TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

400 Chestnut Street Tower II

January 16, 1985

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Chief
Licensing Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Ms. Adensam:

| | | |
|---|---|---|
| In the Matter of the Application of | ) | Docket Nos. 50-390 |
| Tennessee Valley Authority | ) | 50-391 |

Enclosed for NRC review is information concerning the as-built configuration of the underground barrier at Watts Bar Nuclear Plant. This submittal completes TVA action related to resolution of NRC concerns with respect to mitigation of adverse affects due to potentially liquefiable soil along the Essential Raw Cooling Water (ERCW) pipeline.

If you have any questions concerning this matter, please get in touch with D. P. Ormsby at FTS 858-2682.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

J. A. Domer

J. A. Domer
Nuclear Engineer

Sworn to and subscribed before
me this 16th day of Jan. 1985.

Paulette H. White

Notary Public
My Commission Expires 8-24-88

Enclosure
cc: U.S. Nuclear Regulatory Commission (Enclosure)
Region II
Attn: Mr. James P. O'Reilly, Regional Administrator
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30323



B001 1/1

ENCLOSURE
WATTS BAR NUCLEAR PLANT UNITS 1 AND 2
DESIGN CRITERIA AND ANALYSIS
FOR THE UNDERGROUND BARRIER
FOR THE ERCW PIPELINE AND 1E CONDUIT ALIGNMENT

The location of the underground barriers are shown on Figures 1 and 2. The underground barriers were analyzed for the following cases:

| Case | Required Factor of Safety |
|---|---|
| I. During earthquake but prior to liquefaction (reduced passive pressure assumed to act) | 1.0 |
| II. After earthquake and after liquefaction (no passive pressure assumed) | 1.0 |

Figure 3 is a summary of the analysis of the underground barriers. The figure shows: a loading diagram of how the underground barriers were analyzed, a summary of the design parameter and criteria used in the stability analyses, and a summary of results of the stability analysis for each cross section. Figure 4 is a plan of the area showing the locations of the as-built cross sections.

As shown in the summary of the design parameters and criteria, the shear strengths of the alluvial sands (i.e., potentially liquefiable sands) have been assumed to be reduced during the earthquake. This was done to acknowledge the possibility that some strength loss in alluvial sands may occur during the earthquake. The magnitudes of the strength reduction, 50 percent of cohesion and 30 percent of angle of internal fiction, was based on engineering judgment and is considered reasonable and conservative for the material.

The results of the stability analysis for each cross-section are provided for two sets of analyses representing "during earthquake" and "after earthquake" conditions for different potential failure planes. The "during earthquake" analyses show the stability of the barrier when the barrier mass is subjected to the peak acceleration, complete liquefaction of sands for the active earth pressure, and consider partial passive (reduced) earth resistance. The "after earthquake" analyses show the stability of the barrier after the earthquake and consider complete (postulated) liquefaction of the saturated alluvial sands for the active earth pressure and complete loss of downstream passive resistance. Depending on the section geometry and materials used as backfill, between one and five assumed failure planes were analyzed for each cross-section and design case.

Due to the urgency to complete the construction of the barriers prior to fuel load, the trench excavation was started prior to completion of the laboratory testing of the backfill soils. The barrier widths were based on assumed design soil properties. The results of the evaluation of the initial laboratory shear strength tests showed that the design cohesion was approximately half the needed cohesion to stabilize the barriers. To eliminate the need to widen the barrier, additional laboratory shear strength tests were made on backfill soils remolded to a higher level (100-percent standard compaction ASTM D 698) of compaction. The results of this testing showed that the cohesion was increased sufficiently to allow the barriers to be stable.

Since it was not necessary for each entire barrier to be constructed at the higher compaction level (100 percent), additional analyses were made to determine what elevation the lower compaction level (95 percent) could be used. Also since the construction period for the trench B barrier extended though a winter season, the option to use crushed stone in lieu of earthfill was selected to expedite completion of construction. Each change of backfill material in a cross-section presented a potential failure plane which was checked in the analysis.

A study, described in FSAR section 2.5.4.6 was made to determine the design groundwater elevation for the piping and conduit alignments. The groundwater level was revised to reflect a 25-year groundwater. The influence of this higher groundwater on the analysis of the underground barrier was discussed with the NRC. The staff indicated they concur with TVA's judgment that the higher groundwater level will have a minimal effect on the results of the stability analysis, thus not requiring any additional evaluation of the stability of the underground barrier.

Figures 5 through 8 are representative cross-sections along the centerline of Trench A. As shown on figure 3, the results of a stability analysis for station 6 + 78 of trench A are not provided because the soil profile was not identified above the top of shale. This is not considered critical to the overall summary since the other 17 of the 18 cross-sections of trench A were analyzed and found to be adequate. The stability results are provided for two different potential failure planes, which are shown on the representative cross-sections (figures 5 through 8) at (1) the top of weathered shale (A), and (2) the interface between the 95-percent and 100-percent maximum dry density fill (B). Figures 9 through 12 provide the summaries of in-place density and moisture quality control tests conducted on the fill materials during construction of Trench A.

Figures 13 through 16 are representative cross-sections along the centerline of Trench B. Since trench B was backfilled with compacted crushed stone in addition to earthfill, additional potential failure planes were identifed at the various material interfaces and analyzed. The stability summary on figure 3 provides the results on two of these potential failure planes. The first, at the top of weathered shale (A), is provided for each section. The second, at one of the other potential failure planes, represents the lowest factor-of-safety for that cross-section other than at the top of the weathered shale. Figures 17 through 21 provide the summaries of inplace density and moisture quality control tests conducted on the fill materials during construction of trench B.

Figures 19 and 20 show that one quality control test had results that did not meet the required criteria for backfill in trench B compacted to 100 percent of maximum dry density. This failure to meet criteria was identified after trench construction was completed and nonconformance report (NCR) 5804 was issued. The failure to meet required criteria resulted from the inadvertent use of the improper compaction control curve during construction. This resulted in the test sample being undercompacted by 1.3 percent and having too high a moisture content by 0.7 percent. The fill represented by the test sample was located near the top of the 100-percent maximum dry density backfill zone. This location is not critical to the analysis results; therefore, the disposition of the NCR was to use as is.

Figure 4 shows the final grading for the area of the underground barriers. Analyses of the underground barriers reveal that the as-built barriers meet or exceed all design requirements.

# WATTS BAR NUCLEAR PLANT

## SUMMARY OF EARTHFILL TEST DATA - DENSITY

## FIGURE 9

FEATURE: *UNDERGROUND BARRIER — TRENCH A-95% $\gamma_{DMAX}$ FILL*

DATE: *9-30-83* TO: *10-22-83* TEST NO.: *1351* TO: *1390*

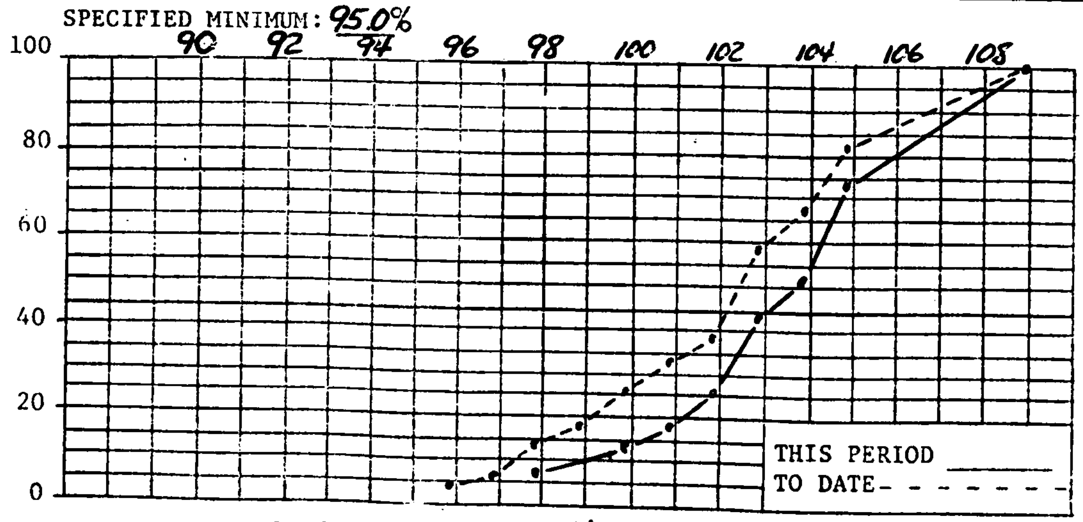
PART: *I* SECTION: *52A (A)* PREPARED BY: *W.S. WOODLEE*

| PERCENT COMPACTION ($\gamma_{df} - \gamma_{dL}$) x 100 | PLOT THIS COL | PREV CUM F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|
| 90.0 | 91.9 | | | | | | | | |
| 92.0 | 92.9 | | | | | | | | |
| 93.0 | 93.9 | | | | | | | | |
| 94.0 | 94.9 | | | | | | | | |
| 95.0 | 95.9 | 3 | | | | | 3 | 3 | 4.5 |
| 96.0 | 96.9 | 4 | | | | | 1 | 4 | 6.0 |
| 97.0 | 97.9 | 8 | II | 2 | 2 | 7.4 | 6 | 10 | 14.9 |
| 98.0 | 98.9 | 10 | | | | | 2 | 12 | 17.9 |
| 99.0 | 99.9 | 13 | II | 2 | 4 | 14.8 | 5 | 17 | 25.4 |
| 100.0 | 100.9 | 14 | I | 1 | 5 | 18.5 | 2 | 19 | 28.4 |
| 101.0 | 101.9 | 19 | II | 2 | 7 | 25.9 | 7 | 26 | 38.8 |
| 102.0 | 102.9 | 27 | 𝍸 | 5 | 12 | 44.4 | 13 | 39 | 58.2 |
| 103.0 | 103.9 | 31 | II | 2 | 14 | 51.9 | 6 | 45 | 67.2 |
| 104.0 | 104.9 | 35 | 𝍸-I | 6 | 20 | 74.1 | 10 | 55 | 82.1 |
| 105.0 | 108.9 | 40 | 𝍸-II | 7 | 27 | 100.0 | 12 | 67 | 100.0 |
| TOTALS | | 40 | – – | – – | 27 | – – | – – | 67 | – – |

SPECIFICATION SOURCE: *DWG #10N213-2 R2*

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL DRY DENSITY, $\gamma_{df}$, pcf | 105.5 | 105.8 | 105.6 |
| AVG MAXIMUM DRY DENSITY, $\gamma_{dL}$, pcf | 104.0 | 102.6 | 103.4 |
| MEAN VARIATION $\gamma_{df} - \gamma_{dL}$, pcf | +1.5 | +3.2 | +2.2 |

SPECIFIED MINIMUM: *95.0%*




REMARKS: *THIS IS THE FINAL ANALYSIS FOR TYPE A FILL COMPACTION.*

INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH REV *4* OF WBNP-QCP-2.01.

WATTS BAR NUCLEAR PLANT

SUMMARY OF EARTHFILL TEST DATA - MOISTURE CONTENT

FIGURE 10

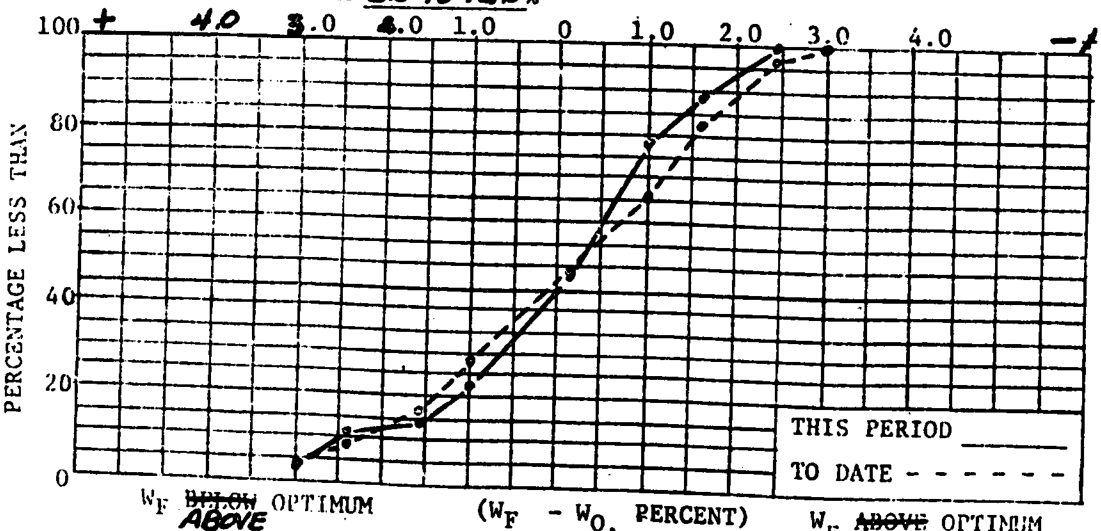
FEATURE: UNDERGROUND BARRIER – TRENCH A - 95% $\gamma_{DMAX}$ FILL
DATE: 9-30-83 TO: 10-22-83 TEST NO.: 1351 TO: 1390
PART: I SECTION: 52A (A) PREPARED BY: W.S. WOODLEE

| $(W_F - W_O)$, PERCENT | PLOT THIS COL. | PREV CUM F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|
| $W_F$ ABOVE OPT +4.6 | 5.2 | | | | | | | | |
| 3.9 | 4.5 | | | | | | | | |
| 3.1 | 3.8 | | | | | | | | |
| 2.5 | 3.0 | 2 | I | 1 | 1 | 3.7 | 3 | 3 | 4.5 |
| 1.8 | 2.4 | 3 | II | 2 | 3 | 11.1 | 3 | 6 | 9.0 |
| 1.1 | 1.7 | 7 | I | 1 | 4 | 14.8 | 5 | 11 | 16.4 |
| 0.4 | 1.0 | 13 | II | 2 | 6 | 22.2 | 8 | 19 | 28.4 |
| PLOT 0 +0.3 | -0.3 | 20 | ~~IIII~~-II | 7 | 13 | 48.1 | 14 | 33 | 49.3 |
| 0.4 | 1.0 | 23 | ~~IIII~~-III | 8 | 21 | 77.8 | 11 | 44 | 65.7 |
| 1.1 | 1.7 | 32 | III | 3 | 24 | 88.9 | 12 | 56 | 83.6 |
| 1.8 | 2.4 | 38 | III | 3 | 27 | 100.0 | 9 | 65 | 97.0 |
| $W_F$ BELOW OPT 2.5 | 3.0 | 40 | | | | | 2 | 67 | 100.0 |
| 3.1 | 3.8 | | | | | | | | |
| 3.9 | 4.5 | | | | | | | | |
| -4.6 | 5.2 | | | | | | | | |
| TOTALS | NA | 40 | -- | -- | 27 | -- | -- | 67 | -- |

SPECIFICATION SOURCE: DWG.# 10N213-2 R2

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL MOISTURE CONTENT, $W_F$, % | 18.9 | 19.8 | 19.3 |
| AVG OPTIMUM MOISTURE CONTENT, $W_O$, % | 19.4 | 20.0 | 19.6 |
| MEAN VARIATION $(W_F - W_O)$, % | -0.5 | -0.2 | -0.3 |

SPECIFIED MINIMUM -3.0 TO +3.0%




REMARKS: THIS IS THE FINAL ANALYSIS FOR TYPE A FILL COMPACTION.

INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH R 4 OF WBNP-QCP-2.01.

TTS BAR NUCLEAR PLANT

SUMMARY OF EARTHFILL
TEST DATA - DENSITY

FIGURE 11

FEATURE: *UNDERGROUND BARRIER – TRENCH A – 100% $\gamma_{DMAX}$ FILL*

DATE: *9-30-83* TO: *10-9-83* TEST NO.: *1347* TO: *1364*

PART: *I* SECTION: *52A (A1)* PREPARED BY: *W.S. WOODLEE*

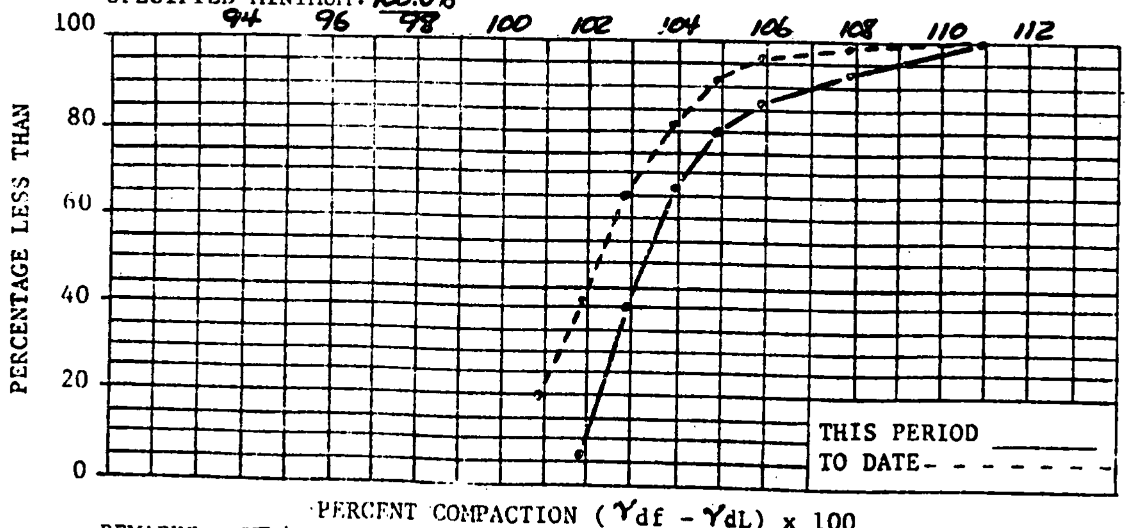
PERCENT COMPACTION ($\gamma_{df} - \gamma_{dL}$) X 100

| | PLOT THIS COL | PREV CUM F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|
| 95.0 | 95.9 | | | | | | | | |
| 96.0 | 96.9 | | | | | | | | |
| 97.0 | 97.9 | | | | | | | | |
| 98.0 | 98.9 | | | | | | | | |
| 99.0 | 99.9 | | | | | | | | |
| 100.0 | 100.9 | 16 | | | | | 16 | 16 | 20.0 |
| 101.0 | 101.9 | 32 | I | 1 | 1 | 6.7 | 17 | 33 | 41.3 |
| 102.0 | 102.9 | 46 | IIIII | 5 | 6 | 40.0 | 19 | 52 | 65.0 |
| 103.0 | 103.9 | 55 | IIII | 4 | 10 | 66.7 | 13 | 65 | 81.3 |
| 104.0 | 104.9 | 61 | II | 2 | 12 | 80.0 | 8 | 73 | 91.3 |
| 105.0 | 105.9 | 64 | I | 1 | 13 | 86.7 | 4 | 77 | 96.3 |
| 106.0 | 106.9 | | | | | | | | |
| 107.0 | 107.9 | 65 | I | 1 | 14 | 93.3 | 2 | 79 | 98.8 |
| 108.0 | 108.9 | | | | | | | | |
| 109.0 | 110.9 | | I | 1 | 15 | 100.0 | 1 | 80 | 100.0 |
| TOTALS | | 65 | – – | – – | 15 | – – | – – | 80 | – – |

SPECIFICATION SOURCE: *DWG. #10N213-2 R2*

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL DRY DENSITY, $\gamma_{df}$, pcf | 104.4 | 105.2 | 104.6 |
| AVG MAXIMUM DRY DENSITY, $\gamma_{dL}$, pcf | 102.1 | 101.2 | 101.9 |
| MEAN VARIATION $\gamma_{df} - \gamma_{dL}$, pcf | +2.3 | +4.0 | +2.7 |

SPECIFIED MINIMUM: *100.0%*




REMARKS: *THIS IS THE FINAL ANALYSIS FOR TYPE A1 FILL COMPACTION. SW*

INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH REV *4* OF WBNP-QCP-2.01.

**WATTS BAR NUCLEAR PLANT**

SUMMARY OF EARTHFILL
TEST DATA - MOISTURE
CONTENT

FIGURE 12

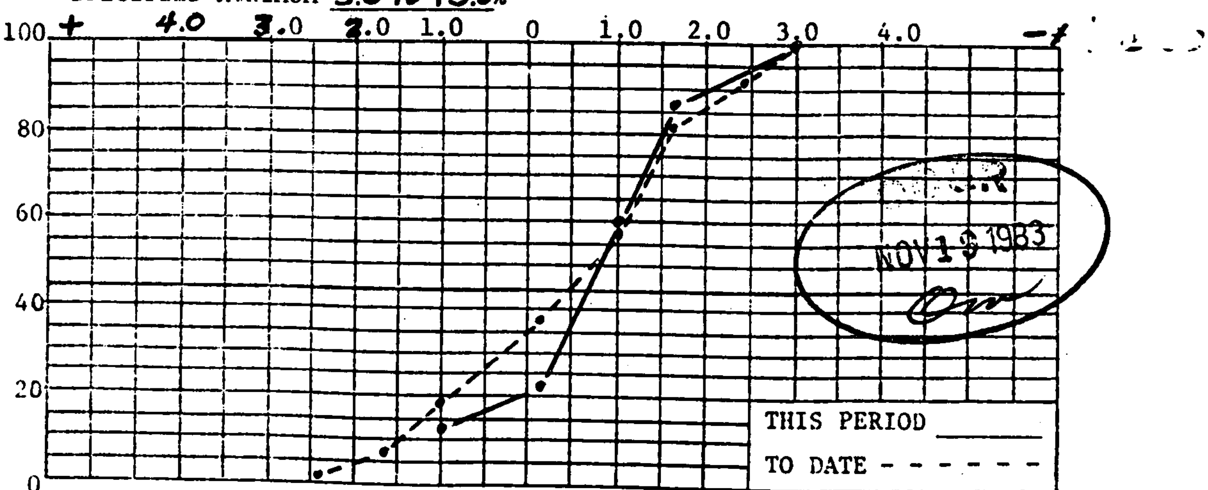
FEATURE: *UNDERGROUND BARRIER — TRENCH A - 100% $\gamma_{DMAX}$ FILL*
DATE: *9-30-83* TO: *10-9-83* TEST NO.: *1347* TO: *1364*
PART: *I* SECTION: *52A (A1)* PREPARED BY: *W.S. WOODLEE*

| $(W_F - W_O)$, PERCENT | | PLOT THIS COL | PREV CUM F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|---|
| $W_F$ ABOVE OPT | +4.6 | 5.2 | | | | | | | | |
| | 3.9 | 4.5 | | | | | | | | |
| | 3.1 | 3.8 | | | | | | | | |
| | 2.5 | 3.0 | | | | | | | | |
| | 1.8 | 2.4 | 1 | | | | | 1 | 1 | 1.3 |
| | 1.1 | 1.7 | 6 | | | | | 5 | 6 | 7.5 |
| PLOT 0 | 0.4 | 1.0 | 13 | II | 2 | 2 | 13.3 | 9 | 15 | 18.8 |
| | +0.3 | -0.3 | 25 | II | 2 | 4 | 26.7 | 14 | 29 | 36.3 |
| | 0.4 | 1.0 | 38 | ~~IIII~~ | 5 | 9 | 60.0 | 18 | 47 | 58.8 |
| $W_F$ BELOW OPT | 1.1 | 1.7 | 52 | IIII | 4 | 13 | 86.7 | 18 | 65 | 81.3 |
| | 1.8 | 2.4 | 61 | | | | | 9 | 74 | 92.5 |
| | 2.5 | 3.0 | 65 | II | 2 | 15 | 100.0 | 6 | 80 | 100.0 |
| | 3.1 | 3.8 | | | | | | | | |
| | 3.9 | 4.5 | | | | | | | | |
| | -4.6 | 5.2 | | | | | | | | |
| | TOTALS | NA | 65 | -- | -- | 15 | -- | -- | 80 | -- |

SPECIFICATION SOURCE: *DWG.#10N213-2 R2*

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL MOISTURE CONTENT, $W_F$, % | 19.7 | 19.9 | 19.7 |
| AVG OPTIMUM MOISTURE CONTENT, $W_O$, % | 20.4 | 20.8 | 20.5 |
| MEAN VARIATION $(W_F - W_O)$, % | -0.7 | -0.9 | -0.8 |

SPECIFIED MINIMUM *-3.0 TO +3.0%*




REMARKS: *THIS IS THE FINAL ANALYSIS FOR TYPE A1 FILL COMPACTION. SL*
INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH R *4* OF WBNP-QCP-2.01.

**WATTS BAR NUCLEAR PLANT**

SUMMARY OF FILL TEST
DATA - DENSITY

FIGURE 17

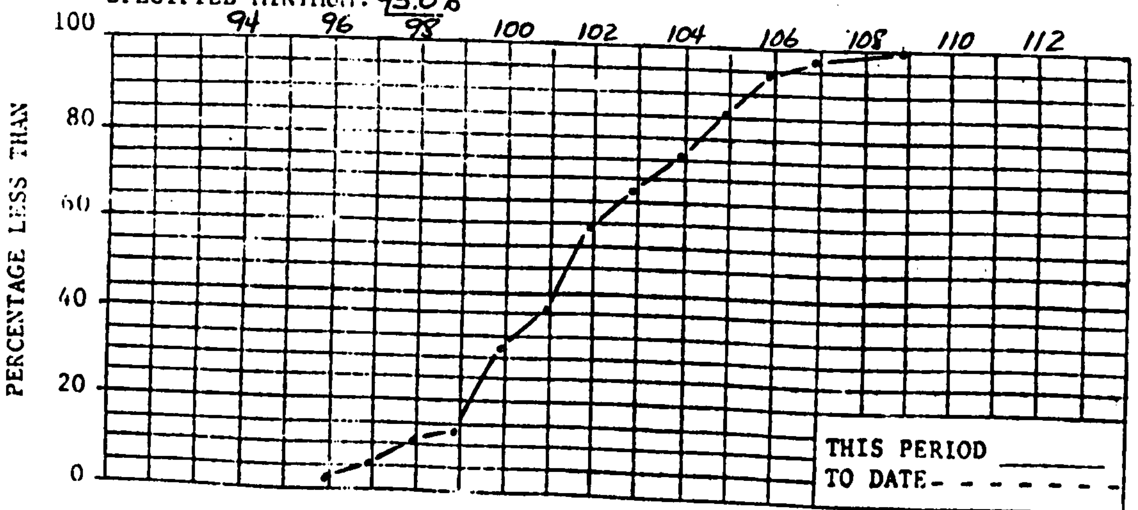
FEATURE: UNDERGROUND BARRIER – TRENCH B-95% $\gamma_{DMAX}$ FILL
DATE: 11-2-83 TO: 6-28-84 TEST NO.: 1397 TO: 1475
PART: I SECTION: 52B (A) PREPARED BY: W.S. WOODLEE

| PERCENT COMPACTION ($\gamma_{df} - \gamma_{dL}$) x 100 | PLOT THIS COL | PREV CUM F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|
| 95.0 | 95.9 | | I | 1 | 1 | 2.7 | | | |
| 96.0 | 96.9 | | I | 1 | 2 | 5.4 | | | |
| 97.0 | 97.9 | | II | 2 | 4 | 10.8 | | | |
| 98.0 | 98.9 | | I | 1 | 5 | 13.5 | | | |
| 99.0 | 99.9 | | HH-II | 7 | 12 | 32.4 | | | |
| 100.0 | 100.9 | | III | 3 | 15 | 40.5 | | | |
| 101.0 | 101.9 | | HH-II | 7 | 22 | 59.5 | | | |
| 102.0 | 102.9 | NA | III | 3 | 25 | 67.6 | NA | NA | NA |
| 103.0 | 103.9 | | III | 3 | 28 | 75.7 | | | |
| 104.0 | 104.9 | | IIII | 4 | 32 | 86.5 | | | |
| 105.0 | 105.9 | | III | 3 | 35 | 94.6 | | | |
| 106.0 | 106.9 | | I | 1 | 36 | 97.3 | | | |
| 107.0 | 107.9 | | | | | | | | |
| 108.0 | 108.9 | | I | 1 | 37 | 100.0 | | | |
| 109.0 | 110.9 | | | | | | | | |
| TOTALS | | | – – | – – | 37 | – – | – – | | - - - |

SPECIFICATION SOURCE: DWG. #10N213-2 R4

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL DRY DENSITY, $\gamma_{df}$, pcf | NA | 107.0 | 107.0 |
| AVG MAXIMUM DRY DENSITY, $\gamma_{dL}$, pcf | NA | 105.3 | 105.3 |
| MEAN VARIATION $\gamma_{df} - \gamma_{dL}$, pcf | NA | +1.7 | +1.7 |

SPECIFIED MINIMUM: 95.0%




PERCENT COMPACTION ($\gamma_{df} - \gamma_{dL}$) x 100

REMARKS: FAILED TESTS NOT INCLUDED IN THIS ANALYSIS.
INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH REV 6 OF WBNP-QCP-2.01.

WATTS BAR NUCLEAR PLANT

SUMMARY OF EARTHFILL
TEST DATA - MOISTURE
CONTENT

FIGURE 18

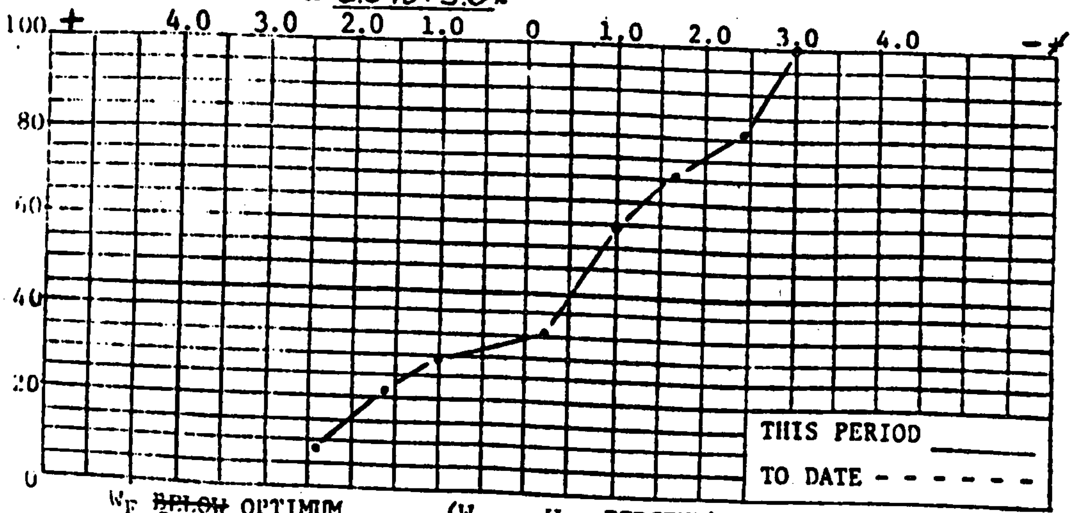
FEATURE: *UNDERGROUND BARRIER - TRENCH B - 95% $\gamma_D$MAX FILL*
DATE: *11-2-83* TO: *6-28-84* TEST NO.: *1397* TO: *1475*
PART: *I* SECTION: *52B (A)* PREPARED BY: *W.S. WOODLEE*

| $(W_F - W_O)$, PERCENT | | PLOT THIS COL | PREV CUM F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|---|
| $W_F$ ABOVE OPT | +4.6 | 5.2 | | | | | | | | |
| | 3.9 | 4.5 | | | | | | | | |
| | 3.1 | 3.8 | | | | | | | | |
| | 2.5 | 3.0 | | | | | | | | |
| | 1.8 | 2.4 | | III | 3 | 3 | 8.1 | | | |
| | 1.1 | 1.7 | | ~~IIII~~ | 5 | 8 | 21.6 | | | |
| | 0.4 | 1.0 | | III | 3 | 11 | 29.7 | | | |
| PLOT 0 | +0.3 | -0.3 | NA | II | 2 | 13 | 35.1 | NA | NA | NA |
| $W_F$ BELOW OPT | 0.4 | 1.0 | | ~~IIII~~-IIII | 9 | 22 | 59.5 | | | |
| | 1.1 | 1.7 | | IIII | 4 | 26 | 70.3 | | | |
| | 1.8 | 2.4 | | IIII | 4 | 30 | 81.1 | | | |
| | 2.5 | 3.0 | | ~~IIII~~-II | 7 | 37 | 100.0 | | | |
| | 3.1 | 3.8 | | | | | | | | |
| | 3.9 | 4.5 | | | | | | | | |
| | -4.6 | 5.2 | | | | | | | | |
| | TOTALS | NA | | -- | -- | 37 | -- | -- | | -- |

SPECIFICATION SOURCE: *DWG.#10N213-2 R4*

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL MOISTURE CONTENT, $W_F$, % | NA | 18.4 | 18.4 |
| AVG OPTIMUM MOISTURE CONTENT, $W_O$, % | NA | 19.0 | 19.0 |
| MEAN VARIATION $(W_F - W_O)$, % | NA | -0.6 | -0.6 |

SPECIFIED MINIMUM *-3.0 TO +3.0%*




REMARKS: *FAILED TESTS NOT INCLUDED IN THIS ANALYSIS.*
INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH R *6* OF WBNP-QCP-2.01.

# WATTS BAR NUCLEAR PLANT

SUMMARY OF FILL TEST
DATA - DENSITY

FIGURE 19

FEATURE: *UNDERGROUND BARRIER – TRENCH B – 100% $\gamma_{max}$ FILL*

DATE: *11-25-83* TO: *5-31-84* TEST NO.: *1408* TO: *1438*

PART: *I* SECTION: *52B (A1)* PREPARED BY: *W.S. WOODLEE*

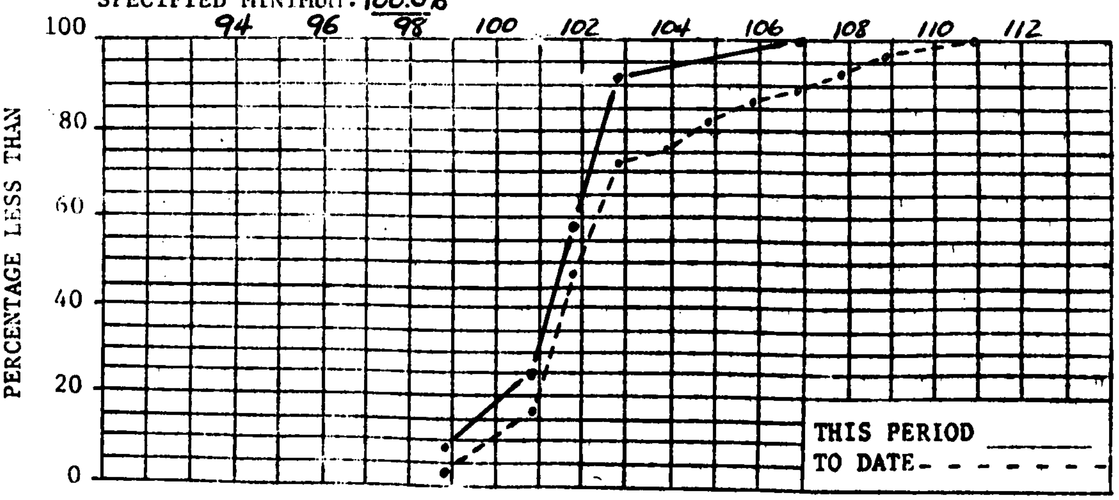
PERCENT COMPACTION ($\gamma_{df}$ - $\gamma_{dL}$) X 100

| | PLOT THIS COL. | PREV CUM F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|
| 95.0 | 95.9 | | | | | | | | |
| 96.0 | 96.9 | | | | | | | | |
| 97.0 | 97.9 | | | | | | | | |
| 98.0 | 98.9 | | I | 1 | 1 | 8.3 | 1 | 1 | 3.4 |
| 99.0 | 99.9 | | | | | | | | |
| 100.0 | 100.9 | 2 | II | 2 | 3 | 25.0 | 4 | 5 | 17.2 |
| 101.0 | 101.9 | 7 | IIII | 4 | 7 | 58.3 | 9 | 14 | 48.3 |
| 102.0 | 102.9 | 10 | IIII | 4 | 11 | 91.7 | 7 | 21 | 72.4 |
| 103.0 | 103.9 | 11 | | | | | 1 | 22 | 75.9 |
| 104.0 | 104.9 | 13 | | | | | 2 | 24 | 82.8 |
| 105.0 | 105.9 | 14 | | | | | 1 | 25 | 86.2 |
| 106.0 | 106.9 | | I | 1 | 12 | 100.0 | 1 | 26 | 89.7 |
| 107.0 | 107.9 | 15 | | | | | 1 | 27 | 93.1 |
| 108.0 | 108.9 | 16 | | | | | 1 | 28 | 96.6 |
| 109.0 | 110.9 | 17 | | | | | 1 | 29 | 100.0 |
| TOTALS | | 17 | – – | – – | 12 | – – | – – | 29 | – – |

SPECIFICATION SOURCE: *DWG. #10N213-2 R4*

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL DRY DENSITY, $\gamma_{df}$, pcf | 104.7 | 105.6 | 105.1 |
| AVG MAXIMUM DRY DENSITY, $\gamma_{dL}$, pcf | 101.0 | 103.6 | 102.1 |
| MEAN VARIATION $\gamma_{df}$ - $\gamma_{dL}$, pcf | +3.7 | +2.0 | +3.0 |

SPECIFIED MINIMUM: *100.0%*




PERCENT COMPACTION ($\gamma_{df}$ - $\gamma_{dL}$) x 100

REMARKS: *ANALYSIS ISSUED TO REFLECT CHANGE DUE TO MISTAKE ON SANDCONE TEST #1426.*

INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH REV *6* OF WBNP-QCP-2.01.

*NCR #5804*

**WATTS BAR NUCLEAR PLANT**

SUMMARY OF EARTHFILL
TEST DATA - MOISTURE
CONTENT

FIGURE 20

FEATURE: *UNDERGROUND BARRIER - TRENCH B - 100% $\gamma_{DMAX}$ FILL*
DATE: *11-25-83* TO: *5-31-84* TEST NO.: *1408* TO: *1438*
PART: *I* SECTION: *52B (A1)* PREPARED BY: *W.S. WOODLEE*

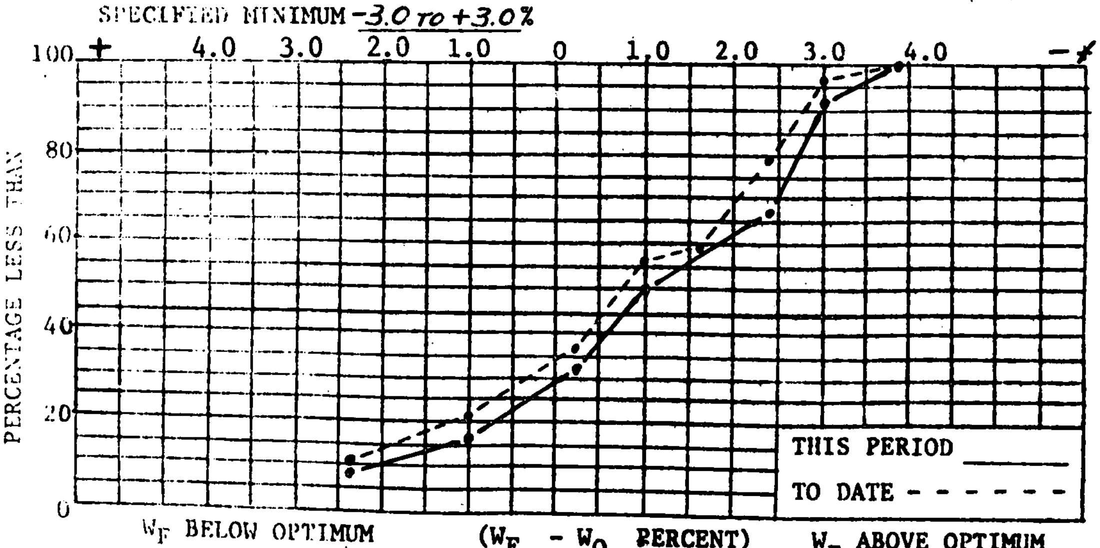
| | | PLOT THIS COL | PREV CUM F | THIS PERIOD FREQUENCY (F) | F | CUM F | CUM % | TO DATE F | CUM F | CUM % |
|---|---|---|---|---|---|---|---|---|---|---|
| $W_F$ ABOVE OPT | +4.6 | 5.2 | | | | | | | | |
| | 3.9 | 4.5 | | | | | | | | |
| | 3.1 | 3.8 | | | | | | | | |
| | 2.5 | 3.0 | | | | | | | | |
| | 1.8 | 2.4 | 2 | I | 1 | 1 | 8.3 | 3 | 3 | 10.3 |
| | 1.1 | 1.7 | | | | | | | | |
| | 0.4 | 1.0 | 4 | I | 1 | 2 | 16.7 | 3 | 6 | 20.7 |
| PLOT 0 | +0.3 | -0.3 | 7 | II | 2 | 4 | 33.3 | 5 | 11 | 37.9 |
| $W_F$ BELOW OPT | 0.4 | 1.0 | 10 | II | 2 | 6 | 50.0 | 5 | 16 | 55.2 |
| | 1.1 | 1.7 | 11 | | | | | 1 | 17 | 58.6 |
| | 1.8 | 2.4 | 15 | II | 2 | 8 | 66.7 | 6 | 23 | 79.3 |
| | 2.5 | 3.0 | 17 | III | 3 | 11 | 91.7 | 5 | 28 | 96.6 |
| | 3.1 | 3.8 | | I | 1 | 12 | 100.0 | 1 | 29 | 100.0 |
| | 3.9 | 4.5 | | | | | | | | |
| | -4.6 | 5.2 | | | | | | | | |
| | TOTALS | NA | 17 | -- | -- | 12 | -- | -- | 29 | -- |

($W_F - W_O$), PERCENT

SPECIFICATION SOURCE: *DWG. #10N213-2 R4*

| | PREV | THIS PERIOD | TO DATE |
|---|---|---|---|
| AVG FILL MOISTURE CONTENT, $W_F$, % | 20.2 | 18.7 | 19.6 |
| AVG OPTIMUM MOISTURE CONTENT, $W_O$, % | 21.1 | 20.2 | 20.7 |
| MEAN VARIATION ($W_F - W_O$), % | -0.9 | -1.5 | -1.1 |

SPECIFIED MINIMUM *-3.0 TO +3.0%*




REMARKS: *ANALYSIS ISSUED TO REFLECT CHANGE, DUE TO MISTAKE ON SANDCONE TEST #1426.*
INSPECTED/CHECKED/VERIFIED IN ACCORDANCE WITH R *6* OF WBNP-QCP-2.01.
*NCR#5604*

**WATTS BAR NUCLEAR PLANT**

SUMMARY OF GRANULAR
FILL TEST DATA -
RELATIVE DENSITY

FIGURE 21

*Feature: UNDERGROUND BARRIER — TRENCH B - 1032 CRUSHED STONE
Period: 4-27-84 to 5-31-84 Test No. 2046 to 2092
Part II Section 29 Prepared by W.S. WOODLEE

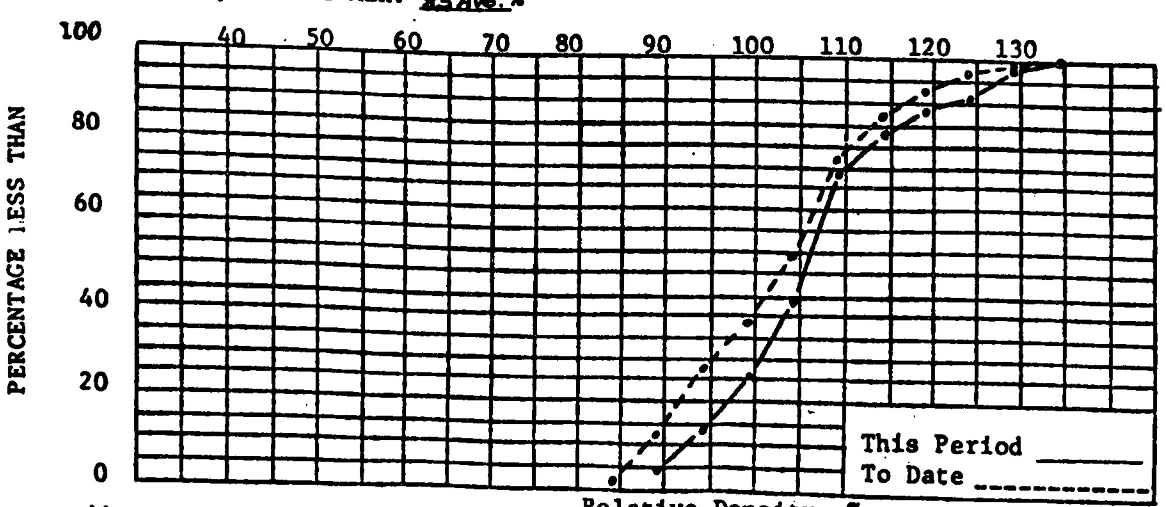
RELATIVE DENSITY, %

| | PLOT THIS COLUMN | PREV. CUM. F | THIS PERIOD FREQUENCY (F) | THIS PERIOD F | THIS PERIOD CUM F | THIS PERIOD CUM % | TO DATE F | TO DATE CUM F | TO DATE CUM % |
|---|---|---|---|---|---|---|---|---|---|
| 60.0 | 64.9 | | | | | | | | |
| 65.0 | 69.9 | | | | | | | | |
| 70.0 | 74.9 | | | | | | | | |
| 75.0 | 79.9 | | | | | | | | |
| 80.0 | 84.9 | 2 | | | | | 2 | 2 | 2.7 |
| 85.0 | 89.9 | 7 | II | 2 | 2 | 4.7 | 7 | 9 | 12.3 |
| 90.0 | 94.9 | 14 | IIII | 4 | 6 | 14.0 | 11 | 20 | 27.4 |
| 95.0 | 99.9 | 17 | 卌 | 5 | 11 | 25.6 | 8 | 28 | 38.4 |
| 100.0 | 104.9 | 21 | 卌-III | 8 | 19 | 44.2 | 12 | 40 | 54.8 |
| 105.0 | 109.9 | 24 | 卌-卌-III | 13 | 32 | 74.4 | 16 | 56 | 76.7 |
| 110.0 | 114.9 | 27 | IIII | 4 | 36 | 83.7 | 7 | 63 | 86.3 |
| 115.0 | 119.9 | 30 | II | 2 | 38 | 88.4 | 5 | 68 | 93.2 |
| 120.0 | 124.9 | | III | 3 | 41 | 95.3 | 3 | 71 | 97.3 |
| 125.0 | 129.9 | | I | 1 | 42 | 97.7 | 1 | 72 | 98.6 |
| 130.0 | 134.9 | | I | 1 | 43 | 100.0 | 1 | 73 | 100.0 |
| TOTALS | | 30 | - - | - - | 43 | - - | - - | 73 | - - |

Specification Source DWG.*10N213-2 R4

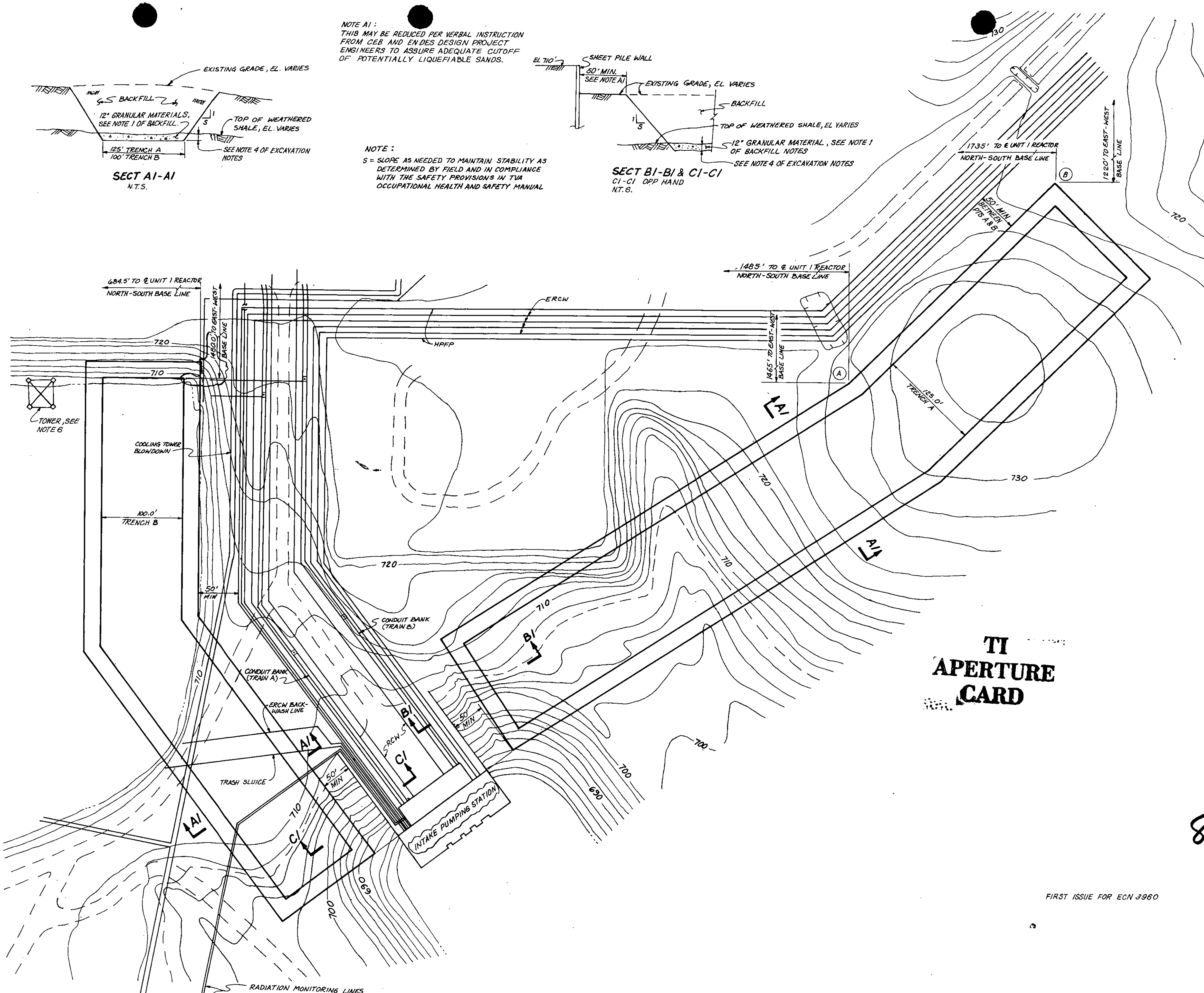
| | PREV. | THIS PERIOD | TO DATE |
|---|---|---|---|
| Avg. Relative Density | 98.5 | 106.3 | 103.1 |

Specified Min. 80 MIN. 85 AVG. %




*Remarks 1032 GRANULAR FILL SUBSTITUTED FOR EARTHFILL IN TRENCH B

Inspected/checked/verified in accordance with R 4 of WBNP-QCP-2.06




**TI APERTURE CARD**

**Also Available On Aperture Card**

GENERAL NOTES:

1. BACKFILL IS CATEGORY 1 AND THE QUALITY ASSURANCE REQUIRED IS DEFINED IN THE FOLLOWING NOTES AND ON DWG. 10N213-2.
2. ALL CONSTRUCTION SHALL BE IN ACCORDANCE WITH GENERAL CONSTRUCTION SPECIFICATION G-9, EXCEPT AS NOTED.
3. ALL EXCAVATION AND BACKFILL SHALL BE DONE UNDER THE DIRECT SUPERVISION OF A QUALIFIED SOILS INSPECTOR, EXCEPT WHEN EXCAVATING FORMERLY SPOILED MATERIAL.
4. AS BUILT CROSS-SECTIONS OF EACH TRENCH SHALL BE RECORDED. THE CROSS SECTIONS SHALL BE MADE AT 50 FOOT STATIONS ALONG THE TRENCH CENTERLINE. THE INFORMATION TO BE RECORDED FOR EACH CROSS-SECTION SHALL INCLUDE:

   a. ELEVATION AND LOCATION OF ALL SURFACE BREAKS IN THE PROFILE.

   b. ELEVATION OF THE TOP OF WEATHERED SHALE, TOP OF BASEL GRAVEL (IF ENCOUNTERED) AND TOP OF SAND OR SILTY SAND IN THE SIDE WALLS OF THE EXCAVATION SLOPES. THE INSPECTOR SHALL PROVIDE THE IDENTIFICATION OF THESE MATERIALS.

   c. FINAL GRADE
5. FINAL GRADING PER DRAWING 10W245 SHALL BE MADE AND SEEDING TO RESTORE VEGETATION TO THE AREAS AFFECTED BY THIS WORK SHALL BE APPLIED AS NECESSARY.
6. COORDINATE WITH POWER, DIVISION OF TRANSMISSION SYSTEM ENGINEERING AND CONSTRUCTION, THE LOCATION OF THE TRENCH WITH RESPECT TO THE TRANSMISSION TOWER FOR THEIR EVALUATION OF THE NEED FOR SUPPORT OF THE TOWER FOUNDATION.

8501230148-01

FIRST ISSUE FOR ECN 3860

| **WATTS BAR NUCLEAR PLANT** |
|---|
| YARD<br>UNDERGROUND BARRIERS<br>FOR POTENTIAL SOIL<br>LIQUEFACTION<br>TVA DWG NO. 10N213-1 R1<br>FIGURE 1 |

EXCAVATION NOTES:

1. A STOCKPILE AREA FOR FINE GRAINED CLAYS AND SILTS, AND A SEPARATE STOCKPILE AREA FOR THE SANDS AND SILTY SANDS ARE TO BE ESTABLISHED. SEPARATE STOCKPILES FOR EACH TRENCH MAY BE ESTABLISHED AT THE OPTION OF THE FIELD. AS EACH TRENCH IS EXCAVATED THE FINE GRAINED CLAYS AND SILTS ARE TO BE VISUALLY SEPARATED FROM THE SANDS AND SILTY SANDS AND DISTRIBUTED TO THE APPROPRIATE STOCKPILE. THE STOCKPILE AREAS ARE TO BE ESTABLISHED IN A MANNER THAT WILL ALLOW DRAINAGE OF THE STOCKPILED MATERIAL IN ORDER THAT IT CAN BE RECLAIMED FOR BACKFILL. THE SURFACES OF THE STOCKPILE AREAS ARE TO BE GRADED TO PREVENT PONDING AND TO MINIMIZE INFILTRATION OF RAINFALL AND RUNOFF.
2. MATERIAL ENCOUNTERED IN THE EXCAVATION ~~THAT WAS PREVIOUSLY SPOILED DURING PLANT CONSTRUCTION SHALL~~ BE SPOILED IN A NEW LOCATION.
3. BASEL GRAVEL MAY BE ENCOUNTERED BELOW THE SANDS AND SILTY SANDS IN MANY AREAS OF THE TRENCH EXCAVATION. THE BASEL GRAVEL SHALL BE SPOILED.
4. EACH TRENCH IS TO BE EXCAVATED TO THE WEATHERED SHALE (SAPROLITE). THE EXCAVATION IS TO BE CARRIED INTO THE WEATHERED SHALE TO A DEPTH WHERE THE SAPROLITE MATERIAL EXHIBITS ROCK-LIKE CHARACTERISTICS SUCH AS BEDDING STRUCTURE AND JOINTS. THE DEPTH OF EXCAVATION INTO THE WEATHERED SHALE SHALL BE DETERMINED BY A QUALIFIED SOILS INSPECTOR. EXCAVATION TO SOUND, UNWEATHERED ROCK IS NOT REQUIRED.
5. BEST MANAGEMENT PRACTICE FOR RUNOFF SHOULD BE USED FOR STOCKPILES AND SPOILPILE AREAS.
6. EACH TRENCH SHALL BE DEWATERED AND MAINTAINED IN A MANNER THAT WILL ALLOW THE EXCAVATION AND PLACEMENT OF EARTHFILL TO BE DONE IN AN ENVIRONMENT SUFFICIENTLY DRY TO COMPLY WITH THE MOSITURE CONTENT REQUIREMENTS OF BACKFILL NOTE 3. DEWATERING IS ALSO NECESSARY TO MAINTAIN THE STABILITY OF EXCAVATION SLOPES AND ADJACENT STRUCTURES AND FEATURES. THE DEWATERING TECHNIQUES USED BY CONST MUST BE EFFECTIVE AND RELIABLE AND MEET THE APPROVAL OF EN DES. PARTICULAR CARE SHALL BE TAKEN TO PREVENT THE MOVEMENT, MIGRATION, FLOW, SLUMPING, OR LOSS OF THE SANDS AND SILTY SANDS IN THE TRENCH EXCAVATIONS. PROGRESSIVELY GRADED REVERSE FILTERS OF SANDS, GRAVELS, AND/OR CRUSHED STONE, AS APPROPRIATE, SHALL BE IMMEDIATELY PLACED OVER ANY SANDY MATERIALS THAT EXHIBIT TENDENCIES FOR MOVEMENT, MIGRATION, FLOW, SLUMPING, OR LOSS.
7. PRIOR TO PLACEMENT OF ANY BACKFILL, THE SURFACE OF THE WEATHERED SHALE SHALL BE REASONABLY WELL CLEANED OF ANY SOIL OR LOOSE DEBRIS AND/OR ANY ROCK OVER 4"± THAT MAY REMAIN AFTER THE EXCAVATION PROCESS. AIR OR WATER SHALL NOT BE USED IN THE CLEANUP OF THE WEATHERED SHALE SURFACE.
8. THE PROCESS OF EXCAVATING INTO THE WEATHERED SHALE TO THE SPECIFIED DEPTH, CLEANING THE SURFACE, AND PLACEMENT OF THE GRANULAR MATERIAL AS SPECIFIED IN BACKFILL NOTE 1 SHALL BE KEPT AS SHORT AS REASONABLE TO PREVENT DETERIORATION OF THE WEATHERED SHALE SURFACE.

BACKFILL NOTES:

AFTER THE TRENCH HAS BEEN EXCAVATED TO THE SPECIFIED DEPTH (EXCAV NOTE 4) THE FOLLOWING STEPS SHALL BE TAKEN TO BACKFILL EACH TRENCH:

1. PLACE AND COMPACT A MINIMUM OF 12 INCHES OF GRANULAR MATERIAL MEETING THE REQUIREMENTS OF SECTION 1075 (BOTTOM LAYER) OF GENERAL CONSTRUCTION SPECIFICATION T-1. THE FOLLOWING GRADATION IS ALSO ACCEPTABLE.

| SQUARE SIEVE SIZE | PERCENT PASSING BY WEIGHT |
|---|---|
| 1-1/2 INCHES | 100 |
| 3/4 INCH | 30-75 |
| 3/8 INCH | 5-15 |
| NO. 4 | 0-5 |

THE GRANULAR MATERIAL SHALL BE PLACED IN MAXIMUM 10 INCH LOOSE LIFTS AND COMPACTED WITH A MINIMUM OF 6 COMPLETE PASSES BY A DYNAPAC CA25 VIBRATORY ROLLER, OR AN EN DES APPROVED EQUAL.

2. EARTHFILL TO FILL THE TRENCHES SHALL BE OBTAINED FROM STOCKPILES AND BORROW AREAS APPROVED BY EN DES. THE PURPOSE OF THE BACKFILLING SEQUENCE PROVIDED BELOW IS TO PLACE THE SANDS AND SILTY SANDS AT A HIGHER ELEVATION AND AT A HIGHER DENSITY THAN THEY NATURALLY EXIST. THE MATERIAL FOR BACKFILLING THE TRENCHES SHALL BE OBTAINED FROM THE FOLLOWING SOURCES IN THE ORDER SHOWN.
   (a) MATERIAL FROM THE STOCKPILE OF FINE-GRAINED CLAYS AND SILTS ESTABLISHED DURING THE TRENCH EXCAVATION. THIS MATERIAL SHOULD BE DISTRIBUTED UNIFORMALLY AND COMPACTED ALONG THE LENGTH OF THE TRENCH.
   (b) MATERIAL FROM THE STOCKPILE OF SANDS AND SILTY SANDS, ESTABLISHED DURING THE TRENCH EXCAVATION. THIS MATERIAL SHOULD BE DISTRIBUTED UNIFORMALLY AND COMPACTED ALONG THE LENGTH OF THE TRENCH.
   (c) MATERIAL FROM APPROVED BORROW AREAS MAY BE USED TO SUPPLEMENT ANY ADDITIONAL MATERIAL NEEDED FOR FILLING THE TRENCHES.
   (d) MATERIAL FOR BACKFILLING TRENCH A SHALL BE OBTAINED FROM TRENCH A STOCKPILE, BORROW AREAS 9,10, AND 2C, AND MATERIAL FROM REGRADING FUTURE 161 KV SWITCHYARD.
   (e) MATERIAL FOR BACKFILLING TRENCH B SHALL BE OBTAINED FROM TRENCH B STOCKPILE, BORROW AREAS 12 AND 2C, AND MATERIAL FROM REGRADING FUTURE 161 KV SWITCHYARD.

   A MINIMUM OF 10 FEET OF FINE GRAINED MATERIAL FROM CATEGORIES (a) AND (c) ABOVE SHALL BE PLACED BEFORE MATERIAL FROM CATEGORY (b) CAN BE PLACED.
3. EARTHFILL SHALL BE PLACED IN LAYERS WHOSE COMPACTED THICKNESS DOES NOT EXCEED 6 INCHES. EARTHFILL SHALL BE UNIFORMLY COMPACTED WITH A TAMPING (SHEEPSFOOT) ROLLER (REX PACTOR 3-50, OR AN DES APPROVED EQUAL).
   MATERIAL IN THE TRENCHES SHALL BE PLACED AS FOLLOWS:
   (a) EARTHFILL COMPACTED TO AT LEAST 100% OF MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D698 (STANDARD PROCTOR) SHALL BE PLACED TO A MINIMUM DEPTH OF 10 FEET FOR TRENCH A AND 5 FEET FOR TRENCH B ABOVE THE TOP OF WEATHERED SHALE. THE TOP OF WEATHERED SHALE (AS DETERMINED IN THE SIDE WALLS OF THE TRENCH CROSS SECTIONS AT 50 FOOT STATIONS, SEE NOTE 4b, SH 1) MAY BE CONSIDERED TO BE A PLANE BETWEEN THE 50 FOOT STATIONS IN ORDER TO ESTABLISH A BASE TO MEASURE FROM.
   (b) EARTHFILL PLACED ABOVE THAT FOR BACKFILL NOTE 3(a) SHALL BE COMPACTED TO 95% OF MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D698 (STANDARD PROCTOR).

   MOISTURE CONTENT OF THE EARTHFILL SHALL BE WITHIN ±3% OF OPTIMUM MOISTURE CONTENT.
4. IN-PLACE DRY DENSITY TESTS USING THE SAND CONE (ASTM D1556) OR RUBBER BALLOON (ASTM D2167) TEST METHODS SHALL BE MADE AT A RATE OF 1 TEST FOR EACH 2000 CUBIC YARDS OF EARTHFILL PLACED.
   BLOCK SAMPLES SHALL BE OBTAINED AS OUTLINED IN SECTION 11.3 OF GENERAL CONSTRUCTION SPECIFICATION G-9, EXCEPT THAT THE MINIMUM FREQUENCY OF SAMPLING SHALL CONFORM TO EACH OF THE FOLLOWING:
   (a) ONE SAMPLE SHALL BE TAKEN FOR EACH 50,000 CUBIC YARDS OF FILL PLACED THROUGHOUT THE COURSE OF THE WORK.
   (b) ONE SAMPLE SHALL BE TAKEN FOR EACH 20 DAYS OF FILL PLACING THROUGHOUT THE COURSE OF THE WORK.
   (c) A MINIMUM OF THREE SAMPLES SHALL BE TAKEN IN EACH TRENCH. A MINIMUM OF ONE OF THESE THREE SAMPLES IN EACH TRENCH SHALL BE TAKEN IN THE SAND OR SILTY SAND (SEE BACKFILL NOTE 2b) IF MORE THAN 10,000 CUBIC YARDS ARE PLACED. A MINIMUM OF ONE OF THESE THREE SAMPLES IN EACH TRENCH SHALL BE TAKEN FROM THE FILL COMPACTED TO 100% OF MAXIMUM DRY DENSITY.
5. EXCEPTIONS AND SUBSTITUTIONS TO THE ABOVE MATERIAL OR PLACEMENT SEQUENCE ARE:
   (a) GRANULAR MATERIAL MEETING THE REQUIREMENTS OF SECTION 1032 OF GENERAL CONSTRUCTION SPECIFICATION T-1 MAY BE USED IN LIEU OF ANY OF THE ABOVE EARTHFILL MATERIALS. THE GRANULAR MATERIAL SHALL BE PLACED IN A MAXIMUM LOOSE LIFT THICKNESS OF 10 INCHES AND UNIFORMALLY COMPACTED WITH A VIBRATORY ROLLER TO AN AVERAGE RELATIVE DENSITY OF 85% OR GREATER FOR ALL TESTS, WITH A MINIMUM OF 80% RELATIVE DENSITY FOR INDIVIDUAL TESTS AS DETERMINED BY ASTM D2049 PROCEDURES.
   THE MOISTURE CONTENT SHALL BE ADJUSTED AS NECESSARY TO ASSURE ADEQUATE COMPACTION. IN-PLACE DENSITY TESTS USING THE SAND CONE (ASTM D1556) OR RUBBER BALLOON (ASTM D2167) OR NUCLEAR MOSITURE-DENSITY GAUGE (ASTM D2922 AND D3017) TEST METHODS SHALL BE MADE AT A RATE OF 1 PER EVERY 500 CUBIC YARDS OF GRANULAR MATERIAL PLACED WITH A MINIMUM OF ONE TEST EACH DAY THE MATERIAL IS PLACED. COMPLETE DOCUMENTATION OF QUANTITY AND LOCATIONS WHERE THE MATERIAL WAS USED SHALL BE RECORDED AND SUBMITTED TO EN DES FOR REVIEW WITH THE MONTHLY FILL QUALITY CO[illegible] REPORTS REQUIRED BY G-9.
   (b) EARTHFILL FROM BORROW AREAS APPROVED FOR USE IN THE TRENCHES BY EN DES MAY BE SUBSTITUTED FOR ANY OF THE MATERIALS EXCAVATED FROM THE TRENCHES AND STOCKPILED FOR USE AS BACKFILL.



8501230148-02

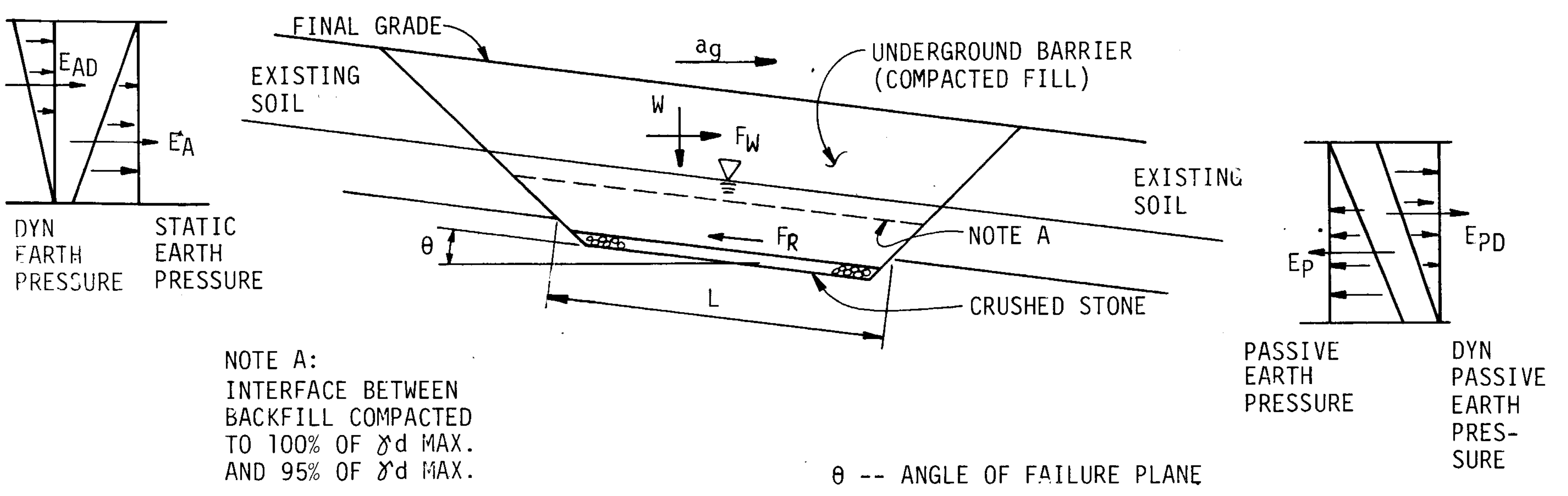
FIRST ISSUE FOR ECN 3960

WATTS BAR NUCLEAR PLANT

UNDERGROUND BARRIERS
FOR POTENTIAL SOIL
LIQUEFACTION
TVA DWG NO. 10N213-2 R2

FIGURE 2

LOAD DIAGRAM




NOTE A:
INTERFACE BETWEEN BACKFILL COMPACTED TO 100% OF $\gamma d$ MAX. AND 95% OF $\gamma d$ MAX.

θ -- ANGLE OF FAILURE PLANE

## ANALYSIS CASES

| CASE | | DESCRIPTION | FACTOR OF SAFETY |
|---|---|---|---|
| I | - | DURING EARTHQUAKE BUT PRIOR TO LIQUEFACTION (REDUCED PASSIVE PRESSURE ASSUMED TO ACT) | $FS = \dfrac{F_R + (E_{PX}-E_{PDX})}{E_{AX} + E_{ADX}+F_{WX}+W_X} \geq 1.0$ |
| II | - | AFTER EARTHQUAKE AND AFTER LIQUEFACTION (NO PASSIVE PRESSURE ASSUMED) | $FS = \dfrac{F_R}{E_{AX}+W_X} \geq 1.0$ |

$F_R$ - SLIDING RESISTANCE DUE TO THE SHEAR STRENGTH OF THE COMPACTED FILL. $F_R = \Sigma N_{EFF} \tan\phi + CL$

$F_W$ - HORIZONTAL SEISMIC FORCE CAUSED BY THE ACCELERATION OF THE UNDERGROUND BARRIER. $F_W = W a_g, (F_{WX} = F_W \cos\theta)$

$E_A$ - EARTH PRESSURE * = $\dfrac{\gamma H^2 K_a}{2}$, $(E_{AX} = E_A \cos\theta)$

$E_{AD}$ - DYNAMIC EARTH PRESSURE * = $E_A\ a_g$, $(E_{ADX} = E_{AD} \cos\theta)$

$E_P$ - PASSIVE EARTH PRESSURE * = $\dfrac{\gamma H^2 K_p}{2}$, $(E_{PX} = E_P \cos\theta)$

$E_{PD}$ - DYNAMIC PASSIVE EARTH PRESSURE * = $E_P\ a_g$, $(E_{PDX} = E_{PD} \cos\theta)$

W - WEIGHT OF BARRIER, $W_X = W \sin\theta$

X - COMPONENT OF FORCE/LOAD ALONG THE FAILURE PLANE

* - INCLUDES WATER PRESSURE

## MATERIAL PROPERTIES

| | UNIT WEIGHTS (PCF) | | | R TEST (NAT'L MOISTURE) | | R TEST (SATURATED) | |
|---|---|---|---|---|---|---|---|
| | $\gamma_M$ | $\gamma_{SAT}$ | $\gamma_{SUB}$ | $\phi$ | C(TSF) | $\phi$ | C(TSF) |
| IN SITU MATERIALS | | | | | | | |
| ALLUVIAL CLAYS AND SILTS | 120 | 123 | 61 | 28° | 0.4 | 14° | 0.2 |
| ALLUVIAL SANDS | | | | | | | |
| PRIOR TO EARTHQUAKE | 119 | 124 | 62 | 28° | 0.4 | 14° | 0.2 |
| DURING EARTHQUAKE | 119 | 124 | 62 | 20° | 0.2 | 10° | 0.1 |
| AFTER LIQUEFACTION | - | 120 | 58 | - | - | 0° | 0 |
| BASEL GRAVEL | 120 | 130 | 68 | - | - | 30° | 0 |
| COMPACTED FILL (BORROW MATERIALS) | | | | | | | |
| @ 95% $\gamma D_{MAX}$ | | | | | | | |
| TRENCH A | 117 | 126 | 64 | - | - | 15° | 0.1 |
| TRENCH B | 117 | 126 | 64 | - | - | 15° | 0.1 |
| @ 100% $\gamma D_{MAX}$ | | | | | | | |
| TRENCH A | 123 | 130 | 68 | - | - | 14° | 0.25 |
| TRENCH B | 123 | 130 | 68 | - | - | 14° | 0.35 |
| SPOIL MATERIAL[7] | 110 | 115 | 53 | - | - | 24° | 0 |
| | | | | Q TEST | | R & S TEST | |
| CRUSHED STONE | | | | $\phi$ | C(TSF) | $\phi$ | C(TSF) |
| 1032 SECTION MATERIAL | 135 | 143 | 81 | 39° | 1.0 | 40° | 0.5 |
| 1075 SECTION MATERIAL | 135 | 143 | 81 | 40° | 0 | 40° | 0 |

## UNDERGROUND BARRIER ANALYSIS SUMMARY

SAFETY FACTORS TRENCH A[1]

| STATION | DURING EARTHQUAKE[5] FAILURE PLANE | | POST EARTHQUAKE[6] FAILURE PLANE | |
|---|---|---|---|---|
| | A[3] | B[4] | A[3] | B[4] |
| 0+78 | 1.36 | 1.62 | 3.09 | 4.79 |
| 1+28 | 1.53 | 1.66 | 5.44 | 7.20 |
| 1+78 | 1.42 | 1.44 | 5.54 | 8.37 |
| 2+28 | 1.35 | 1.35 | 10.32 | 18.43 |
| 2+78 | 1.42 | 1.45 | 6.98 | 8.14 |
| 3+28 | 1.28 | 1.20 | 4.55 | 4.65 |
| 3+78 | 1.22 | 1.21 | 4.05 | 4.21 |
| 4+28 | 1.23 | 1.16 | 4.07 | 4.63 |
| 4+78 | 1.17 | 1.12 | 3.05 | 3.31 |
| 5+28 | 1.11 | 1.10 | 2.69 | 2.90 |
| 5+78 | 1.03 | 1.17 | 1.63 | 2.34 |
| 6+28 | 1.05 | 1.11 | 1.66 | 2.02 |
| 6+78[2] | | | | |
| 7+28 | 1.20 | 1.23 | 1.79 | 1.87 |
| 7+78 | 1.16 | 1.11 | 1.66 | 1.62 |
| 8+28 | 1.22 | 1.17 | 1.64 | 1.76 |
| 8+78 | 1.22 | 1.17 | 1.66 | 1.61 |
| 9+78 | 1.41 | 1.32 | 2.20 | 1.98 |

SAFETY FACTORS TRENCH B[1]

| STATION | DURING EARTHQUAKE[5] FAILURE PLANE | | POST EARTHQUAKE[6] FAILURE PLANE | |
|---|---|---|---|---|
| | A[8] | B[9] | A[8] | B[9] |
| 0+50 | 1.85 | 1.48[10] | 7.00 | 18.32[11] |
| 1+00 | 1.93 | 1.43[10] | 6.00 | 18.13[11] |
| 1+50 | 1.83 | 1.61[10] | 4.57 | 29.71[11] |
| 2+00 | 1.78 | 1.74[10] | 5.24 | 24.03[11] |
| 2+50 | 1.00 | 1.88[11] | 2.28 | 10.02[12] |
| 3+00 | 1.39 | 1.06[4] | 2.57 | 4.14[12] |
| 3+50 | 2.21 | 1.09[4] | 8.73 | 4.37[4] |
| 4+00 | 1.79 | NA | 16.57 | NA |
| 4+50 | 1.78 | NA | 17.50 | NA |
| 5+00 | 1.82 | NA | 18.49 | NA |
| 5+50 | 2.26 | NA | 34.39 | NA |
| 6+00 | 2.18 | NA | 32.65 | NA |

NOTES:
1. SEE FIGURE 2.5-586 FOR A PLAN SHOWING THE LOCATIONS OF THE CROSS-SECTIONS.
2. NOT INCLUDED. SOIL PROFILE NOT IDENTIFIED.
3. FAILURE PLANE IN COMPACTED FILL IMMEDIATELY ABOVE CRUSHED STONE.
4. FAILURE PLANE AT INTERFACE OF 95%/100% $\gamma D_{MAX}$ COMPACTED FILL.
5. STABILITY DURING EARTHQUAKE INCLUDING PASSIVE PRESSURE CALCULATED USING REDUCED STRENGTHS.
6. STABILITY AFTER EARTHQUAKE ASSUMING NO PASSIVE PRESSURE.
7. MATERIAL FROM ORIGINAL POWERHOUSE EXCAVATION, INCLUDES BASEL GRAVEL AND SHALE BLASTED FROM EXCAVATION. SPREAD BY PANS AND ONLY COMPACTION IS BY SPREADING EQUIPMENT.
8. FAILURE PLANE AT BASE OF CROSS-SECTION.
9. THE USE OF CRUSHED STONE AS WELL AS EARTHFILL ALLOWED FOR SEVERAL POTENTIAL FAILURE PLANES. THE FACTORS-OF-SAFETY GIVEN REPRESENT THE MINIMUM FS FOR POTENTIAL FAILURE PLANES OTHER THAN THAT GIVEN IN NOTE. 8.
10. FAILURE PLANE AT INTERFACE BETWEEN 1032 CRUSHED STONE MATERIAL AND 95% $\gamma D_{MAX}$ COMPACTED FILL.
11. FAILURE PLANE AT INTERFACE BETWEEN 1032 AND 1075 CRUSHED STONE MATERIALS.
12. FAILURE PLANE AT INTERFACE BETWEEN 1075 CRUSHED STONE MATERIAL AND 100% $\gamma D_{MAX}$ COMPACTED FILL.
13. NA-NOT AVAILABLE-NO OTHER DEFINED POTENTIAL FAILURE PLANE.

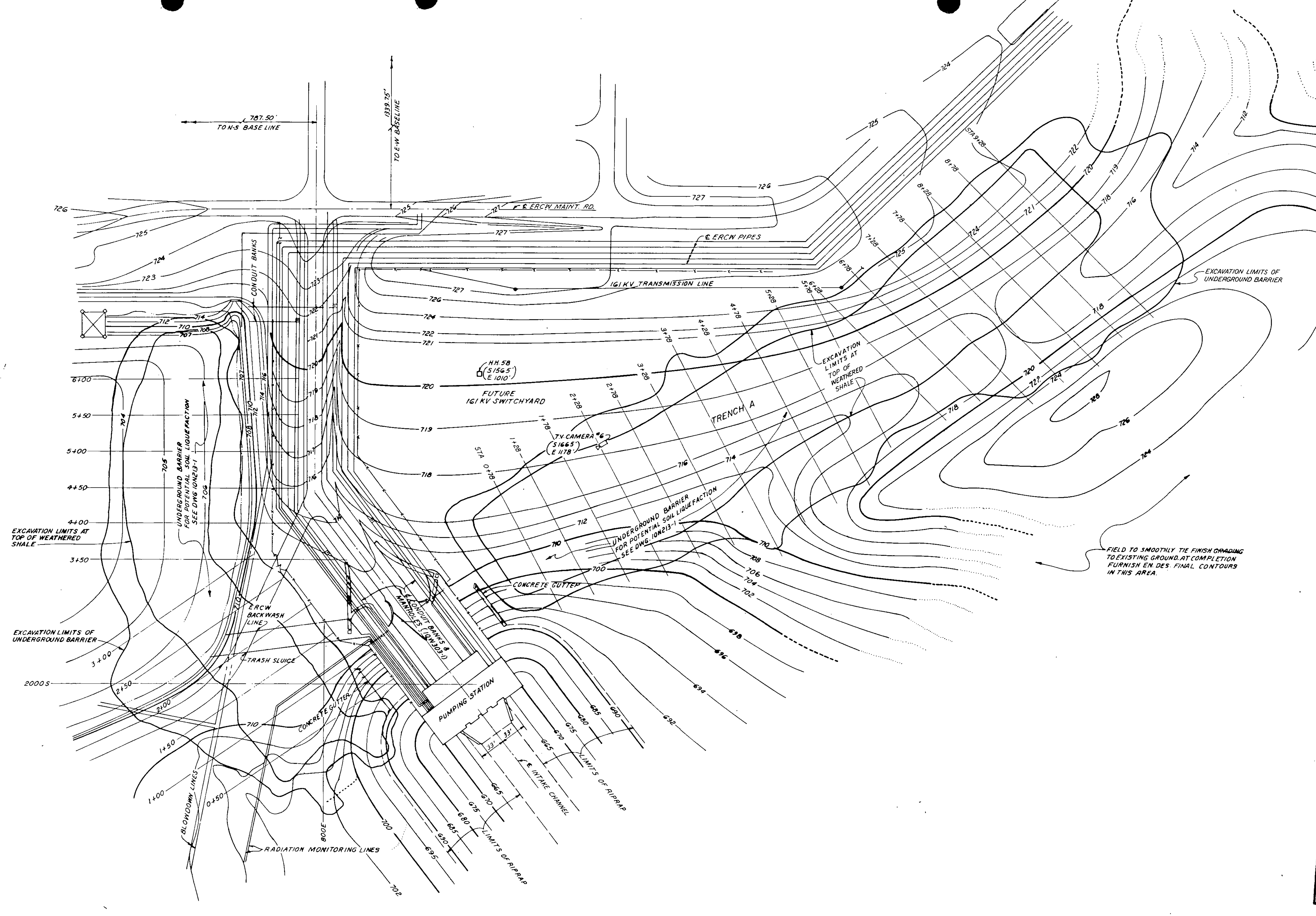
TI APERTURE CARD

**WATTS BAR NUCLEAR PLANT**

REMEDIAL TREATMENT FOR POTENTIAL SOIL LIQUEFACTION STABILITY ANALYSIS SUMMARY

FIGURE 3

8501230148-03




NOTES:
1. DASHED CONTOURS REPRESENT EXISTING GROUND, SOLID CONTOURS REPRESENT FINISHED GRADE.
2. GRASSING PER SECTION 580. FINAL SEEDING SHALL BE MADE WITH TYPE B (FALL SEEDING), AND FERTILIZED AND MULCHED IN ACCORDANCE WITH T-1 SPECIFICATIONS 580 AND 582, RESPECTIVELY.
3. QUALITY ASSURANCE ("Q") AS FOLLOWS: FINISHED GRADES SHALL TIE ACCURATELY AND SMOOTHLY TO ALL STRUCTURAL FEATURES INVOLVED. GRADES ESTABLISHED FROM CONTOURS AWAY FROM STRUCTURES SHALL BE ACCURATE WITHIN HALF THE CONTOUR INTERVAL INDICATED FOR THE AREA. A DRAWING MARKED WITH THE FINAL CONTOURS SHALL BE SUBMITTED TO EN. DES.

TI
APERTURE
CARD

8501230148-04

**WATTS BAR NUCLEAR PLANT**

YARD

FINISHED GRADING UNDERGROUND BARRIER AS-BUILT CROSS-SECTIONS

FIGURE 4


LEGEND:

- △ DENSITY TEST
- 1241 TEST NUMBER
- (101.6%) % MAXIMUM DRY DENSITY ASTM D698.
- ▼ WATER TABLE
- B — POSTULATED FAILURE PLANE AT INTERFACE BETWEEN TYPE A EARTHFILL (95% MAXIMUM DRY DENSITY) AND TYPE AI EARTHFILL (100% MAXIMUM DRY DENSITY)
- A — POSTULATED FAILURE PLANE
- —✱ ASSUMED INTERFACE

TI APERTURE CARD

8501230148-05

WATTS BAR NUCLEAR PLANT

YARD
UNDERGROUND BARRIER
TRENCH A
STA 1+78

FIGURE 5


LEGEND:

| | |
|---|---|
| △ | DENSITY TEST |
| 1251 | TEST NUMBER |
| (101.6%) | % MAXIMUM DRY DENSITY ASTM D698. |
| ▼ | WATER TABLE |
| B | POSTULATED FAILURE PLANE AT INTERFACE BETWEEN TYPE A EARTHFILL (95% MAXIMUM DRY DENSITY) AND TYPE A1 EARTHFILL (100% MAXIMUM DRY DENSITY) |
| A | POSTULATED FAILURE PLANE |
| —* | ASSUMED INTERFACE |

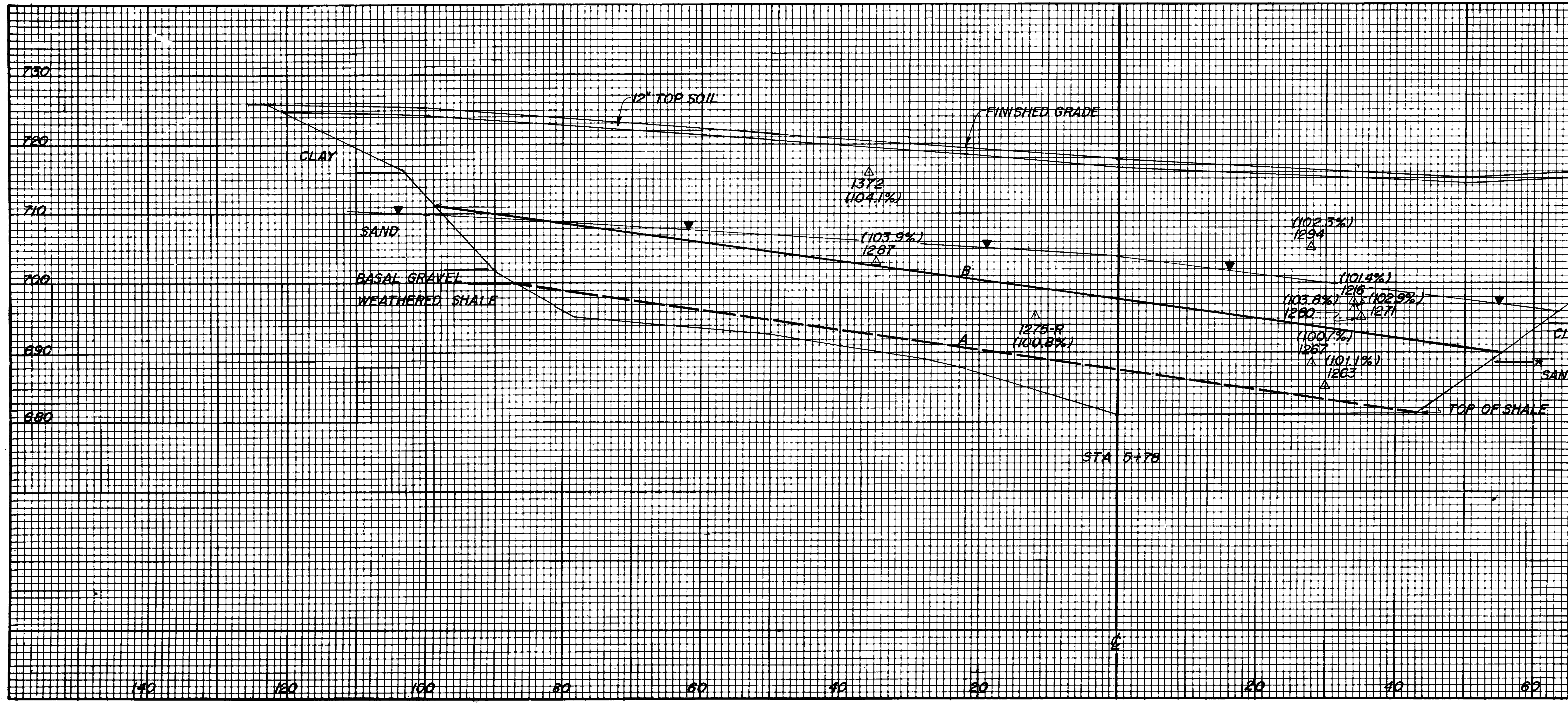
TI APERTURE CARD

8501230148-06

WATTS BAR NUCLEAR PLANT

YARD
UNDERGROUND BARRIER
TRENCH A
STA 3+78

FIGURE 6




LEGEND:

| | |
|---|---|
| △ | DENSITY TEST |
| 1216 | TEST NUMBER |
| (101.6%) | % MAXIMUM DRY DENSITY ASTM D698 |
| ▼ | WATER TABLE |
| B | POSTULATED FAILURE PLANE AT INTERFACE BETWEEN TYPE A EARTHFILL (95% MAXIMUM DRY DENSITY) AND TYPE AI EARTHFILL (100% MAXIMUM DRY DENSITY) |
| A | POSTULATED FAILURE PLANE |
| —✳ | ASSUMED INTERFACE |



8501230148-07

WATTS BAR NUCLEAR PLANT

YARD
UNDERGROUND BARRIER
TRENCH A
STA 5+78
FIGURE 7


LEGEND:

△ DENSITY TEST

1366 TEST NUMBER

(101.6%) % MAXIMUM DRY DENSITY ASTM D698.

▼ WATER TABLE

B POSTULATED FAILURE PLANE AT INTERFACE BETWEEN TYPE A EARTHFILL (95% MAXIMUM DRY DENSITY) AND TYPE A1 EARTHFILL (100% MAXIMUM DRY DENSITY)

A POSTULATED FAILURE PLANE

—✳ ASSUMED INTERFACE

TI APERTURE CARD

8501230148-08

WATTS BAR NUCLEAR PLANT

YARD
UNDERGROUND BARRIER
TRENCH A
STA 7+78

FIGURE 8


LEGEND
⊡ DENSITY TEST
2065 TEST NUMBER
(103.0%) % MAXIMUM DRY DENSITY ASTM D698 OR % RELATIVE DENSITY ASTM D2049

WATER TABLE
Ⓐ POTENTIAL FAILURE PLANE
MATERIAL INTERFACES
1075 AND 1032 CRUSHED STONE
1032 CRUSHED STONE AND 95% $\gamma_{DMAX}$ FILL
100% AND 95% $\gamma_{DMAX}$ FILL

TI APERTURE CARD

8501230148-09

WATTS BAR NUCLEAR PLANT

YARD
UNDERGROUND BARRIER
TRENCH B
STA 1+100

FIGURE 13


LEGEND

⊡ DENSITY TEST

2023 TEST NUMBER

(105.5%) % MAXIMUM DRY DENSITY ASTM D698 OR % RELATIVE DENSITY ASTM D2049

▼ WATER TABLE

Ⓐ POTENTIAL FAILURE PLANE

MATERIAL INTERFACES

1075 CRUSHED STONE AND 100% $\gamma_{DMAX}$ FILL

1075 AND 1032 CRUSHED STONE

1032 CRUSHED STONE AND 100% $\gamma_{DMAX}$ FILL

100% $\gamma_{DMAX}$ AND 95% $\gamma_{DMAX}$ FILL

1032 CRUSHED STONE AND 95% $\gamma_{DMAX}$ FILL

✱ ASSUMED INTERFACE

**TI APERTURE CARD**

8501230148-10

**WATTS BAR NUCLEAR PLANT**

YARD
UNDERGROUND BARRIER
TRENCH B
STA 2+50

FIGURE 14


LEGEND

⊡ DENSITY TEST

2057 TEST NUMBER

(103.8%) % MAXIMUM DRY DENSITY ASTM D698 OR % RELATIVE DENSITY ASTM D2049

▼ WATER TABLE

(A) POTENTIAL FAILURE PLANE

MATERIAL INTERFACE

—— —— 1075 CRUSHED STONE AND 100% γDMAX FILL

— — — — 1075 AND 1032 CRUSHED STONE

———— • 1032 CRUSHED STONE AND 100% γDMAX FILL

———— — 100% AND 95% γDMAX



8501230148-11

**WATTS BAR NUCLEAR PLANT**

YARD
UNDERGROUND BARRIER
TRENCH B
STA 3+00

FIGURE 15


LEGEND
⊡ DENSITY TEST
1425 TEST NUMBER
(102.7%) % MAXIMUM DRY DENSITY ASTM D698
▼ WATER TABLE
Ⓐ POTENTIAL FAILURE PLANE

TI APERTURE CARD

8501230148-12

WATTS BAR NUCLEAR PLANT

YARD
UNDERGROUND BARRIER
TRENCH B
STA 4+50

FIGURE 16