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F-Area Tank Farm
Hydrogeologic Data
Vadose Zone
Saturated Zone

Hydrogeologic Data Summary In Support of the F-Area Tank Farm (FTF) Performance Assessment (PA)

Authors

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July 2007

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Prepared for the U.S. Department of Energy Under Contract Number DE-AC09-96SR18500

SRNL™

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1.0 Purpose

The goal of this report is to provide a summary of available geotechnical and hydrogeologic data for the vicinity of the F-Area Tank Farm (FTF) in support of the FTF Performance Assessment (PA). In particular, this report focuses on sediment descriptions, geotechnical data (e.g., grain size analyses) and interpretations for the vadose zone. However, it also includes potentially significant findings regarding the saturated zone. Results from this review are consistent with current assumptions made for the vadose zone sediments for the F-Area Tank PA modeling.

2.0 Early Characterization Work (US Army Corps of Engineers and Mueser, Rutledge, Wentworth and Johnston Consulting Engineers)

Much of the early characterization work conducted at F-Area was performed by the US Army Corps of Engineers in the 1950's and by Mueser, Rutledge, Wentworth and Johnston Consulting Engineers in the 1970's. Other smaller studies, such as the subsurface exploration study conducted by John A. Blume & Associates, Engineers, are also included in this summary. Much of this work focused on geotechnical characterization for engineering purposes (e.g., slope stability, settlement issues) not for hydrogeologic purposes.

2.1 Identification and Grouting of the Calcareous Zone

One of the major findings of the early US Army Corps of Engineers characterization work was the presence of subsurface calcareous zones consisting of shelly, highly porous material. In cases where the dissolution of calcareous materials was significant, sinks or depressions in the ground surface were observed. An overlying, loose sand was often noted in association with these calcareous voids. Figure 1 shows an example of a biomoldic limestone sample obtained during the foundation grouting by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers in 1975.

These calcareous zones were found in the McBean Formation (Santee Formation) generally at depths of 100 to 200 ft (approximate elevations of 180 to120 ft msl) near F-Area (US Army Corps of Engineers 1952a; Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a) . One of the primary concerns was the ability of these areas to support overlying sediments and structures without significant settlement. This concern led to characterization and foundation grouting activities performed at F-Area in addition to other areas at the SRS.

Mueser, Rutledge, Wentworth & Johnston Consulting Engineers provided maps based on the US Army Corps of Engineers work, which show the locations of sinks and drainage features relative to the existing and proposed tanks at the time (Figure 2). In particular, Tanks 1-8 appear to have been located in an area of a former sink. In 1951 the US Army Corps of Engineers conducted foundation grouting underneath two proposed construction areas (buildings 221 and 241) in F-Area. They drilled a total of 24 holes that were grouted, and they pumped 8,715 cubic ft of grout into the subsurface targeting the calcareous zone. The largest grout consumed by one hole totaled 2,085 cubic feet. No grout connections were found between drill holes in F-Area (US Army Corps of Engineers 1952a; US Army Corps of Engineers 1952b).

Exploratory drilling by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers in 1974 showed similar or perhaps more severe voids beneath the proposed tanks 25-28 and 44-47. In their 1975 document, they reported (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a):

> We believe the data assembled concerning the 1974 borings and the borings made at earlier dates within the F-Area show that conditions beneath proposed tanks Nos. 44 through 47 along the southwesterly side of the project are more severe than data encountered beneath areas of previous construction. Although the data available for the old borings are meager as compared with that for the recent program, we believe more detailed information would have been recorded if problems similar to the recent ones occurred.

Significant mud losses, drops in rods and casings, and grout uptakes were observed in several of the exploratory borings (Figure 3). Further detailed information including mud losses and depths of the calcareous zone for these exploratory borings and older borings drilled near the tanks are provided in Appendix A (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a).

Foundation grouting for tanks 25-28 and 44-47 commenced in 1975 and consisted of drilling 72 holes and testing samples for presence of calcium carbonate (based on their reaction to hydrochloric acid) (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b). Mueser, Rutledge, Wentworth & Johnston Consulting Engineers prepared a cross-section beneath tanks 46 and 27 based on data collected from the exploratory borings and foundation grouting (Figure 4). During the grouting activities, soft zones, in which blow counts were significantly less than surrounding sediments, were encountered in some holes. These soft zones were generally underlain by calcareous zones. Hard, shell-rich samples (e.g., Figure 1) were also observed, particularly beneath tanks 44-47.

A summary of the grout quantities used for the foundation grouting of tanks 25-28 and 44-47 is provided in Figure 5 and in Appendix B. For tanks 25-28, most holes accepted 20 to 55 cubic ft of grout. However, in the northern half of tank 25, five holes took in 100-300 cubic ft of grout and one hole received over 2,000 cubic ft of grout. In the southern part of tank 28, three holes accepted 900 to 3,100 cubic ft of grout. A total of 10,263 cubic feet of grout were used in the grout drill holes for tanks 25-28.

Grouting activities for tanks 44-47 were different than tanks 25-28 in that the holes either took relatively little (24-60 cubic ft) or they accepted very large quantities of grout (up to 4,016 cubic ft). The highest quantities of grout used occurred at the center of tank 44, to the southeast of tank 45, and to the southeast of tank 47 (over 3,000 cubic ft in each hole). The holes with large grout uptakes accepted the grout as fast as it could be pumped (maximum 15 cubic ft per minute). A total of 34,476 cubic ft of grout were used in the grout drill holes for tanks 44-47. After mapping all of the holes with the large uptakes, intermediate holes were drilled to determine if there was a systematic distribution of locations requiring large amounts of grout (Figure 5). However, no correlation could be identified.

In 1976, Mueser, Rutledge, Wentworth & Johnston Consulting Engineers oversaw further exploratory borings, sampling and grouting activities for proposed tanks 52-55, which were to be located west of tanks 44-47. Results of this foundation investigation showed that "the range in thickness of the calcareous deposit and the intensity of voids encountered in this layer and immediately above it, are similar to the conditions encountered beneath adjacent Tanks Nos. 25 through 28 and 44 through 47" (Mueser, Rutledge, Wentworth, & Johnston 1977). A cross-section through the proposed tank 54, and future tanks 46 and 27 illustrate the presence and continuity of the calcareous zone in this region (Figure 6). A total of 31,472 cubic ft of grout were injected into 39 holes for the entire grouting operation for tanks 52-55, yielding an average grout uptake of 807 cubic ft per hole. More detailed information regarding the boring locations, sampling and grout uptakes are provided in Appendix C.

2.2 Early Characterization of the Vadose Zone and Saturated Zone

As part of the US Army Corps of Engineers foundation investigations, split-spoon samples and undisturbed soil samples (using piston-type samplers) were collected in various areas across the SRS. For samples collected from borings (FU-1, FU-2, and FU-3) in F-Area, South Atlantic Division Laboratory performed classification tests (Atterberg limits and grain size analyses) (US Army Corps of Engineers 1951) in addition to consolidation and shear strength tests. A few samples were also analyzed for vertical hydraulic conductivity (Kv). Results of the grain size and hydraulic conductivity analyses are provided in Appendix D. These borings are located northwest of the present day tanks (see Figure 2; FU-1 and FU-2 are located along line labeled B-B'; FU-3 is located along line labeled A-A').

Mueser, Rutledge, Wentworth & Johnston Consulting Engineers also provided early characterization data of the subsurface including cross-sections, soil descriptions and classifications in addition to strength and consolidation test data. Of particular importance is that these data are based on borings and samples collected beneath the current tanks 25-28 and 44-47 and provide one of the most extensive characterizations beneath the F-Area tanks. Because the characterization activities were primarily for foundation design, no saturated or unsaturated hydraulic conductivity data are available. However, soil classifications and cross-sections provide guidance as to whether current assumptions regarding soil types are reasonable.

According to Mueser, Rutledge, Wentworth & Johnston Consulting Engineers, the subsurface beneath tanks 25-28 and 44-47 could be divided into 7 general categories (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a):

1. <u>Fill (F)</u> – it was observed in all of their borings and attributed to excavations and previous work conducted in the area; average thickness was approximately 5 ft.
2. <u>Silty Clay (C1)</u> – stiff mottled red brown and purple silty clay to fine sandy clay with trace gravel; varied in thickness between 5 and 22 ft.
3. <u>Sand with some clay layers (S1)</u> – brown, white and purple fine to medium sand and clayey fine to medium sand with some clay lenses; varied in thickness between 8-32 ft.
4. <u>Sand (S2)</u> – thick deposit of medium to very compacted red and brown and orange fine to medium sand with trace silt and clay; varied in thickness between 24-72 ft with the greatest thickness on western side (particularly under tanks 45-47).
5. <u>Clay (C2)</u> – stiff to hard brown and green clay with trace fine to medium sand lenses; thickness varied up to 11 ft.
6. <u>Clayey Sand (S3)</u> – brown, grey, and yellow clayey sand to fine to medium sand, trace clay, gravel, and organic material
7. <u>Calcareous Clayey Sand (S4)</u> – light grey, white and brown calcareous clayey fine to coarse sand, some shell fragments; varied in thickness between 5-30 ft; some borings indicated extensive solution of calcareous material.

Boring logs and soil classifications were used to construct three cross-sections through tanks 25-28 and 44-47 (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a). The location of each cross-section relative to the tanks is shown on the boring location plan in Figure 7. Figure 8 shows cross-section A-A' from southwest to northeast crossing from tanks 45 and 46 through to tanks 26 and 27. Figure 9 shows cross-section B-B' from southeast to northwest through tanks 25-28. Figure 10 shows cross-section C-C' from southeast to northwest through tanks 44-47.

Mueser, Rutledge, Wentworth & Johnston Consulting Engineers also provided a cross-section through the proposed tanks 52-55 (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977). Although these tanks were never constructed, the cross-section shows the geology to the west of the tanks 44-47 based on their interpretations of borings and soil classifications. The location of the cross-section relative to the tanks (both future and proposed tanks) is shown on the boring location plan in Figure 11. Figure 12 shows cross-section A-A' from southeast to northwest through the proposed tanks 52-55. The soils characterized along this transect were similar to those observed at tanks 25-28 and 44-47 (see numbered sediment types described above, #1-7).

Results of the characterization conducted by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers are consistent with current interpretations of the subsurface at the FTF. Material property recommendations for the undisturbed vadose zone soils at the FTF were provided in SRNL-ESB-2007-00008 (Jones et al. 2007). These estimates were derived from the E-Area LLWF material property values presented in WSRC-STI-2006-00198 (Phifer et al. 2006). E-Area soil properties were recommended for the following reasons:

- the lack of available soil property data for F-Area
- the wealth of data available for the E-Area LLWF (to include grain size data, water retention data, geophysical logs, CPT logs, and foot-by-foot core descriptions)
- the similarity in geology/physiography between E-Area and F-Area
- the close proximity of E-Area and F-Area

As discussed in the E-Area material property report, grain size data, visual foot-by-foot core descriptions, geophysical logs and CPT logs indicated that the vadose zone at the E-Area LLWF could be divided into two zones –

- an upper, finer-grained, more heterogeneous zone
- and a lower, coarser-grained zones with less heterogeneity.

For the FTF, it was recommended that the lower zone material properties be used to represent the undisturbed vadose zone soil beneath the tanks based on excavation depths for the tanks and available CPT logs, geophysical logs, and visual core descriptions. At the time, only CPT logs were available and used for interpreting sediment types directly beneath the FTF. CPT log FTNKC3 was used to illustrate the basis for the recommendation (Figure 13 and Figure 14).

The upper zone is consistent with the strata identified as C1 and S1 by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers. C1 consisted of stiff mottled red brown and purple silty clay to fine sandy clay with trace gravel and S1 consisted of brown, white and purple fine to medium sand and clayey fine to medium sand with some clay lenses. Both C1 and S1 were found associated with the other (either C1 on top of S1 as in Figure 8 and Figure 9 or with C1 in between two S1 layers as in Figure 10 and Figure 12).

As indicated on the cross-sections for tanks 25-28 and 44-47, most of C1 and S1 would have been excavated during construction of the tanks. The remaining undisturbed vadose zone would consist of some S1 material (except for tanks 46 and 47) together with S2 material. S2 was characterized as medium to very compacted red and brown and orange fine to medium sand with trace silt and clay. For tanks 25-28 and 44-47, Mueser, Rutledge, Wentworth & Johnston Consulting Engineers concluded “The results of the borings have shown that the soil profile beneath the tanks is largely sand except for occasional thin clay layers" (1975a). This is consistent with the recommendation of using lower vadose zone material properties to represent the undisturbed vadose zone beneath the tanks.

The strata identified as C2, a stiff to hard brown and green clay with trace fine to medium sand lenses with a thickness up to 11 ft, is consistent with the Tan Clay Confining Zone (TCCZ) based on sediment description, thickness and elevation. The TCCZ is referred to as a "zone" (rather than a competent "unit") because it is not comprised of a single clay bed. Instead, it can consist of multiple clay-rich layers that are laterally discontinuous. Locally, the TCCZ can be significant in retarding the movement of groundwater, however it is still considered a semi-confining zone (Aadland et al. 1995; Denham 1999).

Mueser, Rutledge, Wentworth & Johnston Consulting Engineers primarily found a consistent, single, competent clay layer underneath tanks 25-28 and the proposed tanks 52-55 (Figure 9 and Figure 12). Underneath tanks 44-47, the C2 layer was split into two layers and absent at one location. Table 1 summarizes the C2 layers identified in the cross-sections and compares them to TCCZ interpretations based on CPT logs at the FTF and nearby foot-by-foot descriptions/geophysical logs. The C2 layers are consistent in elevation and thickness with the picks for the TCCZ at the FTF. Of particular note, is the fact that the C2 (or TCCZ) was not identified in the boring 14F-7U (also known as 241-14F-7U), which was located under the existing tank 46. Also in boring 14F-6 (241-14F-6) underneath the present day tank 47 and in boring 14F-9 (241-14F-9) underneath the present day tank 44, the C2 clay was shown in two layers separated by 4 to 10 ft of the sandy S2 sediment. The TCCZ appears to be present in the nearby CPT, FTNKC16 (Figure 15). It is unclear based on the CPT logs whether the TCCZ is one layer (as originally picked) or whether it could perhaps also have smaller clay layers associated with it. This example demonstrates the limits of CPT logs versus core samples.

Table 1: Summary of C2 Layer identified by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers and TCCZ picks from nearby CPTs

Source	TCCZ range of occurrence (elevation, ft msl)[1]	Approximate TCCZ thickness or range in thickness (ft)
Cross-section A-A (GS-1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)	~195 to 210 ft msl	5 to 10 ft
Cross-section B-B (GS-2 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)	~197 to 208 ft msl	4 to 10 ft
Cross-section C-C (GS-3 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)	~190 to 210 ft msl	0 to 8 ft see note[2]
Cross-section A-A (GS-1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)	~194 to 214 ft msl	4-8 ft
CPT FTNKC3 located near tank 26 (Millings 2007)	198.5 to 204.5 ft msl	6 ft
CPT FTNKC10 located near tank 27 just outside of excavation/concrete workslab footprint (Millings 2007)	199.9 to 206.9 ft msl	7 ft
CPT FTNKC16 located between tanks 46 and 47 on edge of excavation/concrete workslab footprint (Millings 2007)	199.4 to 208.4 ft msl	9 ft
Ten "FTNKC" CPTs at the FTF in which TCCZ picks were made (Millings 2007)	190.3 to 217.5 ft msl	4 to 9 ft

Notes: ft msl = feet from mean sea level
[1]"range of occurrence" for cross-sections and the ten "FTNKC#" CPTs means that the TCCZ was found in this range of elevations; for the individual CPTs, the range represents the top and bottom of the TCCZ pick based on the CPT logs.
[2]C2 layer was not found at 14F-7U; at 14F-6 and 14F-9 was identified as two small layers of clay, each 2-4 ft thick

One other item of note documented in the cross-sections and write-up by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a) was the existence of a ramp that was built in 1956 to support construction of the tanks north of tanks 25-28. The area where the ramp existed was later backfilled and subsequently included in the 1974 characterization activities. In particular, Mueser, Rutledge, Wentworth & Johnston Consulting Engineers noted that this area included tanks 25 and 26 and backfill may exist below part of the bottom of tank 25 (NW portion of tank 25). They recommended that the fill should be examined to determine whether it had been suitability compacted (to support the tank) or whether it should be removed and replaced with compacted fill before tank base construction (1975a). It is unclear whether the backfill was removed based on current available documents. Using the cross-section and characterization data (Figure 9 and Figure 16), the backfill is approximately 10 ft thick in the northwest quadrant of tank 25 (where boring 8 is located).

3.0 Other Characterization Studies

3.1 Characterization for Earthquake Analyses (John A. Blume & Associates, Engineers)

In 1971, John A. Blume & Associates, Engineers performed a subsurface exploration study at F-Area and H-Area tanks to determine geotechnical properties necessary for earthquake analyses of the storage tanks (John A. Blume & Associates, Engineers 1971). This study involved drilling two borings in F-Area, one boring (DH-4) to the southeast of tank 8 and the other boring (DH-5) to the west of tanks 17 and 19 (Figure 17). Samples were collected for grain size analyses, bulk property testing (e.g., soil moisture, dry weight density), Atterberg limits, and classification. Laboratory analyses were performed by the Pittsburgh Testing Laboratory and Law Engineering Testing Company. Results of these analyses are provided in Appendix E. Both borings were logged by geologists, however only one log (DH-4) provides a clear and detailed description of sediments. The log for DH-4 is included in Appendix F.

Of particular note, at the first boring location for DH-5, difficulty was encountered at a depth of approximately 104 ft. At this depth, the drill rods dropped to 111 ft and circulation of the drilling fluid was lost. After circulation was restored, the drilling continued to approximately 165 ft, at which point the drill rig could no longer advance the casings. After attempting to continue with a larger drill rig, the hole was abandoned. A total of 400 cubic ft of grout was required to grout the hole. A new boring was located 25 ft north of the abandoned boring location. No cavities were encountered and the hole was successfully completed. The encounter of the void and loss of drilling fluid at the initial DH-5 location is consistent with the calcareous zone characterized by the US Army Corps of Engineers and Mueser, Rutledge, Wentworth & Johnston Consulting Engineers. Calcareous sediments were also identified in both drill logs. In DH-4, sediments with calcium carbonate were located at a depth of 115 ft bls (elevation of 159 ft msl) and at a depth of 155 ft bls (119 ft msl). In DH-5, sediments with calcium carbonate were identified at a depth of 120 ft bls (147 ft msl). Again, these findings are consistent with the calcareous zone reported by US Army Corps of Engineers and Mueser, Rutledge, Wentworth & Johnston Consulting Engineers.

Another significant finding reported in the drilling logs and the laboratory analyses was the presence of fine-grained, silt and clay-rich layers at an elevation that corresponds to the TCCZ. As shown on Table 2 the fine-grained, silt and clay rich layers were found at elevations between 194 and 215 ft msl. These layers are consistent with the elevation of the C2 layer identified by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers and the TCCZ identified in recent CPTs at the FTF (refer to Table 1).

Table 2: Fine-Grained Layers Corresponding to TCCZ in DH-4 and DH-5 Borings

Location	Depth (ft bls)	Elevation (ft msl)	Drill Log/Lab Result
DH-4	58.5	215.7	Pittsburgh Testing Lab classified 58.5 ft sample as MH; 98% was finer than #200 sieve size (<0.074 mm; silt+clay)
DH-4	65	209.2	Geologist recorded presence of a light red clay
DH-4	78-80	196.2-194.2	Geologist recorded presence of a light grey clay; Pittsburgh Testing Lab classified 78.5 ft sample as CH; 51% was finer than #200 sieve size (<0.074 mm; silt+clay)
DH-5	64	203.7	LAW Engineering Testing Company classified 64 ft sample as CH; 95% was finer than #200 sieve size (<0.074 mm; silt+clay); >75% was finer than 0.001 mm Geologist recorded presence of a silty clay

Notes: ft bls = feet below land surface; ft msl = feet from mean sea level; surface elevation for DH-4 = 274.2 ft msl; surface elevation for DH-5 = 267.7 ft msl; for the Unified Soil Classification abbreviations, MH = inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts; CH = inorganic clays of high plasticity, fat clays

3.2 SRP Baseline Hydrogeologic Investigation

As part of the SRP Baseline Hydrogeologic Investigation, a series of wells, which were screened at the water table and within each major water bearing unit down through the McQueen Branch Aquifer, were installed in background areas of the SRS. These wells were installed for the purpose of improving the knowledge of the hydrogeology at the SRS. During the Phase III work in the late 1980's, the P-28 cluster was installed to the north of the F-Area perimeter fence. This cluster was also located near an existing well cluster (FC-2), which was installed during a previous study in the 1970's (Bledsoe 1988).

The deepest boring (P-28TA) was continuously cored. Sediment recovered was described both during the drilling and later in the lab (as foot-by-foot core description per the methodology described in Millings and Flach 2007). The well was also logged using standard geophysical techniques. According to Bledsoe (1988), the vadose zone can be characterized as predominately "tan, red, faintly laminated, silty, clayey, very fine to medium sands" (figure 18 in Bledsoe 1988). More specifically, the lithologic log shows that the upper part of the core (depths of 11-30 ft bls) consists of clayey sands, clay and silty clay (Table 3). Below this zone (depths of 30-70 ft bls) are predominantly fine to coarse sands and silty sands with less clay. Beneath these sands, a clay-rich layer was identified (depths 71-78 ft bls).

Table 3: Summary of Lithologic Log for P28TA

Depth (ft bls)	Elevation (ft msl)	Description Based on Bledsoe (1988)
0	284.8	land surface
0-8	284.4-276.8	Fine sands, well sorted
8-11	276.8-273.8	No recovery
11-16	273.8-268.8	Fine, clayey sand
16-26	268.8-258.8	Clay
26-30	258.8-254.8	Fine, clayey sand
30-70	254.8-214.4	Fine sands, fine silty/clayey sands, coarse sands
70-71	214.8-213.8	Fine, clayey sand
71-78	213.8-206.8	Clay, sandy clay
78-107	206.8-177.8	Medium to coarse sands to silty sands

*Note: summary table constructed based on lithologic logs provided in Bledsoe (1988); ft bls = feet below land surface; ft msl = feet from mean sea level

Foot-by-foot core descriptions performed on P28TA core by Science Applications International Corporation (SAIC) in 1992 also identified an upper zone with fine-grained, clay-rich layers followed by a lower, sandier zone with less clay. In particular, clayey sands to sandy clays were identified between 17 and 21 ft bls (267.8-263.8 t msl). Below 27 ft bls (257.8 ft msl), sediments were predominantly sands (>80%). From 72 to 76 ft (212.8-208.8 ft msl), sediments were characterized as a sandy clay with 50-60% mud (silt and clay).

The core descriptions for P28TA by Bledsoe (1988) and SAIC are consistent with other characterizations of the vadose zone and upper water table aquifer (see 2.2 Early Characterization of the Vadose Zone and Saturated Zone), which have identified an upper, finer-grained zone underlain a sandier zone. In addition, the clay identified between 71 to 78 ft bls (213.8-206.8 ft msl) by Bledsoe (1988) and subsequently noted by SAIC between 72 to 76 ft bls (212.8-208.8 ft ms) is consistent with the elevation of the TCCZ. This clayey zone can also be seen in the gamma log between 70 and 80 ft bls. Lithologic logs from Bledsoe (1988), foot-by foot-core descriptions by SAIC, and the gamma log are provided for the first 100 ft of core in Appendix G.

3.3 SGS Geotechnical Characterization of F-Area

A 1996 Site Geotechnical Services Department (SGS) study entailed reviewing previous geotechnical and geologic data and reports, performing field and laboratory tests, and conducting engineering analyses for the purpose of characterizing foundation material in F-Area. In particular, SGS focused their investigation on 1) establishing site specific geological conditions; 2) determining the engineering properties of subsurface and fill materials under structural loads; and 3) evaluating the lateral and vertical extent of soft zones, slope stability, liquefaction potential, and potential settlements of subsurface materials (SGS 1996).

3.3.1 Laboratory Analyses:

Laboratory analyses included soil classification, dry bulk density, and grain size distribution in addition to analyses to determine plasticity, static strength, consolidation properties, and compaction characteristics. Analyses were performed by LAW Engineering, Atlanta, GA. Table E-2 Summary of Laboratory Test Results in the SGS characterization report provides soil property data collected during this study and from previous studies (SGS 1996). Much of the data on this table is related to engineering properties. Appendix H provides data from locations near the FTF. Included are grain size analyses, dry bulk density, and classification (USCS) for the following locations: FSEPB6, FTNKB3, FTNKB8, FTNKB13, FTNKB16, and FTNKB20. The data in this appendix include analytical results for native materials and structural fill. Data associated with other locations in F-Area (primarily on the north side) are provided in the report by SGS (SGS 1996).

3.3.2 Calcareous Zone Near the FTF:

Out of borings and SCPTUs (seismic piezocone penetration tests) performed as part of this study, only one boring and seven SCPTUs near or within the FTF penetrated the Santee, in which the primary calcareous zones (or soft zones) were identified by the US Army Corps of Engineers and Mueser, Rutledge, Wentworth & Johnston Consulting Engineers. During the boring of FSEPB6, located near Tank 33, drillers encountered low blow counts (SPT N-values), rod drops and loss of circulation between 164.5 and 158.5 ft msl (Figure 18). Even though carbonates were not noted in this boring, drilling observations were characteristic of the calcareous zone. SCPTUs, FTNKC16 near Tank 47 and FTNKC17 north of Tank 2, also showed indications of this calcareous zone based on low tip resistance, low sleeve friction and near hydrostatic pore pressures responses near the bottom of holes (Figure 15 and Figure 19) (SGS 1996). The elevation of the calcareous zone (or soft zone) identified in FSEPB6, FTNKC16, and FTNKC17 is consistent with the elevations of the calcareous zone near the FTF (150-180 ft msl) noted by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers and the the US Army Corps of Engineers.

3.3.3 Calcareous Zone Elsewhere in F-Area:

Closer to the F-Canyon, evidence of the calcareous zone in the Santee at elevations ~155 to 146 ft msl was observed both in borings (e.g., FB1) and SCPTUs (e.g., FSEPC6, FSEPC10, FSEPC13, F235C2, and F235C6). Again, rod drops, low blow counts were observed in the borings whereas low tip resistance, low sleeve friction and high pore pressure responses were observed in the SCPTUs. According to the core logs, sediments from the Santee were described as “tan, very fine to silty and clayey sand with traces of shell fragments” (SGS 1996).

One soil boring and one SCPTU also indicated some calcareous sediment in the Dry Branch Formation at elevation of 187 to 179 ft msl. A SCPTU near the FTF (FTNKC3) also showed indications of calcareous sediments within the Dry Branch. According to the early characterization work of Mueser, Rutledge, Wentworth & Johnston Consulting

Engineers and the the US Army Corps of Engineers in addition to the work by SGS, the calcareous sediments in the Dry Branch Formation do not appear to be as extensive nor to have the voids associated with them like the Santee. In addition, the calcareous sediments in the Dry Branch do not appear to have been the focus of the early grouting activities.

3.3.4 Tan Clay Confining Zone (TCCZ):

According to the SGS 1996 report, the TCCZ was designated as “DB4/DB5”. The investigators noted that this layer typically showed up as moderate to low tip resistances and moderate friction ratios on the SCPTU logs. The top of the TCCZ ranged from 200 to 210 ft msl on the northern side of F-Area and dipped to about 195 ft msl on the southern end of F-Area (see the text on page 2-9 in the 1996 SGS report). The thickness of the TCCZ ranged from approximately 6 ft on the southeastern side of the F-Area to about 15 ft on the northwestern corner of F-Area (page 2-9 in the text). They concluded that “the DB4/DB5 layer is a fairly consistent marker bed that is locally continuous in the F-Area” (SGS 1996).

However, there are discrepancies between the text and information provided in the cross-sections and the table at the bottom of page 2-9, which describes the layer attributes for DB1/DB3 and DB4/DB5 layers. As cited on this table, the DB4/DB5 layer has an average thickness as 6.8 ft, an average top elevation of 175.3 ft msl, and an average bottom elevation of 166.7 ft msl. Several of the cross-sections (e.g., Plates 27, 28, and 29) that are provided in this report also show the DB4/DB5 layer at lower elevations than indicated by the text and other studies. These cross-sections show the DB4/DB5 layer at elevations between 175 ft msl and 160 ft msl, not from 210 ft msl to 195 ft msl as cited in the text. It appears that the cross-sections and table on 2-9 describe a DB4/DB5 layer that is likely more correlative to the S4 layer identified by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (calcareous clayey sand) based on elevation. The layer described as TR3/4 seems to be similar in elevation to the C2 layer identified by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers and the TCCZ identified in other studies (e.g., Smits et al. 1997; Millings 2007) (Figure 20).

As illustrated in the evaluation “Aquitard Thickness at the F-Area Tank Farm”, there have been various hydrostratigraphic picks for the TCCZ. A pick refers to the boundaries (top and bottom elevations) of a lithostratigraphic or hydrostratigraphic layer. The different picks reflect differences in interpretations and professional judgment (SGCP 2006). Differences in TCCZ picks may also result from differences in the definition of this particular zone. For example, SAIC and Savannah River National Laboratory (SRNL) (Smits et al. 1997) defined the TCCZ by the muddiest or most-clay rich zone. This zone was typically easily recognizable in core and geophysical logs, however can be more difficult to pick based on CPT logs (Millings 2007). Table 1 in the Soil and Groundwater Closure Projects (SGCP) report summarizes previous TCCZ picks captured in the Landmark database for the SCPTU completed at the FTF as part of the SGS geotechnical investigation (SGCP 2006). According to this table, the TCCZ has various pick surface names including “TR3/4”, “TCCZ”, and “DB1/DB3”. Table 3 in the SGCP

(SGCP 2006) report provides a summary table of TCCZ picks based on these data. Table 4 in this report shows a comparison between the TCCZ summary picks in the SGCP report (SGCP 2006), the picks provided in Millings (2007), and model generated picks from the 1995 hydrogeologic database for the General Separations Area (GSA). Figure 21 provides a map with these CPT locations and other CPTs in the vicinity of the FTF. Not all CPTs near the FTF were evaluated for TCCZ picks either because the CPTs did not completely penetrate the TCCZ or because the CPTs did not generate good quality logs.

Table 4: FTF Tan Clay Comparison

CPT Location	TCCZ Top Elev (SGCP 2006)	TCCZ Top Elev (Millings 2007)	TCCZ Top Elev (model generated)	TCCZ Thickness (SGCP 2006)	TCCZ Thickness (Millings 2007)	TCCZ Thickness (model generated)
FTNKC10	207	206.9	201.3	10	7	7.3
FTNKC11	210	208.3	195.4	15	5	8.5
FTNKC12	220	217.5	210.2	11	5	8.4
FTNKC13	208	206.7	208.3	5	4	6.8
FTNKC16	210	208.4	201.8	11	9	6.4
FTNKC17	215	214.0	210.9	10	9	5.9
FTNKC3	206	204.5	203.2	8	6	6.0
FTNKC6	202	199.3	199.8	12	9	8.2
FTNKC8	215	213.6	205.9	7	6	5.4
FTNKC9	213	212.1	196.1	8	8	8.6

Notes: TCCZ Top Elev = Tan Clay Confining Zone Top Elevation (feet from mean sea level); thickness is provided in feet

It should be noted that the TCCZ picks from Millings (2007) and the model generated picks (based on the 1995 hydrogeologic database for the GSA) use the same "definition" of the TCCZ. In other words, for these picks (either made by Millings in 2007 or those made for the 1995 database), the intent was to pick the boundaries for the most clay-rich or muddiest (where mud reflects silt and clay sized fractions) facies.

Differences between SGCP (2006) picks and picks in Millings (2007)

Overall, the SGCP (2006) TCCZ top picks are similar (within 1 to 2 feet) to those picks in Millings (2007). However, thicknesses of the TCCZ identified by SGCP (2006) and Millings (2007) can be quite different and most likely reflect a difference in how the TCCZ is defined. The thickness of the TCCZ provided in Millings (2007) is the same or smaller than the thickness provided by SGCP (2006). Also, without continuous core, it is difficult from the CPT logs to precisely define the most clay-rich or muddiest facies.

Differences between model generated picks and picks in Millings (2007) and SGCP (2006)

Most of the model generated TCCZ top picks appear to be lower than the top picks identified in Millings (2007) and SGCP (2006). A few locations have similar elevations (e.g., FTNKC3, FTNKC6 and FTNKC13). However, the thicknesses of the TCCZ generated by the model are similar to the thicknesses provided in Millings (2007). As noted in Millings (2007), the differences in elevations and thicknesses can be attributed to:

- small scale natural variations in the TCCZ, which reflect changes in depositional environments or other geologic processes and are not captured at the model scale
- ambiguity in the CPT logs leading to the inability to pick the muddiest (most clay-rich) zone (e.g., based on the pore pressure, tip resistance and friction ratio, FTNKC10, FTNKC11, and FTNKC12 could actually have lower TCCZ picks, which would more closely match the model generated elevations)

Comparison of these TCCZ picks with geotechnical logs from SGS borings (SGS 1996):
Geotechnical logs from F-Area characterization borings were also included in this SGS investigation. One of the closest borings to FTF is FSEPB6, which is located approximately 115 ft (35 m) southeast of Tank 33 (Figure 18). According to the log describing the sediments recovered, a "tan FAT CLAY (CH)" was identified from approximately 80 ft bls (204.2 ft msl) to 88 ft bls (196.0 ft msl). Other borings completed as part of this investigation in F-Area showed a clay at similar elevations. Table 5 provides a summary of these locations along with elevations and thicknesses of the clay. The thickness and elevations of this clay are consistent with the TCCZ identified in CPTs near the FTF (Table 4) and in borings from other studies (Tables 1-3).

Table 5: Summary of TCCZ Identified in SGS Geotechnical Borings in F-Area

Location ID	UTM E	UTM N	General Location	Elevation of TCCZ (ft msl)	Thickness (ft)	Description
FSEPB6	437051.4	3682532.6	SE of Tank 33	204.2-196.0	8.2	tan FAT CLAY (CH)
FSEPB8	436897.9	3682992.5	North of FTF	219-217.5	1.5	light to medium brown FAT CLAY (CH)
FSEPB13.1	436876.2	3683335.5	North side of F-Area	198.3-195.5 and 192.0-190.0	2.8 and 2.0	sandy FAT CLAY (CH)
FB1	437056.6	3683504.9	North side of F-Area	205.1-203.9 and 203.4-202.6	1.2 and 0.8	yellow brown CLAY (CH)

Notes: summary table based on geotechnical logs in F-Area Geotechnical Characterization Report (U), Volume 4, WSRC-TR-96-0069 (SGS 1996)

Comparison of these TCCZ picks with other locations and studies:
The TCCZ picks presented in Table 4 and Table 5 are consistent in elevation and thickness with other studies that have identified the presence of this clay-rich zone. The C2 layer described by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a; 1977) ranged in elevation from 214 to 190 ft msl and varied in thickness from 4 to 10 ft (where the TCCZ was present). Table 1 provides a comparison among the C2 layers and nearby CPTs at the FTF. Characterization performed by John A. Blume & Associates, Engineers (1971) also showed a clay-rich layer at elevations between 215 and 194 ft msl (Table 2). In addition, core logs from P28TA identified a clay to sandy clay layer between 213.8 and 206.8 ft msl (Table 3) (Bledsoe 1988).

<u>3.3.5 Undisturbed Vadose Zone:</u>
Several characterization borings were performed at the FTF as part of the SGS investigation. Sediment samples were collected for classification and laboratory analyses. Results from the SGS investigation provide an opportunity to compare these sample results, geotechnical descriptions and nearby CPT logs with the lower zone properties, which were recommended in Jones et al. (2007) as initial inputs into the PA modeling. As discussed in Section 2.2 Early Characterization of the Vadose Zone and Saturated Zone, Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a) characterized the undisturbed soil beneath the tanks as primarily sandy with occasional clay layers (layer S2 with some S1 layers still remaining after the excavation in some locations).

In Table E-2 in the SGS characterization report, samples collected from the geotechnical borings are designated as fill or as native material. Figure 22 through Figure 26 show results of grain size analyses from these characterization borings in relation to depth and nearby CPT logs. Only samples that were designated as native material in the SGS report are shown on these figures. Most of the samples consisted of between 80% and 90% sand; only two samples from FTNKB8 (7.5-9.5 ft bls and 17.5-19 ft bls) and one sample from FTNKB13 (31-32.5 ft bls) had mud fractions (silt and clay) greater than 20%. It is unclear using the nearby CPT log whether the sample from FTNKB13 truly represents undisturbed native material or whether it may be part of the backfill material. FTNKB8 is the only location that did not penetrate backfill material (i.e., the logs and samples are all from native, undisturbed sediments) according to the 2006 SGS investigation. As illustrated in Figure 27 the percentages of sand and mud in samples measured in the SGS investigation are consistent with the percentages observed in the lower zone in E-Area. Most of the native vadose zone samples evaluated during the SGS investigation were classified as silty sands (SM) or poorly graded sands, some with silt (SP and SP-SM); four of the twenty-one samples were classified as clayey sands (SC) (Appendix H).

3.3.6 Structural Fill:
Investigations regarding structural fill in F-Area were also included in the 1996 SGS study. Facilities such as the F Canyon and FTF were constructed on native material with structural fill used to backfill excavations. Foundations for structures typically required the use of “test controlled compaction” (TCC) fill. The standard DuPont spec for structural fill was defined in SC-5E, “Fill, Test-Controlled Compaction” (DuPont 1988). According to the SGS investigation, no original records for the field control compaction testing related to the construction of the tanks are available.

However, the SGS study describes a 1986 report, “F-Area Containment Building for Pump Pits and Diversion Boxes” by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers that documents examples of compaction tests performed during the construction operations for the FTF. Mueser, Rutledge, Wentworth & Johnston Consulting Engineers compiled all of the available compaction test data, which had been performed by Pittsburgh Testing Laboratories, in order to investigate whether new structures could be adequately supported by the existing structural fill. As part of their conclusions, they noted that the test data demonstrated that the structural fill had been placed in accordance with specification requirements (SGS 1996).

The SGS study also provides historical information related to a steam line break near Tank 28 in December 1993. Excavation and analysis of fill material during this incident indicated that this fill was poorly compacted (results between 80 and 85% of ASTM D1557). The SGS investigation concluded that “It is likely that because of piping, electrical and other utilities were embedded within the fill as it was placed, compaction around these areas was difficult to achieve” (SGS 1996).

Structural fill samples collected near the FTF as part of the SGS investigation show that most of the sediments are SC (Clayey Sand) or SM (Silty Sand) material according to the USCS (Appendix H). These findings are consistent with the findings in Phifer et al. (2006) and the recommendations made for the vadose zone material properties at the FTF in Jones et al. (2006).

4.0 Flow in the Vadose Zone

Several field and laboratory tests conducted at the SRS in the 1960’s focused on the flow of water through the unsaturated zone (Haskell and Hawkins 1964; Horton and Hawkins 1965; and Hawkins and Horton 1967). Results from these tests were later quoted in reports such as Fenimore’s (1968) “Tracing Soil Moisture and Groundwater Flow at the Savannah River Plant” and Horton’s (1975) “Soil Moisture Flow as Related to the Burial of Solid Radioactive Waste”. Fenimore (1968) assumed a downward tracer movement of 0.95 inches per inch of rainfall based on the work of Haskell and Hawkins (1964) and Hawkins and Horton (1967). Horton (1975) identified a pore velocity of 7ft per year, which appears to reflect the higher flow rate of 1.99 inches per inch of rainfall observed by Haskell and Hawkins (1964). The early field and laboratory tests conducted in 1960’s are summarized below.

4.1 Haskell and Hawkins (1964)

In 1963, Haskell and Hawkins conducted a field experiment in which they used a Na^{24} gamma source and a slow neutron detector to measure the vertical movement of deuterium (D_2O) within the vadose zone at the SRS (Haskell and Hawkins 1964). The test was conducted on three plots, under natural rainfall and evaporation conditions, and in a recently devegetated area with sandy loam to sandy clay sediment. On each plot, an access tube and four monitoring tubes were emplaced. From February 19 through August 7, weekly measurements were made with the Na^{24} probe. The results of their test are shown in Figure 28, which depicts downward movement of the tracer peak versus rainfall. Results showed that the total downward movement of the tracer at plot 3 was approximately twice the amount observed at plots 1 and 2. In addition, they observed that the movement of the tracer in plots 1 and 2 was approximately 20 inches in the 169-day trial and an average of 0.94 inches per inch of rainfall. For plot 3, the tracer moved approximately 41 inches in the 169-day trial and averaged 1.99 inches per inch of rainfall. Haskell and Hawkins hypothesized that the increased rate observed at plot 3 was probably due to the fact that the plot was located on the edge of a former ditch that had been backfilled 2 years earlier. Although soil properties were not measured, they surmised that the variation in structure and density between the disturbed and undisturbed soils might easily explain the different rates of tracer movement (Haskell and Hawkins 1964).

Horton assumed an average precipitation of 47 inches per year (Horton 1975), which would yield the following rates of movement for the various plots in the Haskell and Hawkins study:

<u>For plots 1 and 2:</u>
0.94 inches per inch of rainfall * 47 inches rainfall/year = 44.18 inches per year or 3.68 feet per year

<u>For plot 3:</u>
1.99 inches per inch of rainfall * 47 inches rainfall/year = 93.53 inches per year or 7.79 feet per year

4.2 Horton and Hawkins (1965)

After a series of laboratory experiments on the same sandy clay sediments studied by Haskell and Hawkins (1964), Horton and Hawkins (1965) reported:

> Our studies show that the percolation of rainwater through the soil to the water table is accomplished throughout most of the flow path by downward displacement of water previously retained by the soil at field capacity. This conclusion is contrary to the widely accepted belief that rainwater percolates to the water table primarily through the pores, which are not filled with water at field capacity.

The first series of experiments consisted of a series of columns with various length of a sandy inner core surrounded by the sandy clay sediment. Water was added to the tops of the columns at various rates and volumes to simulate different types of rainfall events. Effluent from the inner sand core and outer sandy clay sediment was collected separately and measured for the trial runs. Results showed that the water, in amounts that would normally infiltrate the soil, flowed from the sand into the sandy clay sediment before penetrating the sand to a great extent. In other words, water flowed readily from the large pores of the sand into the smaller pores of the sandy clay (Horton and Hawkins 1965).

The second series of experiments consisted of measuring the flow of a tritium tracer through a sandy clay soil column. The tritium tracer was added with an initial volume of water (to simulate a 1-inch rainfall event) followed by the daily addition of the same amount of water without tritium. Effluent was measured daily for tritium. Results from these experiments indicated that the flow though the sandy clay sediment occurred mainly through the downward displacement of water remaining in the soil after drainage. According to Horton and Hawkins (1965), if the pores containing air after drainage were the preferential flow path, then the tritium would have been detected in the effluent shortly after its addition. However, they calculated that 87% of the water present in the sediment at the time of the tritium addition was displaced before the peak tritium concentration appeared in the effluent.

4.3 Hawkins and Horton (1967)

As part of a field study to investigate the infiltration potential of a bentonite clay structure, Hawkins and Horton again employed a Na^{24} gamma source and a slow neutron detector to measure the vertical movement of deuterium (D_2O) in the subsurface near the Burial Grounds. The sediments were characterized as a loamy sand grading to a sandy clay-loam below 3 inches and to sandy clay below 5 feet. Two measurement ports were located within 100 feet of the bentonite structure and measurements were made twice a month for 12 months. After 12 months and 48 in of rainfall, the tracer moved 52 inches at one location and 40 inches at the other location for an average of 46 inches. This amount of movement equates to 0.96 inches per inch of rainfall, which is similar to the movement reported in their earlier studies of 0.94 inches per inch of rainfall (for plots 1 and 2) (Haskell and Hawkins 1964).

4.4 Comparison of Early Studies with Results from Numerical Simulations

Numerical simulations using PORFLOW and the upper zone and lower zone properties provided in Table 5-18 in Phifer et al. (2006) yielded suction head and saturation values of 83 cm and 91% in the upper vadose zone and 170 cm and 72% in the lower vadose zone (Phifer et al. 2006). These values were reported as being consistent with field measurements from the Vadose Zone Monitoring System (VZMS) in E-Area (Phifer et al. 2006). Using these saturation values, porosity measurements (Table 5-18 in Phifer et al. 2006), and the estimated infiltration over the local area (30 cm/yr or 12 in/yr, from Phifer et al. 2006), one can estimate pore water velocity by:

Pore water velocity = infiltration/(porosity)*(saturation)

where infiltration is the flux of water into the vadose zone and the term "porosity*saturation" represents the amount of water-filled space through which movement of soil moisture in the subsurface can occur. As discussed in Section 4.2 Horton and Hawkins (1965), water moves through the subsurface by displacing previously retained water, which typically exists as films along grain boundaries.

Calculations for the upper zone and lower zone yield the following estimates of pore water velocity:

- estimate pore water velocity upper zone = (12 in/yr)/(0.39)*(0.91) = ~34 in/yr (~2.8 ft/yr)
- estimate pore water velocity lower zone = (12 in/yr)/(0.39)*(0.72) = ~43 in/yr (~3.6 ft/yr)

These estimates are consistent with field measurements observed in Haskell and Hawkins (1964) (plots 1 and 2) and in Hawkins and Horton (1967) for a sandy loam to sandy clay sediment near the Burial Grounds. Haskell and Hawkins (1964) reported downward movement of water of 0.94 inches per inch of rainfall and Hawkins and Horton (1967) reported a downward movement of 0.96 inches per inch of rainfall. Assuming an average rainfall of 48 in/yr, this would yield a pore velocity around 45.5 in/yr, which is similar to the estimates for the upper and lower zone using infiltration, saturation, and porosity values.

4.5 Comparison of Recommended Vadose Zone Properties to Data from Gruber (1981) and Quisenberry (1985)

Previous modeling efforts in the vicinity of Z-Area incorporated hydraulic properties and soil property curves developed using data from Gruber (1981) and Quisenberry (1985). In their report "Validation of Unsaturated Flow Models Using Tank 24 Lysimeter Data" (1986), INTERA, a subcontracted environmental consultant, provided values for hydraulic conductivity and porosity in addition to relative permeability and capillary pressure (water retention) curves. Table 6 provides a comparison of recommended values from Phifer et al. (2006) (also referenced in Jones et al. 2007) and the values provided by INTERA (1986). The original reports and data from Gruber (1981) and Quisenberry (1985) were not available; therefore their data as reported by INTERA (1986) was used for comparison in this report.

Table 6: Comparison between Recommended Soil Property Values from Phifer et al. (2006) and Values Presented by INTERA (1986)

Material	Recommended in Phifer et al. (2006) and Jones et al. (2007)		Saturated Hydraulic Conductivity in INTERA model (cm/s)	
	Saturated Hydraulic Conductivity (cm/s)	Porosity (%)	Saturated Hydraulic Conductivity (cm/s)	Porosity (%)
Backfill[1]	7.6E-5 (Kh); 4.1E-5 (Kv)	35%	1E-4	42%
Undisturbed, Native Soil	Upper Zone: 6.2E-5 (Kh); 8.7E-6 (Kv) Lower Zone: 3.3E-4 (Kh) 9.1E-5 (Kv)	39%	2.5E-5	36%

[1]Backfill and undisturbed native soil values provided by INTERA (1986) were reported as being consistent with values used in their previous modeling (INTERA 1985) and values measured by Quisenberry (1985) for disturbed and undisturbed Z-Area soils. Quisenberry reported a saturated hydraulic conductivity value of 1.6E-4 cm/s for disturbed Z-Area soil samples (INTERA 1986).

Hydraulic conductivity and porosity values recommended by Phifer et al. (2006) and Jones et al. (2007) were similar to those values used by INTERA (1986) and measured by Quisenberry (1986). It should be noted that Phifer et al. (2006) based their backfill values on measurements of controlled compacted backfill consisting of SC (clayey sands or sand-clay mixtures) or SM (silty sands or sand-silt mixtures) material. No description of the backfill was given by INTERA (1986) except that the samples measured by Quisenberry (1986) represented "disturbed" Z-Area soil samples.

INTERA (1986) also provided unsaturated soil property curves based on data from Gruber (1981) and Quisenberry (1986). Figure 29 shows these curves as presented by INTERA (1986). Figure 30 shows an overlay of the upper and lower vadose zone curves recommended by Phifer et al. (2006) with the curves presented by INTERA (1986). The soil property curves for the upper and lower vadose zone are consistent with the curves presented by INTERA (1986). The water retention curve for the lower vadose zone is outside of the bounds identified based on the data by Gruber (1981), however only at higher suction head values (greater than 200 cm). The difference between the bounding curve based on the Gruber data and the lower vadose zone curve is small (on the order of 5% or less) and may reflect the types of sediments sampled (e.g., the data from Gruber may only reflect shallow vadose zone sediments).

4.6 Lower Zone Soil Property Curves

As described in Phifer et al. (2006), the lower zone soil property curves were generated using CPT data, visual core descriptions, and grain size data in addition to laboratory water retention data (Section 5.2.3 in Phifer et al. 2006). Soil property curves were assigned to textural categories ("clay", "clay-sand" and "sand" sediments) based on laboratory water retention data and grain size data. CPT logs from a representative location in E-Area were then used to determine thicknesses of each textural category within the upper vadose zone and the lower vadose zone. This methodology (i.e., using a representative location, textural soil property curves, and layer thicknesses determined by the CPT logs) appeared to provide soil property curves that were representative of "average" conditions for the upper and lower zones and less influenced by outlier samples compared to a methodology of averaging data and not accounting for thickness of the various soil types. Data points delineating the water retention and relative permeability curves were provided electronically for modeling purposes and in Phifer et al. (2006).

This methodology of generating soil property curves does not entail using or producing van Genuchten parameters. To address interest concerning van Genuchten parameters for the lower zone, an attempt was made to generate soil property curves (using van Genuchten parameters) that mimicked the recommended lower vadose zone curves from Phifer et al. (2006). Figure 31 shows the soil property curves that best matched the lower zone curves for suction levels in the range of observed field measurements (approximately 50 to 200 cm). For the area of concern (yellow shaded box in Figure 31), the water retention curve slightly over predicts the saturation at lower suction levels (<30 cm) and under predicts at higher suction levels (~200 cm). The relative permeability (Kr) curve slightly under predicts Kr at higher saturation (~0.65), but overall appears to match the recommended curve. The water retention curve produced using the van Genuchten parameters do not closely mimic the recommended lower vadose zone curve at higher suction levels (>300 cm) nor does the relative permeability curve at higher saturation (between 0.7 and 0.9). Van Genuchten parameters for the generated curve are provided in Figure 31.

5.0 Flow in the Saturated Zone

5.1 Historical Hydraulic Conductivity Data

Jaegge et al. (1987) and Dennehy et al. (1989) summarized hydraulic conductivity data from earlier laboratory and field studies conducted during the 1970's and 1980's. Jaegge et al. (1987) provided their summary as part of background technical documentation to support closure options for the Radioactive Waste Burial Ground. Dennehy et al. (1989) were interested in evaluating the potential geochemical and hydrologic effects of a concentrated salt-solution waste on sediments in the subsurface. Table 7 provides a summary of the hydraulic conductivity data they presented. Aadland et al. (1995) and Denham (1999) offer similar summaries of hydrogeologic data.

Historical hydraulic conductivity data are sometimes difficult to evaluate because documentation is not always available describing exactly how samples were collected and analyzed. It is noted in the Dennehy et al. (1989) study that hydraulic conductivities were measured using both constant and falling head permeameter tests. However, tests were conducted on disturbed, compacted samples. More specifically, samples were collected from an excavation, then oven-dried and sieved before being compacted into a PVC cylinder. One would expect that hydraulic conductivity measurements from this study would likely be different than measurements made on undisturbed Shelby tube samples or from field tests. Variations in the method of measuring hydraulic conductivity can add to the complexity and range in hydraulic conductivities in addition to the variation that would be expected from the natural heterogeneity of coastal plain sediments. Consequently, hydraulic conductivities on Table 7 show a wide range of values. However, it is noteworthy that the hydraulic conductivities from the transport simulations using the 1995 database and PORFLOW are within the range of values measured in laboratory and field tests.

Table 7: Summary of Saturated Hydraulic Conductivity (cm/s)

Geologic Unit	Hydrogeologic Unit	Regional Data (Christensen and Gordon 1983)	Laboratory Data (D'Appolonia 1981)	Slug Test Data (Parizek and Root 1986)	Small-scale Pump Test Data (Parizek and Root 1986)	Model Determined from Field Data (INTERA 1985)	Laboratory Data (Dennehy et al. 1989)	Model Determined (Jaegge et al. 1987)	Approximate Hydraulic Conductivity Transport Simulations (using 1995 GSA database & PORFLOW)
Upland Unit	Unsaturated Zone	--	--	--		--	1.2E-3 cm/s	--	--
Barnwell Group	Upper Aquifer Zone	3.E-5 to 3.E-3 cm/s	1.2E-4 cm/s (sand) 8.2E-7 cm/s (clay)	7.6E-4 cm/s (median) 3.2E-5 to 5.1E-3 cm/s (range; n=17)	2.0E-4 cm/s (median) 8.1E-5 to 8.4E-4 cm/s (range; n=8)	--	1.2E-4 cm/s	2.3E-4 to 1.3E-3 cm/s	3.5E-3 cm/s
Tan Clay (in Barnwell)	Tan Clay Confining Zone	--	1.4E-6 cm/s			--	--	2.5E-7 to 6.0E-7 cm/s	2.1E-6 cm/s
McBean Formation (Santee Formation)	Lower Aquifer Zone	3.E-5 to 3.E-3 cm/s	--	3.4E-4 cm/s (median) 3.3E-4 to 5.6E-3 cm/s (range; n=23)	2.4E-4 cm/s (median) 1.6E-5 to 2.0E-3 cm/s (range; n=17)	3.E-6 to 3.E-2 cm/s	--	1.4E-3 cm/s	4.6E-3 cm/s
Green Clay (Warley Hill Formation)	Gordon Confining Unit	--	--	--		3.E-8 to 3.E-6 cm/s	--	3.0E-8 to 7.8E-8 cm/s	3.5E-9 cm/s

Table 7 (continued): Summary of Saturated Hydraulic Conductivity (cm/s)

Geologic Unit	Hydrogeologic Unit	Regional Data (Christensen and Gordon 1983)	Laboratory Data (D'Appolonia 1981)	Slug Test Data (Parizek and Root 1986)	Small-scale Pump Test Data (Parizek and Root 1986)	Model Determined from Field Data (INTERA 1985)	Laboratory Data (Dennehy et al. 1989)	Model Determined (Jaegge et al. 1987)	Approximate Hydraulic Conductivity Transport Simulations (using 1995 GSA database & PORFLOW)
Congaree Formation	Gordon Aquifer	2.E-3 cm/s	--	5.2E-4 cm/s (median) 3.4E-7 to 4.4E-3 cm/s (range; n=17)	4.3E-4 cm/s (median) 4.3E-4 to 9.1E-4 cm/s (range; n=3)	3.E-5 to 3.E-2 cm/s	--	--	1.3E-2 cm/s
Original source of data		Christensen and Gordon 1983	D'Appolonia 1981	Parizek and Root 1986	Parizek and Root 1986	INTERA 1985	Dennehy et al. 1989	Jaegge et al. 1987	
Source of Values Presented on this Table		Dennehy et al. 1989	Dennehy et al. 1989	Jaegge et al. 1987	Jaegge et al. 1987	Dennehy et al. 1989	Dennehy et al. 1989	Jaegge et al. 1987	

Value for Upland (Dennehy et al. 1989) comes from the geometric mean of 5 laboratory measurements using samples collected from unsaturated zone; value for Barnwell (Dennehy et al. 1989) comes from the geometric mean of 8 laboratory measurements; tests from Dennehy et al. (1989) were performed on disturbed, compacted samples which had a total porosity of 42% and bulk density of 93.6 lbs/ft^3; values from Jaegge et al. (1987) come from their Table 9 and represent steady state model calibration values

6.0 Discussion and Summary

This study entailed the review, evaluation and documentation of historical and recent geotechnical data and reports as they relate to the PA work for the FTF. These reports provided sediment descriptions, geotechnical data (e.g., grain size analyses) and interpretations for the vadose zone; no new hydraulic conductivity or water retention data were discovered. Potentially significant findings regarding the saturated zone that were discovered during this review were also included in this report. Appendix I provides a summary of the reports that were primarily reviewed during this evaluation.

Results from this review are consistent with current assumptions made for the vadose zone sediments for the F-Area Tank PA modeling. Specific findings are noted below:

- Early characterization efforts by the US Army Corps of Engineers (1952a; 1952b) and Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a; 1975b; 1977) identified a calcareous zone beneath the FTF. This calcareous zone was predominantly found between 190 and 130 ft msl (approximately 100 to 200 ft bls) within the Santee Formation (also known as the McBean Formation). The US Army Corps of Engineers (1952a; 1952b) and Mueser, Rutledge, Wentworth & Johnston Consulting Engineers both implemented a grouting program to fill voids within the calcareous zone.
- Further documentation was discovered during this review relating to the existence of the TCCZ near the FTF. Characterization data regarding the TCCZ were included in reports by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a; 1977), John A. Blume & Associates, Engineers (1971), Bledsoe (1988), Site Geotechnical Services (1996), SGCP (2006) and Millings (2007). All borings showed the existence of the TCCZ except for one boring location (14F-7U under existing tank 46), which was completed by Mueser, Rutledge, Wentworth & Johnston Consulting Engineers.
- Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a; 1977), Bledsoe (1988), Site Geotechnical Services (1996) provide core descriptions, cross-sections and grain size data, which indicate that the lower vadose zone near the FTF predominantly consists of fine to coarse sands to silty sands. These findings are consistent with the findings in Phifer et al. (2006) and the recommendations made for the vadose zone material properties at the FTF in Jones et al. (2006).
- Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a) identified the existence of a ramp built in 1956 on the north side of tanks 25-28. This area was backfilled prior to the construction of tanks 25-28 and therefore backfill (rather than vadose zone sediments) may be the primary materials below part of the bottom of tank 25 (NW portion of tank 25).
- Structural fill samples collected and analyzed during the Site Geotechnical Services (1996) investigation of F-Area were predominantly classified as SC (clayey sands) with some SM (silty sand) material according to the USCS. These findings are consistent with the findings in Phifer et al. (2006) and the

recommendations made for the vadose zone material properties at the FTF in Jones et al. (2006).

- Early work conducted in the vicinity of the Burial Grounds by Haskell and Hawkins (1964), Horton and Hawkins (1965), and Hawkins and Horton (1967) indicated that water travels through the vadose zone on the order of 3.7 ft/yr (~0.95 inches per inch of rainfall). Near a disturbed (backfilled) area, they observed much faster movement (~7.8 ft/yr). Estimates of infiltration, porosity and saturation values for the lower vadose zone generated a pore water velocity (~3.6 ft/yr) similar to the rates observed in undisturbed sediments of these earlier studies.
- Hydraulic conductivities and porosities recommended in Phifer et al. (2006) and Jones et al. (2007) are consistent with values presented by INTERA (1986) based on data from Gruber (1981) and Quisenberry (1985). In addition, water retention and relative permeability curves recommended for the vadose zone in Phifer et al. (2006) and Jones et al. (2007) are similar to curves presented by INTERA (1986) based on data from Gruber (1981) and Quisenberry (1985).
- Hydraulic conductivities for the hydrogeologic units were estimated from the transport simulations using the 1995 database and PORFLOW and are within the range of laboratory and field measurements documented in historical reports.

7.0 References

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Figure 1: Biomoldic limestone recovered during foundation grouting operations prior to excavation for tanks 25-28 and 44-47 in 1975 (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers, 1975b)

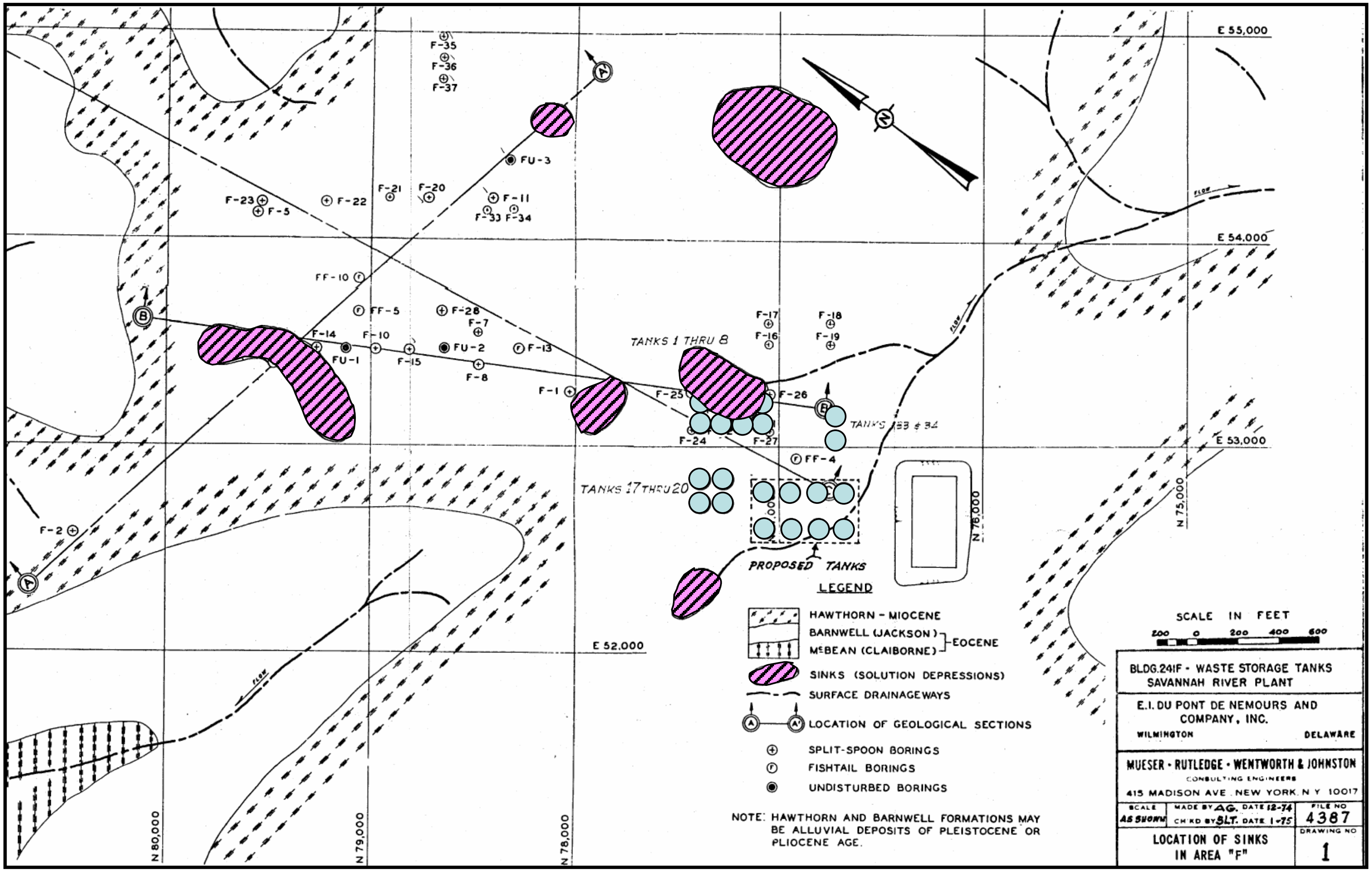


Figure 2: Map modified from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers (1975a) drawing showing mapped sinks and drainage features near FTF

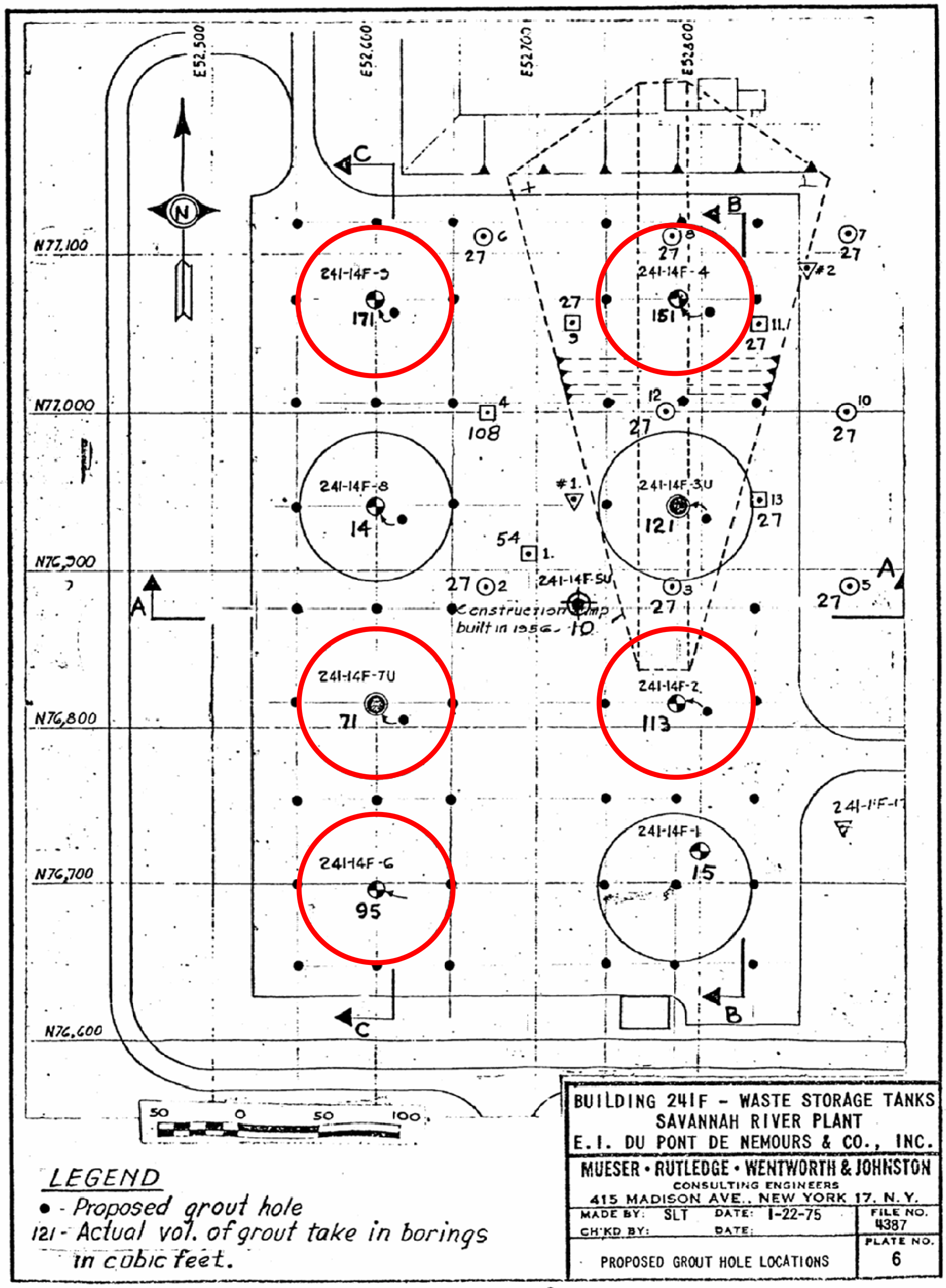
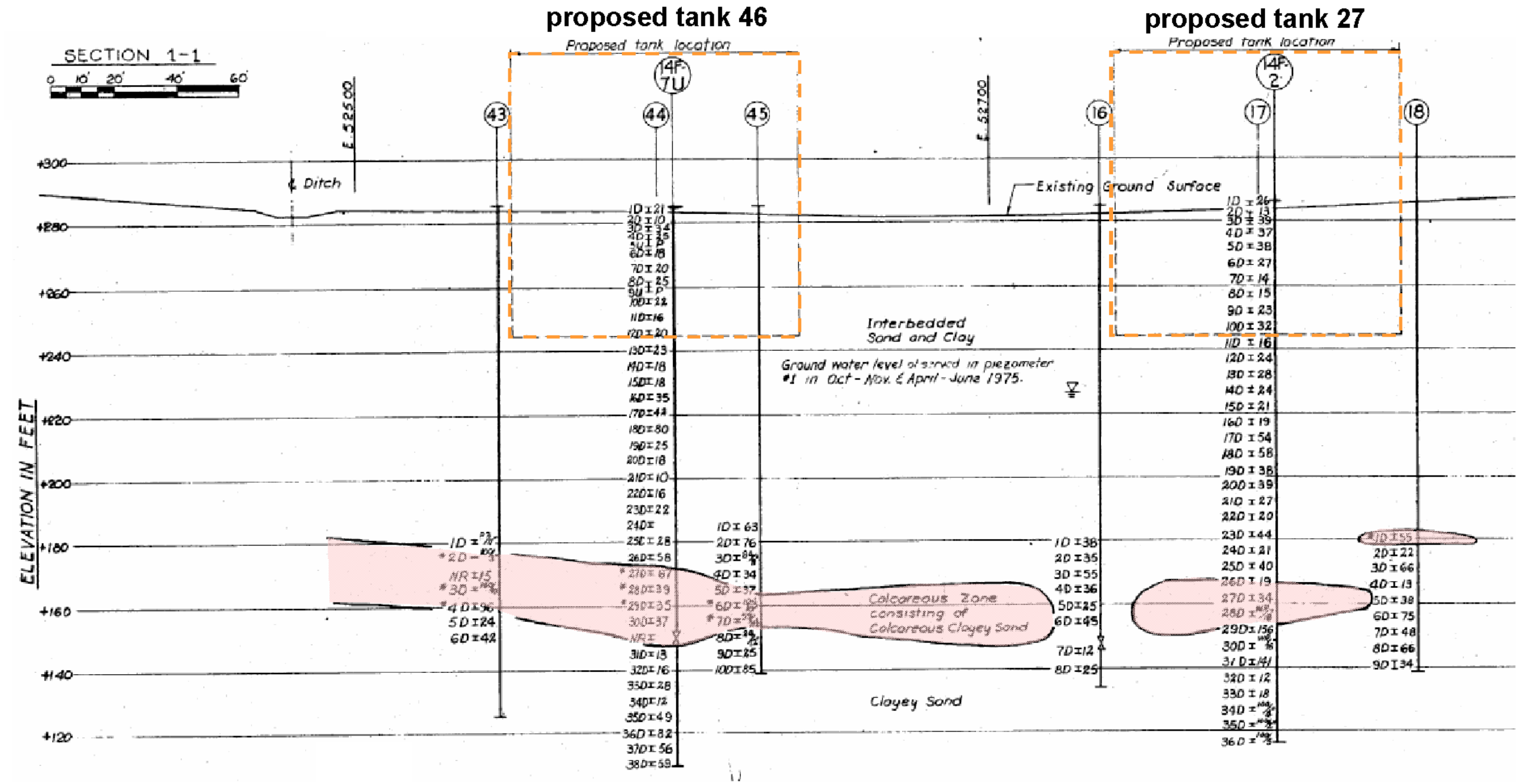


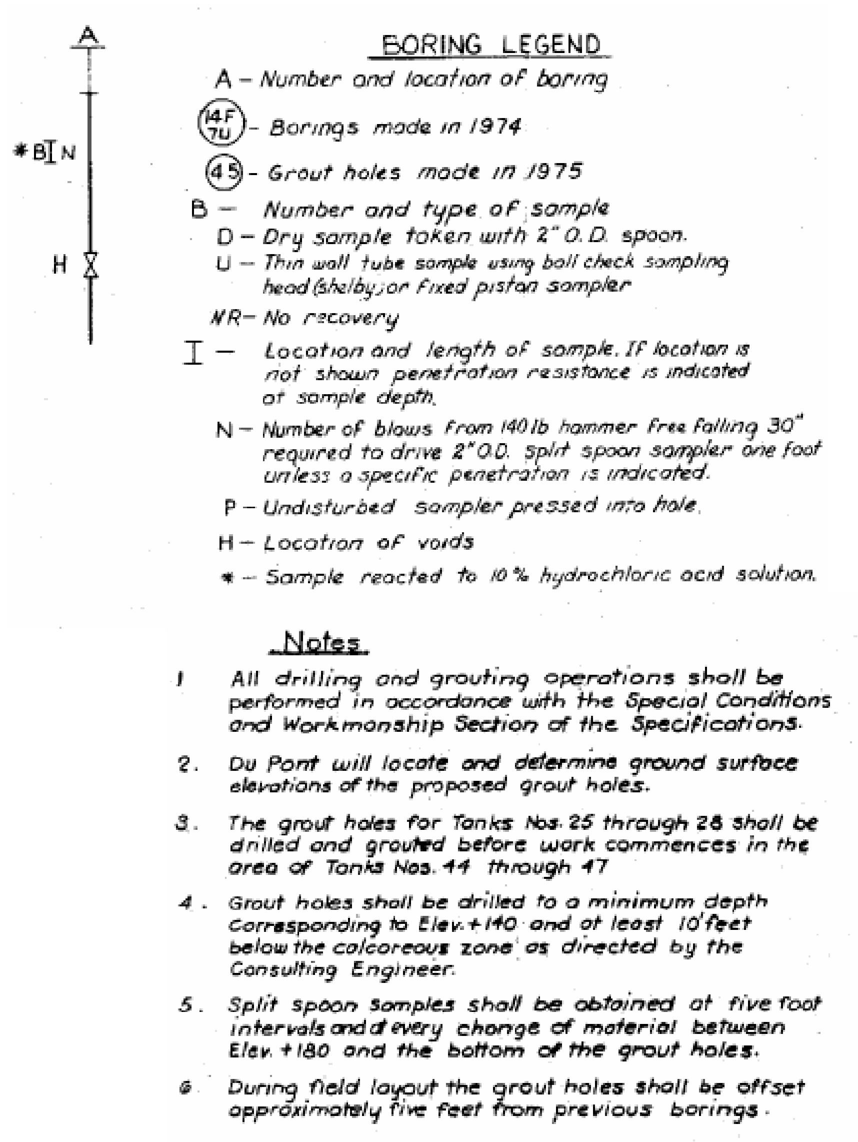
Figure 3: Exploratory borings for Tanks 25-28 and 44-47 (modified from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a); red circles indicate critical borings where they saw significant mud losses, rod/casing drops, and grout uptakes

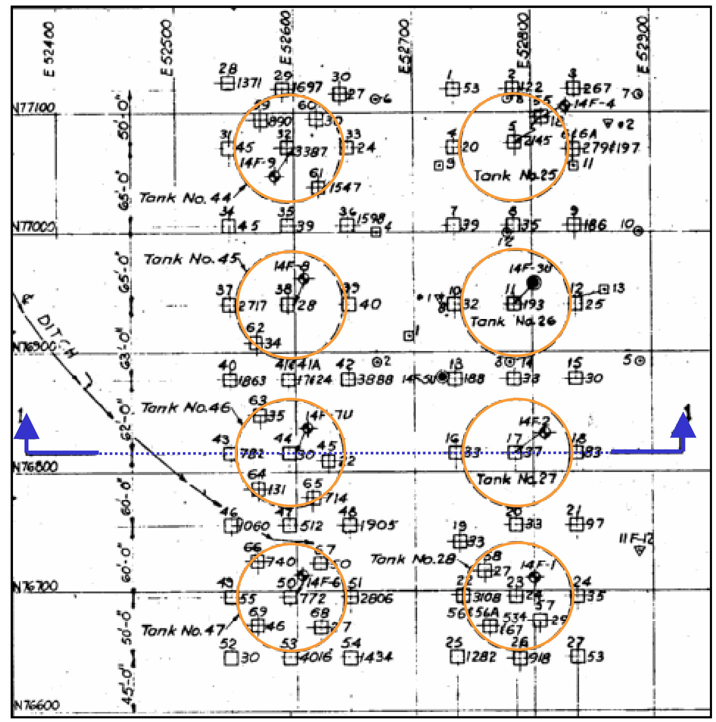
Figure 4: Geologic cross-section showing calcareous zone (shaded pink) beneath tanks 46 and 27 (modified from drawing no. 1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b)



Note: legend, notes and location map for cross-section on following page.

Figure 4 Continued: Geologic cross-section showing calcareous zone (shaded pink) beneath tanks 46 and 27 (modified from drawing no. 1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b)





Location of cross-section (blue dashed line/arrows) relative to tanks (orange circles)

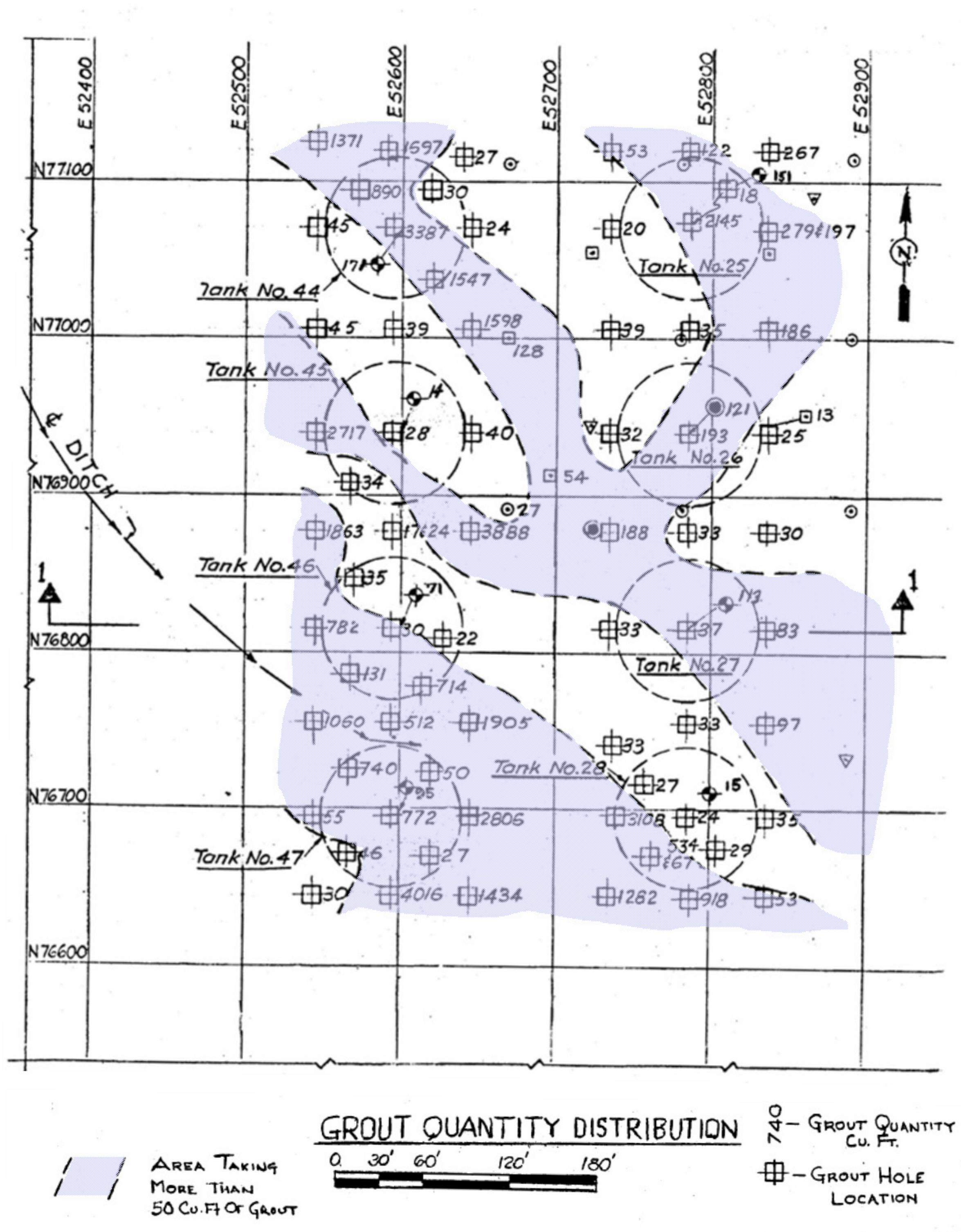
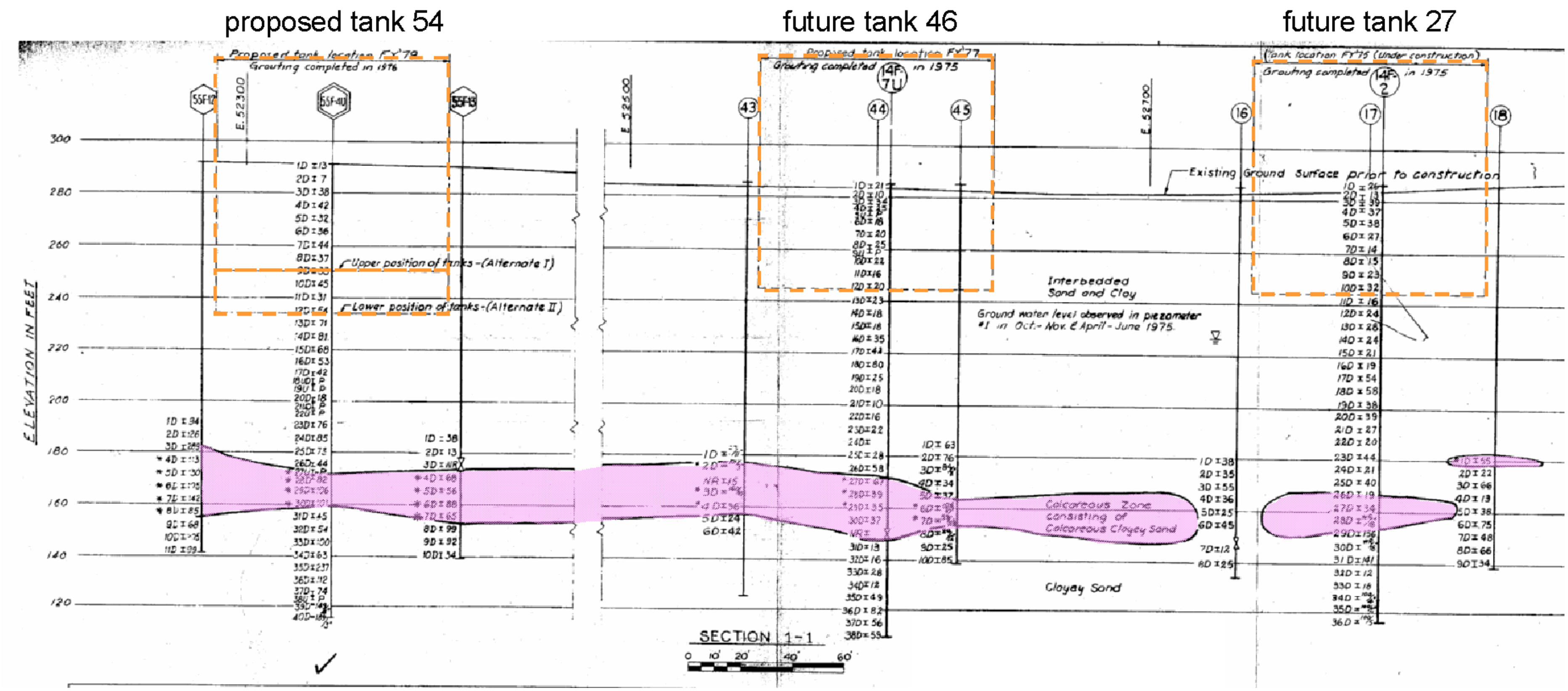


Figure 5: Summary of foundation grouting activities for tanks 25-28 and 44-47 (figure modified from plate no.4 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b; boxes with crosses indicate grout hole locations and numbers signify quantity of grout in cubic feet accepted in each hole

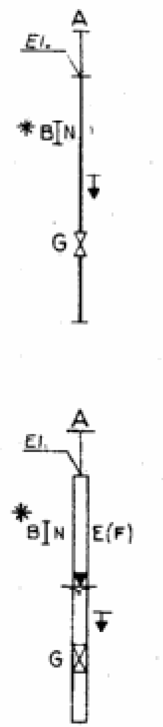
Figure 6: Geologic cross-section showing calcareous zone (shaded pink) beneath proposed tank 54 and future tanks 46 and 27 (modified from drawing no. 2 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)



Note: for accompanying legend, notes, and grout hole location plan see the following two pages.

Figure 6 Continued: Geologic cross-section showing calcareous zone (shaded pink) beneath proposed tank 54 and future tanks 46 and 27 (modified from drawing no. 2 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)

(boring legend and general notes for geologic cross-section)



(See Section A-A)

GROUT HOLE AND BORING LEGEND

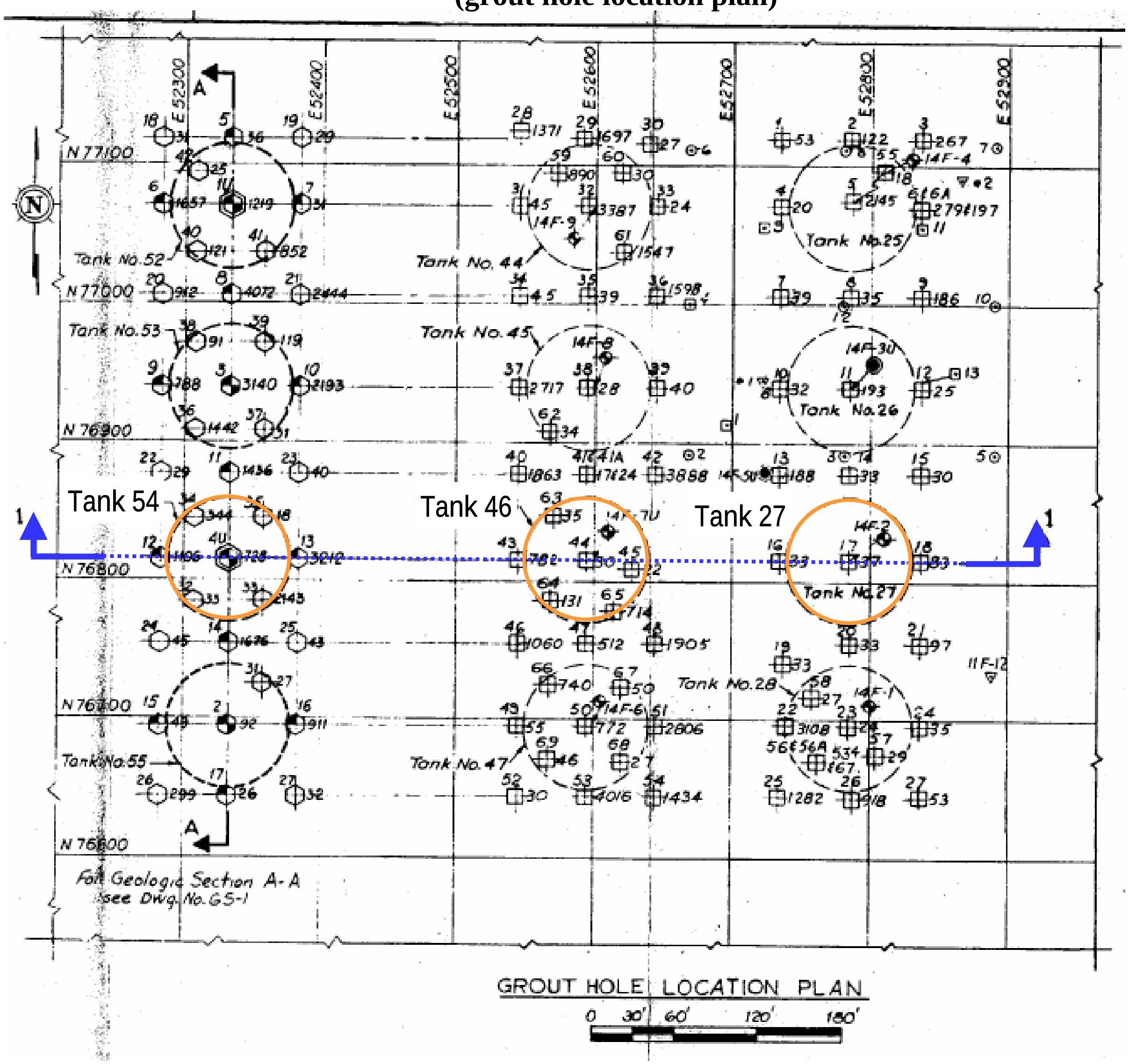
A – Number and location of grout hole or boring
(14F/2) – Boring made in 1974.
(45) – Grout hole made in 1975.
(55F-4) – Grout hole with undisturbed sampling made in 1976.
(55F-3) – Grout hole made in 1976.
El. – Elevation of ground surface at boring.
B – Number and type of sample.
D – Dry sample taken with 2" O.D. split spoon.
U – Thin wall tube sample using ball check sampling head (shelby) or fixed piston sampler.
NR – No recovery
I – Location and length of sample. If location is not shown penetration resistance is indicated at sample depth.
N – Number of blows from 140 lb. hammer free falling 30" required to drive 2" O.D. split spoon sampler one foot unless a specific penetration is indicated.
P – Undisturbed sampler pressed into hole.
WR – Sample taken under weight of rods.
E – Natural water content of sample in per cent of dry weight.
F – United Soils Classification
G – Location of voids
* – Sample reacted to 10% hydrochloric acid solution.
↧ – Lost return of drilling fluid.
⊻ – Mud level observed in boring

GENERAL NOTES:

1. All grout holes for Storage Tanks Nos. 52 through 55 (FY' 79 Tanks) were made by Warren George, Inc. between Nov. 3, 1976 and Dec. 8, 1976 under the continuous inspection of Mueser, Rutledge, Wentworth & Johnston.
2. Locations and ground surface elevations of all 1976 grout holes were determined by E. I. Du Pont de Nemours & Company, Inc.
3. Elevations refer to plan datum used by E. I. Du Pont de Nemours & Company, Inc.
4. All of the 1976 grout holes were advanced using drilling mud to stabilize the borehole.
5. Sample descriptions shown on Section A-A were made by Mueser, Rutledge, Wentworth & Johnston and may not agree with the drillers' classifications.
6. Stratifications shown are necessary interpolations between borings and may not represent actual subsurface conditions.
7. Mud levels shown at boring locations on Section A-A may not be indicative of the stable ground water level. Drilling mud tends to coat the sides of the borehole thereby preventing the mud level from equalizing with the ground water level.
8. The locations of proposed FY'79 Tanks Nos. 52-55 were taken from E. I. Du Pont de Nemours & Co., Inc. Drawing No. W703135 dated Feb. 1, 1977.

Figure 6 Continued: Geologic cross-section showing calcareous zone (shaded pink) beneath proposed tank 54 and future tanks 46 and 27 (modified from drawing no. 2 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)

(grout hole location plan)



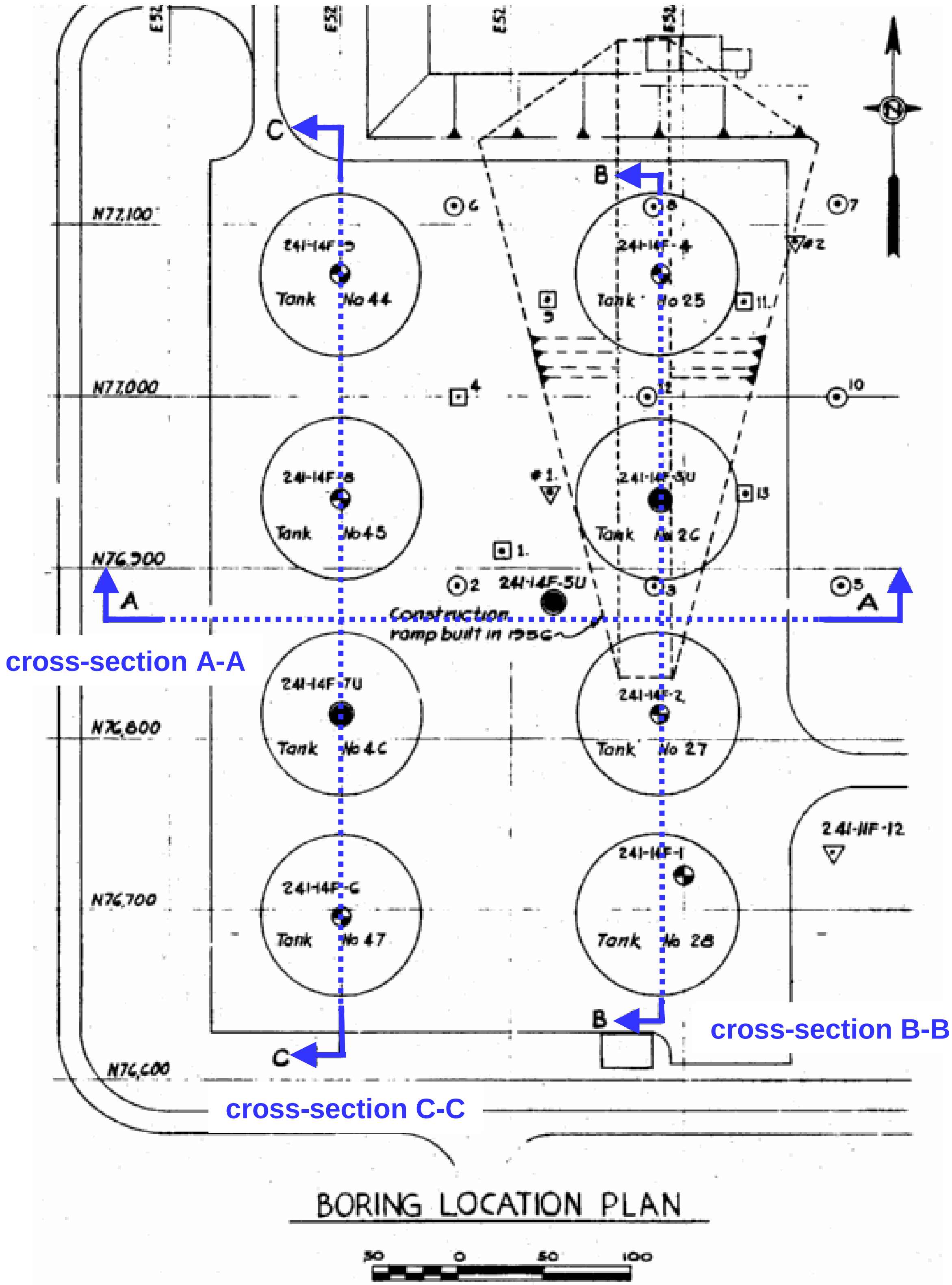


Figure 7: Boring location plan shows location of cross-section relative to tanks 25-28 and 44-47 (modified from drawing GS-1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

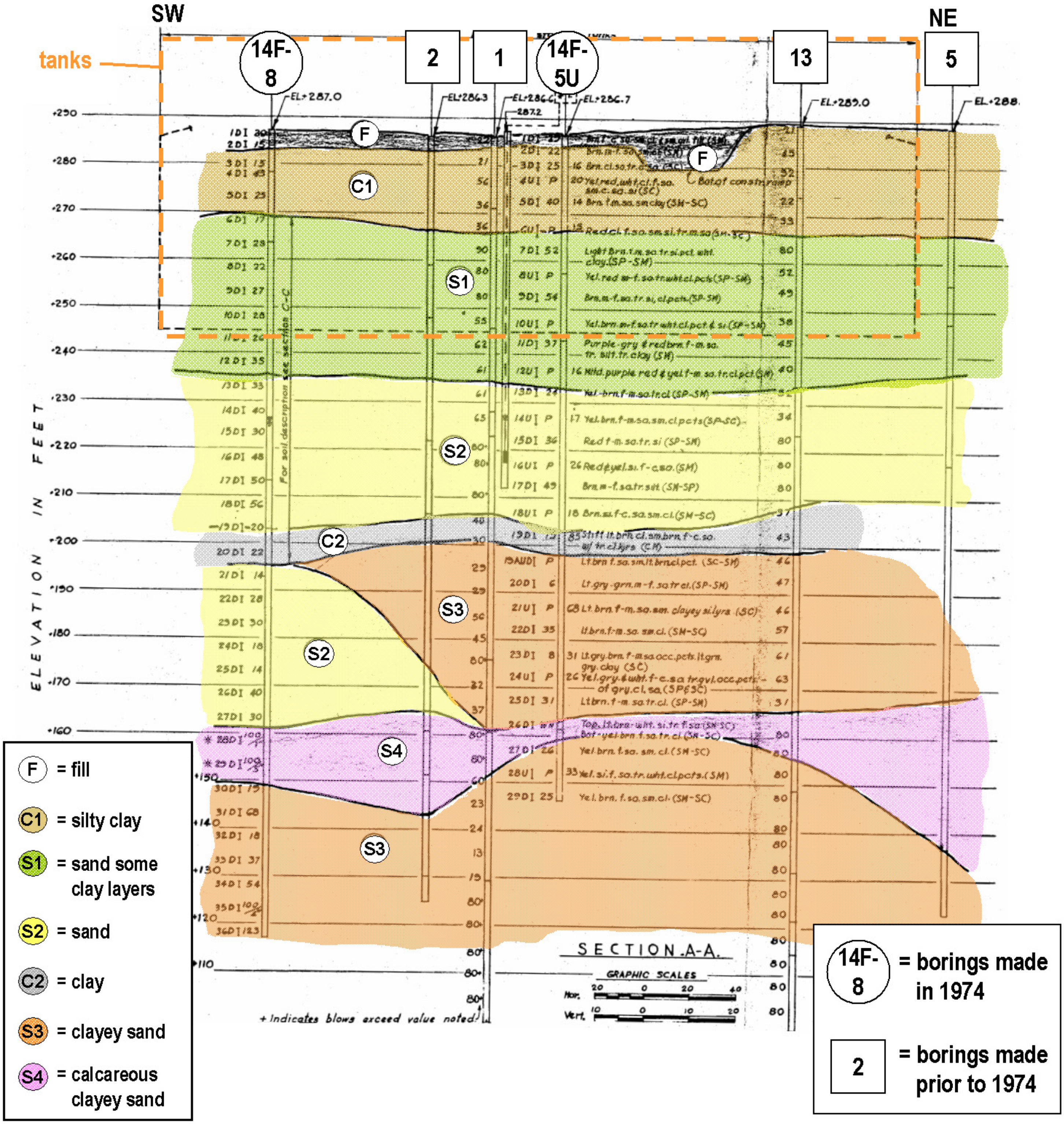


Figure 8: Cross-section A-A (southwest-northeast) through Tanks 25-28 and 44-47 (modified from drawing GS-1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

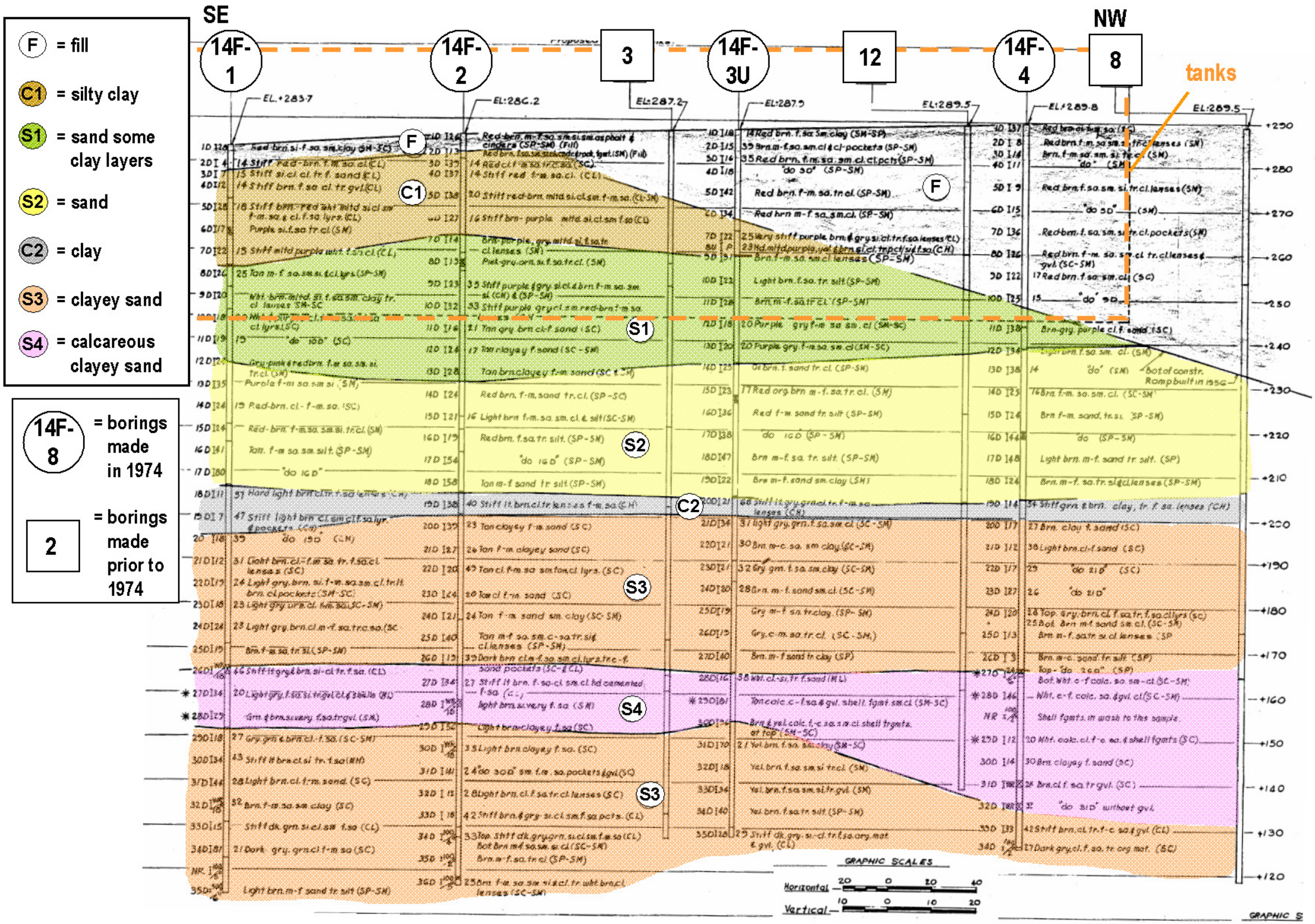


Figure 9: Cross-section B-B through Tanks 25-28 (southeast-northwest) (modified from drawing GS-2 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

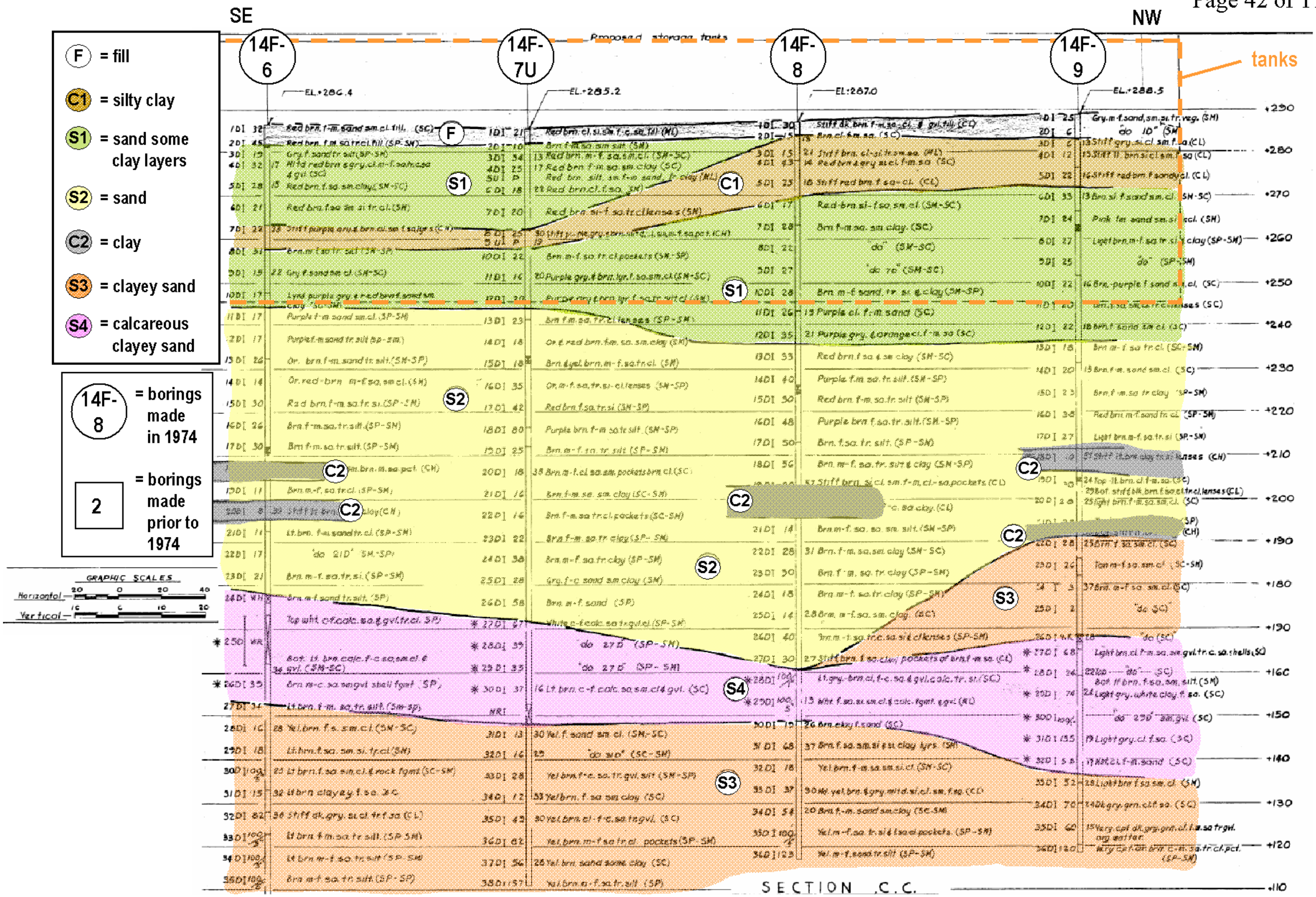


Figure 10: Cross-section C-C through Tanks 44-47 (southeast-northwest) (modified from drawing GS-3 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

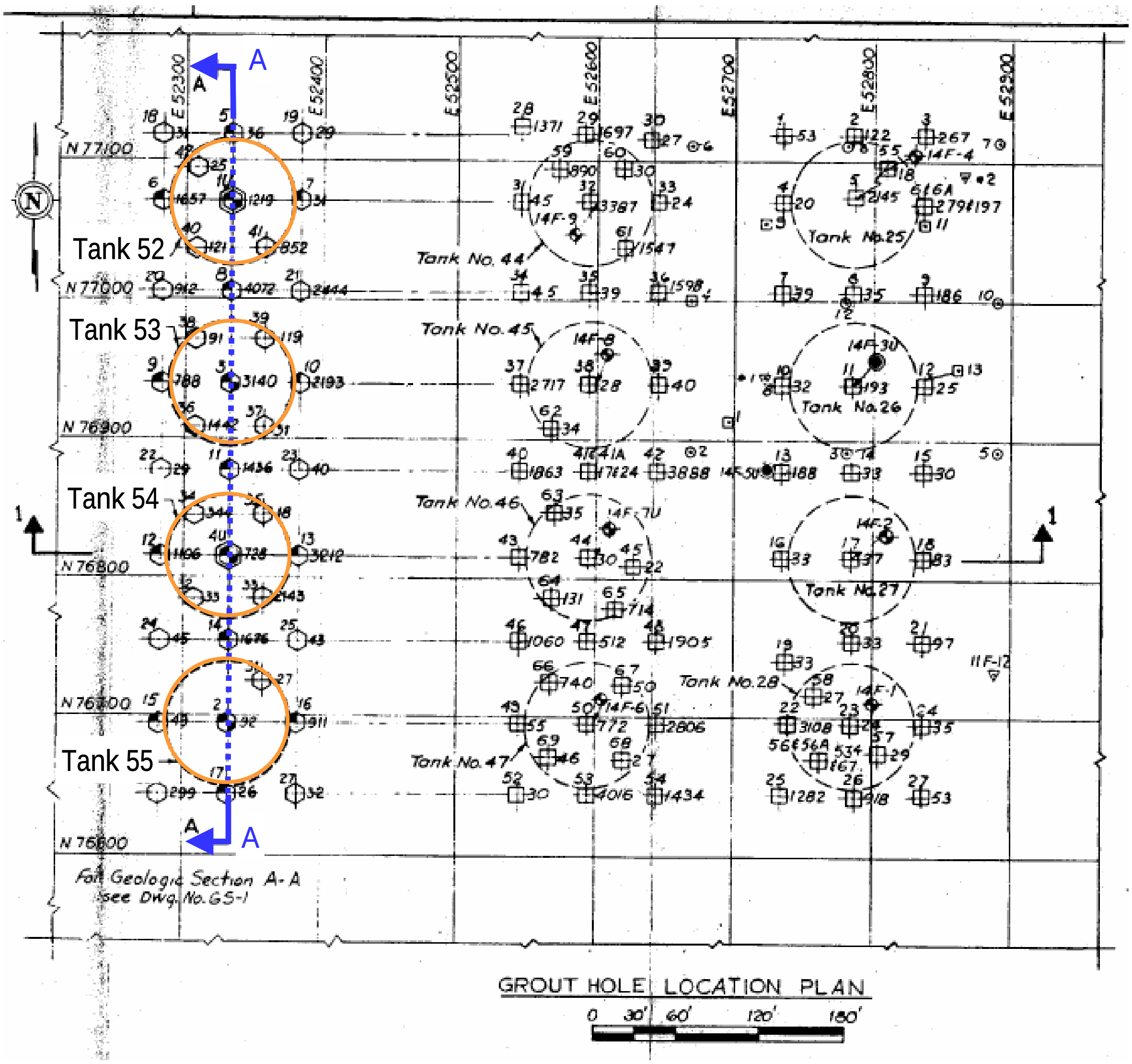


Figure 11: Boring location plan shows location of geologic cross-section A-A relative to the proposed tanks 52-55 (modified from drawing GS-1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)

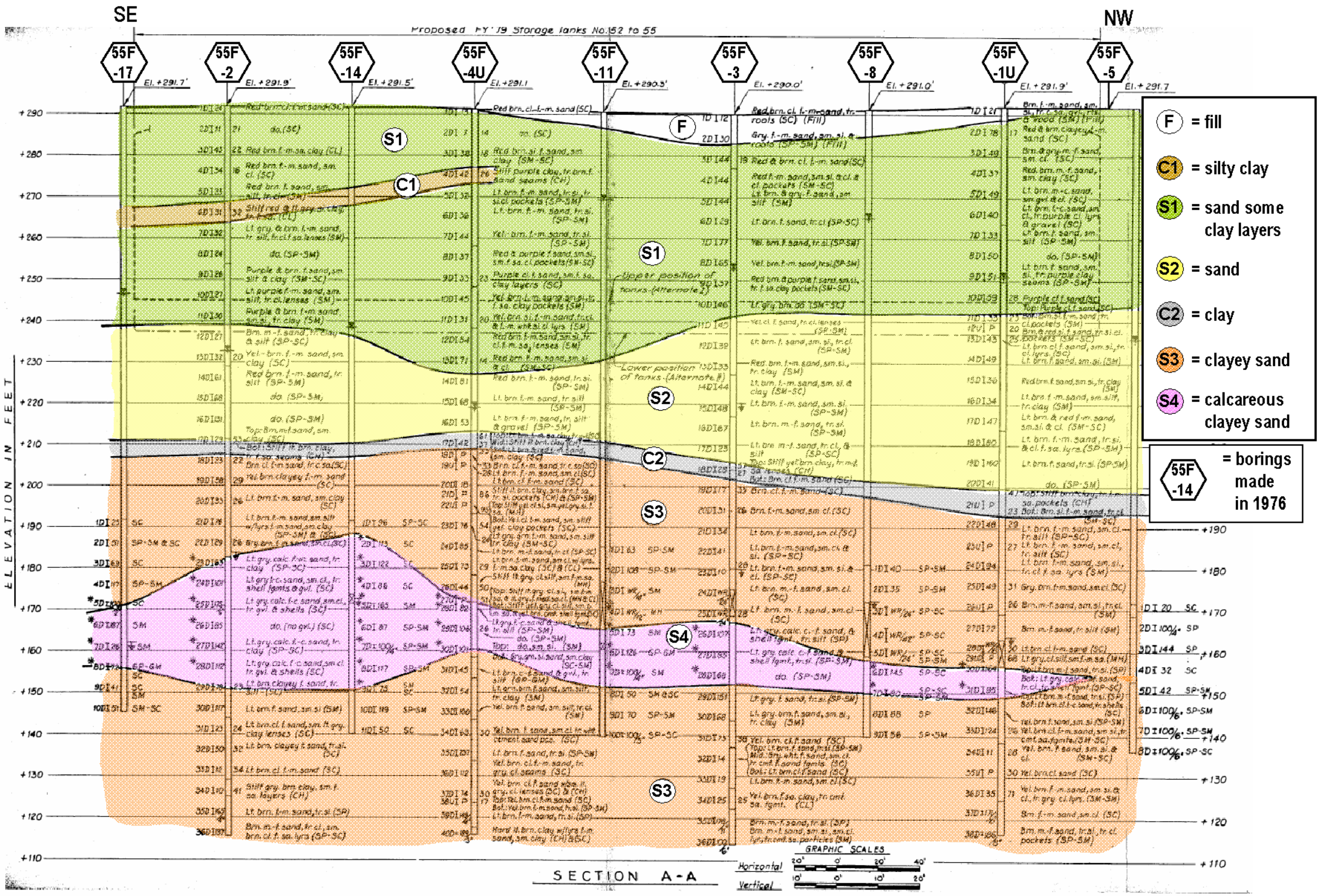
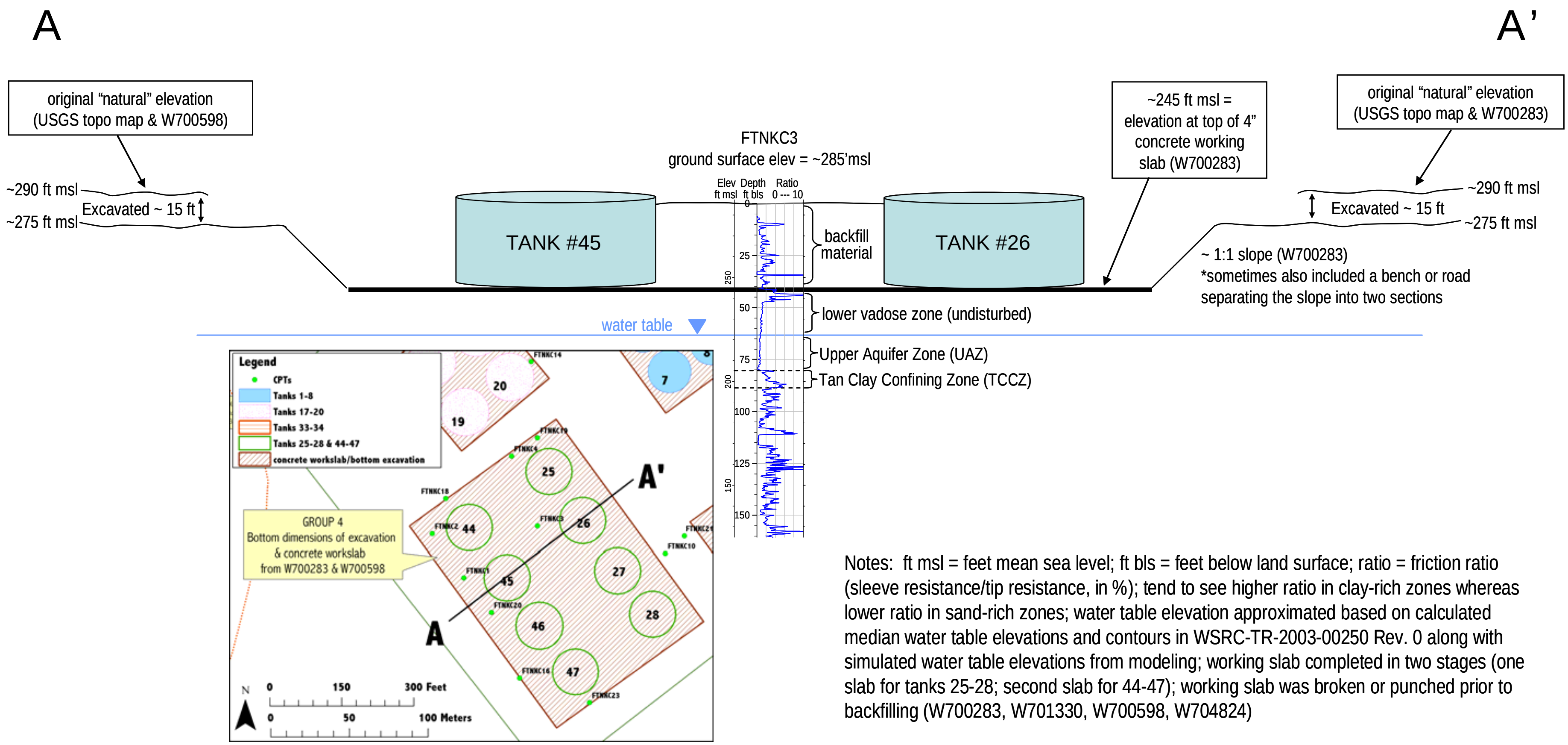


Figure 12: Cross-section A-A through proposed tanks 52-55 (southeast-northwest) (modified from drawing GS-1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)

Figure 13: Tank Bottom Elevations Relative to F-Area Vadose Zone and Water Table (figure 8 in Jones et al. 2007)



Notes: ft msl = feet mean sea level; ft bls = feet below land surface; ratio = friction ratio (sleeve resistance/tip resistance, in %); tend to see higher ratio in clay-rich zones whereas lower ratio in sand-rich zones; water table elevation approximated based on calculated median water table elevations and contours in WSRC-TR-2003-00250 Rev. 0 along with simulated water table elevations from modeling; working slab completed in two stages (one slab for tanks 25-28; second slab for 44-47); working slab was broken or punched prior to backfilling (W700283, W701330, W700598, W704824)

Figure 14: CPT FTNKC3 Subsurface Data with Backfill, Lower Vadose Zone, Water Table and Water Table Aquifer (Upper Aquifer Zone) and Tan Clay Confining Zone (figure 9 in Jones et al. 2007)

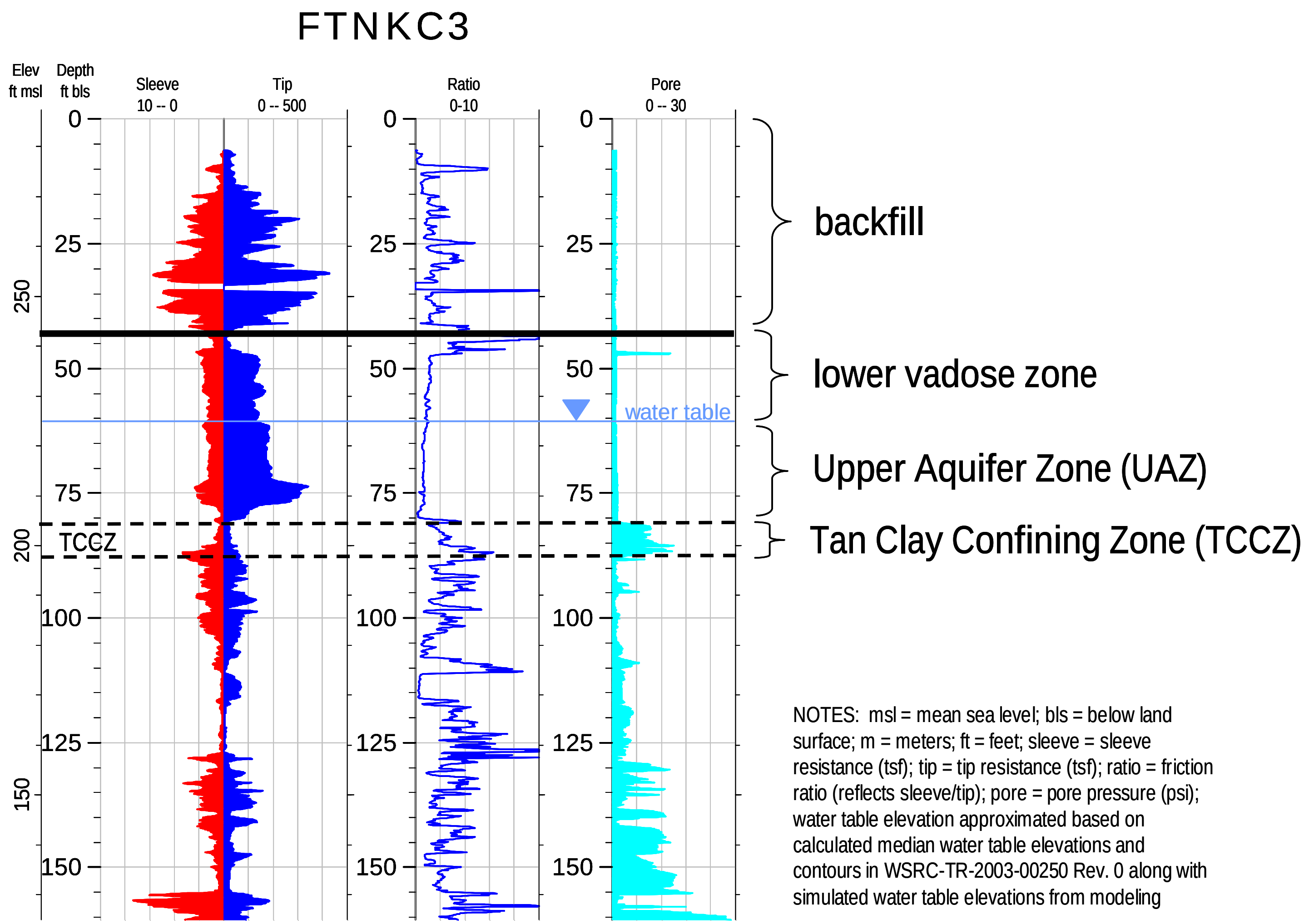
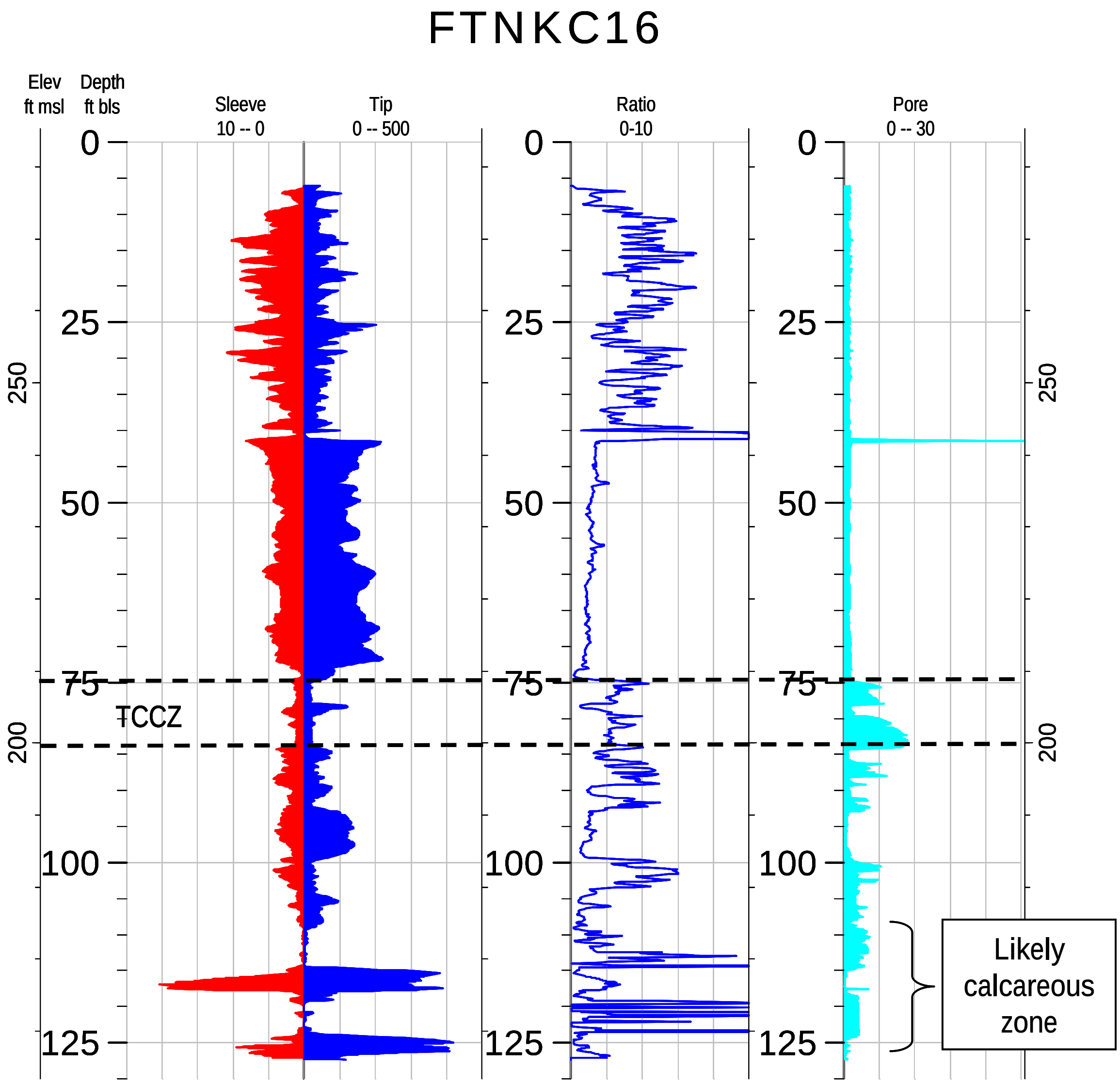
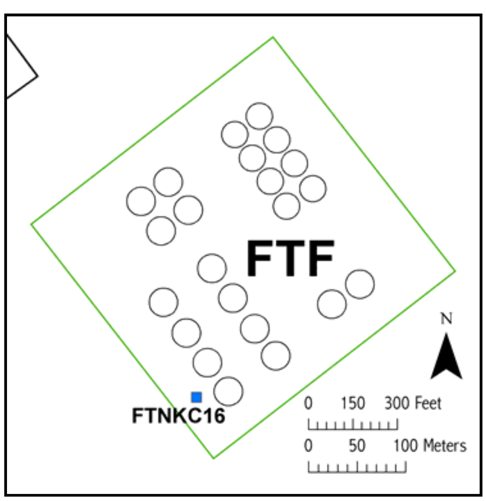


Figure 15: CPT Logs for FTNKC16 (modified from figure 16 in Millings 2007)





Note for figure: msl = mean sea level; bls = below land surface; ft = feet; TCCZ = Tan Clay Confining Zone; sleeve = sleeve resistance (tsf); tip = tip resistance (tsf); ratio = friction ratio (reflects sleeve/tip); pore = pore pressure (psi)

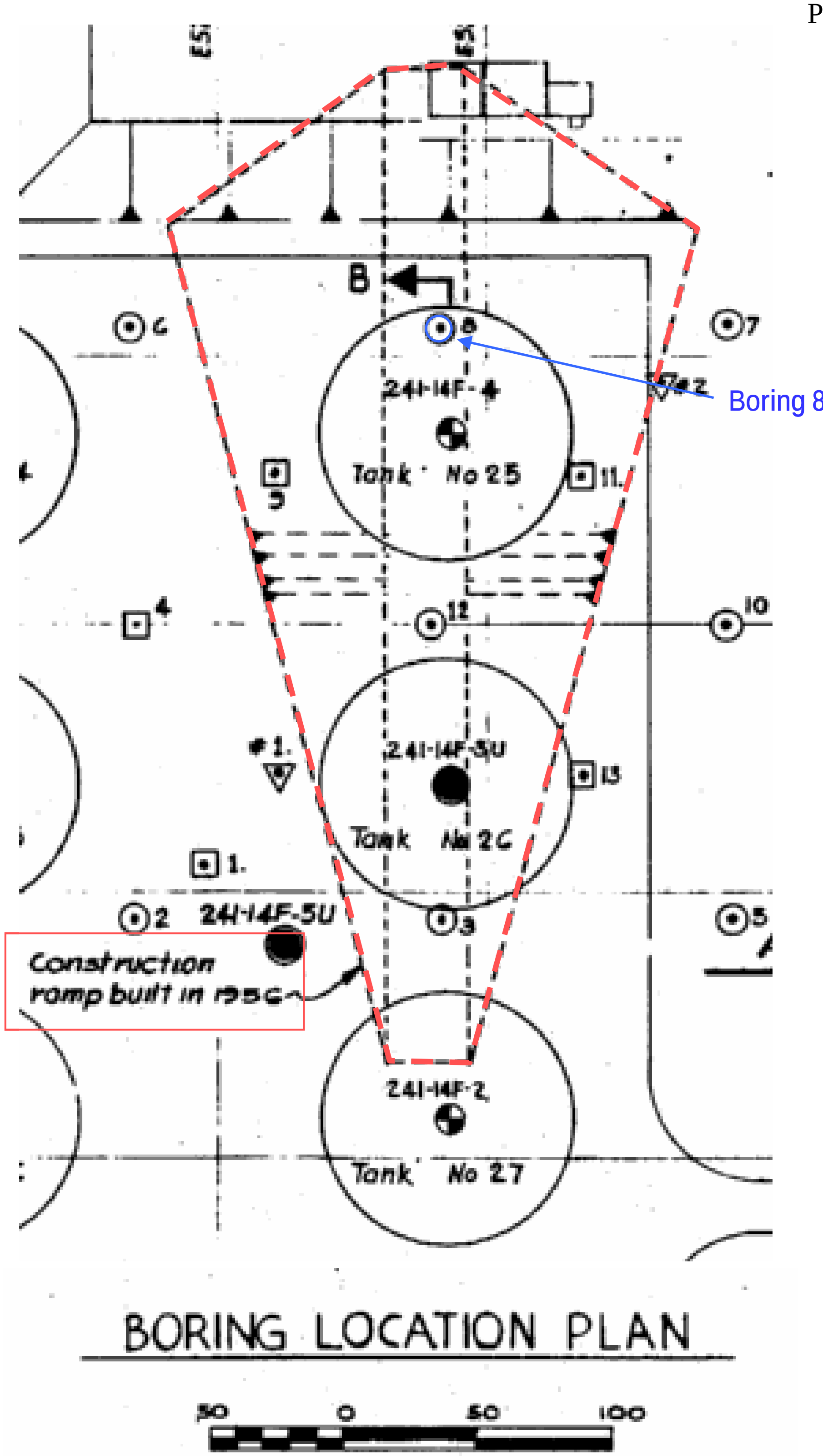


Figure 16: Location of 1956 ramp and subsequent backfilled area and location of boring 8 in relation to tank 25 (modified from drawing GS-1 in Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

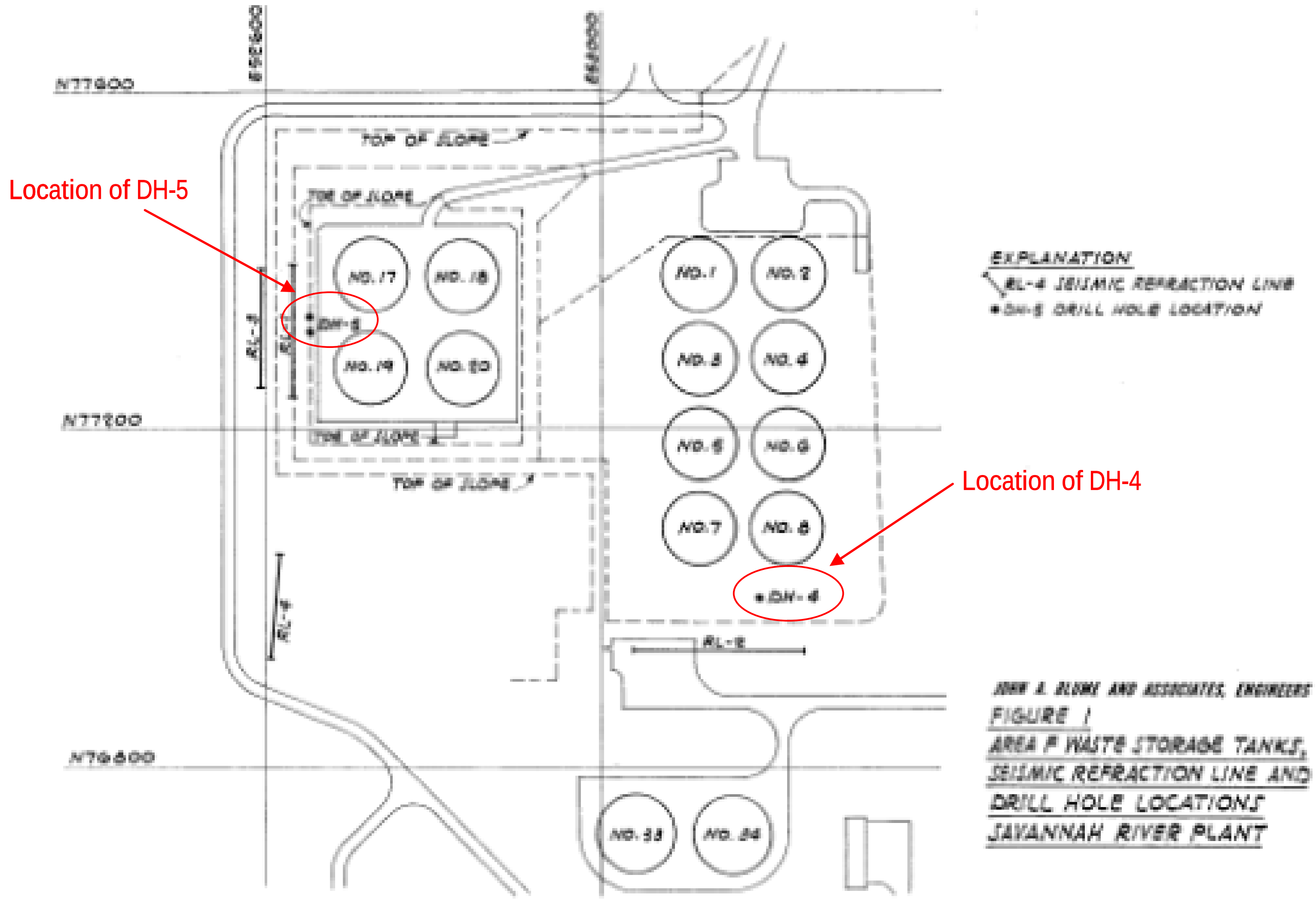


Figure 17: Location of borings DH-4 and DH-5 used in subsurface investigation by John A. Blume & Associates, Engineers (figure modified from figure 1 in John H. Blume & Associates, Engineers 1971)

Figure 18: Locations Where Calcareous Zone Was Identified in Santee during SGS Characterization Work

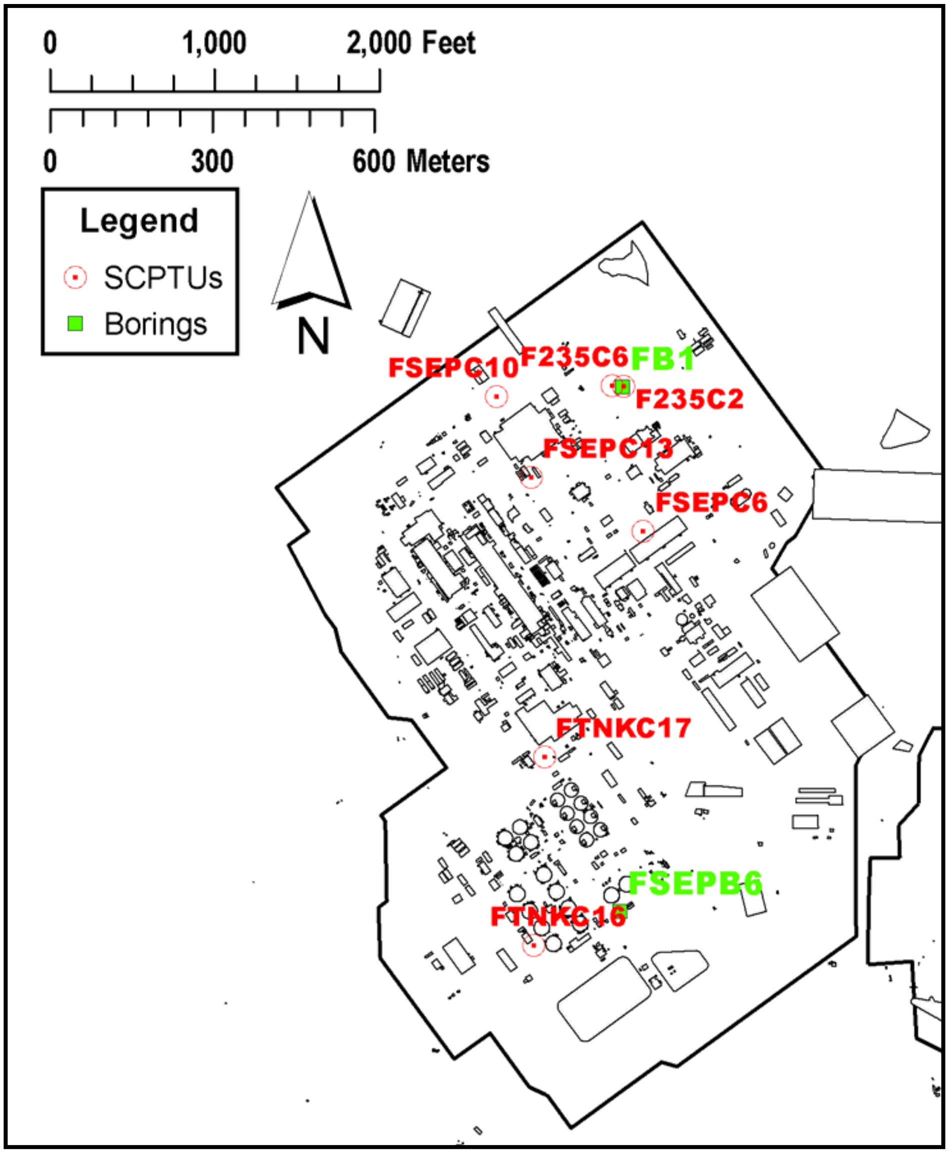
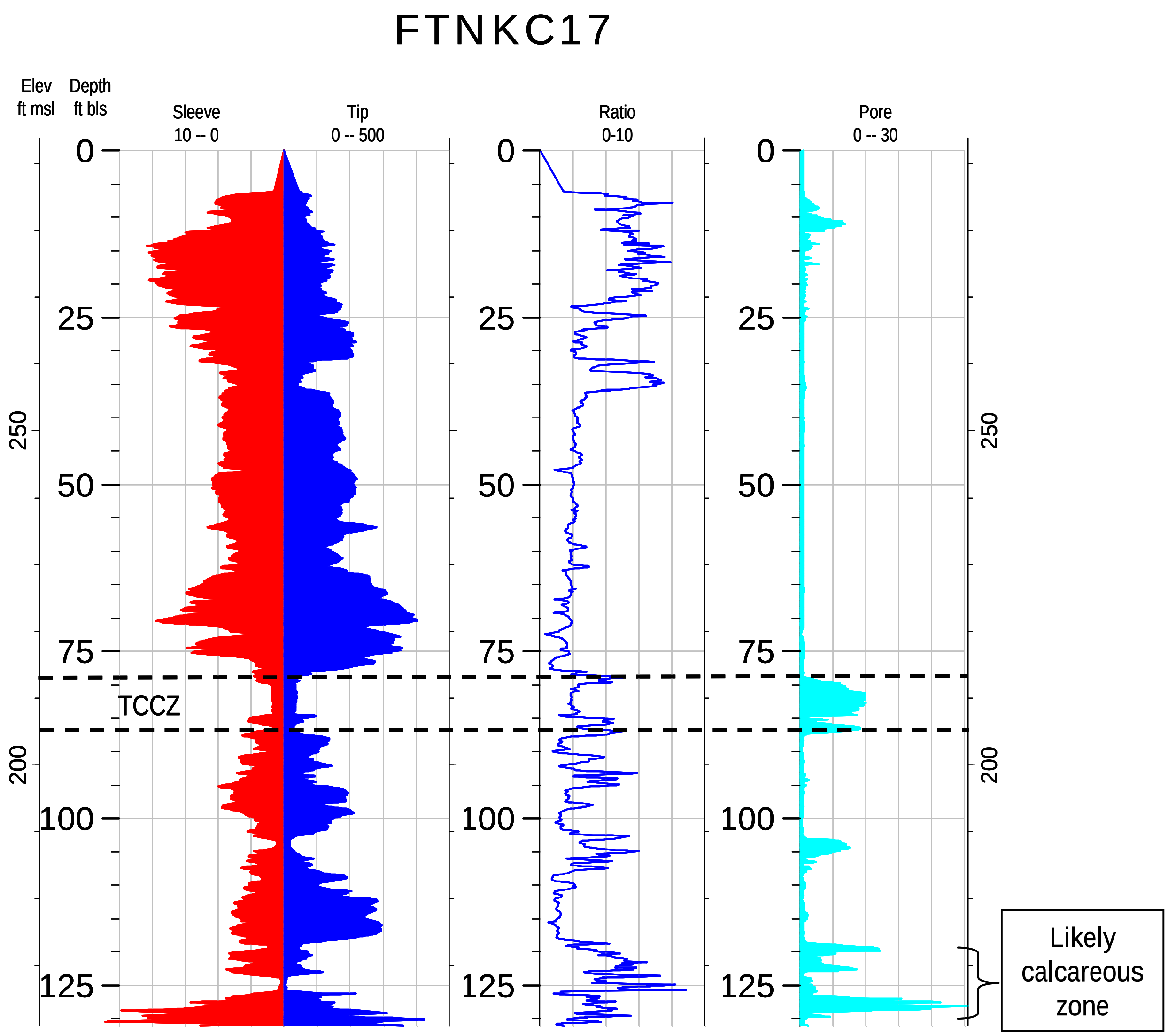
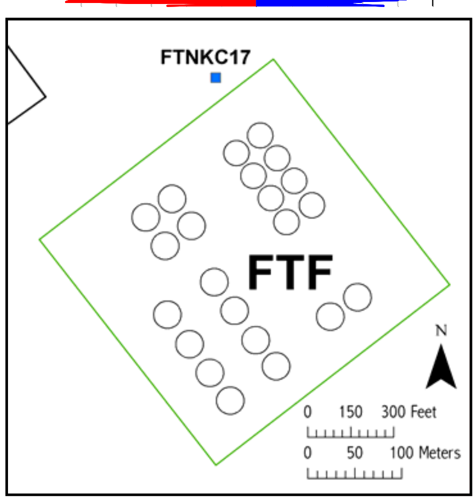


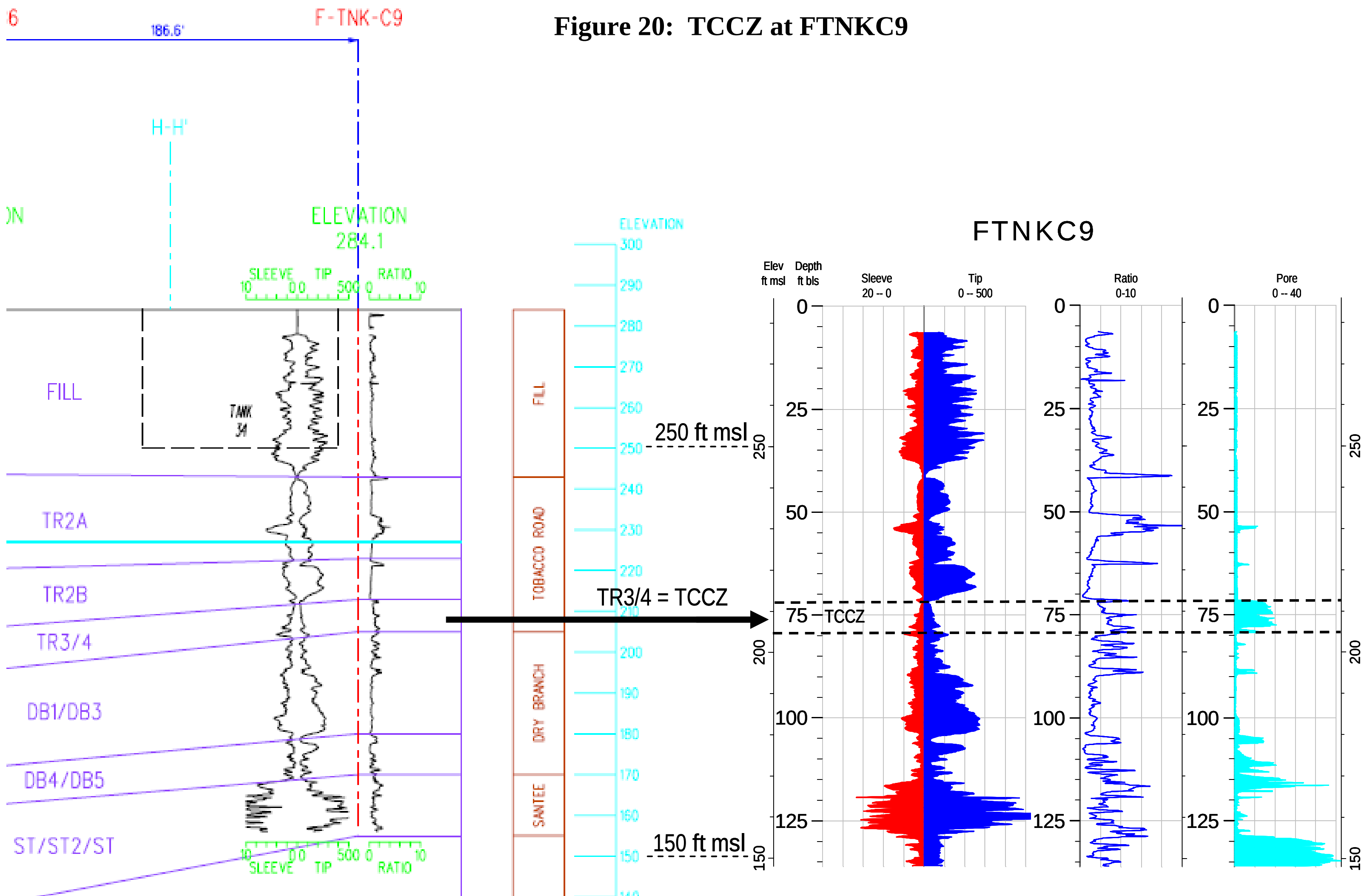
Figure 19: CPT Logs for FTNKC17 (modified from figure 17 in Millings 2007)





Note for figure: msl = mean sea level; bls = below land surface; ft = feet; TCCZ = Tan Clay Confining Zone; sleeve = sleeve resistance (tsf); tip = tip resistance (tsf); ratio = friction ratio (reflects sleeve/tip); pore = pore pressure (psi)

Figure 20: TCCZ at FTNKC9



FTNKC9 above is from Plate 29, volume 3 Site Geotechnical Services Department (1996)

FTNKC9 above is from Millings (2007)

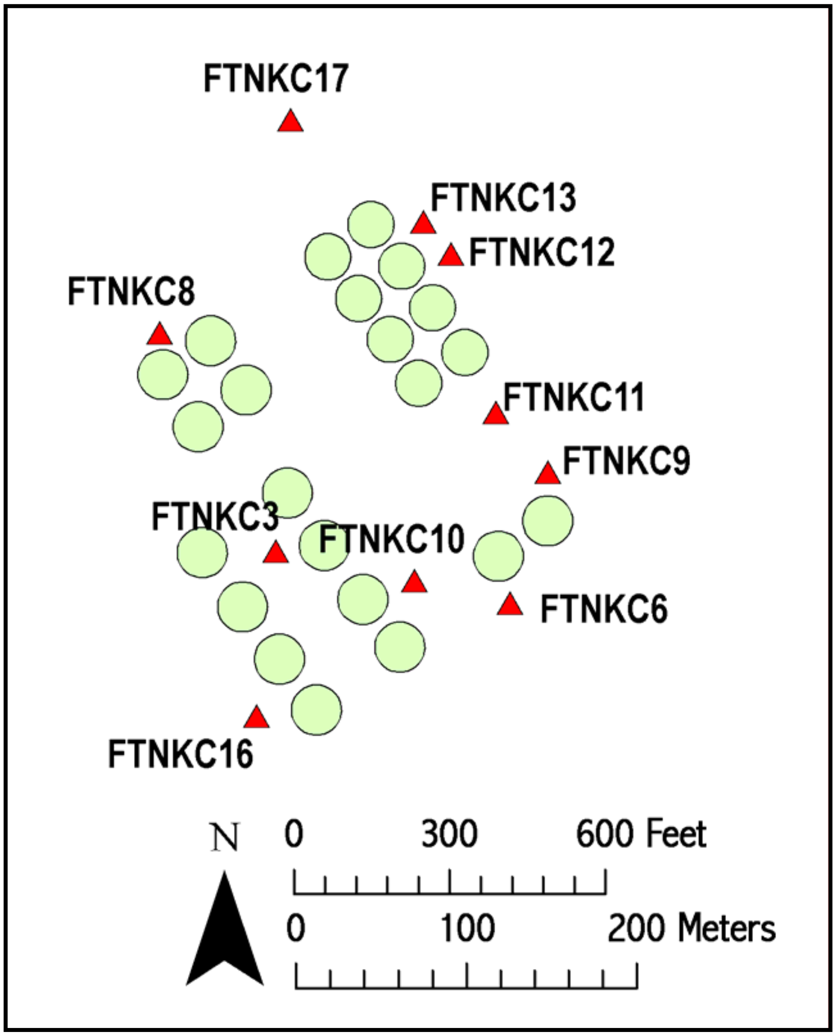
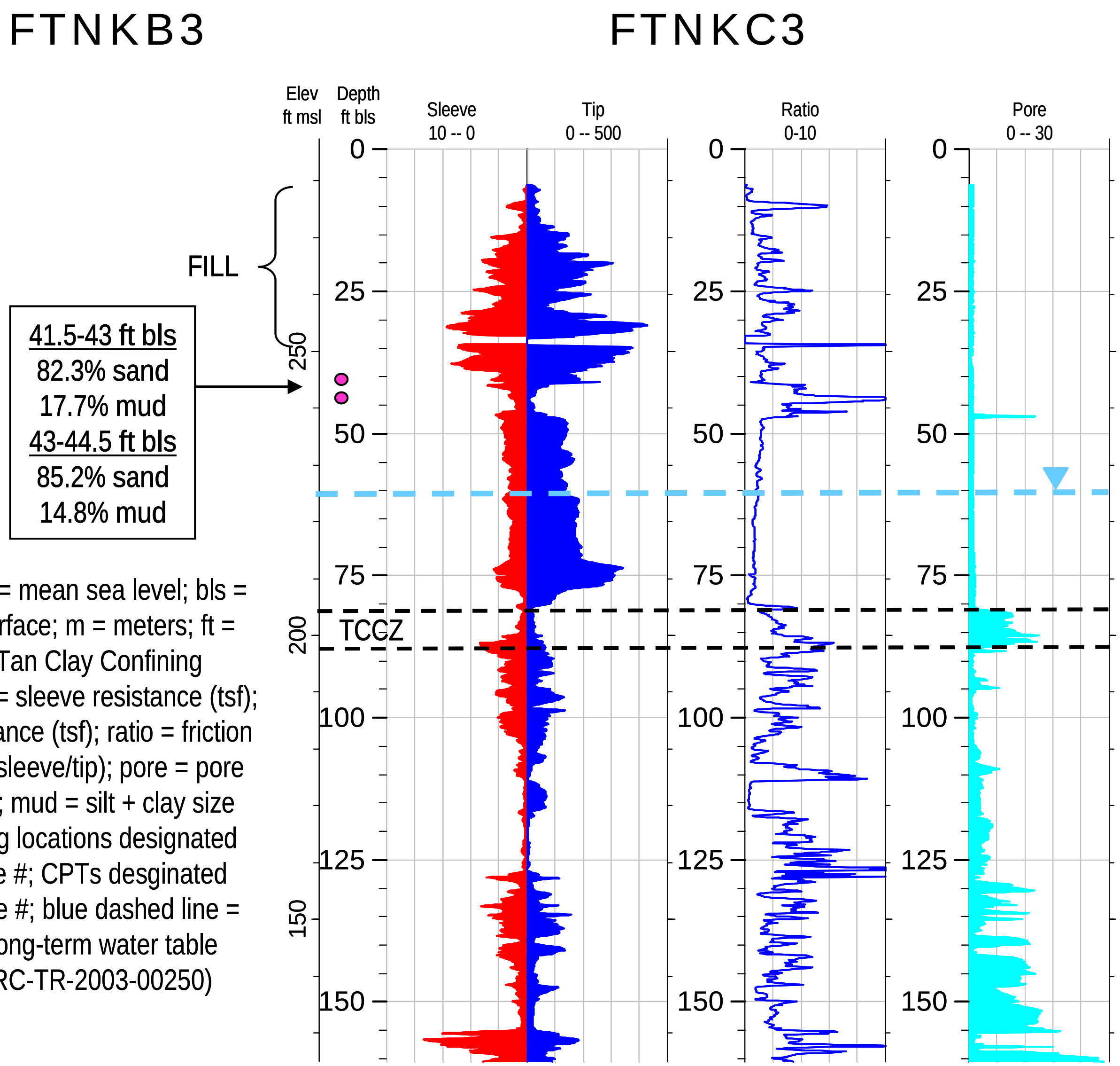


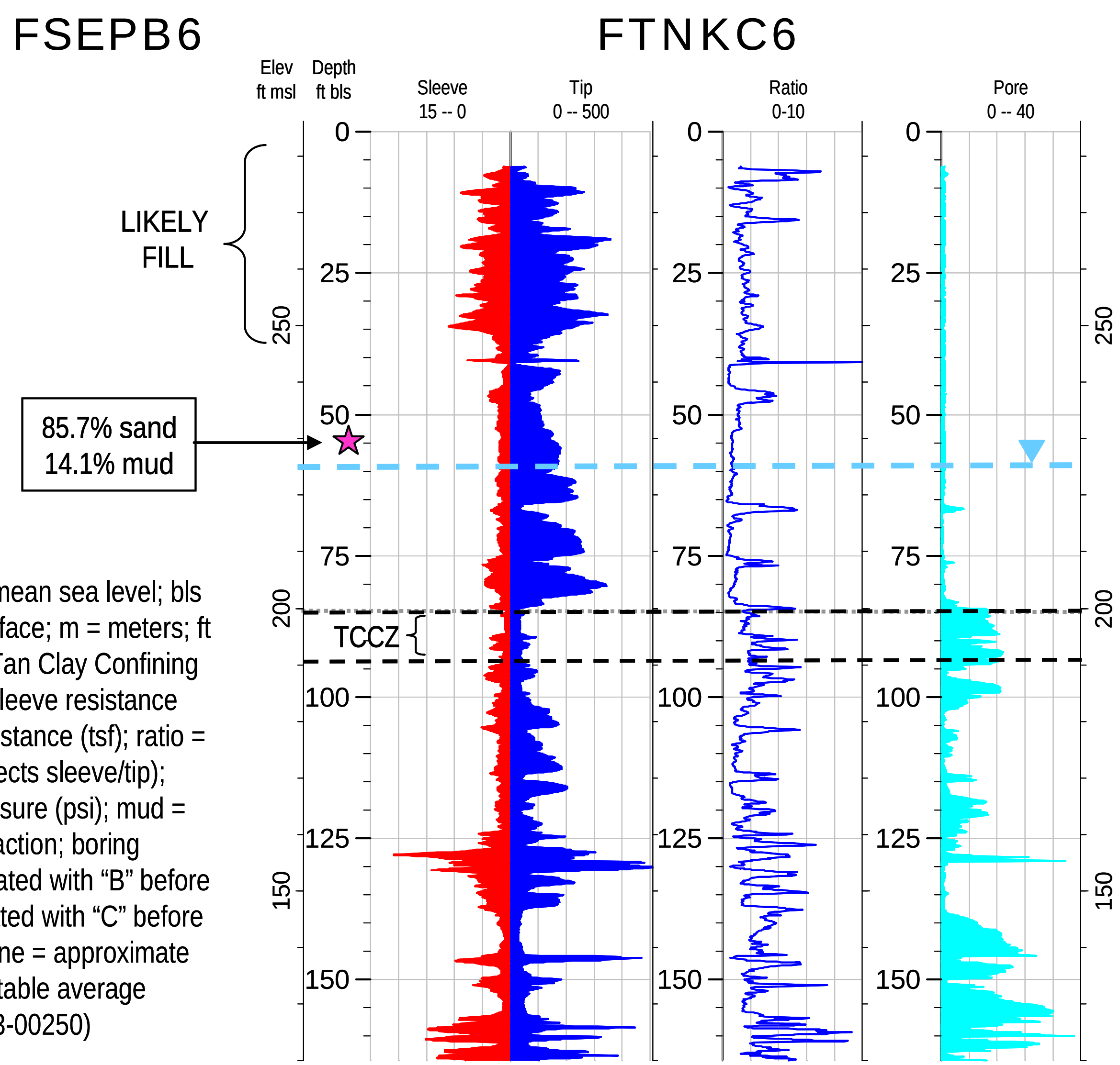
Figure 21: Location of CPTs used in TCCZ Comparison on Table 4

Figure 22: FTNKB3 Grain Size Data and CPT FTNKC3



NOTES: msl = mean sea level; bls = below land surface; m = meters; ft = feet; TCCZ = Tan Clay Confining Zone; sleeve = sleeve resistance (tsf); tip = tip resistance (tsf); ratio = friction ratio (reflects sleeve/tip); pore = pore pressure (psi); mud = silt + clay size fraction; boring locations designated with "B" before #; CPTs desginated with "C" before #; blue dashed line = approximate long-term water table average (WSRC-TR-2003-00250)

Figure 23: FSEPB6 Grain Size Data and CPT FTNKC6



NOTES: msl = mean sea level; bls = below land surface; m = meters; ft = feet; TCCZ = Tan Clay Confining Zone; sleeve = sleeve resistance (tsf); tip = tip resistance (tsf); ratio = friction ratio (reflects sleeve/tip); pore = pore pressure (psi); mud = silt + clay size fraction; boring locations designated with “B” before #; CPTs desginated with “C” before #; blue dashed line = approximate long-term water table average (WSRC-TR-2003-00250)

Figure 24: FTNKB8 Grain Size Data and CPT FTNKC8

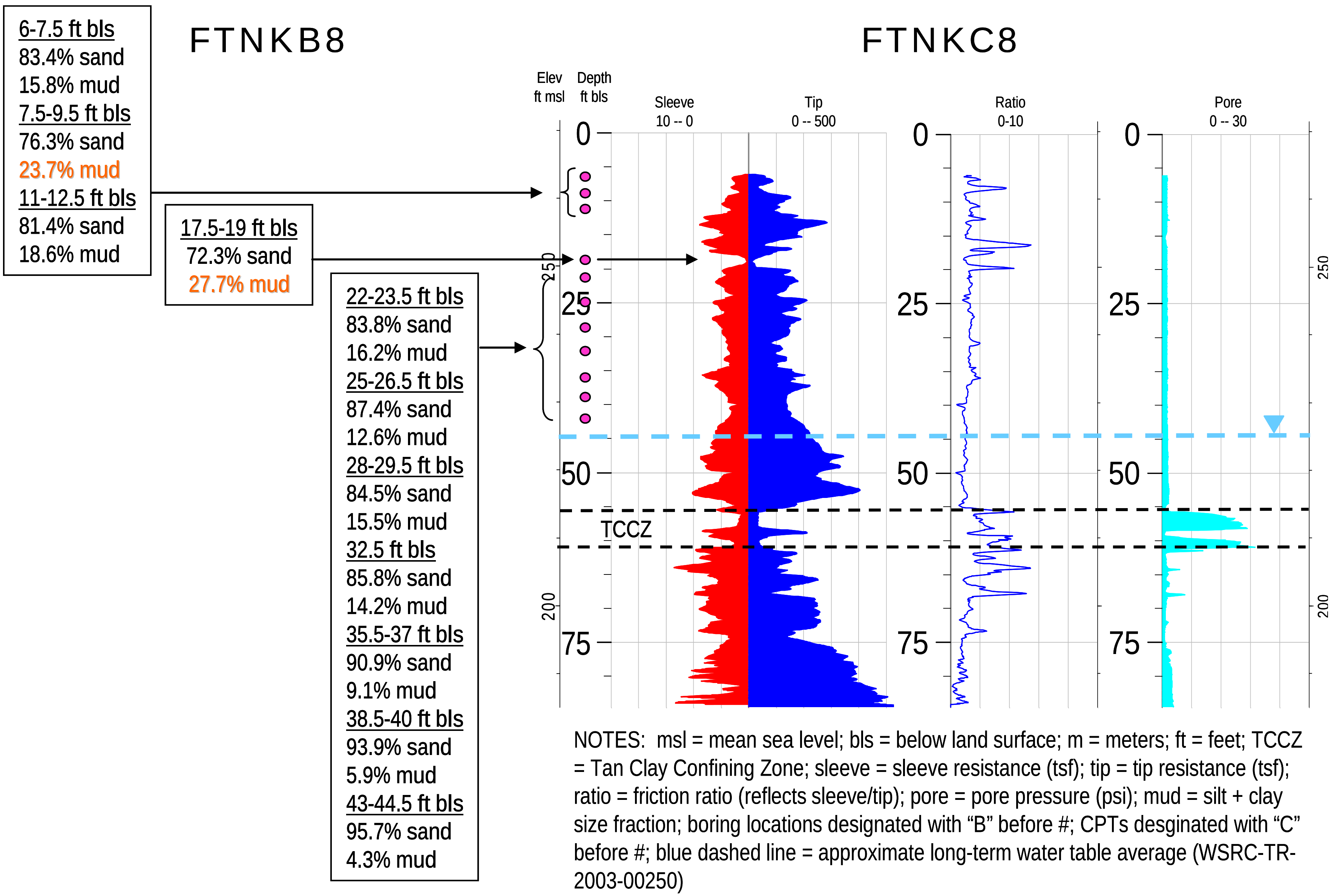
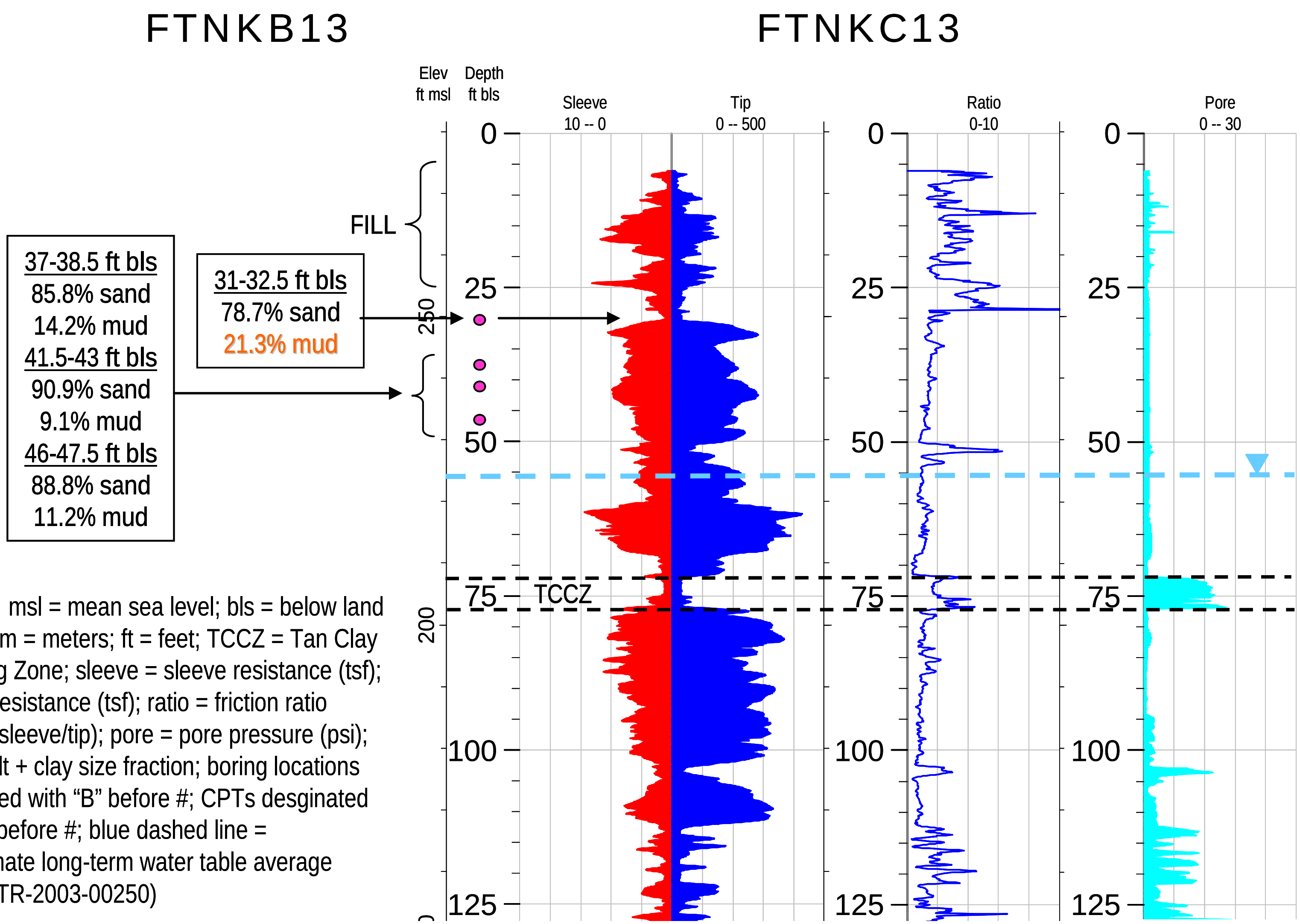
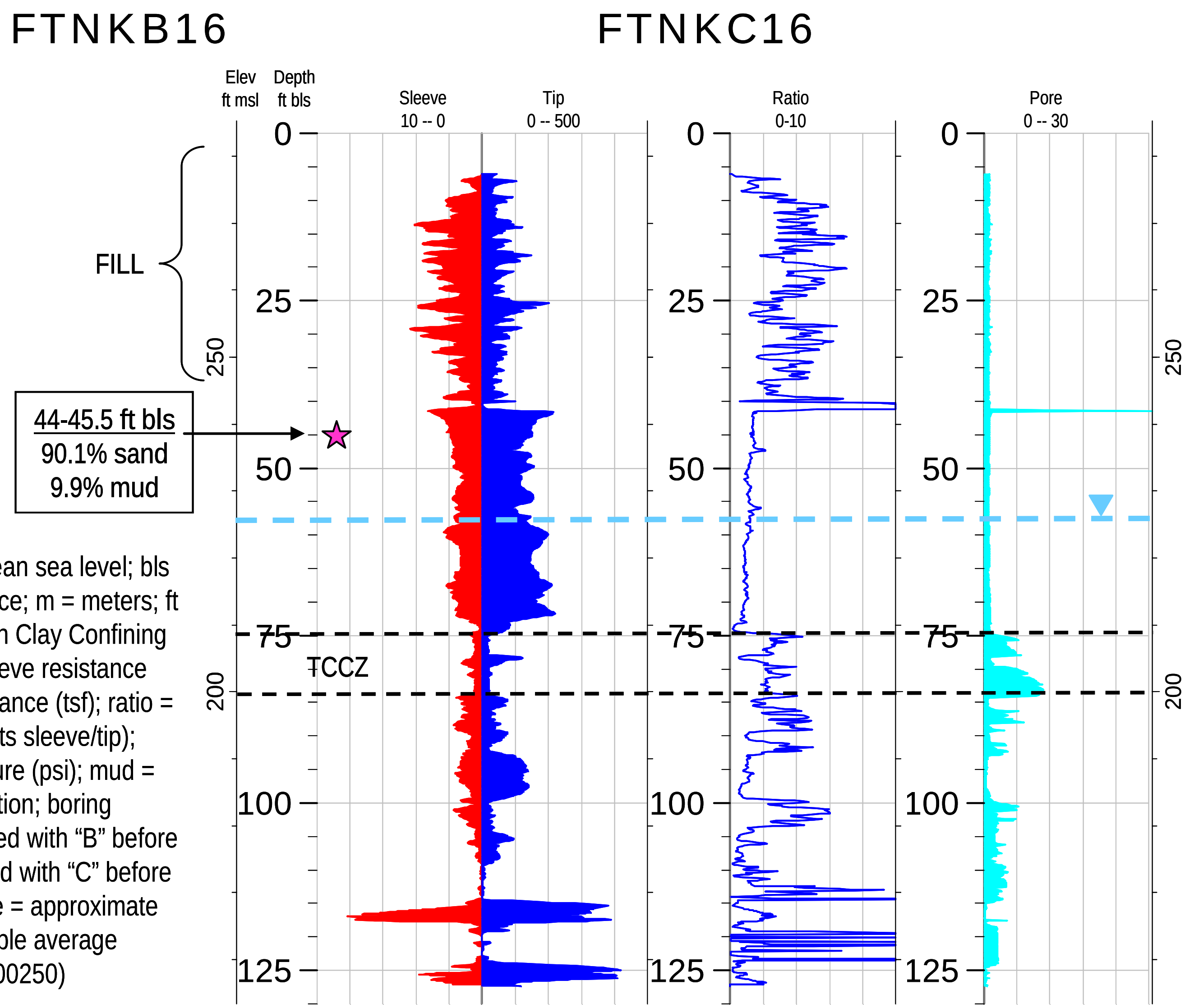


Figure 25: FTNKB13 Grain Size Data and CPT FTNKC13



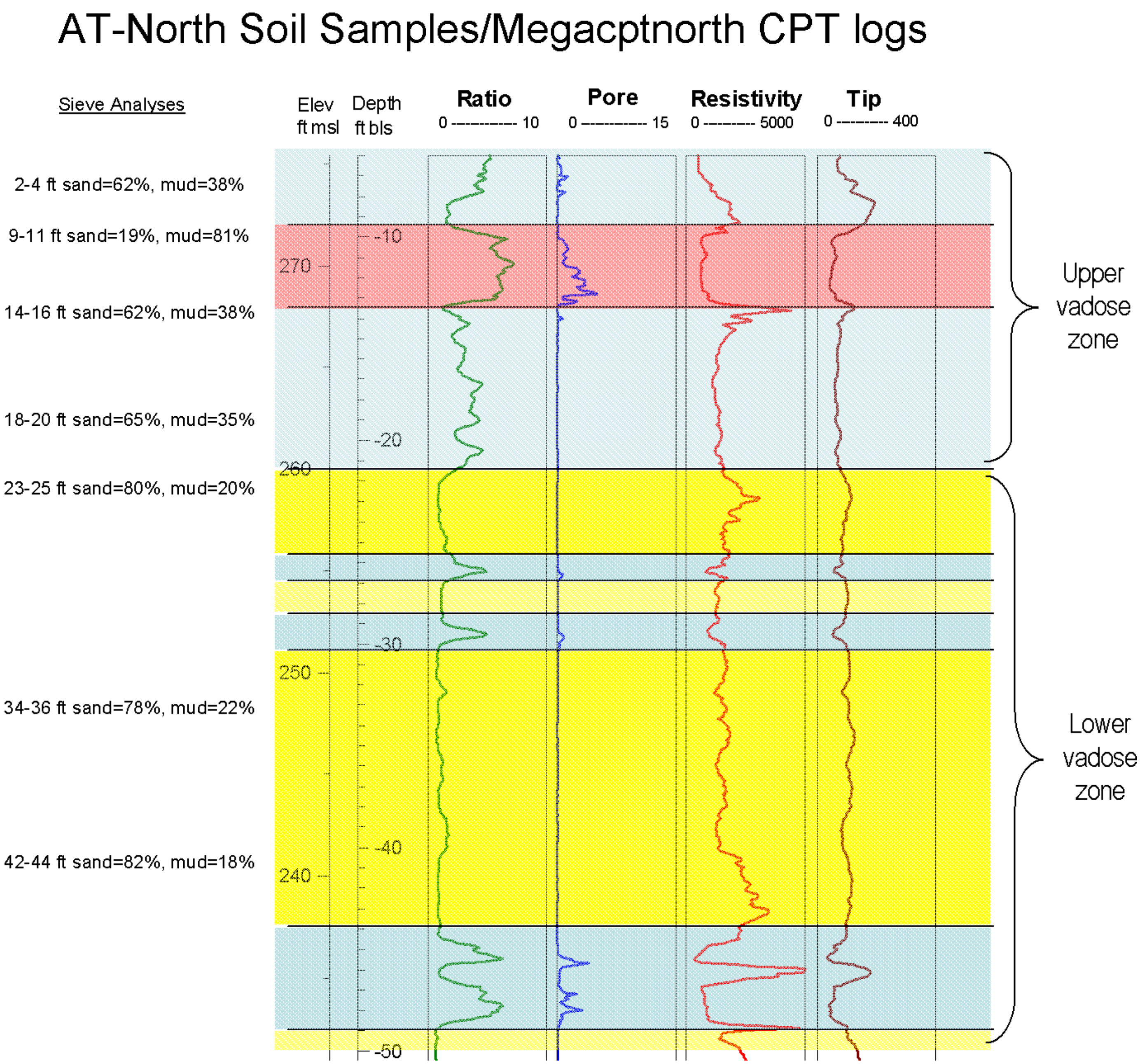
NOTES: msl = mean sea level; bls = below land surface; m = meters; ft = feet; TCCZ = Tan Clay Confining Zone; sleeve = sleeve resistance (tsf); tip = tip resistance (tsf); ratio = friction ratio (reflects sleeve/tip); pore = pore pressure (psi); mud = silt + clay size fraction; boring locations designated with “B” before #; CPTs desginated with “C” before #; blue dashed line = approximate long-term water table average (WSRC-TR-2003-00250)

Figure 26: FTNKB16 Grain Size Data and CPT FTNKC16



NOTES: msl = mean sea level; bls = below land surface; m = meters; ft = feet; TCCZ = Tan Clay Confining Zone; sleeve = sleeve resistance (tsf); tip = tip resistance (tsf); ratio = friction ratio (reflects sleeve/tip); pore = pore pressure (psi); mud = silt + clay size fraction; boring locations designated with “B” before #; CPTs desginated with “C” before #; blue dashed line = approximate long-term water table average (WSRC-TR-2003-00250)

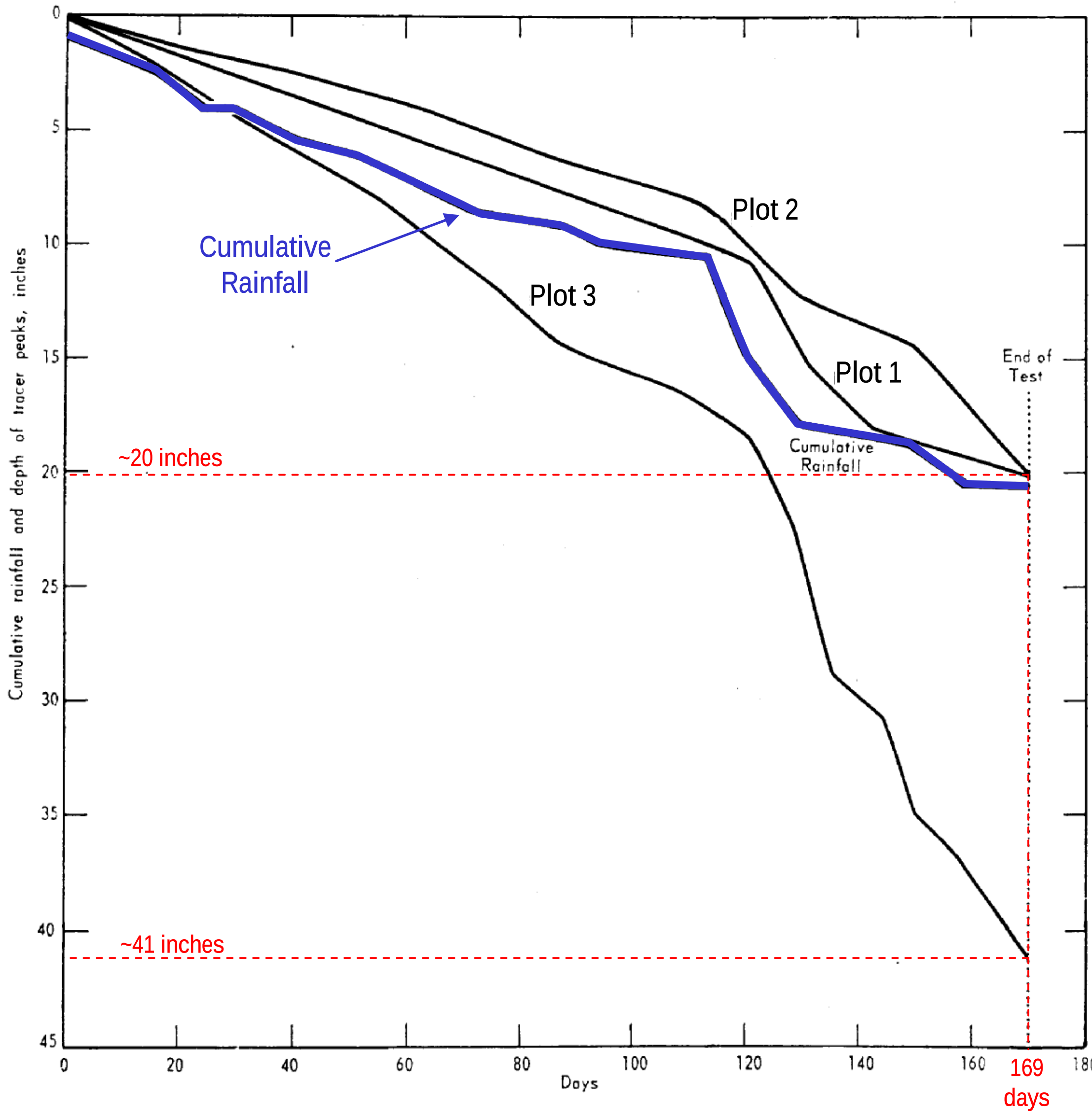
Figure 27: Grain Size Data and CPT Logs from E-Area Illustrating Upper and Lower Vadose Zone



ft msl = feet mean sea level; ft bls = feet below land surface; ratio = friction ratio (sleeve resistance/tip resistance, in %); pore = pore pressure (psi); electrical resistivity (ohms-meters); tip = tip resistance (tsf); mud includes silt and clay size fraction

Figure modified from WSRC-STI-2006-00198

Figure 28: Downward movement of tracer peak versus rainfall for Plots 1, 2, and 3 in Haskell and Hawkins field study (1964)



•For plot 1 & 2, tracer moved ~ 20 inches in 169 days and an average of 0.94 inches per inch of rainfall

•For plot 3, tracer moved ~ 41 inches in 169 days and an average of 1.99 inches per inch of rainfall

Figure modified from figure 6 in Haskell and Hawkins (1964)

Figure 29: Relative Permeability and Water Retention Curves for Natural Soils as Presented by INTERA (1986)

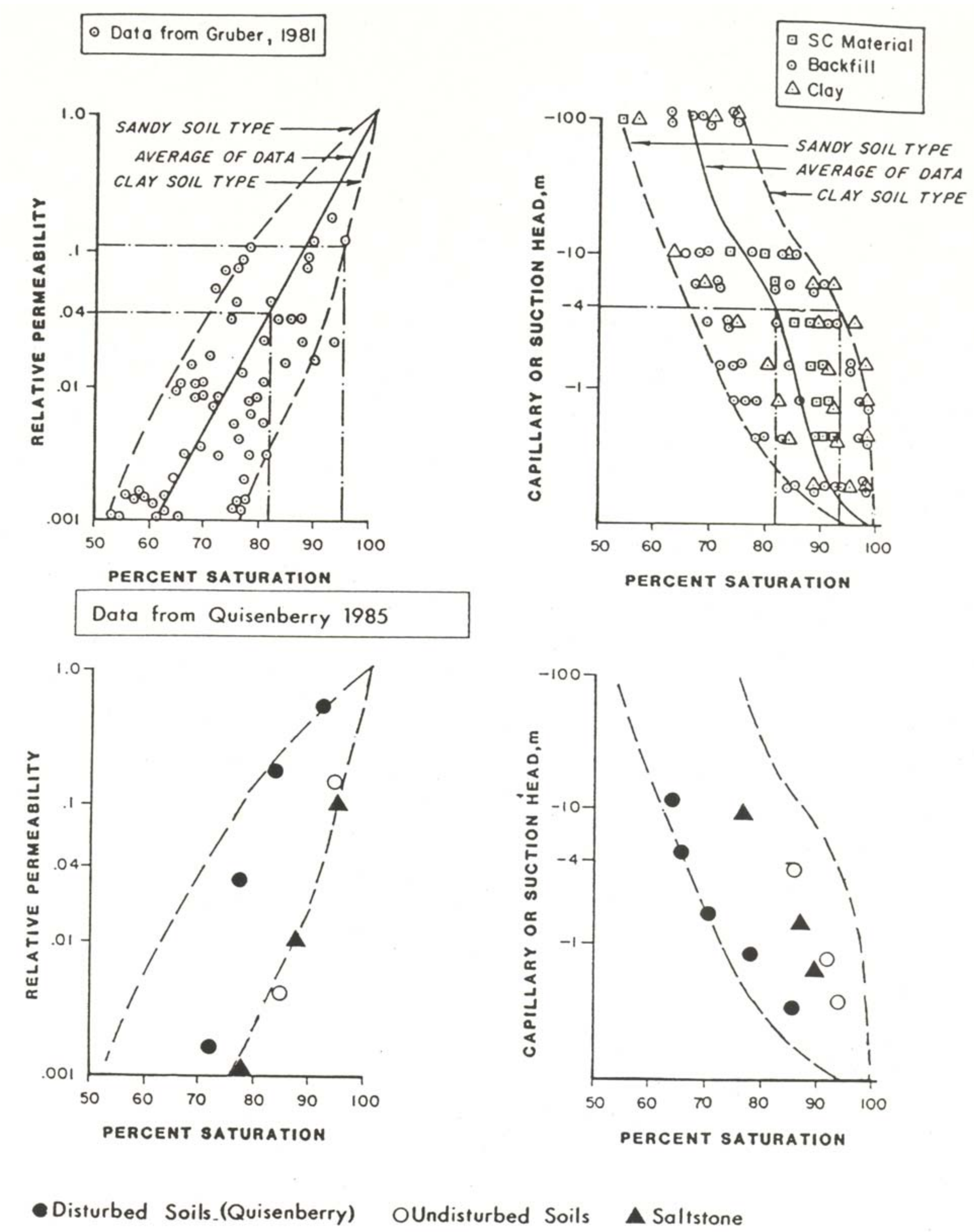


Figure 30: Comparison of Relative Permeability and Water Retention Curves (Phifer et al. 2006 vs INTERA 1986)

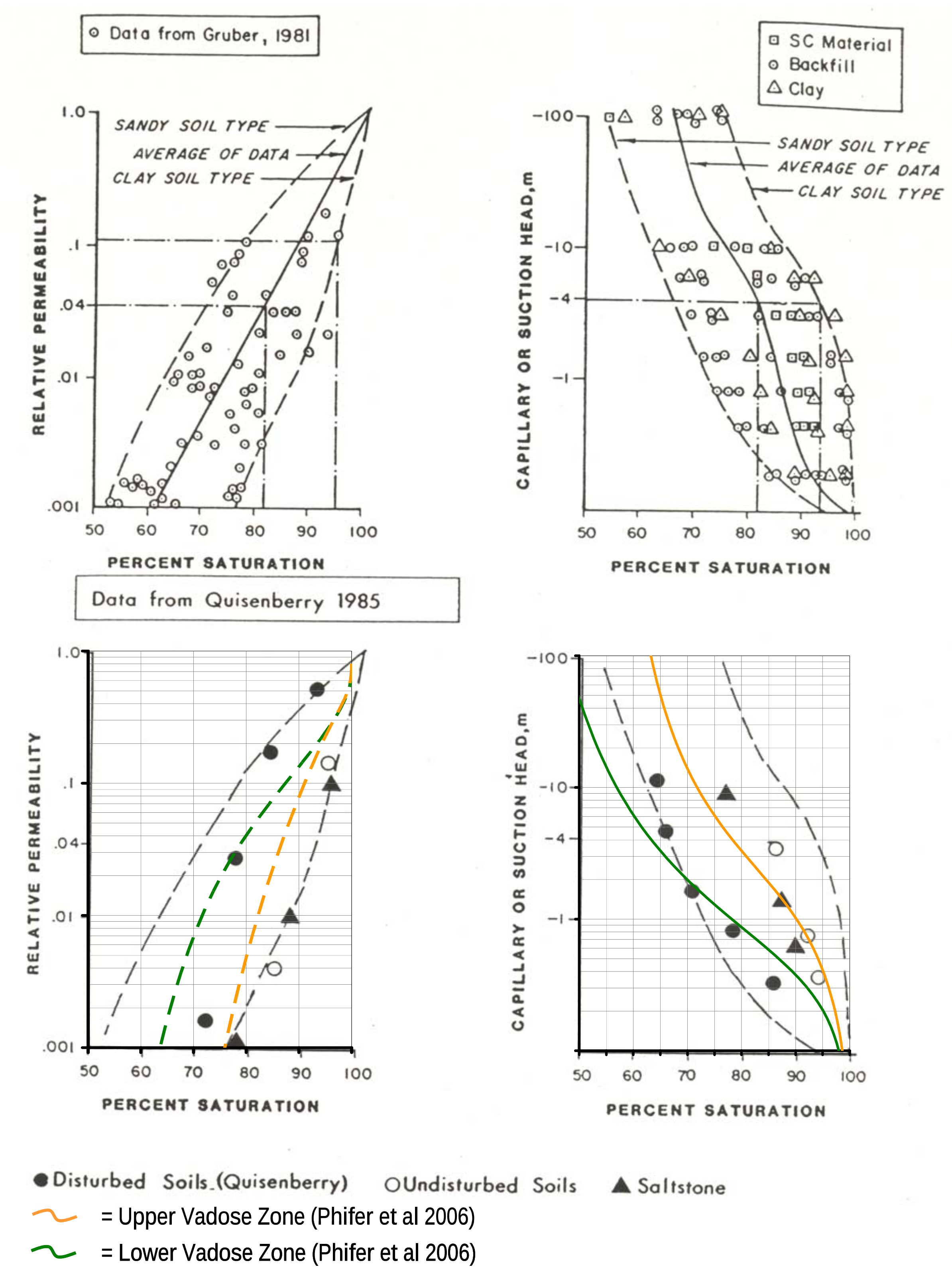
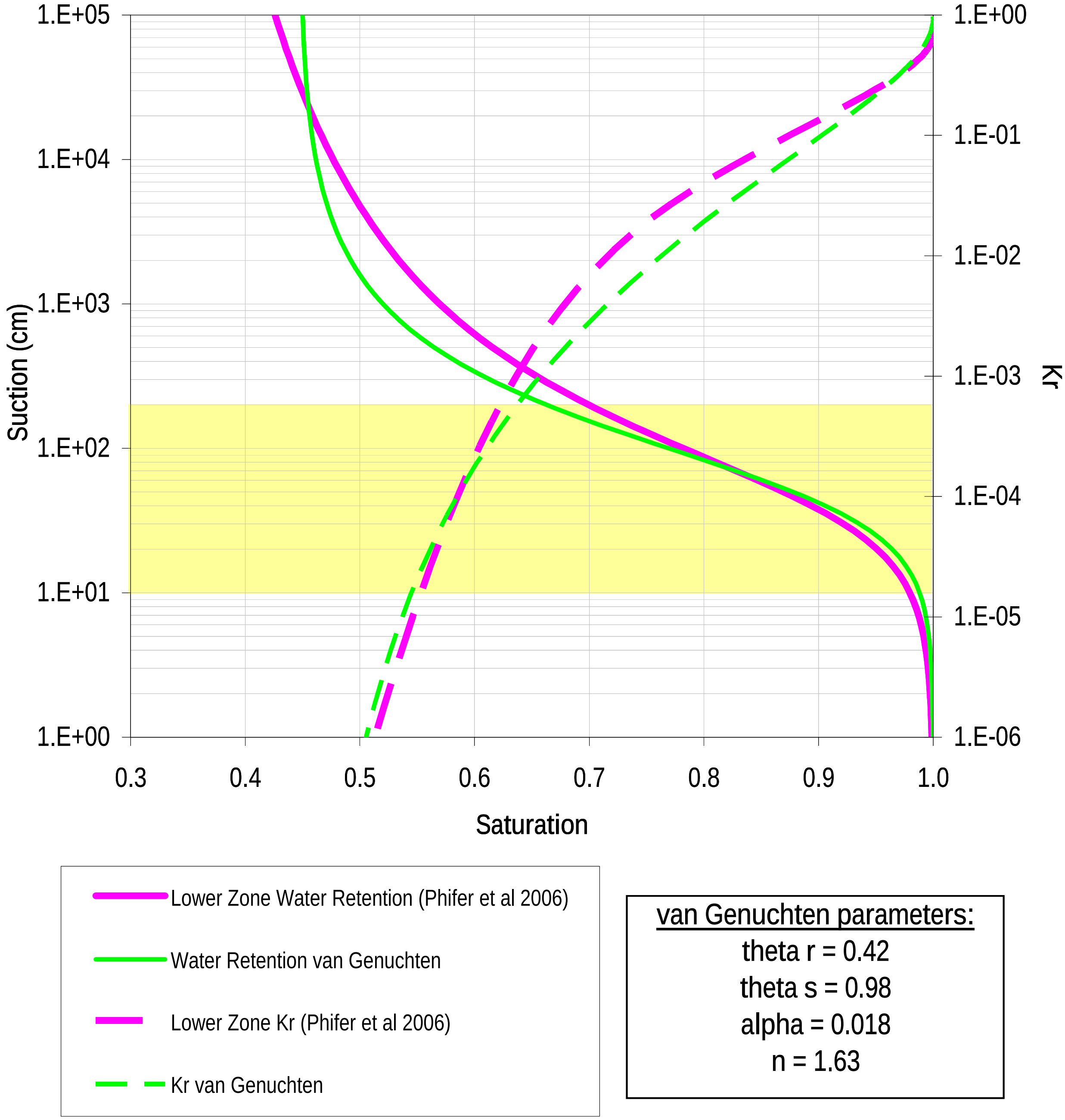


Figure 31: Soil Property Curves for Lower Vadose Zone



Appendix A: Summary of Borings Completed Near FTF Through 1974 (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

Summary of Borings Prior to 1974 (includes the US Army Corps of Engineers borings) (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

SUMMARY OF BORINGS MADE PRIOR TO 1974 - BUILDING 241F - TANKS NOS. 1 THROUGH 8, 17 THROUGH 20, 33 AND 34, SAVANNAH RIVER PLANT

FILE NO. 4387

Boring No.	Type of Boring	Surface Elev.	Depth of Boring	Bottom Elev. Of Boring	Ground Water Level-Depth	Rod, Casing Droppings or Settling-Depths	Drilling Mud Losses Depths	Calcareous Material Depths	Grout Required To Fill Hole Cubic Feet	Remarks
241-11F-1	split spoon	+283.6	160.0 Ft.	123.6	60.0 Ft.	112.5 to 115.5 Ft.	112.5 to 115.5 Ft.	111.0 to 147.5 Ft.	not reported	Casing lowered to 120' depth to maintain hole open.
241-11F-2	do	+281.4	149.5	131.9	56.6	none	none	107.0 to 142.0	do	
241-11F-3	do	+285.5	150.0	135.5	60.0	none	none	119.0 to 131.0	do	
241-11F-4	do	+284.6	155.0	129.6	not given	none	none	---------	do	
241-11F-5	do	+284.6	75.0	209.6	59.0	none	none	58.0 to 69.0	do	Only calcareous lenses noted between 58' to 69' depth.
241-11F-6	do	+282.1	150.0	132.1	55.0	none	none	117.0 to 131.5	do	
241-11F-7	do	+283.9	155.0	128.9	61.0	none	45.5 to 153.5 (slight loss)	121.5 to 126.6	do	
241-11F-8	do	+284.1	150.0	134.1	58.5	none	----	117.0 to 131.5	do	
241-11F-10	fishtail	+283.6	118.5	165.1	59.0	none	98.0 to 98.5 (complete mud loss)	112.5 to 118.5	do	
241-11F-11	do	+283.7	118.5	165.2	64.0	none	40.0 to 118.5 (slight loss)	112.0 to 118.5	do	
241-11F-12	do	+285.4	85.0	200.4	59.0	none	none	---------	do	Piezometer installed in this hole. Shallow boring, did not reach calcareous zone.
F-24	split spoon	+286.4	81.0	205.4	not given	none	none	---------	do	Shallow boring, did not reach calcareous zone.
F-25	do	+285.9	163.9	122.0	do	none	none	---------	do	No sampling below 80' depth.
F-26	do	+282.6	81.0	201.6	do	none	none	---------	do	Shallow boring, did not reach calcareous zone.
F-27	do	+287.3	168.9	118.4	do	none	none	121.0 to 135.0	do	Caved between 164.0 to 168.9 ft.
F-29	do	+281.1	149.6	131.5	do	none	none	118.0 to 134.0	do	No sampling below 82' depth.
F-30	do	+281.5	153.5	128.0	do	none	none	107.7 to 147.0	do	No sampling below 81' depth.
F-31	do	+283.3	154.0	129.3	do	none	none	125.5 to 137.0	do	No sampling below 81' depth.
F-32	do	+282.8	155.0	127.8	do	not given	not given	105.0 to 108.0	do	

Continuation of Summary of Borings Prior to 1974 (includes the US Army Corps of Engineers borings) (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

SUMMARY OF BORINGS MADE PRIOR TO 1974 - BUILDING 241F - TANKS NOS. 1 THROUGH 8, 17 THROUGH 20, 33 AND 34, SAVANNAH RIVER PLANT

FILE NO. 4387

Boring No.	Type of Boring	Surface Elev.	Depth of Boring	Bottom Elev. Of Boring	Ground Water Level-Depth	Rod, Casing Droppings or Settling-Depths	Drilling Mud Losses Depths	Calcareous Material Depths	Grout Required To Fill Hole Cubic Feet	Remarks
241-F-1	split spoon	+292.2	125.9	166.3	do	none	122' (lost 1,200 gallons of drilling mud)	124.9 to 125.9	do	Boring apparently discontinued because of lack of drilling mud circulation.
241-F-2	do	+289.6	141.5	148.1	do	none	none	125.6 to 141.6	do	
241-F-3	do	+292.0	140.1	151.9	do	none	none	125.0 to 140.0	do	
241-F-4	do	+291.8	140.9	150.9	do	none	none	124.8 to 140.8	do	
241-F-5	do	+289.7	141.5	148.2	do	none	none	none	do	
241-F-6	do	+293.2	51.5	241.7	do	none	none	none	do	Shallow boring, did not reach calcareous zone.
241-F-7	do	+291.4	125.8	165.6	do	none	none	none	do	
241-F-8	do	+291.0	126.5	164.5	do	none	none	none	do	
FF-4	do	+291.7	179.0	112.7	do	not given	not given	125.0 to 176.0	do	

TABLE NO. II

Summary of Exploratory Borings Completed in 1974 (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

SUMMARY OF BORINGS MADE IN 1974 - BUILDING 241F - TANKS NOS. 25 THROUGH 28 AND 44 THROUGH 47, SAVANNAH RIVER PLANT

Boring No.	Type of Boring	Surface Elev.	Depth of Boring	Bottom Elev. Of Boring	Ground Water Level-Depth	Rod, Casing Droppings or Settling-Depths	Drilling Mud Losses Depths	Calcareous Material Depths	Grout Required To Fill Hole Cubic Feet
41-14F-1 ✓	split spoon	+283.7	169.0 Ft.	114.7	20.0 Ft.	118.5 to 120.0 Ft.	None	119.0 to 132.0 Ft. HCl reaction	14.5
41-14F-2 ✓	do	+286.2	169.9	116.3	31.5	128.5 to 130.0	131.0 to 133.0 Ft. (100± gal.) 147±	No HCl reaction	112.9
41-14F-3U ✓	undisturbed	+287.9	160.0	127.9	61.0	none	126.0 to 132.0 (275 gal.) 132.0 to 138.5 (150 gal.) 80.0 to 145.0 (Lost 450 gal. during redrilling)	123.0 to 134.0 HCl reaction	120.8
1-14F-4 ✓	split spoon	+289.8	163.7	126.1	70.0	123.5 to 124.5 148.5 to 150.0 153.5 to 155.0	84.5 (50 gal.) 111.0' to 115'(complete drilling mud loss) 121 to 130.	124.5 to 143.5 HCl reaction	151.5
41-14F-5U ✓	undisturbed	+286.7	140.0	146.7	57.5	none	none	123.0 to 125.0 No HCl reaction	9.6
41-14F-6 ✓	split spoon	+286.4	180.0	106.4	75.0	114.5 to 124.0	0 to 75.0	113.5 to 133.5 HCl reaction	94.5
41-14F-7U ✓	undisturbed	+285.2	174.5	110.7	53.0	132.0 to 137.0 (casing dropped)	130.0 (220 gal.)	113.5 to 137.0 HCl reaction	71.1

Note: Boring labels in the original copy were obscured in report binding; all boring identification labels have the following form: 241-14F-# except for the piezometers, which are labeled No. #; from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a

Continuation of Summary of Exploratory Borings Completed in 1974 (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a)

SUMMARY OF BORINGS MADE IN 1974 - BUILDING 241F - TANKS NOS. 25 THROUGH 28 AND 44 THROUGH 47, SAVANNAH RIVER PLANT

Boring No.	Type of Boring	Surface Elev.	Depth of Boring	Bottom Elev. Of Boring	Ground Water Level-Depth	Rod, Casing Droppings or Settling-Depths	Drilling Mud Losses Depths	Calcareous Material Depths	Grout Required To Fill Hole Cubic Feet
'1-14F-8	split spoon	+287.0	170.0	117.0	61.0	none	none	126.0 to 138.0 HCl reaction	14.3
'1-14F-9	split spoon	+288.5	170.0	118.5	26.0	120.0 to 121.5	93.5 to 120.0 (700 gal.) 123.0 (50 gal.)	123.0 to 154.0 HCl reaction	170.9
No. 1	piezometer	+287.2	75.0	212.2	60.6	none	none	none	
No. 2	piezometer	+290.1	51.0	239.1	no water encountered		none	none	

Boring labels in the original copy were slightly obscured by holes of report binding; all boring identification labels have the following form: 241-14F-# except for the piezometers, which are labeled No. #; from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975a

Appendix B: Summary of Foundation Grouting Activities for Tanks 25-28 and 44-47 (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b)

"Hole Numbers" correspond to drill locations at tanks 25-28; maximum grout injected occurred in hole 22 (3, 108 cubic ft); table continued on next page for tanks 44-47 (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b)

TABLE NO. I

SUMMARY OF PAY QUANTITIES
DRILLING AND GROUTING OPERATIONS - AREA F - NEW HIGH LEVEL WASTE TANKS
PROJECT 9S 1493 FY'75 - TANKS NOS.25 THROUGH 28 - PROJECT FY'77 - TANKS NOS.44 THROUGH 47
SAVANNAH RIVER PLANT

ITEM NUMBER	2	3	4	5	6	7			8	9
HOLE NUMBER	DRILLING FOR SOIL SAMPLING AND GROUTING	SPLIT SPOON SAMPLING IN DRILL HOLES	CEMENT FOR GROUTING MIX	BENTONITE FOR MIXING GROUT	SAND FOR MIXING GROUT	GROUTING OF DRILL HOLES	GROUTING OF DRILL HOLES WITH Ca/CL_2	TOTAL GROUT INJECTED	STANDBY TIME PER GROUTING MACHINE	REDRILLING OF GROUTED HOLES
	Lin.Ft.	Lin.Ft.	94 lb. bags	100 lb. bags	Cu.Ft.	Cu.Ft.	Cu.Ft.	Cu.Ft.	Hours	Hours
1	161.50	56.50	6.56	1.09	35.1	53	-	53	-	-
2	163.00	58.00	15.12	2.52	80.5	122	-	122	-	-
3	166.50	61.50	33.10	5.51	176.5	267	-	267	-	-
4	161.50	51.50	2.48	0.41	13.2	20	-	20	-	-
5	170.00	0.00	255.50	33.40	1,419.2	959	1,186	2.145	-	8.75
6	161.16	51.16	34.50	5.75	184.0	279	-	279	-	-
7	151.50	41.50	4.70	0.78	25.0	39	-	39	-	-
8	170.00	0.00	4.28	0.71	22.8	35	-	35	-	-
9	151.50	46.50	23.70	3.95	126.0	186	-	186	-	-
10	161.50	51.50	4.00	0.68	21.3	32	-	32	-	-
11	170.00	0.00	23.40	3.90	125.0	193	-	193	-	-
12	161.50	51.50	3.00	0.50	16.0	25	-	25	-	-
13	170.00	0.00	23.84	3.98	126.2	188	-	188	-	-
14	170.00	0.00	2.25	0.38	12.0	33	-	33	-	-
15	147.00	42.00	2.60	0.60	19.2	30	-	30	-	-
16	151.50	46.50	4.14	0.69	22.0	33	-	33	-	-
17	170.00	0.00	4.46	0.74	23.8	37	-	37	-	-
18	147.00	42.00	10.30	1.71	54.8	83	-	83	-	-
19	146.50	51.50	3.72	0.62	19.6	33	-	33	-	-
20	170.00	0.00	3.56	0.60	19.0	33	-	33	-	-
21	151.00	46.50	11.54	1.92	61.5	97	-	97	-	-
22	146.30	46.50	370.95	54.02	1,978.0	3,108	-	3,108	-	9.66
23	170.00	0.00	2.76	0.46	14.7	24	-	24	-	-
24	145.50	65.00	4.85	0.81	26.0	35	-	35	-	-
25	157.66	57.66	152.50	25.45	813.5	1,282	-	1,282	-	1.75
26	146.50	46.50	105.66	17.60	587.0	918	-	918	-	1.50
27	161.00	81.00	6.35	1.06	33.8	53	-	53	-	-
55	170.00	0.00	1.96	0.25	10.5	18	-	18	-	-
56	170.00	0.00	56.90	8.37	356.8	420	114	534	-	3.00
57	170.00	0.00	3.56	0.41	18.9	29	-	29	-	-
58	160.00	0.00	3.24	0.41	17.3	-	27	27	-	-
6A	170.00	0.00	24.50	4.07	130.5	197	-	197	-	-
56A	130.00	0.00	8.24	1.03	43.9	-	67	67	-	-
Piezometer #1	0.00	0.00	1.00	0.12	5.3	-	8	8	-	-
TOTAL FY'75	5,270.32	994.82	1,219.22	184.50	6,638.9	8,861	1,402	10,263	-	24.66

Continuation of Table No.1 (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b) Summary of Pay Quantities; "Hole Numbers" correspond to drill locations at tanks 44-47; maximum grout injected occurred in hole 53 (4,016 cubic ft)

ITEM NUMBER	2	3	4	5	6	7			8	9
HOLE NUMBER	DRILLING FOR SOIL SAMPLING AND GROUTING	SPLIT SPOON SAMPLING IN DRILL HOLES	CEMENT FOR GROUTING MIX	BENTONITE FOR MIXING GROUT	SAND FOR MIXING GROUT	GROUTING OF DRILL HOLES	GROUTING OF DRILL HOLES WITH Ca/CL_2	TOTAL GROUT INJECTED	STANDBY TIME PER GROUTING MACHINE	REDRILLING OF GROUTED HOLES
	Lin.Ft.	Lin.Ft.	94 lb. bags	100 lb. bags	Cu.Ft.	Cu.Ft.	Cu.Ft.	Cu.Ft.	Hours	Hours
28	170.00	5.00	171.40	21.39	912.0	-	1,371	1,371	-	3.33
29	170.00	5.30	209.50	24.70	1,115.0	-	1,697	1,697	-	2.75
30	166.50	56.50	3.13	0.39	16.7	27	-	27	-	-
31	170.00	43,00	5.63	0.71	30.0	-	45	45	-	-
32	170.00	0.00	417.12	52.09	2,224.2	721	2,666	3,387	-	3.25
33	181.50	71.50	2.78	0.35	14.8	24	-	24	-	-
34	170.00	6.00	5.60	0.70	30.0	-	45	45	-	-
35	170.00	0.00	4.77	0.60	25.4	-	39	39	-	1.50
36	171.00	66.00	190.60	23.31	1,061.1	1,568	30	1,598	-	8.50
37	155.00	24.50	334.87	41.83	1,786.5	-	2,717	2,717	-	6.75
38	170.00	0.00	3.43	0.43	18.3	-	28	28	-	-
39	151.50	46.50	5.11	0.60	27.2	40	-	40	-	-
40	170.00	0.00	232.65	29.04	1,488.0	-	1,863	1,863	-	2.00
41	170.00	0.00	2.00	0.26	10.9	-	17	17	-	-
42	165.25	45.25	475.20	59.36	2,535.9	695	3,193	3,888	-	7.50
43	160.00	31.50	94.44	11.81	504.4	-	782	782	-	2.00
44	170.00	0.00	3.60	0.45	19.2	-	30	30	-	-
45	146.50	46.50	2.66	0.44	14.2	22	-	22	-	-
46	170.00	0.00	129.20	16.15	690.0	-	1,060	1,060	-	1.50
47	170.00	0.00	66.73	8.31	356.5	-	512	512	-	1.50
48	145.00	30.00	237.00	29.58	1,264.0	-	1,905	1,905	-	2.00
49	151.50	36.50	6.90	0.86	36.7	-	55	55	-	-
50	170.00	0.00	91.05	11.39	486.0	-	772	772	-	5.00
51	146.50	36.50	350.60	42.77	1,829.0	715	2,091	2,806	-	5.50
52	151.50	51.50	3.63	0.45	19.3	30	-	30	-	-
53	161.50	56.50	483.44	61.65	2,579.0	744	3,272	4,016	-	7.00
54	151.50	51.50	169.18	28.20	911.6	1,434	-	1,434	-	5.00
59	170.00	0.00	106.20	13.24	567.0	-	830	890	-	5.58
60	170.00	0.00	3.60	0.45	19.2	-	30	30	-	-
61	170.00	0.00	190.22	23.76	1,014.0	-	1,547	1,547	-	2.00
62	170.00	0.00	2.92	0.37	15.6	-	34	34	-	-
63	170.00	0.00	4.37	0.54	23.4	-	35	35	-	-
64	170.00	0.00	16.70	2.09	89.0	-	131	131	-	-
65	170.00	0.00	89.60	11.12	478.6	-	714	714	-	1.50
66	170.00	0.00	92.56	11.57	493.6	-	740	740	-	2.00
67	170.00	0.00	6.25	0.78	33.3	-	50	50	-	-
68	170.00	0.00	3.24	0.40	17.3	-	27	27	-	-
69	170.00	0.00	5.20	0.65	27.6	-	46	46	-	-
41A	170.00	0.00	2.77	0.35	15.0	-	24	24	-	-
TOTAL FY'77	6,454.75	710.05	4,225.85	535.14	22,799.5	6,020	28,459	34,476	-	76.16

Locations and ground surface elevations for grout holes associated with the foundation grouting of tanks 25-28 and 44-47; FY'75 holes = holes associated with tanks 25-28; FY'77 holes associated with tanks 44-47 (from drawing no.1, Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1975b)

TABLE NO. 1

FY'75

HOLE NUMBER	COORDINATES NORTH	COORDINATES EAST	GROUND SURFACE ELEVATION
1	77120.	52735.	288.28
2	77120.	52785.	289.54
3	77120.	52835.	289.83
4	77070.	52735.	288.89
5	77075.	52785.	289.80
6	77070.	52835.	290.54
6A	77070.	52836.	290.54
7	77005.	52735.	287.77
8	77005.	57785.	290.03
9	77005.	52835.	290.34
10	76940.	52735.	287.21
11	76985.	52785.	287.89
12	76939.	52835.	289.60
13	76877.	52735.	286.80
14	76877.	52785.	287.09
15	76877.	52835.	287.63
16	76815.	52735.	285.06
17	76820.	52785.	286.21
18	76815.	52835.	285.70
19	76741.	52737.	283.70
20	76755.	52785.	284.37
21	76755.	52835.	285.41
22	76697.	52739.	283.75
23	76695.	52785.	283.59
24	76695.	52835.	283.22
25	76645.	52735.	282.38
26	76644.	52787.	282.56
27	76645.	52835.	282.47
55	77097.	52808.	289.78
56	76671.	52762.	282.95
56A	76671.	52761.	282.95
57	76676.	52804.	283.22
58	76716.±	52758.±	284±

FY'77

HOLE NUMBER	COORDINATES NORTH	COORDINATES EAST	GROUND SURFACE ELEVATION
28	77126.	52546.	289.8
29	77120.	52591.	289.4
30	77116.	52639.	289.0
31	77070.	52545.	287.91
32	77070.	52595.	288.55
33	77070.	52645.	288.34
34	77005.	52545.	287.01
35	77005.	52595.	287.54
36	77006.	52646.	287.39
37	76940.	52545.	286.58
38	76940.	52595.	287.04
39	76940.	52645.	286.91
40	76877.	52545.	287.13
41	76877.	52946.	287.09
41A	76877.	52946.	287.09
42	76877.	52645.	285.20
43	76815.	52545.	285.59
44	76815.	52595.	285.25
45	76809.	52627.	285.27
46	76695.	52545.	284.91
47	76755.	52595.	283.61
48	76755.	52645.	283.28
49	76695.	52545.	287.37
50	76695.	52595.	285.93
51	76695.	52645.	284.98
52	76645.	52545.	288.01
53	76645.	52595.	286.23
54	76645.	62645.	283.68
59	77094.	52572.	287.7
60	77095.	52619.	289.2
61	77038.	52620.	288.0
62	76908.	52568.	285.90
63	76849.	52570.	286.50
64	76786.	52568.	284.20
65	76779.	52614.	283.60
66	76726.	52567.	284.50
67	76724.	52620.	283.4
68	76670.	52620.	285.1
69	76673.	52567.	286.9

Appendix C: Summary of Foundation Grouting Activities for Proposed Tanks 52-55 (from Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)

Modified from Table No. 1 Summary of Pay Quantities, Drilling and Grouting Operations (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977); columns 5 through 14 of the original table are not included below (these columns provide details for amount of cement, bentonite, and sand used in each grout hole in addition to hours of standby and redrilling required for each hole); all grout holes have the prefix 241-55F before the hole number (e.g., 241-55F-1U); table continued on next page.

ITEM NUMBER	2	2A	3	3A	4	
HOLE NUMBER	DRILLING FOR SOIL SAMPLING AND GROUTING	DRILLING WITH CASING	SPLIT SPOON SAMPLING IN DRILL HOLES	SPLIT SPOON SAMPLING WITH CASING	RECOVERY OF UNDISTURBED SAMPLES	TOTAL GROUT INJECTED IN DRILL HOLE
	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	Samples	Cu.Ft.
1U	175.7	-	175.7	-	5	1219
2	171.5	-	171.5	-	-	92
3	176.5	-	176.5	129.0	-	3140
4U	175.3	-	175.3	-	4	728
5	156.0	-	36.0	-	-	36
6	151.5	-	31.5	-	-	1657
7	151.5	-	31.5	-	-	31
8	151.5	99.0	41.5	-	-	4072
9	156.5	-	56.5	-	-	788
10	151.5	-	51.5	-	-	2193
11	150.9	130.0	45.9	-	-	1436
12	151.5	-	51.5	-	-	1106
13	151.5	-	46.5	-	-	3212
14	151.5	-	51.5	-	-	1626
15	151.5	-	51.5	-	-	49
16	151.5	-	46.5	-	-	911
17	146.5	-	46.5	-	-	26
18	155.0	-	-	-	-	31
19	150.0	-	-	-	-	29
20	155.0	-	-	-	-	912

Modified from Table No. 1 Summary of Pay Quantities, Drilling and Grouting Operations (Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977); columns 5 through 14 of the original table are not included below (these columns provide details for amount of cement, bentonite, and sand used in each grout hole in addition to hours of standby and redrilling required for each hole); all grout holes have the prefix 241-55F before the hole number (e.g., 241-55F-1U).

ITEM NUMBER	2	2A	3	3A	4	
HOLE NUMBER	DRILLING FOR SOIL SAMPLING AND GROUTING	DRILLING WITH CASING	SPLIT SPOON SAMPLING IN DRILL HOLES	SPLIT SPOON SAMPLING WITH CASING	RECOVERY OF UNDISTURBED SAMPLES	TOTAL GROUT INJECTED IN DRILL HOLE
	Lin.Ft.	Lin.Ft.	Lin.Ft.	Lin.Ft.	Samples	Cu.Ft.
21	155.0	-	-	-	-	2444
22	155.0	-	-	-	-	29
23	155.0	-	-	-	-	40
24	155.0	-	-	-	-	45
25	155.0	-	-	-	-	43
26	155.0	-	-	-	-	299
27	155.0	-	-	-	-	32
NOTE: HOLES NOS. 28, 29 & 30 WERE OMITTED						
31	155.0	-	-	-	-	27
32	155.0	-	-	-	-	33
33	155.0	-	-	-	-	2143
34	155.0	-	-	-	-	344
35	155.0	-	-	-	-	18
36	155.0	-	-	-	-	1442
37	155.0	-	-	-	-	31
38	155.0	-	-	-	-	91
39	155.0	-	-	-	-	119
40	155.0	-	-	-	-	121
41	155.0	-	-	-	-	852
42	155.0	-	-	-	-	25
TOTALS	6077.4	229.0	1287.4	129.0	9	31472

Locations and ground surface elevations for grout holes associated with the foundation grouting of tanks 52-55 (from drawing no.2, Mueser, Rutledge, Wentworth & Johnston Consulting Engineers 1977)

FY' 79 WASTE STORAGE TANKS 52 TO 54							
HOLE NUMBER	COORDINATES		GROUND SURFACE ELEVATION	HOLE NUMBER	COORDINATES		GROUND SURFACE ELEVATION
	NORTH	EAST			NORTH	EAST	
1U	77070	52333	291.7	23	76877	52383	290.3
2	76695	52333	291.9	24	76755	52283	291.2
3	76940	52333	290.1	25	76755	52383	291.3
4U	76815	52333	291.1	26	76645	52283	291.2
5	77120	52333	291.7	27	76645	52383	291.5
6	77070	52283	292.6	28	Omitted		
7	77070	52383	291.2	29	Omitted		
8	77005	52333	291.0	30	Omitted		
9	76940	52283	290.8	31	76725	52358	292.5
10	76940	52383	289.7	32	76785	52308	291.8
11	76877	52333	290.3	33	76785	52358	291.5
12	76815	52283	291.8	34	76846	52308	290.8
13	76815	52383	290.3	35	76846	52358	289.6
14	76755	52333	291.5	36	76909	52308	290.5
15	76695	52283	291.7	37	76909	52358	289.6
16	76695	52383	291.4	38	76972	52308	290.6
17	76645	52333	291.7	39	76972	52358	290.6
18	77120	52283	292.1	40	77038	52308	291.4
19	77120	52383	291.7	41	77038	52358	290.4
20	77005	52283	290.7	42	77095	52308	291.8
21	77005	52383	290.2	43	Omitted		
22	76877	52283	290.7				

Appendix D: Summary of Grain Size and Hydraulic Conductivity Data for Samples Collected by Army Corps of Engineers and Analyzed by South Atlantic Division Laboratory (Borings FU-1, FU-2, FU-3)

Summary of Laboratory Data from South Atlantic Division Laboratory for Samples from Borings in F-Area

Boring ID	Top Depth (ft bls)	Bottom Depth (ft bls)	Elevation ft msl	Classification	% <0.42 mm	% <0.074 mm	% <0.005 mm	specific gravity	hydraulic conductivity (cm/sec)
FU1	4	5	303.5	sandy clay (CL)	78	40	35	2.63	
FU1	5.1	6.1	302.4	clayey sand (SC)	74	36	23	n/a	
FU1	7	8	300.5	clayey sand (SC)	70	34	25	n/a	
FU1	8.1	9.3	299.3	clayey sand (SC)	82	26	24	n/a	
FU1	10	11	297.5	clayey sand (SC)	93	31	25	26.9	5.60E-05
FU1	11.1	12.2	296.4	clayey sand (SC)	92	33	28	n/a	
FU1	13	14	294.5	clayey sand (SC)	98	33	27	n/a	4.50E-06
FU1	14.1	15.3	293.3	silty sand (SM)	93	33	23	n/a	
FU1	16	17	291.5	sandy clay (CL)	91	45	38	n/a	
FU1	17.1	18.1	290.4	sandy silt (ML)	92	39	24	n/a	
FU1	19	20	288.5	clayey sand (SC)	95	32	23	n/a	
FU1	20.1	20.9	287.5	clayey sand (SC)	98	32	28	2.57	
FU1	22	23	285.5	clayey sand (SC)	96	31	26	n/a	
FU1	23.1	24.3	284.3	clayey sand (SC)	98	29	24	n/a	
FU1	25	26	282.5	sandy clay (CL)	98	40	22	n/a	
FU1	26.1	27.3	281.3	clayey sand (SC)	98	33	18	n/a	
FU1	29	30.3	278.4	clayey sand (SC)	77	26	15	n/a	
FU1	31	32	276.5	Clayey Sand (SC)	94	28	14	n/a	
FU1	32.19	33.3	275.3	Clayey Sand (SC)	99	24	16	n/a	
FU1	34	35	273.5	Clayey Sand (SC)	97	20	14	2.59	
FU1	35.1	36.4	272.4	Clayey Sand (SC)	75	16	12	n/a	
FU1	37	38	270.5	Clayey Sand (SC)	79	31	12	n/a	

Boring ID	Top Depth (ft bls)	Bottom Depth (ft bls)	Elevation ft msl	Classification	% <0.42 mm	% <0.074 mm	% <0.005 mm	specific gravity	hydraulic conductivity (cm/sec)
FU1	38.1	39.3	269.3	Clayey Sand (SC)	83	23	16	2.63	
FU1	41	42.3	266.4	Clayey Sand (SC)	84	32	23	2.66	
FU1	41	42.3	266.4	Silty Sand (SM)	94	20	17	2.68	
FU1	43	44	264.5	Clayey Sand (SC)	69	23	12	n/a	
FU1	44.1	45.3	263.3	Clayey Sand (SC)	57	22	12	n/a	
FU1	46	47	261.5	Silty Sand (SM)	73	18	8	2.71	
FU1	49	30	258.5	Clayey Sand (SC)	88	23	12	2.7	
FU1	52	52.6	255.4	Clayey Sand (SC)	80	38	19	2.62	
FU1	52.6	53.2	254.8	Sandy Clay (CL)	93	43	17	n/a	
FU1	53.3	54.2	254.2	Clayey Sand (SC)	100	30	14	2.68	
FU1	53.3	54.2	254.2	Sandy Clay (CL)	98	43	17	n/a	
FU1	55	56	252.5	Clayey Sand (SC)	85	31	16	n/a	
FU1	56.1	57.1	251.4	Clayey Sand (SC)	90	20	10	n/a	
FU1	58	59	249.5	Clayey Sand (SC)	88	31	14	n/a	
FU1	59.1	60.4	246.3	Clayey Sand (SC)	88	21	12	n/a	
FU1	65	66.1	242.5	Clayey Sand (SC)	76	14	11	n/a	
FU1	70	71.2	237.4	Clayey Sand (SC)	80	23	17	n/a	
FU1	75	76	232.5	Silty Sand (SM)	95	16	11	2.71	
FU1	75	76	232.5	Clayey Sand (SC)	91	18	10	n/a	
FU1	76.1	77.1	231.4	Silty Sand (ML)	32	7	3	n/a	
FU1	85.1	86.3	222.3	Clayey Sand (SC)	56	18	15	n/a	
FU1	90	91	217.5	Silty Sand (SM)	54	11	4	n/a	

Boring ID	Top Depth (ft bls)	Bottom Depth (ft bls)	Elevation ft msl	Classification	% <0.42 mm	% <0.074 mm	% <0.005 mm	specific gravity	hydraulic conductivity (cm/sec)
FU1	93	94.1	214.5	Clayey Sand (SC)	54	13	7	n/a	
FU1	94.2	95	213.4	Clayey Sand (SC)	43	6	4	n/a	
FU1	96	97	211.5	Clayey Sand (SC)	77	26	14	n/a	
FU1	97	97.5	210.8	Sand (SP)	72	2	0	2.83	
FU1	97	97.5	210.8	Sand (SP)	81	4	2	n/a	
FU1	99	100.1	208.5	Clayey Sand (SC)	83	14	12	n/a	
FU1	103	103.7	204.7	Clayey Sand (SC)	69	17	6	n/a	
FU1	103.8	104.5	203.6	Clayey Sand (SC)	100	98	63	n/a	
FU1	104.5	105.2	202.9	Fat Clay (CH)	93	66	53	n/a	
FU1	106	107.1	201.5	Fat Clay (CH)	100	98	66	2.62	
FU1	106	107.1	201.5	Fat Clay (CH)	100	97	77	n/a	
FU1	107.2	108.4	200.2	Fat Clay (CH)	83	29	22	n/a	
FU1	109	110.1	198.5	Sandy Clay (CH)	92	67	53	n/a	
FU1	110.2	111.4	197.2	Sandy Clay (CH)	79	41	40	2.65	
FU1	110.2	111.4	197.2	Sandy Clay (CH)	81	42	29	n/a	
FU1	112	113.8	195.1	Sandy Clay (CH)	97	56	37	n/a	
FU1	118	119.1	189.5	Sandy Silt (MH)	97	43	36	n/a	
FU1	119.2	120.4	188.2	Sandy Silt (MH)	98	47	30	n/a	
FU1	130	130.9	177.5	Clayey Sand (SC)	28	4	2.5	2.71	
FU1	130	130.9	177.5	Clayey Sand (SC)	35	8	2	n/a	
FU1	140	140.9	167.6	Clayey Sand (SC)	85	22	8	n/a	
FU1	140.9	142	166.5	Silty Sand (SM)	90	12	7	n/a	
FU1	150	151.5	157.3	Silty Sand (SM)	88	19	10	2.6	
FU1	150	151.5	157.3	Silty Sand (SM)	96	24	8	n/a	

Boring ID	Top Depth (ft bls)	Bottom Depth (ft bls)	Elevation ft msl	Classification	% <0.42 mm	% <0.074 mm	% <0.005 mm	specific gravity	hydraulic conductivity (cm/sec)
FU1	160.4	160.9	147.4	Clayey Sand (SC)-H	97	37	20	n/a	
FU1	160.9	162.2	146.4	Sandy Clay (CH)	97	40	28	2.61	
FU1	160.9	162.2	146.4	Clayey Sand (SC)-H	98	42	27	n/a	
FU1	170	171.1	137.5	Silty Clay (SM)	98	23	11	n/a	
FU1	171.2	172.4	136.2	Clayey Sand (SC)-H	87	35	18	n/a	
FU2	9.3	10.4	300.1	clayey sand (SC)	83	38	32	2.67	5.10E-05
FU2	17	18.2	292.6	clayey sand (SC)	77	23	20	2.66	
FU2	35	36.1	274.6	clayey sand (SC)	81	13	10	2.74	
FU2	50	51.1	259.6	silty sand (SM)	80	18	15	2.67	
FU2	70	71	239.6	Silty Sand (SM)	100	38	15	2.7	
FU2	129.1	130.2	180.5	Clayey Sand (SC)	58	20	8	2.65	
FU3	7	8.2	310.6	sandy clay (CH)	95	68	39	2.72	
FU3	8.3	9.2	309.7	sandy clay (CH)	98	73	46	2.79	
FU3	33.1	34.3	284.7	clayey sand (SC)	91	36	22	n/a	
FU3	49.2	50.2	268.7	clayey sand (SC)	67	13	11	2.67	
FU3	96.2	99.4	219.6	Silty Sand (SM)	85	12	7	2.65	
FU3	109	110.2	208.8	Fat Clay (CH)	99	92	69	2.69	
FU3	118	119.2	199.8	Silty Sand (SM)	79	18	16	2.74	

Notes: table reproduced from original datasheet provided by South Atlantic Division Laboratory on July 16, 1951; notes some samples had duplicates analyzed and therefore have the same depth and elevation information; original datasheet al.so included data regarding Atterberg Limits, shear strength, and consolidation.

Appendix E: Analytical Laboratory Results for DH-4 and DH-5 Boring Samples

Results of laboratory tests by Pittsburgh Testing Laboratory; extracted from John A. Blume & Associates, Engineers (1971); sample no. reflects the boring ID and depth (i.e., 4-53.5 = boring DH-4 and depth 53.5 ft)

PITTSBURGH TESTING LABORATORY

SAVANNAH RIVER PROJECT

7 JUNE 1971 (page 1 of 2)

WORK REQUEST: 860147

SUBJECT: SOIL CLASSIFICATION

REQUESTED BY: R. B. HOWARD

REPORTED TO: A. B. CUNNINGHAM, JOHN A. BLUME & ASSOCIATES.

SAMPLE NO.	% NAT. MOIST.	SIEVE ANALYSIS % PASSING #10	#20	#40	#60	#200	ATTERBERG LIMITS L.L.	P.L.	P.I.	CLASS.
2- 90.0	32.1	98	93	85	63	14	NON - PLASTIC			SM
2-130.0	26.9	97	89	82	73	43	27	18	9	SC
2-150.0	24.8	97	96	93	83	19	NON - PLASTIC			SM
3- 45.0	20.0	100	100	97	81	43	41	24	17	SC
3- 85.0	23.0	100	100	74	26	10	NON - PLASTIC			SP-SM
3- 95.0	25.1	99	89	75	66	30	48	28	20	SM
3-130.0	25.2	99	90	61	34	12	NON - PLASTIC			SW-SM
4- 53.5	14.8	99	87	34	18	7	NON - PLASTIC			SW-SM
4- 58.5	38.8	100	100	100	100	98	85	38	47	MH
4- 78.5	39.2	100	95	76	58	51	67	21	46	CH
4- 98.5	17.1	98	87	38	18	8	NON - PLASTIC			SW-SM
4-108.5	18.8	99	96	92	80	22	27	24	3	SM
4-200.2	49.8	100	100	100	100	98	84	45	39	MH
4-220.0	23.0	100	100	100	98	52	47	35	12	ML

Continuation laboratory test results by Pittsburgh Testing Laboratory; extracted from John A. Blume & Associates, Engineers (1971); sample no. reflects the boring ID and depth (i.e., 4-53.5 = boring DH-4 and depth 53.5 ft)

-2-

WORK REQUEST: 860147

DATE: 7 June 1971

SAMPLE NO.	% NAT. MOIST.	SIEVE ANALYSIS % PASSING #10	#20	#40	#60	#200	ATTERBERG LIMITS L.L.	P.L.	P.I.	CLASS.
5- 35.0	15.0	100	92	64	48	17	28	23	5	SM
5- 94.0	24.0	100	90	50	15	6	NON-PLASTIC			SW-SM
5-112.0	28.0	99	99	98	95	11	NON-PLASTIC			SP-SM
5-144.0	21.0	99	91	62	36	20	NON-PLASTIC			SM

B. Ellis
B. ELLIS, Inspector

PITTSBURGH TESTING LABORATORY
R.C. Brineman
R.C. BRINEMAN, SUPERINTENDENT.

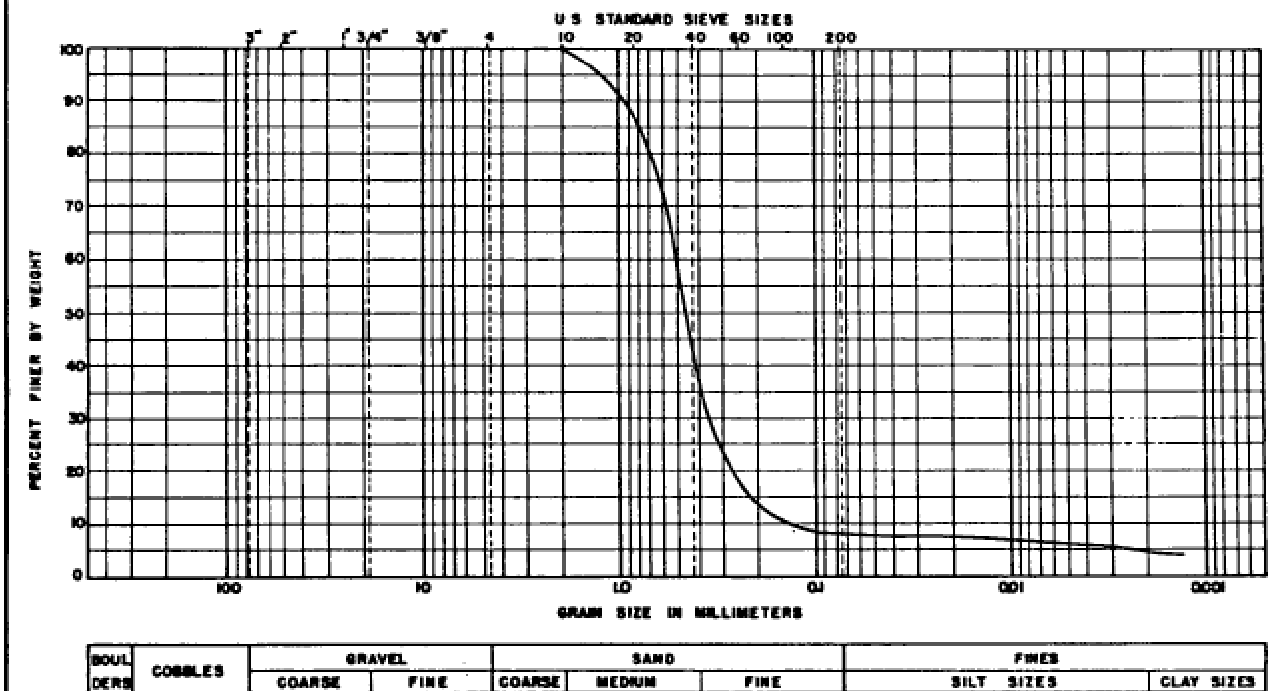
Results of laboratory tests by LAW Engineering Testing Company; Table extracted from John A. Blume & Associates, Engineers (1971)

TABLE 3

SUMMARY OF LABORATORY TEST RESULTS

Bore Hole Sample No.	DH2-55'	DH3-60'	DH4-68.5'	DH5-44.25'	DH5-64'
Unified Soil Classification Sysmol	(CL)	(CL)	(CL)	(ML)	(CH)
Specific Gravity	2.78	2.72	2.75	2.73	2.68
Moisture Content (%)	24.0	16.0	22.6	19.6	48.5
Saturation (%)	89.6	82.0	78.3	82.9	89.3
Void Ratio (e)	0.745	0.531	0.793	0.645	1.454
Unit Dry Weight (pcf)	99.5	110.9	95.8	103.6	68.2
Unconfined Comp. Strength (psi)	30.2	23.9	17.0	10.0	14.5

Grain size distribution for DH-4, sample depth 68.5 ft; analysis performed by LAW Engineering Testing (extracted from John A. Blume & Associates, Engineers 1971)



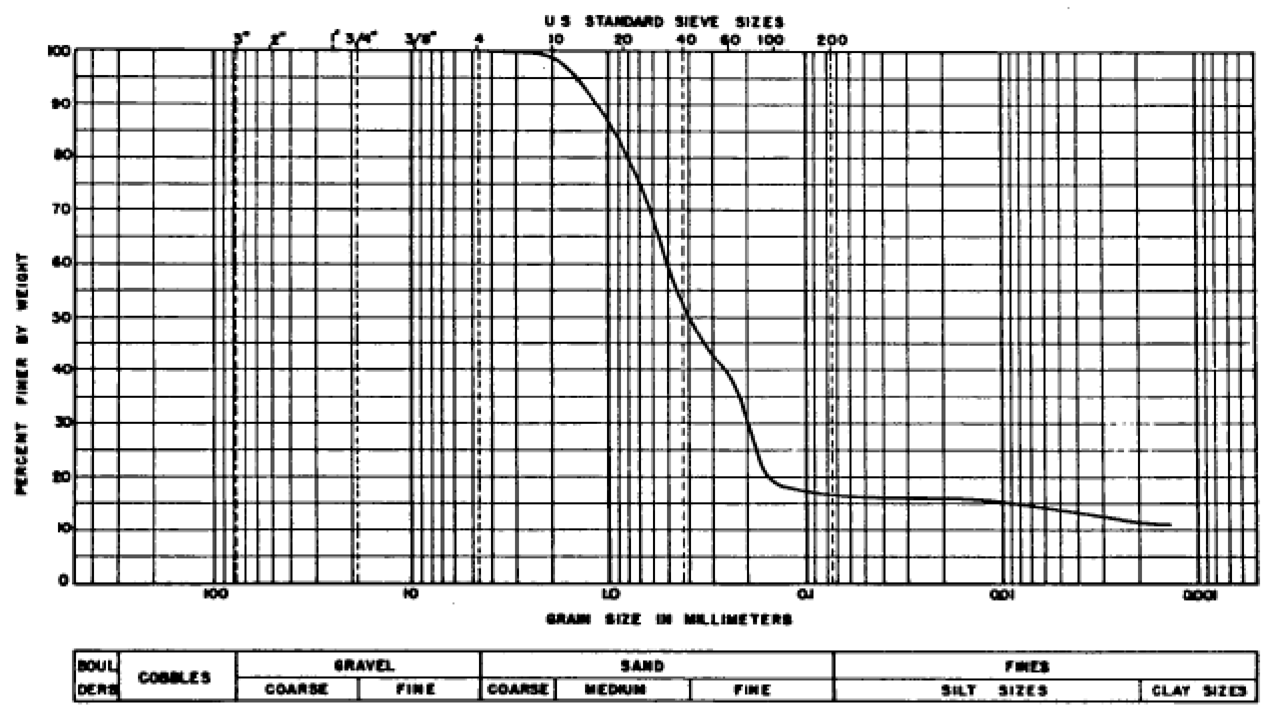
BORING NO	ELEV OR DEPTH	NAT WC	L L	PL	P I	DESCRIPTION OR CLASSIFICATION
DH-4-68.5'	68.5	22.6	55	25	30	Light Brown And Light Tan Medium Sand, Trace Of Clay (CL) Specific Gravity = 2.75

GRAIN SIZE DISTRIBUTI

JOB NO. S-450

LAW ENGINEERING TESTING COMPA

Grain size distribution for DH-5, sample depth 44.25 ft; analysis performed by LAW Engineering Testing (extracted from John A. Blume & Associates, Engineers 1971)



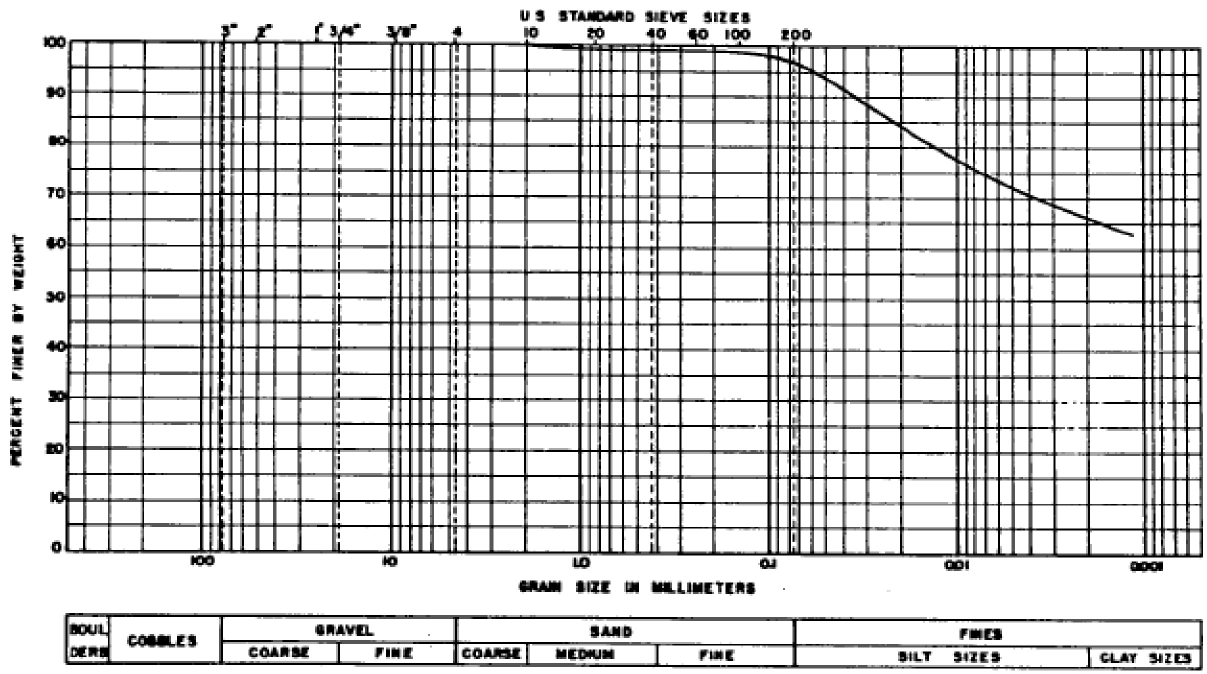
BORING NO	ELEV OR DEPTH	NAT WC	L L	P L	P I	DESCRIPTION OR CLASSIFICATION
DH-44.25	44.25	19.6	44	17	27	Light Brown Slightly Clayey Medium To Fine Sand. (ML) Specific Gravity = 2.73

GRAIN SIZE DISTRIBUTI

JOB NO. S-450

LAW ENGINEERING TESTING COMPAN

Grain size distribution for DH-5, sample depth 64 ft; analysis performed by LAW Engineering Testing (extracted from John A. Blume & Associates, Engineers 1971)



BORING NO	ELEV OR DEPTH	NAT WC	L L	P L	P I	DESCRIPTION OR CLASSIFICATION
H-5-64'	64 BOT	48.5	133	38	95	Tan Clay With Fine Sand Partings (Blocky And Slickensides - heavily Over Consolidated) (CH) Specific Gravity = 2.68

GRAIN SIZE DISTRIBUTION

JOB NO. S-450

LAW ENGINEERING TESTING COMPANY

Appendix F: Drilling Log for Boring DH-4

(extracted from John A. Blume & Associates, Engineers 1971)

DRILL HOLE LOG No. OH-4 **FEATURE** F-AREA, TANKS #1 THRU #3

LOCATION N77000 E 53190 — DATE STARTED 4-26-71

LOGGED BY FRED H. TUTTLE — DATE FINISHED 5-6-71

SURFACE ELEV. 274.2' DATUM M.S.L.

DEPTH (FEET)	DESCRIPTION	REMARKS
0–10	Silty fine to medium sand (80% sand 20% fines), quartz sand w/ scattered mica, red (2.5 YR 5.6), moist, medium dense, no cementation, poorly graded, mottled color w/ purple and yellow brown pieces to 1/2" - 1' clay layer at 4.5', scattered quartz gravel to 1/2".	
10–30		Drilling w/4" auger - "AW" rod to 30'.
20–24	Alternate clayey and silty sand layers w/clean quartz fine to medium sand layer 1 1/2" thick at 19.7'	
25–29	Mottled from 3.5' 33.5' indicating fill material. Colors are spots purple and yellow brown to 1/2" diam.	Difficult to return cuttings w/ auger
30–35		Started drilling w/water and mixing "mud", 3 7/8" tricone bit used - 25-30 gal. to fill hole, (baroid - "Quick Gel" mixed w/water)
36–37		Approximate depth of base of tanks.
38–44	Tip of Shelby: silty fine to medium sand (85% sand 15% Fines) quartz sand yellowish brown (10 YR 6/8) moist no cementation, poorly graded fine to coarse sand w/fines (95% sand 5% fines) sand-subangular to subrounded (SM)	Hard drilling - 7 minutes possibly sand and gravel at base of tanks 1 gal/foot loss in mud

DEPTH	SAMPLE NUMBER
	3.5
5	
	8.5
10	
	13.5
15	
	18.5
20	
	23.5
25	
	28.5
30	
	33.5
35	
	38.5
40	
	43.5

INTERVAL SAMPLED — INTERVAL CORED

DRILL HOLE LOG No. DH-4 **FEATURE** F-AREA, TANKS #1 THRU #8

LOCATION N 77000 E 53190 **DATE STARTED** 4-26-71

LOGGED BY FRED H. TUTTLE **DATE FINISHED** 5-6-71

SURFACE ELEV. 274.2' **DATUM** M.S.L.

DEPTH (FEET)	DESCRIPTION	REMARKS	SAMPLE NUMBER
		Drilling w/"mud"	
50	Tip Shelby: Clean fine to medium sand yellow, (2.5 Y 7/8), dense, quartz sand, moist, sand sub-angular to subrounded (SM)		48.5
55	Very dense - same material with silt reddish yellow (7.5 YR 7/6) (SM)		53.5
60	Tip Shelby tube: silt, light gray, (5 Y 7/2)		58.5
65	Grading light red 10 R 6/8 clay (CL)		63.5
	Sandy clay, mottled light red, white and moderate reddish orange, 10% fine sand, moist, stiff (SC)		
70	Tip of Shelby tube: fine to medium sand with clay - 95% sand, 5% clay, yellow (10 YR 7/6)		68.5
75	Grading to clayey sand with lenses of clay - light gray with orange specks (SC)		73.5
80	Light gray clay with streaks of fine to medium sand (CH)		78.5
85	Grading to sandy clay 85% clay, 15% fine to medium sand light gray, very dense		83.5
	Grading to clayey sand, 85% sand 15% clay, moist, medium dense (SC)		88.5

Page 2 of 6

DRILL HOLE LOG No. OH-4 **FEATURE** F-AREA, TANKS #1 THRU #8

LOCATION N 77000 E 53190 **DATE STARTED** 4-26-71

LOGGED BY FRED H. TUTTLE **DATE FINISHED** 5-6-71

SURFACE ELEV. 274.2' **DATUM** M.S.L.

DEPTH (FEET)	DESCRIPTION	REMARKS	SAMPLE NUMBER
95			
100	Fine to medium sand with silt, angular-subangular quartz, yellow, (10 YR 7/6), wet, very dense (SW-SM)		98.5
105		Continuous medium fast drilling	
110	Silty sand, highly weathered feldspar with fine quartz sand remaining, sand 80%, silt 20%, pale yellow (5 Y 7/4), very dense (SM)		108.5
115	Tip at 109.2': calcium carbonate in small flakes to form hard lime material.	Continuous medium slow drilling	
120	Fine sand with silt, sand 90% silt 10% pale yellow (2.5 Y 7/4), dense, small dark yellow specks scattered throughout (SM)	Possibly shells in cuttings (small hard white pieces) Medium fast drilling w/zones (6") of slow drilling	118.5
125	Grading fine to coarse sand, olive yellow (5 Y 6/6) (SM)		
130			128.5

INTERVAL SAMPLED / INTERVAL CORED

DRILL HOLE LOG No. DH-4 **FEATURE** F-AREA, TANKS #1 THRU #8

LOCATION N 77000 E 53190 **DATE STARTED** 4-26-71

LOGGED BY FRED H. TUTTLE **DATE FINISHED** 5-6-71

SURFACE ELEV. 274.2' **DATUM** M.S.L.

DEPTH (FEET)	DESCRIPTION	REMARKS	SAMPLE NUMBER
140	Silty fine sand, 80% sand - 20% silt, black (5 Y 3/1) (SM)		138.5
145		1/4 bag of drilling mat'l. used to this depth	
150	Silty fine to medium sand 85% sand 15% silt, black (5 Y 3/1) very dense, moist-wet (SM)		148.5
155	Calcareous material in cuttings.	Struck hard drilling at 151.5' very strong reaction of cuttings to HCl Penetrated rock on 4-28-71 with fishtail bit. Returned on 4-29-71 with 4 5/8 tricone bit. 152.5 to 153.5' fast and slow penetration alternating 3"-4" layers.	
160	Fine to medium sand with silt reddish yellow (7.5 YR 6/8), quartz, moist, very dense, (SM)		158.5
165	Clay, light gray (5 Y 7/1), laminated, hard, moist, 2" thick.	2:00 pm. Put 3 5/8" tricone bit on 7' section of drill stem to ream hole for casing to 5:20	
170	Fine to medium sand with silt	166' Secured from sampling	168.5
175			

Page 4 of 6

DRILL HOLE LOG No. DH-4 **FEATURE** F-AREA, TANKS #1 THRU #8

LOCATION N77000 E53190 **DATE STARTED** 4-26-71

LOGGED BY FRED H. TUTTLE **DATE FINISHED** 5-6-71

SURFACE ELEV. 274.2' **DATUM** M.S.L.

DEPTH (FEET)	DESCRIPTION	REMARKS	SAMPLE NUMBER
185			185
190	Fine to medium sand with silt, angular to rounded, quartz, yellow (10 YR 7/8), wet, very dense. (SW)	Dropped 150' of drilling rods in hole when returning to bottom w/ bit at 4:45 pm. 5/3/71 - Hole squeezed in below 90' over weekend. Rods were drilled in below 110'. Reached bottom at 10:00 am.	190 190
195		Drilled w/moderate penetration rate between 190' and 200' using 3 5/8" tricone bit	195
200	Silt, dark gray (5 Y 4/1), moist, laminated, (MH) with layers of fine to medium sand, clean, quartz, gray (10 YR 6/1), wet, very dense.	Change (possibly gravel) 204-204.5 slow drilling - no indication in cuttings other than medium quartz sand. Medium slow drilling	200 200
205			205
210	Fine to medium sand, clean, quartz, gray (7.5 YR 6/0), moist, very dense	Medium fast drilling	210 210
215			215
220	Blue gray clay on tip of bit Sandy silt, micaceous light gray (10 YR 7/1) moist, hard, 20% fine sand 80% silt (ML).		220 220

INTERVAL SAMPLED | INTERVAL CORED

DRILL HOLE LOG No. DH-4 FEATURE F-AREA, TANKS #1 THRU #8
LOCATION N 77000 E 53190 DATE STARTED 4-26-71
LOGGED BY FRED H. TUTTLE DATE FINISHED 5-6-71
SURFACE ELEV. 274.2' DATUM M.S.L.

DEPTH (FEET)	DESCRIPTION	REMARKS	SAMPLE NUMBER
		Relatively easy drilling	
		Medium hard drilling	
230	Fine to medium sand with silt, mica and quartz, gray (7.5 YR 6/0), moist, very dense		230
235		Slow Drilling	
		Very slow drilling	
240		Cleaned tub. Broke water pump drive chain at 1105	
245			
		Finish drilling hole 11:57 am.	
250	250' bottom of hole. Sufficient information obtained. Places Nx casing.	5-4-71 Started placing casing at 1:20 pm - 30' stopped falling freely - 30'-60' up-down w/no extra weight. 60'-80' use hydraulic rams - driving below 80' w/350# drop hammer - 18'' drop	

Appendix G: Logs for P28TA

From Bledsoe (1988); lithologic log for P28TA

LITHOLOGIC LOG, P28(TA)

Depth (ft.)	Thickness (ft.)	Description
0 - 1	1	No recovery
1 - 2	1	Sand, fine; well sorted; heavy minerals; brown; F-B-2
2 - 8	6	Sand, fine, silty; well sorted; heavy minerals, lignite; brown to tan; F-Y-2(2 - 5)
8 - 11	3	No recovery
11 - 16	5	Sand, fine, clayey; poorly sorted; heavy minerals; dark red to dark reddish yellow; F-B-1(11)
16 - 19	3	Clay; well sorted; muscovite; red brownish yellow to tan reddish brown
19 - 26	7	Clay, silty; well sorted; heavy minerals; muscovite; dark tan pinkish white to light brownish red
26 - 30	4	Sand, fine, clayey; poor to moderately sorted; muscovite; light brown reddish white
30 - 32	2	Sand, fine, silty, clayey; moderately sorted; muscovite; dark brown reddish white
32 - 38	6	Sand, fine, silty; moderate to well sorted; muscovite; light brownish white to light brownish yellow; F-O-1(37)
38 - 40	2	Sand, fine, silty clayey; well sorted; heavy minerals; muscovite; feldspar; light brown reddish yellow
40 - 46	6	Sand, fine to coarse, silty; moderately sorted; dark yellowish brown to dark reddish brown
46 - 49	3	Sand, coarse; well sorted; dark reddish brown
49 - 50	1	Sand, coarse, silty, clayey; moderately sorted; mottled; muscovite; dark red brownish tan
50 - 51	1	Sand, medium, clayey; moderately sorted; mottled; muscovite; dark red brownish tan
51 - 52	1	Sand, fine, silty, clayey; poorly sorted; mottled; muscovite; dark red brownish tan
52 - 53	1	Sand, fine, clayey; poorly sorted; heavy minerals; brown tannish white
53 - 55	2	Sand, fine, silty; poorly sorted; brownish tan to tannish orange

LITHOLOGIC LOG, P28(TA)

Depth (ft.)	Thickness (ft.)	Description
55 - 56	1	No recovery
56 - 62	6	Sand, fine, silty; very poorly sorted; heavy minerals; light brownish tan; F-O-1(60 - 61)
62 - 66	4	Sand, fine, silty, clayey; well to moderately sorted; heavy minerals; light brownish tan to light brown orangish yellow
66 - 70	4	Sand, fine to medium; poorly sorted; heavy minerals, muscovite; orangish yellow to brown orangish yellow; F-O-1(67)
70 - 71	1	Sand, medium, clayey; moderately sorted; heavy minerals, muscovite, lignite; brown orangish tan
71 - 72	1	Clay; moderately sorted; heavy minerals; muscovite; lignite; light brownish tan
72 - 73	1	Clay, sandy; moderately sorted; lignite; light brown; F-Y-1
73 - 75	2	Clay; well sorted; heavy minerals; muscovite; lignite; light brownish tan
75 - 78	3	Clay, sandy; moderately sorted; interbedded clay; mottled; lignite; light brown
78 - 80	2	Sand, medium, silty, clayey; well sorted; lignite; light brown; F-O-1
80 - 94	14	Sand, medium; silty; well sorted; muscovite, lignite; light brownish tan to light brownish orange; F-B-1(83), F-O-1 (87)
94 - 96	2	Sand, medium, silty, clayey; well sorted; muscovite; lignite; light brownish orange; F-O-1
96 - 98	2	Sand, medium, silty; well sorted; muscovite; lignite; light brownish tan; F-B-1(97)
98 - 102	4	Sand, coarse; well sorted; muscovite; lignite; light grayish tan; F-O-1(99, 103)
102 - 105	3	Sand, medium, silty; well sorted; lignite; light grayish tan; F-O-1(102 - 103)
105 - 107	2	Sand, medium, silty; clayey; well sorted; heavy minerals; muscovite; lignite; light grayish tan
107 - 108	1	Sand, medium, clayey; well sorted; heavy minerals; muscovite; lignite; light brown

Foot-by-foot core description performed by SAIC for P28TA core

SRS CORE LOG SHEET

LOGGED BY: SP Conner, SAIC   DATE: 16/11/92   PAGE 1 OF 34

WELL LJ	WELL RJ	WELL LJ	DEPTH	RECOV	INDUR	COLOR	STRUCTURE	SILICATE =100% %GR	SILICATE %SD	SILICATE %MD	SIZE MX	SIZE MD	RND	CARBONATE =100% %GR	CARBONATE %SD	CARBONATE %MD	%CMT	%CAR	NAME	SORT	%POR	PORE TYPE	%MUSC	%GLAU	%LIGN	%SULP	HEAV	FOSSILS
1–3	4–6	7–8	9–12	13	14	15–19	20–27	28–29	30–31	32–33	34–35	36–37	38	39–40	41–42	43–44	45–46	47–48	49–56	57	58–59	60–61	62–63	64–65	66–67	68–69	70	71–80
P	Ø28	TA	1	0																								
			2		1	DGY	MTYEGYRT	0	90	10	VC	M	4					0	SD	M	G	BP	0	0	.1	0	C	
			3		1	DGY	RTMTDGY	0	90	10	VC	M	4					0	SD	M	G	BP	0	0	.1	0	C	
			4	6	1	DGY	RTMTDTA	0	90	10	VC	M	4					0	SD	M	G	BP	0	0	.1	0	C	
			5	5	1	MYEGY		0	92	8	VC	M	4					0	SD	M	G	BP	0	0	.1	0	C	
			6		1	MYEGY		0	94	6	VC	M	4					0	SD	M	G	BP	0	0	.1	0	C	
			7		1	MGYOR	VARLBRRT	0	94	6	VC	M	3					0	SD	M	G	BP	0	0	.1	0	A	
			8		1	MGYOR	VARLBRRT	.1	94	6	GR	M	3					0	SD	M	G	BP	0	0	.1	0	A	
			9	0																								
			10	0																								
			11	0																								
			12		2	MOR	MTGYORRT	0	80	20	VC	M	4					0	SD	P	M	BP	0	0	.1	0	C	
			13		2	MOR	MTDYEOR	.1	80	20	GR	F	4					0	SD	P	M	BP	0	0	0	0	C	
			14		2	MOR	WSPCL	.1	85	15	GR	F	4					0	SD	M	G	BP	0	0	0	0	C	
			15		2	MOR	WSPCL	1	79	20	GR	F	4					0	SD	P	M	BP	0	0	0	0	C	
			16		2	MOR	FE	1	79	20	LP	M	4				.1	0	SD	P	M	BP	0	0	0	0	C	
			17		2	MTDYE	WSPLRE	.1	25	75	GR	CL	3					0	SDCL	P	P	MI	1	0	0	0	C	
			18		2	MTDYE	WSPMRE	.1	35	65	GR	CL	3					0	SDCL	P	P	MI	1	0	0	0	C	
			19		2	MTDYE	CLBWSPWH	10	55	35	LP	F	3					0	CLSD	P	P	BP	1	0	0	0	C	
			20		2	MTDYE	CLBWSPWH	10	65	25	LP	F	3					0	CLSD	P	M	BP	1	0	0	0	C	
			21		2	MYEOR	WSPWH	0	80	20	VC	M	3					0	SD	M	G	BP	1	0	0	0	C	
			22		2	MYEOR	WSPWH	0	85	15	VC	M	3					0	SD	M	G	BP	1	0	0	0	C	
			23		2	DYEOR	WSPWH	0	85	15	VC	M	3					0	SD	M	G	BP	1	0	0	0	A	
			24		2	DYEOR	WSPWH	0	80	20	VC	F	3					0	SD	P	M	BP	1	0	0	0	A	
P	Ø28	TA	25		2	DYEOR	CLBWSPNH	10	75	15	LP	F	3					0	SD	P	M	BP	1	0	0	0	A	

CORE: WET ☐ DRY ☒

LOGGED BY: SPConner, SAIC DATE: 13/11/92

SRS CORE LOG SHEET

PAGE 2 OF 34

WELL LJ	WELL RJ	WELL LJ	DEPTH	RECOV	INDUR	COLOR	STRUCTURE	SILICATE =100% %GR	SILICATE %SD	SILICATE %MD	SIZE MX	SIZE MD	RND	CARBONATE =100% %GR	CARBONATE %SD	CARBONATE %MD	%CMT	%CAR	NAME	SORT	%POR	PORE TYPE	%MUSC	%GLAU	%LIGN	%SULP	HEAV	FOSSILS
1 2 3	4 5 6	7 8	9 10 11 12	13	14	15 16 17 18 19	20 21 22 23 24 25 26 27	28 29	30 31	32 33	34 35	36 37	38	39 40	41 42	43 44	45 46	47 48	49 50 51 52 53 54 55 56	57	58 59	60 61	62 63	64 65	66 67	68 69	70	71 72 73 74 75 76 77 78 79 80
P	Ø28	TA	26		2	LREPU	WSPWHBOR	1	79	20	GR	F	3					0	SD	P	M	BP	1	0	0	0	C	
			27		2	DYEOR	WSPWHBPU	.1	80	20	GR	M	3					0	SD	P	M	BP	1	0	0	0	C	
			28		2	DYEOR	WSPWHBPU	.1	80	20	GR	M	3					0	SD	P	M	BP	1	0	0	0	C	
			29		2	LREPU	BORBWH	1	84	15	GR	M	3					0	SD	M	G	BP	1	0	0	0	C	
			30		2	LREPU	BORBWH	.1	85	15	GR	M	3					0	SD	M	G	BP	1	0	0	0	C	
			31		2	LREPU	BYEORBWH	.1	80	20	GR	M	3					0	SD	P	M	BP	1	0	0	0	A	
			32		2	MYEOR	BLREBWH	.1	80	20	GR	M	3					0	SD	P	M	BP	1	0	0	0	A	
			33		2	MYEOR	BLREBWH	.1	85	15	GR	M	3					0	SD	M	G	BP	1	0	0	0	A	
			34		2	MYEOR	CLBBWH	.1	85	15	GR	M	3					0	SD	M	G	BP	1	0	0	0	A	
			35		2	MYEOR	VARREBWH	.1	85	15	GR	C	3					0	SD	M	G	BP	.1	0	0	0	A	
			36	0																								
			37		2	MYEOR	VARREBWH	.1	85	15	GR	C	3					0	SD	M	G	BP	.1	0	0	0	C	
			38		2	MYEOR	RWH	1	84	15	GR	M	3					0	SD	M	G	BP	.1	0	0	0	C	
			39		2	MYEOR	VARREBWH	.1	85	15	GR	M	3					0	SD	M	G	BP	1	0	0	0	C	
*			40		2	MYEOR	VARREBWH	.1	85	15	GR	M	3					0	SD	M	G	BP	1	0	0	0	A	
*			41		2	MTLRE	BWH	0	85	15	VC	M	4					0	SD	M	G	BP	.1	0	0	0	C	
			42		2	DYEOR	MTLBR	.1	85	15	GR	C	4					0	SD	M	G	BP	0	0	0	0	C	
			43		2	DYEOR	BWH	.1	85	15	GR	C	4					0	SD	M	G	BP	0	0	0	0	R	
			44		2	MRE	BDYEOR	.1	85	15	GR	C	4					0	SD	M	G	BP	0	0	0	0	R	
			45		2	MTMRE		.1	90	10	GR	C	4					0	SD	M	G	BP	0	0	0	0	R	
			46		2	MTMRE		.1	85	15	GR	C	4					0	SD	M	G	BP	0	0	0	0	R	
			47		2	MTMRE		1	79	20	GR	C	4					0	SD	P	M	BP	0	0	0	0	R	
			48		2	MTMRE		2	83	15	GR	C	4					0	SD	M	G	BP	0	0	0	0	R	
			49		2	MTMRE		0	85	15	VC	C	4					0	SD	M	G	BP	0	0	0	0	R	
P	Ø28	TA	50		2	MTMRE		.1	80	20	GR	C	3					0	SD	P	M	BP	0	0	0	0	R	

CORE: WET ☐ DRY ☒

SRS CORE LOG SHEET

LOGGED BY: SPConner, SAIC DATE: 13/11/92 PAGE 3 OF 34

	WELL LJ	WELL RJ	WELL LJ	DEPTH	RECOV	INDUR	COLOR	STRUCTURE	SILICATE =100% %GR	SILICATE =100% %SD	SILICATE =100% %MD	SIZE MX	SIZE MD	RND	CARBONATE =100% %GR	CARBONATE =100% %SD	CARBONATE =100% %MD	%CMT	%CAR	NAME	SORT	%POR	PORE TYPE	%MUSC	%GLAU	%LIGN	%SULP	HEAV	FOSSILS
	P	Ø28	TA	51		2	MTMRE	WSPCL	1	74	25	GR	M	3					0	CLSD	P	M	BP	0	0	0	0	C	
				52		2	MPIRE	MTDYEOR	.1	80	20	GR	M	3					0	SD	P	M	BP	0	0	0	0	C	
*				53		2	DYEOR	MTMPIRE	.1	80	20	GR	M	3					0	SD	P	M	BP	0	0	0	0	C	
				54		2	LGYOR	BDYEOR	.1	85	15	GR	M	3					0	SD	M	G	BP	0	0	0	0	C	
				55	8	2	LGYOR	MTDYEOR	.1	90	10	GR	M	3					0	SD	M	G	BP	0	0	0	0	C	
				56	0																								
				57		1	GYOR	MTDYEOR	2	83	15	LP	C	3					0	SD	M	G	BP	0	0	0	0	C	
				58		2	LGYOR	MTDYEOR	3	87	10	LP	C	3					0	SD	M	G	BP	0	0	0	0	C	
				59		2	LGYOR	MTDYEOR	3	87	10	LP	M	3					0	SD	M	G	BP	0	0	0	0	C	
				60		2	LGYOR	BDYEOR	2	88	10	GR	M	3					0	SD	M	G	BP	0	0	0	0	C	
				61		2	MGYOR	BDYEOR	1	89	10	GR	M	3					0	SD	M	G	BP	0	0	0	0	C	
				62		2	MGYOR	BDYEOR	.1	90	10	GR	M	3					0	SD	M	G	BP	0	0	0	0	C	
				63		2	DYEOR		.1	85	15	LP	M	3					0	SD	M	G	BP	.1	0	0	0	C	
				64		2	DYEOR		.1	85	15	LP	M	3					0	SD	M	G	BP	.1	0	0	0	C	
				65		2	DYEOR		1	84	15	GR	M	3					0	SD	M	G	BP	0	0	0	0	C	
				66		2	DYEOR		1	89	10	LP	M	3					0	SD	M	G	BP	0	0	0	0	C	
				67		2	DYEOR		2	88	10	LP	M	3					0	SD	M	G	BP	0	0	0	0	C	
				68		2	DYEOR		.1	90	10	GR	M	3					0	SD	M	G	BP	0	0	0	0	R	
				69		2	MGYOR	WSPWH	2	83	15	LP	M	3					0	SD	M	G	BP	0	0	0	0	C	
				70		2	DYEOR	WSPCL	1	84	15	LP	C	3					0	SD	M	G	BP	0	0	0	0	C	
*				71		2	DYEOR	WSPBK	4	81	15	LP	M	4				.1	0	SD	P	G	BP	.1	0	0	0	C	
				72		3	MYEOR	ISDBBK	.1	40	60	GR	CL	4				1	0	SDCL	V	P	MI	1	0	0	0	C	
				73		3	LYEOR	ISDBBK	.1	45	55	GR	CL	4				1	0	SDCL	V	P	MI	1	0	0	0	C	
				74		3	DYEOR	ICLSDBBK	.1	40	60	GR	CL	4				2	0	SDCL	V	P	MI	1	0	0	0	C	
*	P	Ø28	TA	75		2	LYEBR	IDYEORCL	2	45	53	GR	CL	4				1	0	SDCL	V	P	MI	1	0	0	0	C	

CORE: WET ☐ DRY ☒

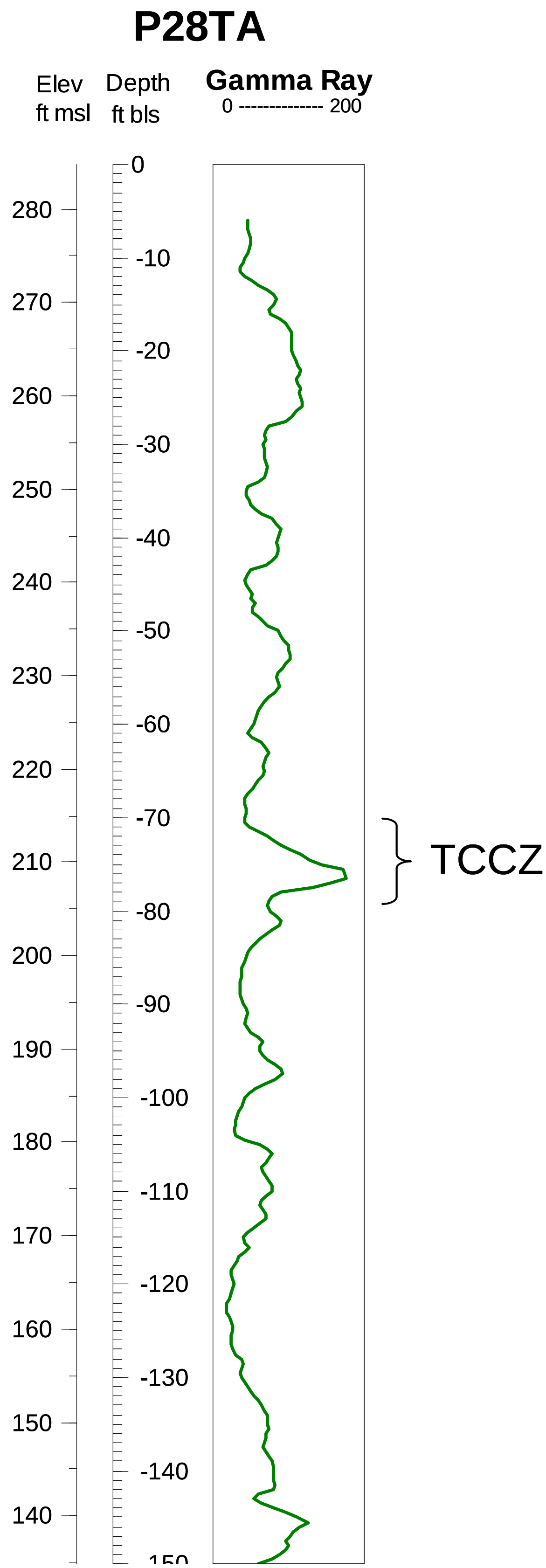
SRS CORE LOG SHEET

LOGGED BY: SP Conner, SAIC DATE: 13/11/92 PAGE 4 OF 34

	WELL LJ	WELL RJ	WELL LJ	DEPTH	RECOV	INDUR	COLOR	STRUCTURE	SILICATE %GR	SILICATE %SD	SILICATE %MD	SIZE MX	SIZE MD	RND	CARBONATE %GR	CARBONATE %SD	CARBONATE %MD	%CMT	%CAR	NAME	SORT	%POR	PORE TYPE	%MUSC	%GLAU	%LIGN	%SULP	HEAV	FOSSILS
*	P	Ø28	TA	7.6		2	DYEOR	WSPBKBOR	1	84	15	GR	M	4				1	0	SD	M	G	BP	.1	0	0	0	R	
*				7.7		2	MYEBR	BWHWSPBK	1	84	15	LP	M	4				.1	0	SD	M	G	BP	.1	0	0	0	R	
				7.8		2	MYEBR	WSPDORCL	.1	80	20	LP	M	4				.1	0	SD	M	G	BP	.1	0	0	0	C	
				7.9		2	MGYOR	BDYEOR	.1	85	15	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				8.0		2	MGYOR	WSPORCL	.1	85	15	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				8.1		2	MBROR	BMBR	1	84	15	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				8.2		2	MBROR	BMBR	1	89	10	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				8.3		2	MGYOR	WSPBK	0	90	10	VC	C	4				.1	0	SD	M	G	BP	.1	0	0	0	C	
				8.4		2	MGYOR	BBK	.1	90	10	GR	C	4				.1	0	SD	M	G	BP	.1	0	0	0	C	
				8.5		2	MGYOR	WSPBK	.1	85	15	GR	C	4				.1	0	SD	M	G	BP	.1	0	0	0	C	
				8.6		2	MGYOR	WSPBK	.1	85	15	GR	C	4				.1	0	SD	M	G	BP	.1	0	0	0	C	
				8.7		2	MYEOR		.1	90	10	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				8.8		2	MYEOR		0	92	8	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				8.9		2	MOR		.1	92	8	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				9.0		2	MOR		0	92	8	VC	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				9.1		2	MOR	WSPBK	1	89	10	GR	M	4				.1	0	SD	M	G	BP	.1	0	0	0	C	
				9.2		2	MOR		1	84	15	GR	M	4					0	SD	M	G	BP	.1	0	0	0	C	
				9.3		2	DYEOR		2	83	15	GR	M	4					0	SD	M	G	BP	0	0	0	0	C	
				9.4		2	DYEOR	WSPGYOR	2	83	15	GR	M	4					0	SD	M	G	BP	0	0	0	0	C	
				9.5		2	MORBR	WSPBK	2	83	15	LP	M	4				1	0	SD	M	G	BP	0	0	0	0	A	
				9.6		2	MYEBR		2	88	10	LP	M	4					0	SD	M	G	BP	0	0	0	0	C	
				9.7		2	LGYOR	WSPBKBWH	.1	90	10	GR	C	4				1	0	SD	M	G	BP	0	0	0	0	C	
				9.8		2	LGYOR	BWHWSPBK	.1	92	8	GR	C	4				1	0	SD	M	G	BP	0	0	0	0	C	
*				9.9		2	LGYOR	IMORPISD	1	91	8	GR	C	3				.1	0	SD	M	G	BP	0	0	0	0	C	
*	P	Ø28	TA	10.0	6	2	LGYOR		.1	94	6	GR	C	3				.1	0	SD	M	G	BP	0	0	0	0	C	

CORE: WET ☐ DRY ☒

Gamma log for P28TA



Appendix H: Summary of Laboratory Results from SGS Characterization Borings in F-Area

Undisturbed Vadose Zone Samples

Location ID	Ground Surface Elev	Top Sample Elev (ft msl)	Bottom Sample Elev (ft msl)	Top Sample Depth (ft bls)	Bottom Sample Depth (ft bls)	% Gravel (>4.5 mm)	% Sand (4.5 – 0.074 mm)	% Mud (Silt + Clay) (<0.074 mm)	% Clay size*	USCS	Dry Density (pcf)	Liquid Limit	Plasticity Index
FESPB6	284	268.5	267	15.5	17	0	81	19	--	Clayey Sand (SC)	--	30	12
FESPB6	284	230	228.5	54	55.5	0.2	85.7	14.1	8.8	Silty Sand (SM)	117.1	--	NP
FTNKB3	285.5	244	242.5	41.5	43	0	82.3	17.7	--	Silty Sand (SM)	--	--	NP
FTNKB3	285.5	242.5	241	43	44.5	0	85.2	14.8	11.2	Silty Sand (SM)	--	--	NP
FTNKB8	269.5	263.5	262	6	7.5	0.8	83.4	15.8	--	Silty Sand (SM)	--	--	NP
FTNKB8	269.5	262	260	7.5	9.5	0	76.3	23.7	14.6	Silty Sand (SM)	102.7	--	NP
FTNKB8	269.5	258.5	257	11	12.5	0	81.4	18.6	--	Silty Sand (SM)	--	--	--
FTNKB8	269.5	252	250.5	17.5	19	0	72.3	27.7	23.1	Clayey Sand (SC)	--	37	20
FTNKB8	269.5	247.5	246	22	23.5	0	83.8	16.2	--	Silty Sand (SM)	--	--	NP

Location ID	Ground Surface Elev	Top Sample Elev (ft msl)	Bottom Sample Elev (ft msl)	Top Sample Depth (ft bls)	Bottom Sample Depth (ft bls)	% Gravel (>4.5 mm)	% Sand (4.5 – 0.074 mm)	% Mud (Silt + Clay) (<0.074 mm)	% Clay size*	USCS	Dry Density (pcf)	Liquid Limit	Plasticity Index
FTNKB8	269.5	244.5	243	25	26.5	0	87.4	12.6	--	Silty Sand (SM)	--	--	NP
FTNKB8	269.5	241.5	240	28	29.5	0	84.5	15.5	12.1	Silty Sand (SM)	--	--	NP
FTNKB8	269.5	237	237	32.5	32.5	0	85.8	14.2	--	Silty Sand (SM)	--	32	8
FTNKB8	269.5	234	232.5	35.5	37	0	90.9	9.1	6.5	Poorly Graded Sand with Silt (SP-SM)	--	--	NP
FTNKB8	269.5	231	229.5	38.5	40	0.2	93.9	5.9	--	Poorly Graded Sand with Silt (SP-SM)	--	--	--
FTNKB8	269.5	226.5	225	43	44.5	0	95.7	4.3	2.1	Poorly Graded Sand (SP)	--	--	NP
FTNKB13	279.13	248.13	246.63	31	32.5	0	78.7	21.3	--	Clayey Sand (SC)	--	36	14

Location ID	Ground Surface Elev	Top Sample Elev (ft msl)	Bottom Sample Elev (ft msl)	Top Sample Depth (ft bls)	Bottom Sample Depth (ft bls)	% Gravel (>4.5 mm)	% Sand (4.5 – 0.074 mm)	% Mud (Silt + Clay) (<0.074 mm)	% Clay size*	USCS	Dry Density (pcf)	Liquid Limit	Plasticity Index
FTNKB13	279.13	242.13	240.63	37	38.5	0	85.8	14.2	--	Silty Sand (SM)	--	29	4
FTNKB13	279.13	237.63	236.13	41.5	43	0	90.9	9.1	--	Poorly Graded Sand with Silt (SP-SM)	--	--	NP
FTNKB13	279.13	233.13	231.63	46	47.5	0	88.8	11.2	--	Poorly Graded Sand with Silt (SP-SM)	--	--	NP
FTNKB16	282.7	238.7	237.2	44	45.5	0	90.1	9.9	--	Poorly Graded Sand with Silt (SP-SM)	--	--	NP
FTNKB20	268.7	224.2	222.7	44.5	46	0	80.6	19.4	16.5	Clayey Sand (SC)	--	35	14

Notes: Elev = elevation; ft bls = feet below land surface; ft msl; feet from mean sea level; pcf = pounds per cubic foot; % mud includes silt and clay size fraction; %clay size* = % silt and % clay were analyzed for selected samples and so % clay is specified in addition to % mud; USCS = Unified Soil Classification System; NP = nonplastic; analyses conducted by LAW Engineering, Inc; for original laboratory results, refer to WSRC-TR-96-0069, volume 4 (Site Geotechnical Services Department 1996)

Structural Fill Samples

Location ID	Ground Surface Elev	Top Sample Elev (ft msl)	Bottom Sample Elev (ft msl)	Top Sample Depth (ft bls)	Bottom Sample Depth (ft bls)	% Gravel (>4.5 mm)	% Sand (4.5 – 0.074 mm)	% Mud (Silt + Clay) (<0.074 mm)	% Clay size*	USCS	Dry Density (pcf)	Liquid Limit	Plasticity Index
FTNKB3	285.5	278	276.5	7.5	9	0.9	63.7	35.4	28.4	Clayey Sand (SC)	--	37	22
FTNKB3	285.5	273.5	272	12	13.5	0.2	77.9	21.9	--	Silty Sand (SM)	--	--	NP
FTNKB3	285.5	269	267.5	16.5	18	0	78.1	21.9	17	Clayey Sand (SC-SM)	--	26	7
FTNKB3	285.5	263	261.5	22.5	24	0	84.1	15.9	--	Clayey Silty Sand (SC-SM)	--	23	6
FTNKB3	285.5	258	256.5	27.5	29	0	85.2	14.8	--	Clayey Sand (SC)	106.9	29	9
FTNKB3	285.5	256	254.5	29.5	31	0	77	23	--	Clayey Sand (SC)	--	27	11
FTNKB3	285.5	251.5	250	34	35.5	0	78	22	16.9	Clayey Sand (SC)	--	27	13
FTNKB3	285.5	248.5	248.5	37	37	0	79.3	20.7	--	Silty Sand (SM)	--	--	NP

Location ID	Ground Surface Elev	Top Sample Elev (ft msl)	Bottom Sample Elev (ft msl)	Top Sample Depth (ft bls)	Bottom Sample Depth (ft bls)	% Gravel (>4.5 mm)	% Sand (4.5 – 0.074 mm)	% Mud (Silt + Clay) (<0.074 mm)	% Clay size*	USCS	Dry Density (pcf)	Liquid Limit	Plasticity Index
FTNKB13	279.13	273.13	273.13	6	6	6.2	62.7	31.1	--	Clayey Sand with Gravel (SC)	--	40	19
FTNKB13	279.13	268.63	267.13	10.5	12	8.8	66.2	25	--	Clayey Sand with Gravel (SC)	--	34	18
FTNKB13	279.13	264.13	262.63	15	16.5	0.8	76.2	23	--	Clayey Sand (SC)	--	32	17
FTNKB13	279.13	257.63	256.13	21.5	23	1.1	84.5	14.4	--	Clayey Sand (SC)	--	30	10
FTNKB13	279.13	254.63	253.13	24.5	26	0	87.7	12.3	--	Silty Sand (SM)	--	--	NP
FTNKB13	279.13	251.63	249.63	27.5	29.5	0	79	21	15	Silty Sand (SM)	--	--	NP
FTNKB16	282.7	276.2	275.2	6.5	7.5	0	60.9	39.1	--	Clayey Sand (SC)	--	42	24
FTNKB16	282.7	272.2	270.7	10.5	12	0	53.1	46.9	26.6	Clayey Sand (SC)	--	41	24
FTNKB16	282.7	264.7	263.2	18	19.5	0	72.5	27.5	--	Clayey Sand (SC)	--	33	14

Location ID	Ground Surface Elev	Top Sample Elev (ft msl)	Bottom Sample Elev (ft msl)	Top Sample Depth (ft bls)	Bottom Sample Depth (ft bls)	% Gravel (>4.5 mm)	% Sand (4.5 – 0.074 mm)	% Mud (Silt + Clay) (<0.074 mm)	% Clay size*	USCS	Dry Density (pcf)	Liquid Limit	Plasticity Index
FTNKB16	282.7	258.2	256.7	24.5	26	0.3	66.7	33	--	Clayey Sand (SC)	--	33	12
FTNKB16	282.7	253.7	252.2	29	30.5	0.2	67.3	32.5	--	Clayey Sand (SC)	--	35	19
FTNKB16	282.7	250.7	243.7	32	39	0	67.5	32.5	--	Clayey Sand (SC)	--	27	13
FTNKB16	282.7	247.2	245.7	35.5	37	0	63.9	36.1	--	Clayey Sand (SC)	--	34	17
FTNKB16	282.7	244.2	242.7	38.5	40	0.8	65.2	34	26.8	Clayey Sand (SC)	--	33	17
FTNKB20	268.7	261.2	259.7	7.5	9	0	79.6	20.4	16.1	Silty Sand (SM)	--	--	NP
FTNKB20	268.7	256.7	255.2	12	13.5	0	69.8	30.2	--	Clayey Sand (SC)	--	30	16
FTNKB20	268.7	252.2	250.7	16.5	18	1	69.9	29.1	23.2	Clayey Sand (SC)	--	34	20
FTNKB20	268.7	247.7	245.7	21	23	0	83.6	16.4	13.1	Clayey Sand (SC)	105	27	8
FTNKB20	268.7	245.7	244.2	23	24.5	0.3	80.6	19.1	--	Silty Sand (SM)	--	--	NP

Location ID	Ground Surface Elev	Top Sample Elev (ft msl)	Bottom Sample Elev (ft msl)	Top Sample Depth (ft bls)	Bottom Sample Depth (ft bls)	% Gravel (>4.5 mm)	% Sand (4.5 – 0.074 mm)	% Mud (Silt + Clay) (<0.074 mm)	% Clay size*	USCS	Dry Density (pcf)	Liquid Limit	Plasticity Index
FTNKB20	268.7	237.7	236.2	31	32.5	0	80.3	19.7	--	Silty Sand (SM)	--	--	--
FTNKB20	268.7	233.2	231.7	35.5	37	0	79.3	20.7	--	Silty Sand (SM)	--	--	NP
FTNKB20	268.7	228.7	227.2	40	41.5	0	86.9	13.1	--	Silty Sand (SM)	--	--	--

Notes: Elev = elevation; ft bls = feet below land surface; ft msl; feet from mean sea level; pcf = pounds per cubic foot; % mud includes silt and clay size fraction; %clay size* = % silt and % clay were analyzed for selected samples and so % clay is specified in addition to % mud; USCS = Unified Soil Classification System; NP = nonplastic; analyses conducted by LAW Engineering, Inc; for original laboratory results, refer to WSRC-TR-96-0069, volume 4 (Site Geotechnical Services Department 1996)

Appendix I: Summary of Reviewed Reports

Title	Author(s)	Document Information	Publication Date	Comments
Report of Preliminary Studies Foundation Investigations, Savannah River Plant, Volume 1	US Army Corps of Engineers	N/A	March 1951	Presents the results of preliminary soil investigations related to the engineering/construction of structures (including F-Area) at the SRS.
Geologic-Engineering Investigations Savannah River Plant, Volume 1	US Army Corps of Engineers	N/A	March 1952	Addresses general geology and engineering considerations related to geology for construction areas (including F-Area) SRS.
Foundation Grouting Operations Savannah River Plant	US Army Corps of Engineers	N/A	June 1952	Describes the foundation and grouting operations performed in areas of potential construction where subsurface calcareous zones were found.
D_2O-Na^{24} Method for Tracing Soil Moisture Movement in the Field	C. C. Haskell and R. H. Hawkins	Soil Science Society of America Proceedings, vol 28, p 725-728	1964	Describes field tests measuring the downward movement of deuterium tracer through the vadose zone (sandy clay sediment); tracer movement for plots 1 & 2 was ~20 inches for 169-day test and rate of 0.94 inches per inch of rainfall; tracer movement for plot 3 was ~41 inches for 169-day test and rate of 1.99 inches per inch of rainfall.
Flow Path of Rain form the Soil Surface to the Water Table	J. H. Horton and R. H. Hawkins	Soil Science, vol 100, no 6, p 377-383	December 1965	Describes results of laboratory column experiments on sandy clay sediment; results show that infiltrating water moved from the larger sandy pores to the smaller sandy clay pores before water penetrated to a great depth in the sand; results also indicated that flow through the sandy clay sediment occurred primarily through the downward displacement of water that remained in the soil after drainage.
Bentonite as a Protective Cover for Buried Radioactive Waste	R. H. Hawkins and J.H Horton	Health Physics, vol 13, p 287-292	July 1966	Describes a field test conducted near the Burial Grounds in which a bentonite structure was tested to determine whether it sufficiently prevented the infiltration of rainwater; also conducted D_2O-^{24}Na field test to trace soil moisture both under the bentonite structure and in the native soil beside it; showed average movement in native soil of 46 inches from the 48 inches of rainfall (0.96 inches per inch of rainfall).
Tracing Soil Moisture and Groundwater Flow at the Savannah River Plant	J. W. Fenimore	DP-MS-68-23	March 1968	Summarizes tracer tests at the H-Area Tanks, the F and H Area Seepage Basins and the Burial Ground; also summarizes the soil moisture studies conducted in the 1960's and identifies a movement of 0.95 inches per inch

Title	Author(s)	Document Information	Publication Date	Comments
				of rain as representative unsaturated flow in the Burial Ground vadose zone.
Savannah River Plant Areas 200H and 200F Radioactive Waste Storage Tanks Subsurface Geologic Investigations	John A. Blume & Associates, Engineers	N/A	August 1971	Provides log descriptions and laboratory analyses (grain size, classification, bulk soil properties) for two borings located at FTF as part of study to collect geotechnical properties needed to conduct earthquake analysis of tanks.
Soil Moisture Flow as Related to the Burial of Solid Radioactive Waste	J. H. Horton	DPST-75-218	January 1975	Summarizes field and laboratory experiments related to flow through unsaturated soil related to the Burial Grounds; identifies a flow of 7ft/yr through unsaturated sandy clay soil for the SRS.
EWR 860438 Foundation Investigation Building 241F Additional High Level Waste Storage Tanks Project 9S 1493 FY75 Tanks Nos. 25 though 28 Project FY77 Tanks Nos. 44 through 47	Mueser, Rutledge, Wentworth & Johnston Consulting Engineers	N/A	May 1975	Presents illustrations to describe subsurface conditions and results of laboratory tests on borings; includes historical data from US Army Corps; provides data related to 9 borings (Nos. 241-14F-1 through 241-14F-9) completed to investigate beneath proposed tanks; provides cross-sections and notes regarding the types of soil borings, number of blow counts, soil classification (USCS), groundwater levels, and the presence of voids/carbonates.
Foundation Grouting New High Level Waste Storage Tanks Building 241-14F Savannah River Plant	Mueser, Rutledge, Wentworth & Johnston Consulting Engineers	N/A	October 1975	Documents grouting activities performed at Tanks 25-28 and Tanks 44-47.
Building 241-F New High Level Waste Storage Tanks Nos. 52 Through 55	Mueser, Rutledge, Wentworth & Johnston Consulting Engineers	N/A	February 1977	Proposed tanks were to be located directly west of Tanks 42-47; report summarizes the subsurface investigation and grouting program for proposed tanks.
Validation of Unsaturated Flow Models Using Tank 24 Lysimeter Data	INTERA Technologies, Inc	N/A	January 1986	Provided saturated hydraulic conductivity for backfill and host soil used in modeling; provides soil property curves for backfill and host soil used in modeling; soil property parameters based on work by Quisenberry (1985) and Gruber (1981); report provides some data related to work by Quisenberry (1985) and Gruber (1981)
Environmental Information Document Radioactive Waste Burial Grounds	W. J. Jaegge, N. L. Kolb, B. B. Looney, I. W. Marine, O. A.	DPST-85-694	March 1987	Provides modeling parameters used in modeling the Burial Grounds; includes hydraulic conductivity values from lab tests, slug tests, tracer tests, small-scale and large-scale

Title	Author(s)	Document Information	Publication Date	Comments
	Towler, and J. R. Cook			pumping tests & numerical simulations; includes a short summary of tracer tests in the unsaturated and saturated zone beneath the burial grounds.
SRP Baseline Hydrogeologic Investigation – Phase III	H. W. Bledsoe	DPST-88-627	August 1988	Provides data related to wells installed in background areas of SRS to further knowledge and understanding of hydrogeology; includes P28 cluster located just outside F-area
F-Area Geotechnical Characterization Report (U), Volumes 1-5	Site Geotechnical Department	WSRC-TR-96-0069	September 1996	Provides CPT data, and laboratory data related to engineering properties for the purpose of characterizing foundation material in F-Area.
Reconnaissance Hydrogeologic Investigation of the Defense Waste Processing Facility and Vicinity, Savannah River Plant, South Carolina	K. F. Dennehy, D. C. Prowell, and P. B. McMahon	USGS Water-Resources Investigations Report 88-4221	1989	Provides summary table of hydraulic conductivity values from previous reports/studies; provides hydraulic conductivity data for disturbed, compacted samples collected in GSA to evaluate potential geochemical and hydrologic effects of concentrated salt-solution waste on subsurface sediments
Aquitard Thickness at the F-Area Tank Farm	Soil & Groundwater Closure Projects Engineering and Technology	ERD-EN-2006-0066	May 2006	Provides comparison among TCCZ and Green Clay picks from Landmark; also provides summary table of picks for locations
Determination of the Tan Clay Confining Zone (TCCZ) near the F-Area Tank Farm (FTF)	M. R. Millings	SRNL-ESB-2007-00006	February 2007	Provides evaluation of TCCZ picks and thickness based on CPTs and core logs near the FTF; also provides comparison of these picks to model generated picks based on the 1995 hydrogeologic database for the GSA
F-Area Tank Farm Vadose Zone Material Property Recommendations	W. Jones, M. Millings and M. Phifer	SRNL-ESB-2007-00008	February 2007	Provides initial material property recommendations for native (undisturbed) vadose zone sediments, backfill material and concrete work slabs for input into the FTF PA modeling