A-7, A-8, A-39)
(5) Anticipated transients without scram (A-9)
(6) BWR nozzle cracking (A-10)
(7) Reactor vessel materials toughness (A-11)
(8) Fracture toughness of steam generator and reactor coolant pump supports (A-12)
(9) Systems interaction in nuclear power plants (A-17)
(10) Environmental Qualification of safety-related electrical equipment (A-24)
(11) Reactor vessel pressure transient protection (A-26)
(12) Residual heat removal requirements (A-31)
(13) Control of heavy loads near spent fuel (A-36)
(14) Seismic design criteria (A-40)
(15) Pipe cracks in boiling water reactors (A-42)
(16) Containment emergency sump reliability (A-43)
(17) Station blackout (A-44)
(18) Shutdown decay heat removal requirements (A-45)
(19) Seismic qualification of equipment in operating plants (A-46)
(20) Safety implications of control systems (A-47)
(21) Hydrogen control measures and effects of hydrogen burns on safety equipment (A-48)
(22) Pressurized thermal shock (A-49)

Ten of the 27 tasks identified with the unresolved safety issues are not applicable to South Texas Unit 1 and six of these ten tasks (A-6, A-7, A-8, A-10, A-39, and A-42) are peculiar to boiling water reactors. Tasks A-4 and A-5 address steam generator tube problems in Combustion Engineering and Babcock and Wilcox plants. A-46 deals with seismic qualification of equipment in operating plants and does not apply to South Texas. The staff's evaluation of South Texas seismic equipment qualification is reported in Sections 3.9.2 and 3.10 of this SER. Also, Task A-48 is related to PWR plants with ice-condenser containments or BWRs with pressure suppression type containments. With regard to the remaining tasks that are applicable to this facility, the NRC staff has issued NUREG reports providing its proposed resolution of ten of these issues (Table C.1). Each of these has been addressed in this Safety Evaluation Report or will be addressed in a future supplement. Table 1 lists those issues and the section of this SER in which they are discussed.

The remaining issues applicable to the facility are:

A-3 Westinghouse steam generator tube integrity
A-17 Systems interaction in nuclear power plants
A-40 Seismic desgin criteria
A-44 Station blackout
A-45 Shutdown decay heat removal requirements
A-47 Safety implications of control systems
A-49 Pressurized thermal shock

Task Action Plans for Unresolved Safety Issues for which no staff NUREG report has been issued and for which work is continuing are presented in NUREG-0649, Revision 1, "Task Action Plans for Unresolved Safety Issues Related to Nuclear Power Plants".

Each task action plan provides a description of the problem; the staff's approach to its resolution; a general discussion of the basis upon which continued plant licensing or operation can proceed pending completion of the task; the technical organizations involved in the task and estimates of the manpower required; a description of the interactions with other NRC offices, the ACRS, and outside organizations; estimates of funding required for contractor-supplied technical assistance; prospective dates for completing the task; and a description of potential problems that could alter the planned approach or schedule.

In addition to the Task Action Plans, the staff issues the "Unresolved Safety Issues Summary, Aqua Book" (NUREG-0606) on a quarterly basis; this report provides current schedule information for each of the Unresolved Safety Issues. It also includes information relative to the implementation status of each Unresolved Safety Issue for which technical resolution is complete.

The staff has reviewed the Unresolved Safety Issues listed above as they relate to South Texas. Discussion of each of these issues, including references to related discussions in the Safety Evaluation Report, is in Section C.3.

Based on its review, the staff concludes for the reasons set forth in Section C.3 that there is reasonable assurance that South Texas can be operated before the ultimate resolution of these generic issues without endangering the health and safety of the public. Task A-47 is accepted subject to the resolution of those confirmatory items identified in Section C.3.

C.3 DISCUSSIONS OF USIS AS THEY RELATE TO SOUTH TEXAS UNITS 1 & 2

This section provides the NRC staff's evaluation of South Texas for each of the applicable Unresolved Safety Issues. This includes the staff's bases for licensing before ultimate resolution of these issues.

A-3 <u>Westinghouse Steam Generator Tube Integrity</u>

The primary concern is the capability of steam generator tubes to maintain their integrity during normal operation and postulated accident conditions.

Westinghouse steam generators have experienced tube degradation in several forms. These are wastage, intergranular attack, stress corrosion cracking, denting and mechanical vibrations. Each of these forms of degradation is discussed below, and the specific measures to prevent their occurrence at South Texas are included.

1. Wastage is characterized by general loss of metal from the tube wall because of a chemical corrosive reaction. Wastage has occurred only in steam generators which used sodium phosphate as a chemical additive. The South Texas steam generators will use a water treatment consisting of hydrazine and ammonium hydroxide (this is called all volatile treatment or AVT). Wastage has not been observed in steam generators using all volatile chemistry control.

(2) Intergranular attack is a corrosion phenomena in which the grain boundaries of the Inconel 600 tube are preferentially attacked without a preferential stress related orientation. Intergranular attack has occurred in steam generators in which the tubes were not expanded the full depth of the tube sheet. The resulting crevice can provide a site for concentrating impurities in the bulk environment. The South Texas generator tubes have been expanded the full depth of the tube sheet by rolling in Unit No. 1 and by hydraulic expansion in Unit No. 2. Thus, the elimination of the crevice should preclude the occurrence of intergranular attack. In addition, in some plants, intergranular attack has occurred slightly above the tube sheet where sludge tends to accumulate. The South Texas steam generators contain a flow distribution plate located below the preheat section which encourages recirculating flow to sweep the tubesheet before turning upward through the tube bundle.

(3) Stress corrosion cracking (SCC) refers to the type of corrosive intergranular attack in which cracks grow in the direction of an applied or residual tensile stress. SCC has occurred in smaller radius inner row U-bend tubes of some Westinghouse steam generators. Early instances were related to applied stresses caused by denting and the actions taken by the applicant to mitigate denting are discussed next. Other instances of U-bend cracking were related to residual stresses and are under active staff investigation. However, the design of the South Texas steam generators is such that the minimum inner tube U-bend radius is greater than that in other designs which have experienced SCC. This should substantially improve one potential cause of U-bend cracking.

(4) Denting has been probably the most serious degradation problem encountered in Westinghouse steam generators. Denting is caused by rapid corrosion of the tube support plates at the holes where the tubes pass through the support plates. Denting is known to be caused by operation of the steam generators outside the allowable range of water chemistry control parameters, specifically during times of major

condenser leakage. It appears that the use of copper materials in the feed and condensate systems contributes to the severity of denting. The following actions will be taken to prevent denting:

(a) Under the sponsorship of the Steam Generator Owners Group (SGOG), a set of chemistry guidelines for the satisfactory operation of steam generators has been written. These guidelines provide, based on the best available research data on the steam generator tube corrosion problem, limits which will ensure that problems such as denting do not occur. The applicant commits to operate in accordance with these guidelines.

(b) The use of copper containing alloys in the secondary loop has been completely eliminated. Condenser integrity is improved through the use of titanium tubes and full flow condensate polishers are utilized. A full flow deairator has been provided to achieve steady state oxygen concentrations of 2ppb at full and low load operation.

There is no industry experience available to assess the long-term reliability of the Westinghouse Model E steam generator. South Texas Project is a member of the Steam Generator Owners Group and fully supports the objectives of that organization. Included in the work of the SGOG are long-term evaluations of the applications of the chemistry guidelines, improved nondestructive examination techniques, research into the causes of known tube degradation mechanisms, and development of analytical techniques to predict steam generator performance.

Tube vibration in the region near the feedwater nozzle has been a problem at earlier units with the Westinghouse pre-heater type steam generators. Modifications have been made to address this problem. The staff's evaluation of these modifications is contained in NUREG-1014, "Review of Model D4/D5 Preheat Steam Generator Modifications," October 1983.

Pending completion of Task A-3, the measures taken at this facility should minimize the steam generator tube problems encountered. Further, the inservice inspection and Technical Specification requirements will assure that the applicant and the NRC staff are alerted to tube degration should it occur. Appropriate actions such as tube plugging, increased and more frequent inspections and power derating could be taken if necessary. Since the improvements that will result from Task A-3 are expected to be procedural, i.e., improved inspection of the steam generators, they can be implemented by the applicant after operation of this facility begins, if necessary.

Based on the foregoing, we have concluded that there is reasonable assurance that the South Texas plant can be operated prior to final resolution of this generic issue without undue risk to the health and safety of the public.

Task A-17 Systems Interactions in Nuclear Power Plants

The staff's systems interaction program was initiated in May 1978 with the definition of Unresolved Safety Issue A-17 (Systems Interactions in Nuclear Power Plants). The concern arises because the design, analysis, and installation of systems are frequently the responsibility of teams of engineers with functional specialties such as civil, electrical, mechanical, or nuclear. Experience at operating plants has led to questions of whether the work of these functional specialists is sufficiently integrated to enable them to minimize adverse interactions among systems. Some adverse events that occurred in the past might have been prevented if the teams had ensured the necessary independence of safety systems under all conditions of operation.

The applicant has not described a comprehensive program that separately evaluates all structures, systems, and components important to safety for adverse systems interactions. However, the plant has been evaluated against current licensing requirements that are founded on the principle of defense-in-depth. Adherence to this principle and conformance to the regulations (e.g., General Design Criteria) results in requirements such as physical separation and independence of redundant safety systems as well as protection against hazards such as high-energy line ruptures, missiles, high winds, flooding, seismic events, and fires. These design provisions are subject to review against the Standard Review Plan (NUREG-0800), which requires interdisciplinary reviews of safety-grade equipment and addresses various types of potential systems interactions. Also, the quality assurance program that is followed during the design, construction, and operational phases for each plant contributes to the prevention of introducing adverse systems interactions.

The NRC staff's current review procedures assign primary responsibility for review of various technical areas to specific organizational units and secondary responsibility to other units where there is a functional interface. Designers follow somewhat similar procedures and provide the analyses of systems and interface reviews. Task A-17 is investigating the potential safety significance of adverse systems interactions and possible methods that could identify adverse systems interactions that were not uncovered by current review procedures. After the resolution of A-17, the staff will determine whether the applicant must perform further evaluations for adverse systems interactions.

Based on the foregoing discussion, the staff concludes that there is reasonable assurance that South Texas Units 1 & 2 can be operated safely before ultimate resolution of this generic issue without undue risk to the health and safety of the public.

Task A-40 Seismic Design Criteria

NRC regulations require that nuclear power plant structures, systems, and components important to safety withstand the effects of seismic events. Detailed requirements and guidance regarding the seismic design of the plants are provided in NRC regulations and Regulatory Guides. However, there are a number of plants with licenses that were issued before NRC's

current regulations and guides were in place. Task A-40 is an effort to reevaluate the older plants to assure no undue public risk is involved and to make revisions to the Standard Review Plan (SRP) and Regulatory Guides to bring them in line with the state of the art in seismic design requirements. A-40 basically consists of a number of seismic design criteria changes which upgrade the SRP to reflect advanced technical knowledge and in some cases to reflect current industry practice.

Safety-related structures, systems, and components for South Texas are designed to withstand the effects of earthquakes in accordance with current NRC regulations, regulatory guides, and the Standard Review Plan, as discussed in Sections 3.7, 3.8, 3.9, and 3.10 of the FSAR. Specifically, the five subjects identified in the NRC's issue description for task A-40, i.e., magnitude of earthquakes (SSE), free-field motion (SSE), soil-structures interaction, motion of plant equipment, and load combination, are discussed therein. Design of structure for protection against natural phenomena such as earthquake is described in Section 3.8. Should the resolution of USI A-40 indicate that a change is needed in these licensing requirements, all operating reactors, including South Texas will be re-evaluated on a case-by-case basis.

Accordingly, the staff concludes that there is reasonable assurance that South Texas Units 1 and 2 can be operated before ultimate resolution of this generic issue without undue risk to the health and safety of the public.

<u>Task A-44 Station Blackout</u>

Electrical power for safety systems at nuclear power plants must be supplied by at least two redundant and independent divisions. The systems used to remove decay heat to cool the reactor core following a reactor shutdown are included among the safety systems that must meet these requirements. Each electrical division for safety systems includes two offsite alternating current (ac) power connections, a standby emergency diesel generator alternating current power supply, and direct current sources.

Task A-44 involves a study of whether or not nuclear power plants should be designed to accommodate a complete loss of all alternating current power, that is, a loss of both the offsite and the emergency diesel generator alternating current power supplies. This issue arose because of operating experience regarding the reliability of alternating current power supplies. A number of operating plants have experienced a total loss of offsite electrical power, and more occurrences are expected in the future. In almost every one of these loss-of-offsite power events, the onsite emergency alternating current power supplies were available immediately to supply the power needed by vital safety equipment. However, in some instances, one of the redundant emergency power supplies has been unavailable. In a few cases there has been a complete loss of ac power, but during these events, ac power was restored in a short time without serious consequences. In addition, there have been numerous instances of emergency diesel generators failing to start and run in operating plants during periodic surveillance tests.

A loss of all ac power was not a design-basis event for South Texas. Nonetheless, a combination of design, operating, and testing requirements has been imposed to ensure that this unit will have substantial resistance to a loss of all alternating current and that, even if a loss of all ac power should occur, there is reasonable assurance the core will be cooled. These design, operating, and testing requirements are discussed below.

A complete loss of offsite ac power involves the loss of both the preferred and backup sources of offsite power to South Texas. The staff's review and basis for acceptance of the design, inspection, and testing provisions for the offsite power system are described in Section 8.2 of this SER.

If offsite ac power is lost, three independent and physically separate diesel generators and their associated distribution systems will deliver emergency power to safety-related equipment. The staff's review of the design, testing, surveillance, and maintenance provisions for the onsite emergency diesels is described in Sections 8.3 and 9.5 of this SER. Staff requirements include preoperational testing to ensure the reliability of the installed diesel generators in accordance with the provisions of Regulatory Guide 1.108. In addition, the applicant has been required to implement a program for enhancing diesel generator reliability to ensure the long-term reliability of the diesel generators. This program resulted from recommendations of NUREG/CR-0660, "Enhancement of Onsite Emergency Generator Reliability."

If both offsite and onsite ac power are lost, cooling water can still be provided to the steam generator by the auxiliary feedwater system employing a steam turbine-driven pump that does not rely on ac power for operation. The auxiliary feedwater system design and operation is described in SER Section 10.4.9 of the SER.

In addition to the above, the Commission has determined that some interim measures should be taken at all plants to accommodate a station blackout pending resolution of the issue. Consequently, the NRC requested (Generic Letter 81-04, dated February 25, 1981) a review of plant operation to determine the applicant's capability to mitigate a station blackout event and properly implement, as necessary, emergency procedures and training programs for station blackout events. Appropriate review of the procedures and training programs for station blackout events will be completed before fuel load. South Texas will utilize the Westinghouse Owner's Group Loss of All AC Power Guidelines for development of emergency operating procedures.

Based on the above considerations, the staff concludes that there is reasonable assurance that South Texas Units 1 & 2 can be operated before the ultimate resolution of this generic issue without undue risk to the health and safety of the public.

Task A-45 Shutdown Decay Heat Removal Requirements

Under normal operating conditions, power generated within a reactor is removed as steam to produce electricity through a turbine generator. Following a reactor shutdown, a reactor produces insufficient power to operate the turbine; however, the radioactive decay of fission products continues to produce heat (so-called "decay heat"). Therefore, when the

reactor is shut down, other measures must be available to remove decay heat from the reactor to ensure that high temperatures and pressures do not develop that could jeopardize the reactor and the reactor coolant system. It is evident, therefore, that all light-water reactors (LWRs) share two common decay-heat-removal functional requirements: (1) to provide a means of transferring decay heat from the reactor coolant system to an ultimate heat sink, and (2) to maintain sufficient water inventory inside the reactor vessel to ensure adequate cooling of the reactor fuel. The reliability of a particular power plant to perform these functions depends on the frequency of initiating events that require or jeopardize decay heat removal operations and the probability that required systems will respond to remove the decay heat.

The TMI-2 accident demonstrated how a relatively common fault, with which the operator should have been able to cope easily, could escalate into a potentially hazardous situation, with severe financial losses to the utility, as a result of difficulties arising in the decay heat removal (DHR) process.

Other circumstances, of a more unusual nature (e.g., damage to systems by external events such as floods or earthquakes, or by sabotage), which could make removal of the decay heat difficult, can also be foreseen.

The question arises, therefore, whether current licensing design requirements are adequate to ensure that LWRs do not pose unacceptable risk as a result of a failure to remove shutdown decay heat, and whether, at a cost commensurate with the increase in safety that could be achieved, improvements could be made in the effectiveness of shutdown decay heat removal in one or more transient or accident situations. Resolution of this question is considered to be of sufficient importance to merit raising it to the status of an unresolved safety issue.

To some extent, the effectiveness of the DHR systems is linked to that of the onsite and offsite electrical supplies; the performance and reliability of those supplies is being considered in A-44, Station Blackout. Consequently, the scope of work required in relation to the decay heat removal systems is complementary to Task A-44 above.

The overall purpose of Task A-45 is to evaluate the adequacy of current licensing design requirements to ensure that nuclear power plants do not pose an unacceptable risk because of a failure to remove shutdown decay heat. This will require the development of a comprehensive and consistent set of shutdown cooling requirements for existing and future LWRs, including the study of alternative means of shutdown decay heat removal and of diverse "dedicated" systems for this purpose.

This task will evaluate the benefit of providing alternate means of DHR that could substantially increase the plant's capability to handle a broader spectrum of transients and accidents. The study will include a number of plant-specific DHR systems evaluations and will result in recommendations regarding the desirability of, and possible design requirements for, improvements in existing systems of an alternate decay heat removal method, if the improvements or alternatives can significantly reduce the overall risk to the public in a cost-effective manner.

The principal means for removing the decay heat in a PWR under normal conditions immediately following reactor shutdown is through the steam generators, using the auxiliary feedwater system. In addition to the WASH-1400 study (NUREG-75/014), later reliability studies and related experience from the Three Mile Island Unit 2 (TMI-2) accident have reaffirmed that the loss of capability to remove heat through the steam generator is a significant contributor to the probability of a core melt event. The staff's review of the auxiliary feedwater system design and operation is described in Section 10.4.9 of this SER.

It should be noted, as discussed below, that the NRC required licensees to implement many improvements to the steam generator auxiliary feedwater system following the TMI-2 accident. However, the staff still believes that providing an alternative means of decay heat removal could substantially increase the plant's capability to deal with a broader spectrum of transients and accidents and potentially could, therefore, significantly reduce the overall risk to the public. Consequently, this task will investigate alternative means of decay heat removal in PWR plants, including but not limited to, using existing equipment where possible. This study will include a representative sample of plant-specific DHR system evaluations. It will result in recommendations regarding the adequacy of existing DHR requirements and the desirability of, and possible design requirements for, an alternative DHR method, other than that normally associated with the steam generator and secondary coolant system.

The auxiliary feedwater (AFW) system is a very important safety system in a PWR in terms of providing a heat sink via the steam generators to remove core decay heat. As mentioned above, the TMI-2 accident and subsequent studies have further highlighted the importance of the AFW systems. As discussed below, the NRC staff has required certain upgrading of the AFW systems for all LWRs following the TMI-2 accident. Although this task will investigate alternative means of decay heat removal, the NRC staff concludes that in general (not on a plant-specific basis) if the licensees comply with the upgrading of requirements for the AFW system, the action taken following the TMI-2 accident justifies continued operation and licensing pending completion of this task. Further discussion and the bases for this view are provided below.

TMI-2 Accident

The accident at TMI-2 on March 28, 1979, involved a main feedwater transient coupled with a stuck-open pressurizer power-operated relief valve and a temporary failure of the auxiliary feedwater system, and subsequent operator intervention to severely reduce flow from the safety injection system. The resulting severity of the ensuing events and the potential generic aspects of the accident on the other operating reactors led the NRC to initiate prompt action to: (1) ensure that other reactor licensees, particularly those with plants similar in design to TMI-2, took the necessary action to substantially reduce the likelihood for TMI-2-type events, and (2) investigate the potential generic implications of this action for other operating reactors.

The Bulletins and Orders Task Force (BOTF) was established within the NRC Office of Nuclear Reactor Regulation (NRR) in early May 1979 and completed its work on December 31, 1979. This task force was responsible for reviewing and directing the TMI-2-related staff activities associated with the NRC Office of Inspection and Enforcement (IE) Bulletins, Commission Orders, and generic

evaluations of loss-of-feedwater transients and small-break loss-of-coolant accidents for all operating plants to ensure their continued safe operation. NUREG-0645, "Report of the Bulletins and Orders Task Force," summarizes the results of the work performed.

Generic and Plant-Specific Studies

For B&W-designed operating reactors, an initial NRC staff study was completed and published in NUREG-0560, "Staff Report on the Generic Assessment of Feedwater Transients in Pressurized Water Reactors Designed by the Babcock & Wilcox Company." This study considered the particular design features and operational history of B&W-designed operating plants in light of the TMI-2 accident and related current licensing requirements.

Generally, the activities involving the B&W-designed reactors are reflected in the actions specified in the Commission Orders. Consequently, a number of actions have been specified regarding transient and small-break analyses, upgrading of auxiliary feedwater reliability and preformance, procedures for operator action, and operator training. The results of the NRC staff review of the B&W small-break analysis are published in NUREG-0565, "Generic Evaluation of Small-Break Loss-of-Coolant Accident Behavior in Babcock & Wilcox-Designed Operating Plants."

Similar studies have been completed for operating plants designed by Westinghouse (W), Combustion Engineering (CE), and General Electric (GE). Those studies, which also focus specifically on the predicted plant performance under different accident scenarios involving feedwater transients and small-break LOCAs, are published in NUREG-0611, "General Evaluation of Feedwater Transients and Small-Break Loss-of-Coolant Accidents in Westinghouse-Designed Operating Plants."

Based on the review of the operating plants in light of the TMI-2 accident, the NRC staff reached the following conclusions:

(1) The continued operation of the operating plants is acceptable provided that certain actions related to the plants' design and operation and training of operators identified in NUREG-0645 are implemented, consistent with the recommended implementation schedules.

(2) The actions taken by the licensees with operating plants in response to the IE Bulletins (including the actions specified in NUREG-0623, "Generic Assessment of Delayed Reactor Coolant Pump Trip During Small Break Loss-of-Coolant Accidents in Pressurized Water Reactors") provided added assurance for the protection of the health and safety of the public.

In addition, the BOTF independently confirmed the safety significance of those related actions recommended by other NRR task forces as discussed in NUREG-0645.

Pressurized Water Reactors

The primary method for removal of decay heat from PWRs is via the steam generators to the secondary system. This energy is transferred on the secondary side to either the main feedwater or auxiliary feedwater systems, and is rejected to either the turbine condenser or the atmopshere via the secondary coolant system safety/relief valves. Following the TMI-2 accident, the importance of the AFW was highlighted and a number of improvements were made to improve the reliability of the AFW (NUREG-0645). It was also required that operating plants be capable of providing the required AFW flow for at least 2 hours from one AFW pump train independent of any ac power source; that is, if both offsite and onsite ac power sources are lost.

Some PWRs potentially have at least one alternate means of removing decay heat if an extended loss of feedwater is postulated. This method is known as "feed and bleed" and uses the high-pressure injection (HPI) system to add water coolant (feed) at high pressure to the primary system. The decay heat increases the system pressure and energy is removed through the power-operated relief valves (PORVs) and/or the safety valves (bleed), if necessary. Limited vendor analyses have shown that the core can be adequately cooled by this means, provided that the containment pressure can be controlled to a safe level and that the process is initiated by the time of steam generator dryout.

When the primary system is at low pressure, the long-term decay heat is removed by the residual heat removal system to achieve and maintain cold shutdown conditions. Task A-45 will also consider the adequacy of reliability and performance criteria and standards for RHR systems. The staff's review of the RHR system design and operation is described in Section 5.4.7 of the SER.

Conclusion

In summary, because of the upgrading of current DHR systems that was required following the TMI-2 accident, the staff concludes that, in general, plants may continue to be licensed and operated before the ultimate resolution of this generic issue without endangering the health and safety of the public. However, licensee compliance with the upgrading of DHR system requirements must be examined by the staff on an individual case basis. For South Texas Units 1 and 2, the staff has concluded that there is reasonable assurance that South Texas Units 1 and 2 can be operated prior to ultimate resolution of this generic issue without undue risk to the health and safety of the public.

Task A-47 Safety Implications of Control Systems

This issue concerns the potential for transients or accidents being made more severe than those identified in the FSAR analysis and previously analyzed as a result of control system failures or malfunctions. These failures or malfunctions may occur independently or as a result of the accident or transient under consideration. One concern is the potential for a single failure--such as a loss of a power supply, short circuit, open circuit, or sensor failure--to cause simultaneous malfunction of several control features. Such an occurrence could conceivably result in a transient more severe than those transients analyzed as anticipated operational occurrences. A second concern is that a postulated accident could cause control system

failures that would make the accident more severe than analyzed. Accidents could conceivably cause control system failures by creating a harsh environment in the areas of the control equipment or by physically damaging the control equipment. Although it is generally believed that such control system failures would not lead to serious events or result in conditions that safety systems could not safely handle, indepth studies have not been rigorously performed to verify this belief. The potential for an accident that would affect a particular control system, and effects of the control system failures, may differ from plant to plant. Therefore, it is not possible to develop generic answers to all these concerns. It is possible to develop generic criteria that can be used for future plant-specific reviews. The purpose of this Unresolved Safety Issue task is to verify the adequacy of existing criteria for control systems or propose additional generic criteria (if necessary) that will be used for plant-specific review.

South Texas safety systems have been designed with the goal of ensuring that control system failures (either single or multiple) will not prevent automatic or manual initiation and operation of any safety system equipment required to trip the plant or to maintain the plant in a safe shutdown condition following any anticipated operational occurrence or accident. This has been accomplished by either providing independence between safety- and nonsafety-grade systems or providing isolating devices between safety- and nonsafety-grade systems. These devices preclude the propagation of nonsafety-grade system equipment faults so that operation of the safety-grade system equipment is not impaired.

A wide range of bounding transients and accidents is presently analyzed to ensure that the postulated events would be adequately mitigated by the safety systems. In addition, systematic reviews of safety systems have been performed with the goal of ensuring that the control system failures (single or multiple) will not defeat safety system action.

Also, the applicant has been requested (NRC Information Notice 79-22, "Qualification of Control Systems," September 17, 1979) (1) to review the possibility of high-energy line breaks (HELBs) and (2) to adopt new operator procedures, where needed, to ensure that the postulated events would be adequately mitigated. As part of the review, the staff is also evaluating the qualification program to ensure that equipment that may potentially be exposed to HELB environments has been adequately qualified or an adequate basis has been provided for not qualifying the equipment to the limiting hostile environment. The staff's evaluation of the applicant's response to Information Notice 79-22 and the adequacy of the qualification program are reported in Sections 7.7.2.2 and 3.11 of this SER, respectively.

With the recent emphasis on the availability of postaccident instrumentation (Regulatory Guide 1.97), "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant Conditions During and Following an Accident"), the staff's reviews evaluate the designs to ensure that control system failures will not deprive the operator of information required to maintain the plant in a safe shutdown condition after any anticipated operational South Texas occurrence or accident. The applicant was requested to evaluate [redacted] control systems and identify any control systems whose malfunction could impact plant safety. The applicant has been requested to evaluate South Texas control systems and identify the use (if any) of common power supplies and the use of

common sensors or common sensor impulse lines whose failure could have potential safety significance. The status of these reviews and the staff's evaluation are discussed in Sections 7.7.2.1 of the SER.

In addition, IE Bulletin 79-27 ("Loss of Non-Class IE Instrumentation and Control Power System Bus During Operation," November 30, 1979) was issued to the applicant requesting that evaluations be performed to ensure the adequacy of plant procedures for accomplishing shutdown on loss of power of any electrical bus supplying power for instruments and controls. The results of this review are in SER Section 7.5.2.3.

The subtask of this issue concerning the steam generator overfill transient in pressurized water reactors is currently under review by the staff. Pending ultimate resolution of this item, the applicant has incorporated in the South Texas design a safety grade two out of four high-level initiation trip signal to trip the main feedwater pumps, the feedwater isolation control and bypass valves and the main turbine to prevent the occurrence of overfill transients. The status of this review and the staff evaluation are discussed in Section 7.3.2.5 of the SER.

On the basis of these above considerations, and subject to the satisfactory resolution of the open items identified in Section 3.11 and items identified in Sections 7.5.2.4, the staff concludes that there is reasonable assurance that South Texas Units 1 and 2 can be operated before the ultimate resolution of this generic issue without undue risk to the health and safety of the public.

A-49 Pressurized Thermal Shock

The issue of pressurized thermal shock (PTS) arises because in pressurized water reactors (PWRs) transients and accidents can occur that result in severe overcooling (thermal shock) of the reactor pressure vessel, concurrent with or followed by repressurization. In these PTS events, rapid cooling of the reactor vessel internal surface results in thermal stress with a maximum tensile stress at the inside surface of the vessel. The magnitude of the thermal stress depends on the temperature profile across the reactor vessel wall as a function of time. The effects of this thermal stress are compounded by pressure stresses.

Severe reactor system overcooling events simultaneous with or followed by pressurization of the reactor vessel (PTS events) can result from a variety of causes. These include system transients, some of which are initiated by instrumentation and control system malfunctions (including stuck open valves in either the primary or secondary system), and postulated accidents such as small break loss-of-coolant accidents (LOCAs), main steam line breaks (MSLBs), and feedwater line breaks.

The PTS issue is a concern for PWRs only after the reactor vessel has lost its fracture toughness properties and is embrittled by neutron irradiation. The standards and regulatory requirements to which the South Texas reactor vessels were designed and fabricated are described in Sections 5.2 and 5.3 of the FSAR.

As long as the fracture resistance of the reactor vessel material is relatively high, overcooling events are not expected to cause vessel failure. However, the fracture resistance of reactor vessel materials decreases with exposure to fast neutrons during the life of a nuclear power plant. The rate of decrease is dependent on the metallurgical composition of the vessel walls and welds. If the fracture resistance of the vessel has been reduced sufficiently by neutron irradiation, severe overcooling events could cause propagation of small flaws that might exist near the inner surface. The assumed initial flaw might be enlarged into a crack through the vessel wall of sufficient extent to threaten vessel integrity and, therefore, core cooling capability.

For the reactor pressure vessel to fail and constitute a risk to public health and safety, a number of contributing factors must be present. These factors are (1) a reactor vessel flaw of sufficient size to initiate and propagate; (2) a level of irradiation (fluence) and material properties and composition sufficient to cause significant embrittlement (the exact fluence depends on materials present; i.e., high copper content causes embrittlement to occur more rapidly); (3) a severe overcooling transient with repressurization; and (4) the crack resulting from the propagation of initial cracks must be of such size and location that the vessel fails.

As a result of the evaluation of the PTS issue, the staff recommended to the Commission in SECY 83-465 (November 23, 1982) actions to prevent PTS events in operating reactors. The Commission accepted the staff recommendations and the staff has published Notice of Final Rulemaking Federal Register, 29937 July 23, 1985) for a rule that establishes an RT_{pts} screening criterion (below which PTS risk is considered acceptable), requires early analysis and implementation of such flux reduction programs as a reasonably practicable method to avoid reaching the screening criterion, and requires plant-specific PTS safety analyses before plants are within three calendar years of reaching the screening criterion including analyses of proposed alternatives to minimize the PTS problem (10 CFR 50.61). The applicant has not yet submitted the detailed RT_{pts} information required by the new PTS rule (10 CFR 50.61) to be submitted on or before January 23, 1986. However, the applicant has stated in Section 5.3.2.1 of the STP FSAR that the end-of life RT_{pts} for the South Texas Unit 1 vessel is 88°F, and that the end of life RT_{pts} for the South Texas Unit 2 vessel is 68°F. These valves are significantly below the applicable criterion; which is 270°F.

On the basis of the above considerations, the staff concludes that there is reasonable assurance that South Texas Units 1 and 2 can be operated before the ultimate resolution of this generic issue without undue risk to the health and safety of the public.

C.5 References

---, NUREG-0410, "NRC Program for the Resolution of Generic Issues Related to Nuclear Power Plants," January 1978.

---, NUREG-0460, "Anticipated Transients Without Scram for Light Water Reactors," Vol. 4, March 1980.

---, NUREG-0588, "Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment," Revision 1, July 1981.

---, NUREG-0606, "Office of Nuclear Reactor Regulation Unresolved Safety Issues, Aqua Book," issued quarterly.

---, NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants," July 1980.

---, NUREG-0649, Revision 1, "Task Action Plans for Unresolved Safety Issues Related to Nuclear Power Plants," September 1984.

---, NUREG-0660, "NRC Action Plan as a Result of the TMI-2 Accident," May 1980.

---, NUREG-0705, "Identification of New Unresolved Safety Issues Relating to Nuclear Power Plants, Special Report to Congress," March 1981.

---, NUREG-0744, "Resolution of the Task A-11 Reactor Vessel Materials Toughness Safety Issues," Vols I and II, Revision 1, October 1982.

---, NUREG-0800, "Standard Review Plan," July 1981.

---, NUREG/CR-0660, "Enhancement of Onsite Emergency Generator Reliability," February 1979.

---, NUREG-0927, Revision 1, "Evaluation of Water Hammer Occurrence in Nuclear Power Plants," March 1984.

TABLE 1 - Unresolved Safety Issues Applicable to Vogtle Unit 1 and 2 Addressed in This Report

Task #	NUREG Report and Title	SER Section
A-1	NUREG-0927, "Evaluation of Water Hammer Occurrence in Nuclear Power Plants"	---
A-2	NUREG-0609, "Asymmetric Blowdown Loads on PWR Primary Systems"	3.9.2.3
A-9	NUREG-0460, "Anticipated Transients Without Scram for Light Water Reactors," Vol. 4	15.3.8
A-11	NUREG-0744, "Resolution of the Task A-11 Reactor Vessel Materials Toughness Safety Issue," Vols. I and II, Revision 1	5.3
A-12	NUREG-0577, "Potential for Low Fracture Touchness and Lamellar Tearing in PWR Steam Generator and Reactor Coolant Pump Supports," Revision 1	---
A-24	NUREG-0588, "Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment," Revision 1	3.11
A-26	NUREG-0224, "Reactor Vessel Pressure Transient Protection for Pressurized Water Reactors"	5.2.2
A-31	NUREG-0800, SRP Section 5.4.7 and BTP RSB-1, "Residual Heat Removal Systems"	5.4.3
A-36	NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants"	9.1.4
A-43	NUREG-0897, "Containment Emergency Sump Performance," Revision 1	6.2.2