NORTH ANNA
INDEPENDENT SPENT FUEL STORAGE INSTALLATION
SAFETY ANALYSIS REPORT
REVISION 3 INSTRUCTIONS

These instructions apply for implementing Revision 3 of the North Anna ISFSI Safety Analysis Report (SAR). The SAR update package consists of:

(1) Instruction Sheet

(1) Set Replacement Pages with Tabs

UPDATE INSTRUCTIONS

1. In *Technical Specifications And Safety Analysis Report* binder, remove and set aside the pages behind the **Safety Analysis Report Amendment Record** tab.
2. Remove and discard the contents beginning with the **Safety Analysis Report Amendment Record** tab through the end of the binder, *in its entirety*, including all previously issued tabs, table of contents, text pages, table pages, figure pages, appendices, and list of effective pages.
3. Insert the new pages and tabs into the binder.
4. In the new pages inserted, remove the generic "NORTH ANNA ISFSI SAFETY ANALYSIS REPORT RECORD OF CHANGES" place holder page and replace it with the pages that were set aside in step 1.
5. Date and initial the Record of Changes entry for Revision 3 on the "NORTH ANNA ISFSI SAFETY ANALYSIS REPORT RECORD OF CHANGES" page inserted in step 4.

   [*end*]

NORTH ANNA ISFSI SAFETY ANALYSIS REPORT
RECORD OF CHANGES

	DATE	INITIAL		DATE	INITIAL
REVISION 0	XX	XX	REVISION 25		
REVISION 1	XX	XX	REVISION 26		
REVISION 2	XX	XX	REVISION 27		
REVISION 3	XX	XX	REVISION 28		
REVISION 4			REVISION 29		
REVISION 5			REVISION 30		
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REVISION 7			REVISION 32		
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REVISION 17			REVISION 42		
REVISION 18			REVISION 43		
REVISION 19			REVISION 44		
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REVISION 21			REVISION 46		
REVISION 22			REVISION 47		
REVISION 23			REVISION 48		
REVISION 24			REVISION 49		

REVISION SUMMARY

Revision 3—06/02

Chapter/Section	**Changes** Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
4.4.5.1, 8.2.5.1	Clarified the description of the placement of fire extinguishers at the ISFSI site as well as the availability of fire fighting equipment and personnel.
5.1.1.1	Changed cask receipt procedure consistent with the North Anna Power Station Updated Final Safety Analysis Report.
9.2.2.1	Deleted incorrect testing requirements for electrical and communications systems.
A.1.1, Appendix A.1 Attachment 1	Incorporated the modified TN-32 cask lid bolt analysis.
A.1.1, Appendix A.1 Attachment 3	Modified the TN-32 cask protective cover and overpressure system.
A.1.7, Appendix A.1 Attachment 2	Incorporated structural analyses for missile impacts on TN-32 casks.

Revision 2

Chapter/Section	**Changes** Made under the provisions of 10 CFR 72.48 except where indicated in brackets.
3.1.1, A.1.2	Added information on the storage of burnable poison rod assemblies and thimble plug devices in TN-32 casks. [10 CFR 72.56 License Amendment]
A.1.1	Revised the description of the weld in the neutron shield outer shell of TN-32 casks.
A.1.1	Clarified the location of borated aluminum plates in the fuel basket of TN-32 casks.

Revision 1

Chapter/Section	Changes
3.1.1, 3.3.6, 4.2.1, 4.4.4.1, 4.5, Table 4-1, Chapter 6, 7.2.2, A.1.1, A.1.2, A.1.5, A.1.6, Appendix A.1 Attachment 1	Delete references to fuel insert components, clarify the maximum capacity of the backup diesel generator fuel tank, update as-built parameters of the concrete pad, add 120V circuit description, clarify the status of cask handling equipment, delete statement that emergency actions are neither credible nor postulated to occur, discuss operational practices to prevent weather-driven spread of contamination, add I^{129} and Co^{60} inventories per assembly, incorporate TN-32 lid bolt analysis, add TN-32 Cask Sliding and Tip-over Analysis, and add Evaluation of Tornado Missiles.
A.1.1	Include fillet weld as an alternative to the groove weld for the fuel basket.
A.1.3	Add discussion of dose rate and exposure estimates.

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1. Introduction and General Description

Chapter 1
INTRODUCTION AND GENERAL DESCRIPTION OF STORAGE SYSTEM

1.1 INTRODUCTION

Discharged spent fuel assemblies from the North Anna Power Station, Units 1 and 2 are currently stored in a spent fuel pool common to both Units. The spent fuel pool provides for interim storage of 1,737 fuel assemblies in high density storage racks. Typically, 64 spent fuel assemblies are discharged from each Unit about every 18 months. Section 3.1.1 provides a description of the spent fuel. Additional information on the fuel design is available in Section 4.2 of the North Anna Power Station Updated Final Safety Analysis Report (UFSAR).

Based on the current fuel management strategy and refueling outage schedule, the spent fuel pool will lose the capacity for single unit full core discharge in late 1998. Storage capacity in the pool will be completely exhausted in 2000, therefore, additional spent fuel storage capacity is needed. To support this need, sealed surface storage casks (SSSCs) have been chosen for use at an Independent Spent Fuel Storage Installation (ISFSI) at the North Anna site.

The North Anna ISFSI is designed to store all the anticipated spent fuel resulting from the operation of the North Anna Power Station Units 1 and 2 in excess of that which can be stored in the spent fuel pool, or approximately 1,824 fuel assemblies. Construction of the North Anna ISFSI is scheduled to begin in June 1997 and the first SSSC should be placed at the ISFSI in August 1998.

The North Anna ISFSI is located within the site boundary of the North Anna Power Station, which is owned 88.4% by Virginia Electric and Power Company (Virginia Power) and 11.6% by the Old Dominion Electric Cooperative. Virginia Power is responsible for operations at the Station.

This SAR is primarily directed towards analyzing the safety aspects of SSSC handling and storage once the SSSCs have been lifted by the cask transporter, and how the safety requirements in 10 CFR 72 are satisfied. Handling of the SSSCs inside the Fuel and Decontamination Buildings and cask crane bay is performed in accordance with the operating license for the North Anna Power Station under 10 CFR 50, however, these operations are also described in this SAR.

1.2 GENERAL

The North Anna site comprises approximately 1,043 acres in Louisa County, Virginia. The ISFSI is located near the center of the site, approximately 2,000 feet southwest of the protected area for North Anna Units 1 and 2. Figure 1-1 shows a general layout of the North Anna site.

North Anna Power Station Units 1 and 2 consist of two closed-cycle pressurized water reactors (PWR) provided by Westinghouse. Operating licenses were issued by the NRC in April 1978 and August 1980 for Units 1 and 2, respectively. Unit 1 started commercial operation

in June 1978 and Unit 2 in December 1980. A complete description of the power station is provided in the North Anna Power Station UFSAR, NRC dockets 50-338/339.

The North Anna ISFSI consists of three concrete storage pads on which the loaded SSSCs are placed. The storage pads will be built in sequence, as needed, and in an order which minimizes radiation exposures. The storage pads will be surrounded by a security fence and a nuisance fence. Another fence will enclose the perimeter of the ISFSI site (hereinafter referred to as the ISFSI perimeter fence).

1.3 GENERAL STORAGE SYSTEM DESCRIPTION

The North Anna ISFSI uses SSSCs to store fuel irradiated at the North Anna Power Station. Typically, the SSSCs are large cylindrical vessels capable of storing up to 32 unconsolidated PWR fuel assemblies. The SSSCs are made of carbon steel, stainless steel, or cast iron. They are about 16 feet long and 8 feet in diameter, have walls several inches thick and weigh 100 to 125 tons fully loaded. The fuel is stored in a helium atmosphere and held in place by a basket or rack.

Figure 1-2 shows the general arrangement of the North Anna ISFSI.

The loading and preparation of an SSSC takes place within the Fuel and Decontamination Buildings of the North Anna Power Station. The SSSC is loaded under water in the spent fuel pool where a lid is positioned on the SSSC prior to lifting it out of the water. Water in the SSSC is removed, the interior is further dried under vacuum and then filled with helium. Following decontamination of the outer surface, the SSSC is placed in a transporter outside the Decontamination Building. The SSSC is then transferred to the ISFSI, where it is emplaced on one of the three storage pads.

The SSSCs are totally passive systems, with natural convection cooling sufficient to maintain safe fuel clad temperatures. The SSSC walls provide adequate shielding, and no radioactive products are released under any credible conditions.

1.4 IDENTIFICATION OF AGENTS AND CONTRACTORS

SSSCs to be used in the North Anna ISFSI are designed and fabricated by other organizations and will be purchased by Virginia Power. The SSSC suppliers are responsible for SSSC fabrication, testing, and delineation of specific SSSC requirements, if any. Information related to the qualifications of the SSSC suppliers is contained in the Topical Safety Analysis Reports referenced in Section 1.5.

Site preparation and necessary construction will be performed by Virginia Power's Site Services Department, using specialty subcontractors, as required.

1.5 MATERIAL INCORPORATED BY REFERENCE

Detailed information describing the SSSCs is provided in the SSSC Topical Safety Analysis Reports referenced in Appendix A, Table A-1 of this Safety Analysis Report (SAR). General

references to the SSSC Topical Safety Analysis Reports are made in sections of this SAR, as needed, to supplement information contained in the SAR. Each SSSC type is described in a sub-appendix of Appendix A. Also, the sub-appendices provide SSSC-specific information not contained in the SSSC Topical Safety Analysis Reports. The combination of this SAR, including appendices, and any one of the reports describing the SSSCs (one per type of SSSC) provides all the information described in Regulatory Guide 3.62 (February 1989), *Standard Format and Content for the Safety Analysis Report for Onsite Storage of Spent Fuel Storage Casks.*

The following documents, which are already on file with the NRC, are referenced throughout this SAR:

1. *North Anna Power Station Units 1 and 2, Updated Final Safety Analysis Report,* NRC dockets 50-338 and 50-339.
2. *North Anna Power Station Units 1, 2, 3 and 4, Environmental Report,* submitted March 15, 1972.
3. *North Anna Power Station, Emergency Plan.*
4. *Virginia Electric and Power Company Operational Quality Assurance Program Topical Report VEP-1-5A (Updated).* (The updated version is contained in Section 17.2 of the North Anna UFSAR.)
5. *Surry Power Station, Independent Spent Fuel Storage Installation, Safety Analysis Report.*

Figure 1-1
ISFSI LOCATION ON NORTH ANNA SITE

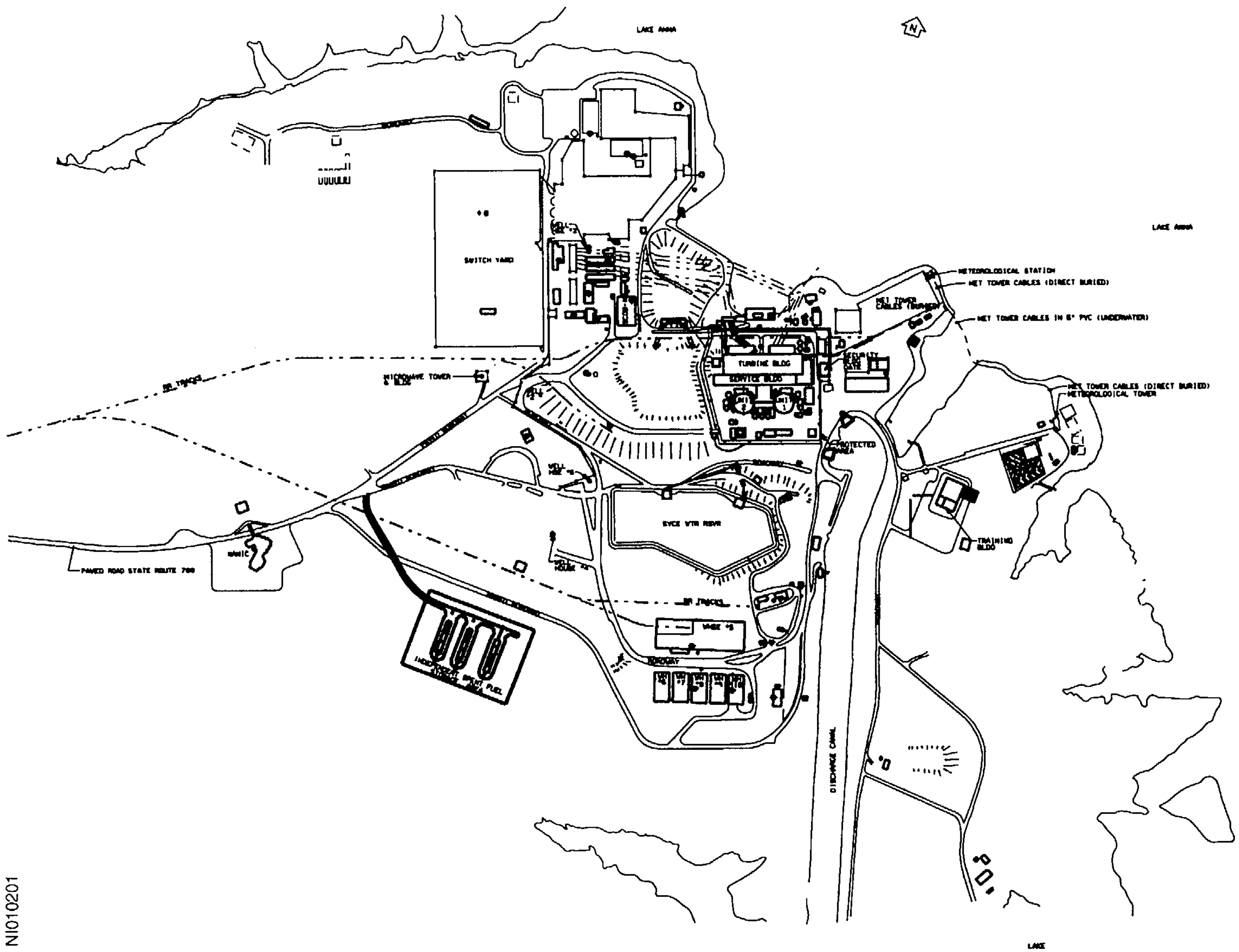

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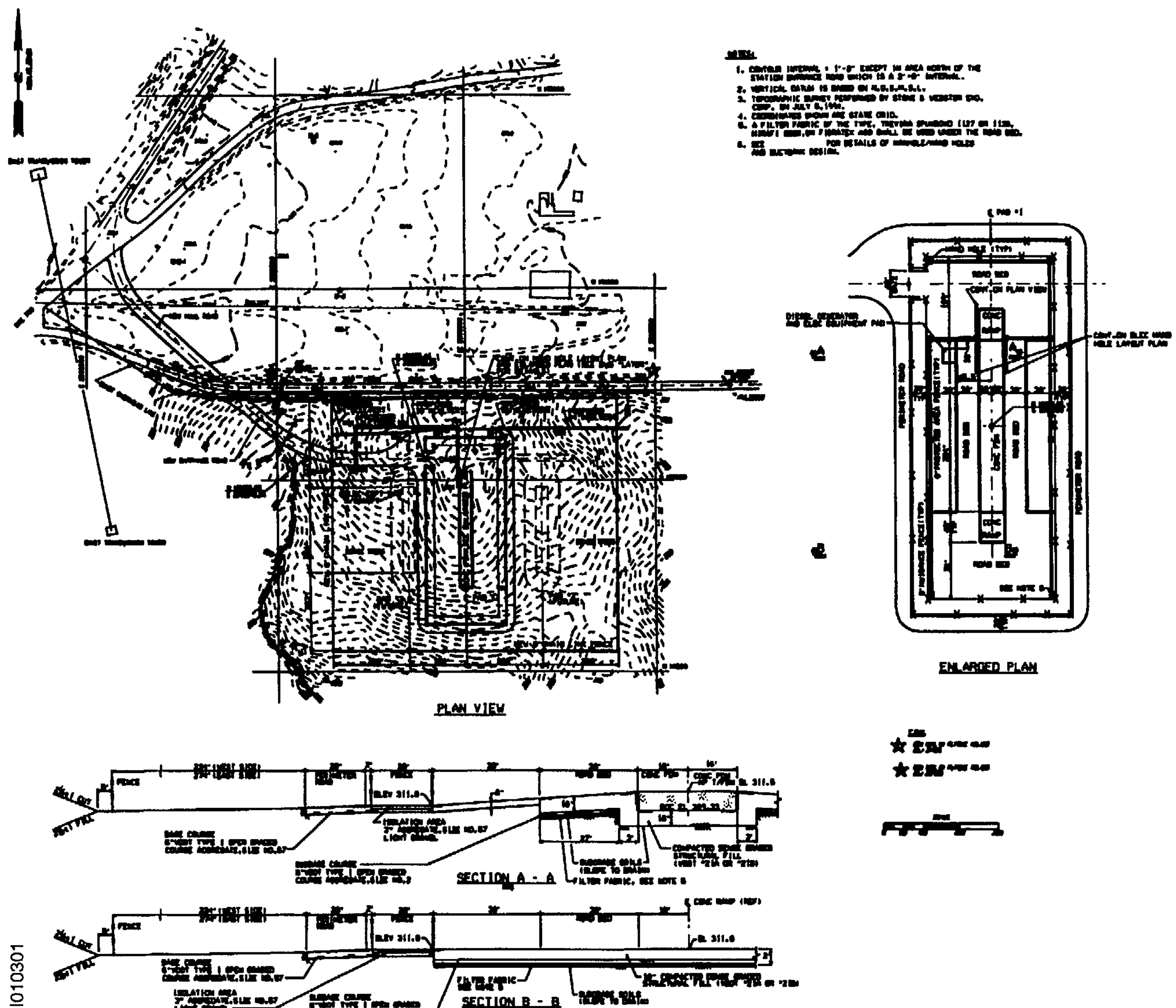
Figure 1-2
ISFSI GENERAL ARRANGEMENT



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Chapter 2
SITE CHARACTERISTICS

2.1 GEOGRAPHY AND DEMOGRAPHY OF SITE SELECTED

2.1.1 Site Location

The location of the Independent Spent Fuel Storage Installation (ISFSI) is approximately 2,000 feet southwest of the North Anna Power Station Units 1 and 2 protected area and within the boundaries of the North Anna site (see Figure 1-1). The ISFSI occupies approximately 11 acres.

The North Anna site is located in the north-central portion of Virginia in Louisa County. The site is on a peninsula on the southern shore of Lake Anna at the end of State Route 700. The earth dam that creates the lake is approximately 5 miles southeast of the site. The North Anna River flows southeasterly, joining the South Anna River to form the Pamunkey River approximately 27 miles southeast of the site.

The largest community within 10 miles of the site is the Town of Mineral (Louisa County), which had a 1990 population of 452 persons, and is approximately 6 miles west-southwest of the site. The community of Louisa, which had a 1990 population of 1,088 persons, is approximately 12 miles to the west of the site. Figure 2-1 shows the general location of the site and the surrounding localities within 10 miles.

Regionally, as indicated in Figure 2-2, the site is approximately 40 miles north-northwest of Richmond; 36 miles east of Charlottesville; 22 miles southwest of Fredericksburg; and 70 miles southwest of Washington, D.C. Interstate highways 95 and 64, the two principal highways serving Richmond, pass within 16 miles east and 16 miles southwest of the site, respectively.

The approximate coordinates of the ISFSI are:

Latitude-Longitude	Universal Transverse Mercator
38° 3.8' N - 77° 47.5' W	4,215,900 mN - 255,100 mE; Zone 18S

2.1.2 Site Description

The North Anna site property comprises 1,803 acres, of which approximately 760 acres are covered by water. The site boundary is shown in Figure 2-3. Virginia Power owns, in fee simple, all of the land within the site boundary, both above and beneath the surfaces, including those portions of the reservoir and waste heat treatment facilities (cooling lagoons) that lie within the site boundary. The controlled area is all of the area within the site boundary. Virginia Power also owns, in fee simple, all land outside the site boundary that forms the reservoir and the cooling lagoons up to their expected high-water marks. The Station and all supporting facilities including the reservoir, cooling lagoons, earthen dam, dikes, railroad spur, and roads constitute approximately 13,775 acres.

The site plan for the North Anna ISFSI and its relative location to the North Anna Power Station are presented on Figure 2-3. Consistent with Section 2.1.2.1 of the North Anna Power Station UFSAR, the restricted area for the ISFSI is the North Anna site boundary. The controlled area boundary is also the site boundary. As shown on Figure 2-3, the minimum distance to the controlled area boundary from the ISFSI is approximately 2,500 feet and occurs in the southwest sector relative to the ISFSI.

Since the controlled area for the North Anna ISFSI is wholly within the property lines for the North Anna site, Virginia Power has full authority to determine all activities including the exclusion and the removal of personnel and property. No activities unrelated to operation of the North Anna Power Station or the ISFSI are permitted within the controlled area.

The topography in the site region is characteristic of the central Piedmont Plateau with a gently undulating surface varying from 200 to 500 feet above sea level (see Figure 2-7). The surrounding region is covered with forest and brushwood interspersed with an occasional farm. The land adjacent to the reservoir is becoming increasingly residential as the land is developed.

Figure 2-8 shows the topography in the vicinity of the ISFSI. Drainage of surface water at the ISFSI will be provided by channels to a small creek to the south and west. The area inside the ISFSI perimeter fence will be graded level. Areas not needed for ISFSI operations will be seeded with grass, while areas needed for ISFSI operations will be covered with course gravel. The areas surrounding the west, south and east sides of the ISFSI perimeter fence will remain forested. Based on this description, the potential for erosion at the ISFSI is small, and the potential for forest fires exists only outside the ISFSI perimeter fence.

2.1.3 Population Distribution and Trends

Cities within 50 miles of the site are shown on Figure 2-2. Section 2.1.2 of the North Anna ISFSI Environmental Report provides detailed information on population projections.

2.1.4 Use Of Nearby Land and Waters

The North Anna site is located in a predominantly rural area of Louisa County, Virginia. In Louisa County and the four adjacent counties of Spotsylvania, Orange, Hanover and Caroline, an average 42.5% of the total county acreage is used for agriculture. Approximately 38% of the 508,443 agricultural acres in these five counties is cropland, 15% is pastureland, and the balance is woodland. Principal crops are barley, tobacco, corn, wheat, hay and soybeans. Poultry, livestock and dairy products are also major agricultural products of the area and represent the greatest share of the area's cash farm income.

Section 2.1.2.3 of the North Anna ISFSI Environmental Report provides information on recreational activities on Lake Anna. Section 2.2.1 that follows provides information on industrial activities in the area.

2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

2.2.1 Description

Currently, there are none of the following facilities within 5 miles of the North Anna site: military bases, manufacturing plants, chemical plants and storage facilities, airports, major railroad lines, major water transportation routes or oil and gas pipelines. Also, there are no mining activities within 5 miles of the site.

There are no significant industrial activities within 5 miles of the site. Based on trends of industrial growth and projected population figures, it is not expected that any major industrial expansion will occur in this area.

Roads within 10 miles of the site are shown on Figure 2-1. Virginia Route 208 and US Route 522 are the major transportation routes serving the site area that pass within 5 miles of the site, however, there are no specific data on the types and quantities of products and materials transported on these roads.

State Route 700, east from State Route 652, is the only land access to the North Anna site. It ends at the site west boundary. No chemicals or cargo are expected to be transported on this portion of Route 700 unless the chemicals or cargo are used by the North Anna Power Station.

The railroad line closest to the site is the line owned by CSXT. It passes through the towns of Louisa, Mineral, Fredericks Hall and Bumpass; its closest approach to the site is approximately 5.5 miles southwest. A spur line connects the site with this line.

There are only two airports within 10 miles of the site: Lake Anna (Rest-A-While) Airport and Cub Field. The Louisa County Airport is located 11 miles west-southwest of the site. Operations at these airports involve light aircraft. None of these airports are expected to grow significantly in the foreseeable future. Section 2.2.1.6.2 of the North Anna Power Station UFSAR includes a discussion of airways over the site.

2.2.2 Effects of Potential Accidents

The only sources of explosion and formation of flammable vapor clouds are explosive materials/chemicals carried by truck traffic.

The largest possible explosive load routinely transported contains 8,500 gallons of gasoline (set by highway weight limits). Based on an analysis in Section 2.2.2.1.1 of the North Anna Power Station UFSAR, if this amount of gasoline were to explode at the closest point to the site, 1.5 miles on State Route 652, a peak overpressure of 1 psi would be experienced approximately 1,900 feet away from the point of explosion. The overpressure experienced by the SSSCs 1.5 miles away from the explosion would be significantly less than 1 psi.

2.3 METEOROLOGY

Meteorology at the North Anna Power Station is described in Section 2.3 of the North Anna Power Station UFSAR. Information from the UFSAR concerning meteorology is summarized and supplemented below.

2.3.1 Regional Climatology

The climate of the site is basically modified continental. The summers are warm and humid while winters are generally mild. The Blue Ridge Mountains to the west act as partial barriers to winter storms, modifying their intensity as they move across the rolling Piedmont to the Tidewater region adjacent to the Atlantic Ocean.

Climatic characteristics are illustrated in Figure 2-4 through Figure 2-6 which show daily average temperatures, daily extreme temperatures, and the probability of an extreme l-mile wind passage for Richmond, Virginia. Temperatures in the site region rarely exceed 95°F or fall below 10°F.

Rainfall averages approximately 44 inches per year around the site region and is fairly well distributed throughout the year, with the exception of the months of July and August, when thunderstorm activity raises the monthly totals to approximately 5 inches. Tropical storms may also contribute significantly to precipitation during the late summer and fall. Records indicate that the maximum rainfall during a 24 hour period was 8.79 inches, which occurred in August 1955.

Snowfalls of 4 inches or more occur an average of once per year. Snow usually only remains on the ground from 1 to 4 days at a time. Richmond averages 14.6 inches of snow per year.

Tornadoes are infrequent in Virginia. In the period from 1916 through 1987, only 65 tornadoes were reported within a 50-mile radius of the North Anna site (Reference 1). This averages to less than one tornado per year within this radius. Based on statistical methods proposed by Thom (Reference 2) and as described in detail in Section 2.3.1.3.2 of the North Anna Power Station UFSAR, the probability of a tornado striking a point within the 50-mile radius is 3.25×10^{-5} per year, or a recurrence interval of 30,800 years.

Richmond averages 37 thunderstorm days per year with a quarter of these typically occurring in July. Cloud-to-ground lightning strike data within an approximate 10-kilometer radius of the site region was analyzed for the ten year period of 1984 to 1993. Results indicate a minimum yearly strike frequency of 1.1 strikes per square kilometer in 1992 and a maximum yearly strike frequency of 3.9 strikes per square kilometer in 1988.

2.3.2 Local Meteorology

2.3.2.1 **Data Sources**

Meteorology in the North Anna Power Station site area was evaluated as part of its Operating License application review. Data acquired by the National Weather Service and

summarized by the Environmental Data Service (Reference 3) were used to determine the normals, means, and extremes of temperature and precipitation applicable to the North Anna site region.

Temperature extremes for Richmond, Virginia are shown in Figure 2-5. In August 1918 a record high of 107°F was recorded and in January 1940 a record low of -12°F was recorded. The extreme temperatures used as the design criteria for the SSSCs, -20°F and 115°F, were selected because they exceed the recorded temperature extremes.

The design solar insolation values for casks stored at the ISFSI are adapted from 10 CFR 71.71(c). The insolation values are 800 gm-cal/cm^2 for flat surfaces and 400 m-cal/cm^2 for curved surfaces applied over a 12-hour daylight period. These insolation values may be averaged over a 24-hour period for long-term thermal analyses.

Joint frequency distributions of wind speed and horizontal atmospheric stability for both the lower and upper tower levels are presented in Tables 2.3-9 and 2.3-10 of the North Anna Power Station UFSAR. In addition, the joint frequency distribution of lower level wind speed and vertical atmospheric stability are presented in Table 2.3-11 of the North Anna Power Station UFSAR. The distributions are for Stability Classes A through G as defined in Regulatory Guide 1.23.

2.3.2.2 **Topography**

The North Anna Power Station site and exclusion area consist of approximately 1,043 acres located in the north-central portion of Virginia in Louisa County beside Lake Anna. The site region is characterized by gently rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna and is cut by the North Anna River. The topography in the site region is characteristic of the Central Piedmont Plateau, which has a gently undulating surface that varies from 200 to 500 feet above sea level.

Figure 2.3-24 of the North Anna Power Station UFSAR is a map showing detailed topographic features within an 8-kilometer (5 mile) radius centered on the site area.

2.3.3 Onsite Meteorological Measurement Program

The North Anna Power Station will also provide meteorological monitoring for the ISFSI. A detailed description of the meteorological monitoring program is provided in Section 2.3.3 of the North Anna Power Station UFSAR. Data from this program, however, will not be used to estimate offsite concentrations of airborne effluents from the ISFSI, as no credible mechanism for the release of airborne effluents has been postulated.

As illustrated in Figure 2.3-25 of the North Anna Power Station UFSAR, the ISFSI is located approximately 3,500 feet from the primary meteorological tower, with the service water reservoir and the Units 1 and 2 discharge canal between the ISFSI and the tower. Based on the analysis in Section 2.3.3.6 of the Surry Power Station ISFSI SAR, the separation between the

North Anna ISFSI and the meteorological tower, and the intervening topography and other heat sources, no effect is expected on the tower from the heat source represented by a fully loaded ISFSI.

2.3.4 Diffusion Estimates

2.3.4.1 Basis

No routine or accidental releases are planned or postulated as a result of ISFSI operation. Nevertheless, χ/Q values have been calculated which can be used to estimate radiological doses from the accidental release analyzed in Section 8.2.10.

2.3.4.2 Calculations

Five years of meteorological data from 1989 through 1993 were used to calculate dispersion factors (χ/Q) for use in the dose assessment of accident airborne releases. Wind speed, direction, distance from the ISFSI to the North Anna Power Station site boundary, and atmospheric stability class (based on the temperature gradient determined from instrumentation at the 10 meter and the 158.9 foot elevations) serve as inputs to the dispersion model described in Regulatory Guide 1.145 (Reference 4).

Table 2-1 provides the χ/Q values at the site boundary for an instantaneous accidental release from the ISFSI. Time-dependent χ/Q values are not provided since routine releases are neither planned nor anticipated. The χ/Q values provided in Table 2-1 represent the most limiting χ/Q values to members of the public with the SE sector having the greatest χ/Q at 1,100 meters from the ISFSI to the site boundary. According to the dispersion model, the topographical features surrounding the North Anna site are such that the χ/Q values monotonically decrease with distance from the site boundary. Therefore, the limiting dose to members of the public will occur at the site boundary in the SE sector and dose to members of the public will decrease as the distance from the site boundary increases.

2.3.5 References

1. Storm Data, National Oceanic and Atmospheric Administration, National Weather Records Center, Environmental Data Service, Asheville, North Carolina.

2. H. C. S. Thom, "Tornado Probabilities," *Monthly Weather Review,* Vol. 91, Nos. 10-12, pp. 730-736.

3. Richmond, Virginia 1987 Local Climatological Data, Annual Summary With Comparative Data, National Oceanic and Atmospheric Administration, National Weather Records Center, Environmental Data Service, Asheville, North Carolina.

4. U. S. NRC Regulatory Guide 1.145, *Atmospheric Dispersion Models for Post Accident Consequence Assessments at Nuclear Power Plants,* Revision 1, November 1982, Reissued February 1983.

2.4 HYDROLOGY

The data and analyses in this section were obtained from the material presented in Section 2.4 of the North Anna Power Station UFSAR (References 1 & 2). In addition, hydrologic data for the period from 1971 to 1993 were also reviewed. No severe event occurred from 1973 to the present which exceeded the maximum flood on record that has occurred on the North Anna River. The subsurface hydrology section includes site specific data produced as a result of the ISFSI site soils investigation, and follow-up monitoring.

2.4.1 Hydrologic Description

2.4.1.1 Site and Structures

The general site grade for the ISFSI is at Elevation 311 feet msl. This grade varies somewhat to permit proper drainage. The top elevation of the storage pads will be at 311.5 feet msl. Areas outside of the ISFSI generally slope to the south, towards Lake Anna. There is an ISFSI access road to the west of the ISFSI which is graded from Elevation 332 feet msl to Elevation 311 feet msl into the site. Site grade is above the probable maximum flood level, as discussed in Section 2.4.2.2. There are no above-ground enclosed structures associated with this facility.

2.4.1.2 Hydrosphere

Regional topography and characteristics are shown on Figure 2-7. The region surrounding the North Anna Power Station site is characterized by gently rolling terrain that rises to an average height of 50 to 150 feet above Lake Anna and is bisected by the North Anna River. The topography in the site region is characteristic of the Central Piedmont Plateau, which has a gently undulating surface that varies from 200 to 500 feet above sea level.

An earth dam approximately five miles southeast of the site forms Lake Anna, which extends approximately 17 miles along the old North Anna river bed. The lake and waste heat treatment facility cover a surface area of 13,000 acres and contain approximately 100 billion gallons of water.

The ISFSI site is located more than 60 feet above normal lake level elevation, and 45 feet above the flood elevation assumed to occur due to the Probable Maximum Flood postulated to occur on Lake Anna. The terrain near the ISFSI site varies from Elevation 336 feet msl northwest of the ISFSI to Elevation 250 feet msl near the lake.

The North Anna River rises in the eastern slopes of the southwestern mountains in the Appalachian Range near Gordonsville, Virginia, flows into the Lake, and then continues along a southeasterly course to its confluence with the South Anna River 5 miles northeast of Ashland, Virginia, where the Pamunkey River is formed. The Pamunkey River continues on a general southeasterly course to West Point, Virginia, where it is joined by the Mattaponi to form the York River. The York River flows into the Chesapeake Bay approximately 15 miles north of Hampton, Virginia.

The North Anna River drains a watershed of 343 square miles above the dam. The dam is located approximately 4 miles north of Bumpass, Virginia and approximately 0.5 mile upstream of Virginia Route 601. The nearest United States Geological Survey (USGS) stream gauging station on the North Anna River was at the bridge at Virginia Route 601. This stream gauge had been operating from October 1978 to January 1997. There have also been gauges located at Doswell and Hart Corner, Virginia, approximately 15 miles downstream from the dam. These gauges have provided coverage since 1929. The current USGS gauge at Hart Corner monitors flow over a watershed of approximately 463 square miles. Table 2-2 summarizes the records at these gauging stations and tabulates basic stream flow data for the dam site, which have been estimated using the gauge records as a guide for years prior to 1971, and the Partlow gauge data for years after 1977.

No river control structures exist on the North Anna River other than the dam described above.

There is one industrial user of water on the North Anna River downstream of the dam, Bear Island Paper Company, and this facility is located approximately 26 miles from the North Anna Power Station. There are no known industrial users of water on the Pamunkey River until it reaches the York River some 60 miles downstream at West Point, where a large pulp and paper manufacturing plant is located. There is one known potable water withdrawal on the North Anna River, the Hanover County Treatment Plant near Doswell. This plant is located approximately 24 miles downstream from the power station.

2.4.2 Floods

The North Anna ISFSI is a flood-dry site due to the elevation of the site with respect to Lake Anna and the conservative design of storm drainage facilities within the local site area. Local intense precipitation is the controlling case for storm drainage design.

2.4.2.1 **Flood History**

Floods due to precipitation on the watershed of the North Anna River are the only flooding conditions applicable to historical consideration. Surges due to tropical systems, or tsunamis are not applicable to this site. The site is also not influenced by tidal effects. Gauge records have been available since the late 1920s at the USGS gauge near Doswell and in later years at Hart Corner (Reference 3). In this time the most serious flooding on the North Anna River that occurred took place in 1969 due to the remnants of Hurricane Camille (Reference 4). The second largest event on gauged record was in 1972 with the passing of the remnants of Hurricane Agnes through the watershed. Two smaller events occurred in 1928 and 1937 (Reference 5). The largest twelve floods on gauged record are listed in Table 2-3.

The average annual flood on the North Anna River near Doswell is approximately 7,000 cfs.

2.4.2.2 **Flood Design Considerations**

A discussion of flood elevation levels compared to the ISFSI site is provided in Section 2.4.1.2. A discussion of the analysis of the Probable Maximum Flood and its basis is contained in Section 2.4.3 and Appendix 2A of the North Anna Power Station UFSAR. The effects of local intense precipitation have been taken into account in the design of the storm drainage system for the ISFSI site. Detailed discussion of this item is contained in Section 2.4.2.3.

2.4.2.3 **Effects of Local Intense Precipitation**

The ISFSI site is at a higher elevation than the surrounding area as shown on Figure 2-8. The site is drained by gradual fine grading away from the storage pads, and a combination of earthen, and concrete channels to the exterior of the site. The southern eight acres of the site are drained by a system of earthen and concrete trapezoidal channels, and the remainder of the site is drained via concrete culverts. This is shown on Figure 2-8. The drainage system was designed using a 10-year storm rainfall intensity. Storm drainage channels were checked and provided with additional depth to accommodate the 100-year storm (References 6, 7 & 8). These channels were checked to confirm that adequate hydraulic capacity existed in the storm drain system, and that the hydraulic grade line elevations were less than the top elevations of the storage pads. Since the storage pads are located at the highest part of the ISFSI, severe flooding or hydrodynamic loading due to floodwater is not credible based on the 100-year storm.

2.4.3 Probable Maximum Floods On Streams and Rivers

Based on information presented in Section 2.4.3 and Appendix 2A of the North Anna Power Station UFSAR, the probable maximum flood on Lake Anna would result in a lake level of 264.2 feet msl at the Main Dam. The water level at the Power Station site was calculated to be 267.3 feet msl, including possible wave effects. The effects in the Sedges creek area of the Waste Heat Treatment facility would be similar to that in the main lake, however, the wave effects would be less due to decreased fetch. The ISFSI is sited at an elevation approximately 45 feet above the postulated PMF lake elevation.

2.4.4 Potential Dam Failures (Seismically Induced)

As stated in Section 2.4.4 of the North Anna Power Station UFSAR, there are no dams in existence on the North Anna River, other than the Lake Anna dam, either upstream or downstream. The only impoundments in the area would be small farm ponds whose failure would not produce any measurable effect on Lake Anna, the Lake Anna dam, or any safety-related systems. Thus, because the ISFSI is at a higher elevation than the station, the ISFSI is unaffected by flood levels due to seismically induced dam failures.

2.4.5 Probable Maximum Surge and Seiche Flooding

Surge and seiche flooding effects are considered in coastal or tidal areas where cyclonic activity results in increased water levels. These increased levels are due to the momentum of the storm event and the reduction in volumetric flow area near the coast (References 9 & 10). The

North Anna Power Station is approximately forty miles upstream from the confluence of the North Anna river with the South Anna near Doswell. The Pamunkey River becomes tidal in the region of the US 360 bridge approximately thirty-six miles downstream of this confluence. Surge effects would dissipate with distance from the coast, available storage of floodwater, elevation above sea level, etc. Therefore, surge flooding is not considered credible. Since the Power Station and the ISFSI site are not within an enclosed or semi-enclosed bay or harbor, seiche due to free oscillations is not applicable. Seiche due to forced oscillations is applicable primarily to coastal situations and as stated previously, the ISFSI site is inland.

2.4.6 Probable Maximum Tsunami Flooding

Tsunami flooding is not a consideration for the North Anna site because of its inland location (Reference 9).

2.4.7 Ice Flooding

As discussed in Section 2.4.1.2, the North Anna ISFSI is approximately 60 feet above the normal level of Lake Anna. The formation of ice on Lake Anna would not have an effect on the ability of the North Anna ISFSI site to drain properly.

2.4.8 Flooding Protection Requirements

The ISFSI is situated well above the maximum water level occurring on Lake Anna. As stated in Section 2.4.1.2, the ISFSI site grade is 60 feet above the normal stillwater level of Lake Anna. There are no special precautions that need to be taken to protect SSSCs on the storage pads.

2.4.9 Environmental

There are no liquid or gaseous releases that could result from operation of the North Anna ISFSI.

2.4.10 Subsurface Hydrology

2.4.10.1 Regional Characteristics and Site Characteristics

The hydrologic boundaries of the North Anna Power Station site proper are Lake Anna on the north and east, Freshwater Creek approximately three miles to the west, and Elk Creek approximately four miles to the south. A description of groundwater conditions and onsite use are discussed in Section 2.4.13 of the North Anna Power Station UFSAR.

The hydrologic boundaries of the North Anna ISFSI site consist of a tributary to Sedges Creek to the west and south of the site, Canal A to the east, and Lake Anna to the north. The closest distance to Lake Anna to the north is located near the Unit 2 intake structure which is approximately 3,000 feet away. The distance to Canal A is approximately 2,500 feet to the east. The closest distance to Lake Anna in the Waste Heat Treatment Facility is 1,500 feet to the southeast. A tributary to Sedges Creek, however, varies from less than 100 feet to the west of the

ISFSI to 1,000 feet directly to the south of the ISFSI. Figure 2-9 depicts the ISFSI and its location with respect to the lake.

The elevation of rock surface varies at the ISFSI site from Elevation 272 feet msl to Elevation 245 feet msl. The groundwater generally moves along this rock surface until it exits the ground surface as springs, or into the lake. There are three permanent groundwater monitoring wells that have been installed onsite, one upgradient and two downgradient. The average groundwater elevation of the upgradient well is 296.3 feet msl. The average groundwater elevation of the southwesterly downgradient well is 289.0 feet msl. The average groundwater elevation of the southeasterly downgradient well is 280.3 feet msl. The average elevations cited are based on a three month period in which the readings were taken. The southwesterly gradient is approximately 0.01 ft/ft, and the southeasterly gradient is approximately 0.02 ft/ft. Using a horizontal coefficient of permeability of 10^{-6} cm/sec, an estimate of the seepage rate is between 1.5 and 3.0 gal/day/ft near the ISFSI. Groundwater from below the ISFSI site will tend to migrate towards the lake via springs, which will accumulate in the tributary stream to Sedges Creek. This groundwater will eventually move into the lake at the Sedges Creek "arm" of the Waste Heat Treatment Facility.

2.4.10.2 **Onsite and Offsite Water Use**

Water for domestic use at the plant site is taken from groundwater wells. There are currently seven wells in use at the Power Station. The closest of these to the ISFSI site is approximately 1,500 feet away to the east near the North Anna Nuclear Information Center (NANIC).

The closest offsite well to the ISFSI site is in a residential area approximately 3,500 feet away to the south. As discussed in Section 2.4.10.1, the groundwater regime below the ISFSI site will tend to move water to the tributary of Sedges Creek directly to the south of the site, and eventually into the Lake. The wells in this residential area are drilled very close to the lake and the effects of the presence of the lake (hydrostatic pressure), and distance from the site would preclude any groundwater movement from the ISFSI to this location.

2.4.11 References

1. *Site Environmental Studies, Proposed North Anna Power Station, Louisa County, Virginia,* Dames & Moore.

2. *Site Environmental Studies, North Anna Power Station Proposed Units 3 & 4, Louisa County, Virginia,* Dames & Moore.

3. Water Resources Data for Virginia, U.S. Geological Survey Water-Data Reports, 1961 through 1993.

4. Flood of August 1969 in Virginia, U.S. Department of the Interior, Geological Survey, Water Resources Division, 1970.

5. Floods in Virginia, Magnitude and Frequency, U.S. Department of the Interior, Geologic Survey, Water Resources Division, E. M. Miller, 1969.

6. Drainage Manual, Virginia Department of Transportation, 1989.

7. *Applied Hydrology,* Chow, Maidment and Mays, 1988.

8. *Open Channel Hydraulics,* Chow, 1959.

9. *Handbook of Coastal and Ocean Engineering,* Vol. 1, Wave Phenomenon and Coastal Structures, John B. Herbich, Editor.

10. *Shore Protection Manual,* Vol. 1, Coastal Engineering Research Center, Department of the Army, 1984.

2.5 GEOLOGY AND SEISMOLOGY

2.5.1 Basic Geologic and Seismic Information

This section presents information developed from analysis of borings, laboratory tests and additional bedrock exposures at the ISFSI site. The geology and seismology for the North Anna Power Station as previously presented from the original plant licensing and other documents is discussed in Section 2.5 and Appendices 2B, 2C and 3E of the North Anna Power Station UFSAR. Also presented is a general update to Section 2.5 of the North Anna Power Station UFSAR based on geologic information developed over the last 15 to 20 years, including a reclassification of the basic Piedmont geologic nomenclature as a result of geologic mapping in the Northern Virginia Piedmont.

2.5.1.1 **Storage Site Geomorphology**

The ISFSI site is contiguous with that of the North Anna Power Station, and is collectively called the site hereinafter. The site is located within the Piedmont Plateau Province, which is characterized by an undulating, rolling topography with as much as 100 feet of relief in the general site area. The Piedmont Province is bounded on the east by the Atlantic Coastal Plain Province, some 15 miles east-southeast of the site, and the Blue Ridge Province to the northwest, some 40 miles distant from the site. Bedrock within the Piedmont is typically metasedimentary and metavolcanic, with some plutonic granitic rocks. The bedrock typically is deeply weathered into a saprolitic cover of up to 100 feet in thickness.

2.5.1.2 **Geologic History of Storage Site and Surrounding Region**

The ISFSI site is located within an area of the eastern North American craton that has undergone extensive tectonism since Precambrian time. This has resulted in a complex pattern of regional folding and faulting. Three of the periods of tectonism in the Paleozoic era were the result of a collisional or accretionary tectonic style, while the last period of tectonism was generally a continental rifting, or extensional style of deformation. This last period of tectonism in

the late Jurassic and early Triassic resulted in the formation of the numerous downfaulted Triassic basins that exist along the eastern margin of North America, from Connecticut to Georgia.

2.5.1.3 **Specific Structural Features of Significance**

The ISFSI site lies adjacent to the North Anna Power Station upon a bedrock lithology mapped previously (Reference 1), and shown in Figure 2-10, as hornblende gneiss. The hornblende gneiss, which is the dominant lithology, is generally an interbedded sequence of hornblende gneiss, biotite granite gneiss and granite gneiss. As shown in Figure 2-10, the dominant lithology onsite is the interbedded hornblende gneiss/biotite granite gneiss/granite gneiss sequence, with the massive granite gneiss unit being subordinate. Both units as mapped onsite are part of the Ta River Metamorphic Suite, mapped and classified by Bobyarchick, et al. (1981) (Reference 2). The Ta River occurs west of the Spotsylvania Lineament (a northeast-southwest trending aeromagnetic lineament described below), and is generally composed of amphibolites, amphibole gneiss and minor biotite granite gneiss and schist units.

The dominant structural features noted during detailed geologic mapping at the site in 1973 (Reference 1) are shown in Figure 2-10. The site is located on the northwest flank of a northeasterly trending, gently plunging (15 degrees) to the north, antiform. During the Paleozoic era, these rocks were deformed repeatedly and resulted in the polydeformational expression seen in the rocks today. Boundaries between the different units at the site were primarily affected by flexural slip folding during that era as the antiform was forming. The resulting deformation along one of these boundaries formed the Zone A Chlorite Seam that was the object of the very detailed geologic investigation in 1973 because of its location relative to Units 1 through 4 of the North Anna Power Station. Details describing this geologic investigation can be found in Section 2.5.2.4 of the North Anna Power Station UFSAR.

The closest fault to the site other than that described above is located near Mineral, Virginia, some six to seven miles west of the site. The fault has no surface expression and is known only from exposures in underground mine workings near Mineral. The known length of the fault is approximately 1,000 feet, with a projected maximum length of several miles. If projected along its strike of N20°E, it would pass approximately 4-1/2 miles northwest of the site (Section 2.5.2.4 of the North Anna Power Station UFSAR).

The locations of recent borings drilled at the ISFSI site for purposes of developing subsurface information for foundation design and for confirming bedrock geology characteristics are shown on Figure 2-11. Figure 2-12 presents a subsurface cross-section of the bedrock and overlying soils beneath the storage pads. The bedrock encountered in the core retrieved from the borings confirms the previous bedrock mapping and interpretation made in 1973. Additionally, fractures identified in the core were consistent in both frequency and general orientation relative to the core as those observed and mapped in the excavations for Units 3 and 4 and elsewhere onsite in 1973. No structural zones similar to what was observed in Units 3 and 4 during the 1973 geologic investigation were observed in the core retrieved from the recent ISFSI borings.

Foliation observed in the core ranged from 35 to 50 degrees (interpreted to be dipping to the northwest based on previous mapping onsite).

Details regarding the recovery and RQD values are contained in Table 2-4. The boring logs and logs of the rock coring for the bedrock investigation, are provided in Appendix 2A.

A brief description of structural features of significance is provided below. Additional details regarding the site can be found in Section 2.5.3.1 of the North Anna Power Station UFSAR.

1. Hylas Zone

   In a section of the Piedmont and Triassic subprovince approximately 25 km west of Richmond, and to the south-southeast of the site, lies the Hylas zone which trends roughly northeast (Figure 2-13). This is a group of mylonitic rocks produced by late Paleozoic ductile shearing of pre-existing biotite gneiss, granite gneiss, and amphibolite. The rocks west of the Hylas zone (between Columbia and the Hylas zone), referred to as the Goochland complex, are metamorphosed sedimentary and igneous rocks consisting of biotite gneiss and schist, granite gneiss, amphibolite, and granite.

   The Petersburg granite, a coarse-grained unit, bounds the eastern margin of the Hylas zone at Hylas and northeastward to the Taylorsville Basin. It is a two-feldspar muscovite-biotite granite with at least one poorly to moderately developed tectonic foliation. Emplacement of the Petersburg granite occurred prior to the formation of the Hylas zone since field mapping indicates mylonitic rocks are gradational into relatively unaltered granite (Reference 3).

   Rocks in the Goochland complex west of the Hylas zone underwent at least two deformations (D_1, D_2) prior to ductile shearing in the Hylas zone (D_3). D_3 was responsible for a mylonitic foliation (S_c) and a later widely-spaced shear cleavage (S_s) to be formed in rocks in the Hylas zone. At about 220 Ma, brittle deformation was superimposed on the Hylas zone in the form of high-angle faulting and locally intense fracturing (D_4) which is probably equivalent to the Palisades disturbance of New England. D_4 was associated throughout the Piedmont with synchronous downwarping and dominantly continental sedimentation to form a series of parallel Triassic basins represented locally by the Richmond Basin. Northwest-oriented high-angle faults that apparently displace Triassic sedimentary rocks are interpreted to have occurred prior to the Late Cretaceous (Reference 3).

   The Goochland complex underwent regional prograde metamorphism to amphibolite facies (M_1) and included D_1 and D_2; structural elements that compose these deformational events consist mainly of oriented metamorphic minerals. Well-equilibrated microstructures seen in the gneiss suggest that the M_1 peak persisted past D_2. M_1 is interpreted to have occurred approximately 340 Ma. During the late Paleozoic time, D_3 was accompanied by retrograde metamorphism (M_2) to greenschist facies in the Hylas zone. The Hylas zone may continue to the north in the Brandywine area of the Coastal Plain as indicated by Cenozoic reverse

faulting 90 km along the strike of the Hylas zone (Reference 4). Current stress release beneath the Coastal Plain may be influenced by the Hylas zone and analogous fault systems throughout the Piedmont (Reference 2).

2. Stafford Fault System

Various field investigations of the upper Mesozoic and Cenozoic deposits of the Inner Coastal Plain of Virginia between Washington, D.C. and Richmond, Virginia have revealed evidence of faulting of Coastal Plain beds. In 1976 Newell and others (Reference 5) recognized and described the Stafford fault system which is a series of end echelon, northeast striking, northwest dipping, high-angle reverse faults that displace both the Apostolic rocks of the Piedmont and the overlying Coastal Plain sediments. The Stafford fault extends for more than 33 miles along the Virginia Fall Line and the northeast-trending reach of the Potomac River. Mixon and Newell (1977) (Reference 6) believe that the position of the Stafford fault system supports the hypothesis that the Fall Line and major river deflections along it have been tectonically influenced (Reference 7).

Fault movement along the Stafford system began as compressional deformation at least as early as the Early Cretaceous. A detailed trench study of the Dumfries fault zone west of Stafford, Virginia is of special significance: Ordovician slate, phyllite, and schist have been thrust at a high angle over the lower Cretaceous Potomac Formation. Likewise, major deformation occurred in the middle Tertiary and pre-Choptank time. There is as much as 1-1/2 feet of reverse fault offset at the base of the upland gravel in an artificial cut near the US 1 highway bypass in south Fredericksburg, Virginia which indicates that at least some Pliocene deformation occurred along the Stafford system. "Approximately 1.0 foot of fault offset of the base of high-level Rappahannock River terrace deposits by the Fall Hill fault, which is a major strand of the Stafford system, indicates middle to late Pliocene or, possible, younger faulting." (Reference 7)

Mixon and Newell (1977) (Reference 6) noted the alignment of zones of compressional faulting in the Maryland and Virginia Coastal Plain in linear zones of early Mesozoic extensional faulting in the Piedmont and in the crystalline basement beneath the Coastal Plain. The early Mesozoic extensional faults and the Coastal Plain compressional fault zones are, in turn, aligned with Paleozoic thrusts and shear zones in the underlying basement rock. In Virginia, for example, the Stafford fault system is aligned with the border faults of the early Mesozoic Farmville basin trend and with the Spotsylvania magnetic lineament (Reference 5).

During 1976, Dames & Moore (Reference 4) investigated the age and geologic origin of the Stafford fault system, which approaches the site at its closed point, approximately 22 km northeast in the vicinity of Fredericksburg. The detailed drilling, trenching and mapping program demonstrated that the youngest identifiable fault movement on any one of the four

structures making up the Stafford fault system was pre-mid-Miocene in age, or more than 10 million years ago. Accordingly, the Stafford fault system is not capable in the meaning or intent of Appendix A to 10 CFR 100.

3. Spotsylvania Lineament

The Spotsylvania lineament is a northeast-trending aeromagnetic anomaly that separates the Ta River and Po River Metamorphic Suites. To the west of the lineament, and where the North Anna Power Station is located, the Ta River rocks are characterized by linear, northeast trending medium to high intensity anomalies; however, to the east of the lineament, the Po River terrane is characterized by relatively lower intensity, north-trending anomalies. Researchers believe that the Spotsylvania lineament represents a fault or system of faults to explain its regional linearity. Microstructures and field data indicate that the Spotsylvania lineament, if it represents a fault, formed during or before regional metamorphism (Reference 2).

Inasmuch as the Spotsylvania lineament is directly on strike with a projected extension of the Stafford fault system to the southwest, Dames & Moore (1977) (Reference 8) investigated the minimum age of the Spotsylvania lineament (then known as Neuschel's lineament) by categorizing and mapping the extent and continuity of a Pre- or Early Cretaceous erosion surface across the extent of the lineament. Dames & Moore's findings were that the lines of evidence discerned indicated a minimum age of movement of 100 million years (Early Cretaceous) if the lineament were indeed a fault zone, and that it is not structurally related to the Stafford fault system.

4. Mountain Run Fault Zone

The Mountain Run fault zone (MRFZ) is a regional feature approximately 75 km in length. It is best defined as a physiographic feature, in the form of a northeast-trending linear fault-scarp, in the Unionville, Virginia quadrangle. The northern end of the MRFZ forms part of the southeast boundary of the early Mesozoic Culpeper basin. The scarp is "held up" by phyllonite which extends over a width of at least 2-1/2 km to the southeast of the scarp. On the northwest side of the scarp lies an alluvium-filled valley. The northwest side of this valley is a narrow zone of faulted and sheared rocks that form the northwest boundary of the MRFZ. Mapping indicates that the MRFZ extends from about the Mesozoic basin near the Rappahannock River southwestward to near Charlottesville, Virginia (Reference 9).

On its southeast side, the MRFZ separates a thrust-faulted early Paleozoic (pre-440 Ma) melange terrane from a phyllite, slate, and limestone unit that uncomformably overlies the Precambrian Catoctin Greenstone; together these are considered as part of ancestral (pre-400 Ma) North America. Therefore, the MRFZ is thought to be a suture which "juxtaposed a Cambrian island arc (Central Virginia volcanic-plutonic belt) and its associated fault-imbricated back-arc basin (melange terrane) onto or against ancestral North America in pre-440 Ma." In early Mesozoic time, part of the MRFZ was reactivated to partly delineate the southeast boundary of the Triassic-Jurassic Culpeper basin. According to Pavlides (1986)

(Reference 9), there may have been additional local reactivation within the MRFZ during the late Cenozoic time indicated by the recent (ca. 1986) discovery of a thrust fault within the MRFZ that offsets gravels of probably post-Pliocene age (Reference 9).

5. Giles County Zone

   A series of five extensional faults were recently uncovered in new excavation for landfill material adjacent to the New River in Giles County, Virginia, some 220 miles west-southwest of the site (Figure 2-13). The faults strike about N50°E and dip either northwesterly or southeasterly. The structures displace alluvial terrace deposits of suspected Tertiary or Quaternary age. Seismic monitoring in this part of the Valley and Ridge Province over the past 20 years indicate that earthquake foci are located at depths greater than 5 km (Reference 10).

2.5.1.3.1 Regional Geology

The predominant lithologies in the region surrounding the site include rocks of the Central Virginia Volcanic-Plutonic Belt, the Ta River and Po River Metamorphic Suites and interlayered mafic and felsic metavolcanic rocks. The Falmouth Intrusive Suite and the Quantico Formation are rocks of the Central Virginia Volcanic-Plutonic Belt. The Falmouth Intrusive Suite is composed of fine-grained to pegmatitic granite, quartz monzonite, granodiorite, and tonalite and also consists of dike, sills and small plutons. This unit has been dated at about 300 to 325 Ma and locally intrudes the Ta River Metamorphic Suite and the Quantico Formation. The Quantico Formation is predominantly a slate and porphyroblastic schist. This unit contains gray to black, graphitic, pyritic phyllite and slate (in the northern Piedmont) whose metamorphic grade increases to the southwest to produce porphyroblastic staurolite-, kyanite-, and garnet-biotite-muscovite schists. This unit reaches a thickness of up to 3,000 feet. The Quantico Formation is Ordovician in age and unconformably overlies older units in the northeastern Piedmont. It is correlated with the Arvonia Formation to the southwest (Reference 11).

The Ta River Metamorphic Suite is a layered sequence which consists mainly of greenish-gray to black, medium to coarse-grained, poorly to well lineated, massive to well-layered amphibolite and amphibole-bearing gneiss and schist. Likewise, this suite contains interlayered ferruginous quartzite, and minor biotite gneiss and schist, felsic volcanic rocks, gabbro and granite. The amphibolitic rocks commonly contain quartz-epidote lenses and veins. The grade of regional metamorphism increases from northeast to southwest along strike as does the proportion of biotite gneiss and schist. Pavlides (Reference 12) correlated the Ta River with the James Run and Chopawamsic Formations, and considered the Ta River to be a more oceanward facies of a Chopawamsic island arc sequence, based on geologic and geochemical factors. The Ta River is Cambrian in age. The Quantico Formation generally overlies the boundary between the Ta River and the Chopawamsic, obscuring the contact relationships (Reference 11).

The Po River Metamorphic Suite, which lies to the east of the Ta River Metamorphic Suite, is characterized primarily by biotite gneiss with lesser amounts of hornblende gneiss and schist. Furthermore, pegmatoid and granitoid dikes are abundant. "The age of the Po River is uncertain, but may be considered Proterozoic Z and (or) early Paleozoic based on its stratigraphic position underlying the Ta River Metamorphic Suite and the Holly Corner Gneiss, both correlated with the Lower Cambrian Chopawamsic Formation." (Reference 12)

Ferruginous quartzites, which are distinctive local marker units, locally delineate map-scale structures in some places. "This lithology is recognizable in rocks of variable degree of deformation and metamorphic grade; it has been mapped within the Ta River Metamorphic Suite and within correlative unnamed interlayered mafic and felsic metavolcanic rocks to the southwest." (Reference 11)

2.5.1.3.2 Regional Tectonics

Since the time of the initial geologic investigation at the North Anna Power Station, two major tectonic models have emerged to explain the evolution of the central and southern Appalachians. The initial model was presented in 1972 by Hatcher, which proposed that the eastern Piedmont volcanics (Charlotte, Caroline Slate, Raleigh, and eastern slate belts) represented a late Precambrian to Early Ordovician island arc on the eastern edge of Laurentia. An Andean-type orogeny during the Middle Ordovician-Silurian was presumed to have formed by westward subduction of oceanic crust. Collision with Africa, during Mid-Late Devonian to Permian, resulted from continued westward subduction and produced the Acadian and Alleghanian orogenies. Following Hatcher's model in 1972, Odem and Fullagar and Rankin suggested models in which the Brevard zone along the Eastern Blue Ridge was a suture (Reference 13).

In 1978, Hatcher revised his earlier model increasing the number of sutures from one to three. Between 800 and 700 Ma, the basements of the Inner Piedmont and Charlotte/slate belts were thought to be continental fragments rifted from Laurentia. From about 700 to 450 Ma, subduction towards the west draped the outer fragment with Charlotte/slate belt volcanics. Concurrently, the oceanic basins between the Laurentian continent/Inner Piedmont and Charlotte belt/slate belt fragments were closing, culminating in the Taconic Orogengy during the Middle/Late Ordovician. Oceanic crust continued to subduct to the west beneath the Charlotte/slate belt, which eventually closed the Iapetan Ocean. Continental collision with Africa took place in the Acadian/Alleghanian orogenies during the Late Paleozoic (Reference 13).

In 1980, Hatcher and Odom modified the 1978 model to include: Taconic collision between the North American craton and the Piedmont fragment; Acadian collision between the Piedmont-North American block and Avalonia; and the Alleghanian collision between Africa and Avalonia (Reference 13).

Coney and others (1980) established the suspect terrane concept which was formalized in the western North American Cordillera. This concept initiated the beginning of a new tangent in

the development of Appalachian tectonic models. In 1982, Williams and Hatcher published a paper on the accretionary history of the Appalachians, essentially discarding the model proposed by Hatcher in 1978 for the southern and central Appalachians, but added several new terranes thought to possibly be bounded by suture zones. Since that time, others have proposed that the southern and central Appalachians are divided into numbers of micro-terranes each bounded by possible sutures (Reference 13).

In 1982, Glover and others presented another model, different than the one proposed by Williams and Hatcher, to explain the tectonic configuration of the Appalachians. They concluded that the only suture in the Piedmont and the Blue Ridge of the central and southern Appalachians is the Taconic suture, based on the ages of ductile deformation and metamorphism in the central and southern Appalachians. The Taconic suture is found along the western boundary of the Kings Mountain belt in North Carolina and extends into Virginia along the western boundary of the Charlotte belt and Chopawamsic volcanics. Likewise, Glover and others believe that other sutures, of Acadian and/or Alleghanian ages, must lie under the Atlantic Coastal Plain or offshore in basement rocks (Reference 13).

In 1987, Hatcher further revised the Hatcher and Odom (1980) model to include the Penobscottian orogeny (early Cambrian to Early Ordovician) as an early stage in the collision of the "Piedmont arc" with the North American craton (Reference 13). Additional details regarding the regional tectonic characteristics of the area around North Anna Power Station can be found in Section 2.5.2.4 of the North Anna Power Station UFSAR.

2.5.1.4 **Large Scale Geologic Map**

The locations of the structural feature discussed in Section 2.5.1.3 are shown in Figure 2-13.

2.5.1.5 **Plot Plan and Site Investigations**

Soil borings and laboratory tests were performed as part of the development of the North Anna Power Station license application. The boring logs and site maps showing the boring locations are contained in Appendix 2C of the North Anna Power Station UFSAR. Additional borings and laboratory tests were performed in the area of the Service Water Reservoir. Results of these borings and tests are contained in Appendix 3E of the North Anna Power Station UFSAR. An investigation consisting of soil test borings, rock coring, and laboratory tests was performed at the ISFSI site to identify and document site geotechnical conditions and to develop soil parameters required for evaluation of design requirements. Results of the borings and rock coring are contained in Appendix 2A and laboratory tests are contained in Appendix 2B of this document.

The geologic portion of the field investigation for the siting of the ISFSI at the North Anna Power Station consisted of:

1. The logging and preparation of bedrock boring logs for eight borings, using standard techniques; and

2. Examination of weathered bedrock exposures in a borrow pit west of the North Anna Power Station switchyard and close to a tributary arm of Lake Anna.

The purpose of the field geologic investigation was to ascertain the physical nature and characteristics of the bedrock from the cores retrieved from the borings, as well as the limited exposure afforded in the borrow pits, in order to compare them to previous onsite geologic investigations in 1973 and 1974. The field geologic investigation was performed by a geologist from Dames & Moore.

2.5.1.5.1 Field Investigation

At the direction of Virginia Power, eight borings (F-4 through F-11) were drilled in June through July of 1994 at the proposed ISFSI storage pad locations as shown on Figure 2-11. The borings were located in plan and elevations by Stone & Webster surveyors. Boring F-2, drilled in April 1994 for a preliminary investigation and located at the North end of the center storage pad is also included herein. In addition, seven shallow borings designated P-l through P-7 were drilled along the transport route. The soil test borings were drilled by Froehling & Robertson, Inc. (F&R) using a Central Mining Equipment (CME), Model 55 truck mounted drill rig by mechanically advancing continuous flight hollow stem augers into the soil. At regular intervals a standard 1.4-inch i.d., 2.0-inch o.d., 20-inch long split spoon sampler was driven into the soil with a 140 lb hammer falling 30 inches in accordance with ASTM D1586 Standard Penetration Test (SPT) procedures (Reference 14). SPT results provide an indication of compaction, strength and support capacity of the soil. SPT tests were performed continuously to depths of 4.5 feet, from 6.0 to 7.5 feet, 9.0 to 10.5 feet, and at five-foot intervals thereafter to spoon or auger refusal (rock). Disturbed split-spoon samples were collected with each SPT and visually classified by a geotechnical engineer from Virginia Power. The boring logs showing elevation and depth of samples, penetration resistances (blow count), soil stratum description and Unified Classification, and groundwater information are contained in Appendix 2A.

Where borings could no longer be advanced with standard soil boring equipment, rock was cored. A water-cooled double-tube NX-size core barrel with diamond studded bit was used to secure the rock cores. The core recovery from each five foot long run was examined and classified by a geologist from Dames & Moore. The percent recovery, which is the ratio of the recovered length to the total length of run, was calculated for each run. The Rock Quality Designation (RQD) was also calculated for each five-foot run. RQD is the ratio of the cumulative length of pieces of core greater than 4 inches long compared to the total length of run. RQD is an index to the soundness and quality of the rock. Core recoveries and RQD values for all core runs are contained on the boring logs and are provided in tabular form in Table 2-4.

Split spoon samples are suitable for visual examination and classification (index) tests but are not sufficiently intact for quantitative laboratory testing. Six relatively undisturbed samples were obtained by forcing sections of 3-inch o.d., 16 gauge, steel tubing into the soil at the desired sampling levels. This sampling procedure is described by ASTM Specification D-1587

(Reference 15). Each tube, together with the encased soil, was carefully removed from the ground, made airtight, and transported to the laboratory. Locations and depths of undisturbed samples are shown on the boring logs. Five additional undisturbed samples were obtained by pushing sampling tubes into the soil using a backhoe bucket.

Five monitoring wells were installed at locations across the site. These wells consist of slotted well screens attached to 2-inch diameter PVC riser pipe. Filter sand was placed around the screen and a bentonite seal was placed above the well screen and sand. The annular space around the pipe and soil above the seal was filled to the surface with cement grout. Logs of the monitoring wells are also contained in Appendix 2A.

2.5.1.5.2 Laboratory Testing

The following tests were performed on selected split spoon, bulk, and undisturbed samples. Results of the test are contained in Appendix 2B:

Name of Test	ASTM Standard	Reference No.	Test Performed
Particle (Gradation) Size Analysis	D422 and D1140	16 and 17	19
Atterberg Limits	D4318	18	3
Natural Moisture Content	D2216	19	19
Moisture Density Determination	D1557	20	2
California Bearing Ratio (CBR)	D1883	21	6
Consolidation Test	D2435	22	3
Triaxial Shear Test	D2850	23	2
Unconfined Compression Test	D2166	24	5
Constant Head Permeability	D2434	25	1

Note: 1 ASTM D2850 is the standard for the Unconsolidated Undrained Triaxial Shear Tests. One Consolidated Undrained Shear Test with pore pressure was also performed. Currently there is no ASTM standard for the Consolidated Undrained Shear Test.

2.5.1.5.3 Borrow Pit Exposure

A borrow pit, located approximately 1,000 feet west of the North Anna Power Station switchyard (Figure 2-10), was used to provide fill for a number of onsite projects over the last five to ten years. Its location in relation to a previously-mapped fold axis would have provided additional confirmation of the presence of the fold axis and the interpreted bedrock geology from saprolite exposures during the 1973 onsite geologic mapping.

During the onsite logging of the core retrieved from the ISFSI site borings, the borrow pit was visited by the geologist from Dames & Moore to map the exposed bedrock. The borrow pit, unfortunately, had been in-filled and graded to reclaim and replant the exposed saprolite slopes. Enough exposed saprolite bedrock could be observed, however, to confirm that the interpreted

bedrock at that location was indeed granite gneiss, and that the fold axis was within the exposure limits. It was observed that the fold axis, although not directly measurable because of the lack of complete exposure of the saprolite bedrock, would have been aligned in a northerly direction and plunging gently. This is consistent with the orientation of F2 folds in the Lake Anna East Quadrangle west of the Spotsylvania Lineament (Reference 1).

2.5.1.6 **Geologic Profiles**

Based on the information gathered from the eight borings and associated sampling and testing obtained in June and July 1994, the following stratigraphic sequence is inferred to underlay the site.

Surface elevations, depth of residual soil and quality of rock varied moderately across the site. The materials encountered consist of residual soil derived from the in-place weathering of the parent metamorphic rock. The typical soil profile consists of clay minerals near the ground surface which were converted from the feldspars, micas, and ferro magnesian minerals contained in the parent rock. At depth, these minerals become less weathered and only partially altered, retaining their inter-particle bonding. Below the firm surficial clays and clayey silts (ML and MH), the soil grades from a fine sandy silt to a silty fine sand (SM to SP) with varying amounts of mica. The soils possess highly plastic fines in varying amounts, therefore, the characteristics of the fine grained soils and predominantly granular soils with some fines and mica are similar. The transition between the surficial fine grained soils and the more granular soils encountered with depth is gradual.

The penetration resistances (SPT) are higher in the surficial clays and clayey silts, drop off in the highly micaceous silty soils, and pick back up in the sandy soil and decomposed rock above the less weathered parent rock. The deeper residual soils retain the original fabric or bonding of the parent rock and are termed saprolites. The saprolite retains the foliation of the parent rock along with interparticle bond. There is no well defined boundary between soil and rock, only a transition.

The generalized soil profile as encountered by the borings across the ISFSI site is as follows. The surficial fine grained clayey silts (ML and MH) extend to depths of 7 to 29 feet in all but two borings. In borings F-5 and F-8, the clayey silt extends all the way to rock. These soils are stiff to hard in consistency and possess good to excellent strength and support capacity.

The more granular sandy micaceous silt and micaceous silty fine sand (SM and SP) are encountered below the cohesive material and normally extend to rock. However, in two of the borings, F-9 and F-10, silty fine sand was present from the ground surface to the top of rock. This material was medium dense to very dense in consistency with only a few SPT results falling below 10 blows per foot.

As shown on the boring logs (contained in Appendix 2A), the lithologies penetrated by the borings are entirely consistent with those mapped and shown on Figure 2-10. The ISFSI is located

entirely within a unit mapped as interbedded hornblende gneiss, biotite granite gneiss and granite gneiss, with the predominant lithology being hornblende gneiss.

Rock as defined by auger or spoon refusal and the initiation of rock coring was encountered at elevations varying from 245 to 272 feet. All of the cores retrieved, except for portions of Borings F-10 and F-4, were extremely weathered. Primary structures in the rock, however, are still recognizable. Table 2-4 provides a summary of the percent recovery and percent rock quality designation (RQD) values for all eight borings. Recovery varies from 0 to 95%, and RQD values vary from 0 to 35.8%.

Fractures are clearly observable, even in the most weathered of the cores. Typically, fractures vary from near horizontal to about 70 degrees from the vertical. Almost all fractures observed have iron and manganese staining on the fracture surfaces, indicative of groundwater flow. Slickensides were not observed on any of the fractures. This is not surprising, as the borings penetrate a rock mass away from those boundaries (such as Zone A) that underwent primarily flexural slip deformation during tectonism in the Paleozoic.

Foliation in the hornblende gneiss is well developed, with elongation of individual hornblende crystals. Foliation dip observed was between 35 and 50 degrees, which is consistent with the closest field observation point (Figure 2-10).

Groundwater was encountered at depths of 19 to 27 feet below existing grade (Elevation 289 to 296 feet) across the site several days after completion of individual borings. The groundwater level is at least 20 feet below the proposed final elevation of Elevation 311 feet.

Figure 2-12 presents a geologic profile across the site showing the soil and rock stratigraphy as discussed above.

2.5.1.7 **Plan and Profile Drawings**

Figure 2-8 shows the site grading plan. Figures 2-14, 2-15, and 2-16 show sections through the centerline of the three storage pads and details of cut and fill.

2.5.1.8 **Local Geologic Features Affecting Site Location**

The location of recent borings drilled at the ISFSI site for the purposes of developing subsurface information for foundation design and for confirming bedrock geology characteristics are shown in Figure 2-11. Figure 2-12 presents a subsurface cross-section of the bedrock beneath the ISFSI storage pads. The bedrock encountered in the core retrieved from the borings confirms the previous bedrock mapping and interpretation made in 1973. Additionally, fractures identified in the core were consistent in both frequency and general orientation relative to the cores observed and mapped in the excavations for Units 3 and 4 and elsewhere onsite in 1973. No structural zones similar to those observed during the 1973 geologic investigation were observed in the core retrieved from the recent ISFSI borings. Foliation observed in the core ranged in depth from 35 to 50 degrees (interpreted to be dipping to the northwest based on previous mapping onsite).

Details regarding the recovery and RQD values, and the boring logs for the bedrock investigation, are found in Appendix 2A.

2.5.1.9 Site Groundwater Conditions

The depth to the water table was measured in each of the borings taken in June and July 1994. The depth to the ground water was 19 to 27 feet (Elevation 289 to 296 feet). Water levels in groundwater monitoring wells three months after installation varied from Elevation 280 to 296 feet which is consistent with water levels obtained initially.

Site groundwater conditions are discussed in Section 2.4.2. Additional groundwater information is provided in Section 2.4 of the North Anna Power Station UFSAR.

2.5.1.10 Geophysical Surveys and Studies

Section 2.5 of the North Anna Power Station UFSAR summarizes geophysical surveys and studies which have been performed to evaluate the stratigraphic structure and bedrock in the region of the North Anna Power Station.

2.5.1.11 Engineering Properties of Soil and Rock

The static and dynamic engineering properties of the site are described in this section. The engineering properties of the weathered rock (saprolite) and crystalline rock are described in Section 2.5.4.3 of the North Anna Power Station UFSAR, and further referenced in Appendices 2B and 2C of the North Anna Power Station UFSAR.

Physical property tests conducted on the saprolitic soils and fresh rock included:

- Dry density tests on selected samples
- Moisture Content Tests
- Triaxial Compression on undisturbed samples
- Particle Size Analysis (Gradation)
- Consolidation Tests on undisturbed samples
- Cyclic Triaxial Tests
- Shock Scope Tests

Additional onsite investigations that provide information on seismic wave propagation properties of the subsurface saprolite and rock included:

- Birdwell 3D Seismic Logs
- A Refraction Seismic Survey of the site area C
- A Cross Hole Shear Wave Survey of the rock supporting the reactor containments

Soil and rock properties defined by the borings and laboratory test results at the ISFSI site are contained in Appendices 2A and 2B. The properties developed from the ISFSI site investigation compare closely to the properties previously documented in the North Anna Power Station UFSAR and other references provided below.

Shear strength tests consisting of Unconfined Compression Test and Unconsolidated Undrained Triaxial Shear tests performed on the partially saturated surficial clayey silts (ML and MH) indicated these soils possess a cohesion (c) of 1,500 psf and an angle of internal friction (ϕ) of 15 degrees for the total stress condition. This compares closely with an average c of 1,800 psf and ϕ of 14.5 degrees obtained on extensive testing at the main dam site (Reference 26).

Consolidated Undrained Triaxial Shear test on the more granular silty sand (SM) encountered at a greater depth and near below the water table yield a cohesion of 700 psf and a ϕ of 27 degrees for the effective stress condition. This compares closely with a c of 720 psf and a ϕ of 26 degrees previously obtained and used as design parameters (Reference 26).

Consolidation Tests performed on samples of residual soil did not exhibit the sharp curvature or break-in-slope usually present in over-consolidated deposited soils. The test results on the surficial soils tested (4 to 6 feet) show a slight curvature, but no distinctive break. This is probably the result of sample disturbance or rebound due to stress changes during and after sampling or both.

The deeper sample (F-7A, 16 to 18 feet) which classifies as a SM, is predominantly granular. Consolidation tests performed on material shows significant curvature at slightly less than the expected overburden pressure. Disturbance may also be present in this sample.

For these reasons results of these Consolidation Tests were not used in estimating settlement on this project. Results of previous testing on similar material from the same geologic formation was used. An average Recompression Ratio of 0.024 was used to estimate consolidation settlement. An average initial target modulus (E_S) of 500 ksf was used in elastic settlement estimates (Reference 27).

The average unit weight and natural moisture content as determined from the laboratory tests contained in Appendix 2B are 100 pcf and 36% respectively. The vertical permeability, as obtained from a constant head permeability test, was 4×10^{-7} cm/sec, which compares closely with previously developed permeabilities.

Results of CBR tests performed for this project were compared to corresponding values for Modulus of Subgrade Reactor (k_S) provided by a chart giving the interrelationship of soil classifications and bearing values (Reference 28). The average unsoaked CBR of the near surface soils was 39 and soaked 7.5. The corresponding k_S from the chart was 375 pci and 175 pci which is higher than the conservative k_S of 115 pci (100 tcf) for saprolite as described in Section 3.8 of the North Anna Power Station UFSAR.

No new testing was performed on the rock encountered at the ISFSI site. Due to the depth of the rock and the very small increase in loading which the storage pad and SSSC would impose on the rock, the physical properties of the rock are not a factor. Rock was encountered at sufficient depth as not to be an influence in bearing capacity or settlement. The rock is competent and possesses no solution cavities, sink holes, voids or caverns.

No new dynamic testing was performed during the investigation for the ISFSI since the results of recent borings and laboratory tests were similar to those previously obtained and documented at the station and main dam site. Dynamic soil and rock properties for the site are contained in Section 2.5 of the North Anna Power Station UFSAR. A shear modulus (G) of 19,800 psi and Poisson's Ratio (μ) of 0.3 were used in design of the storage pads.

2.5.1.12 **Analysis Techniques and Calculated Results**

The factor of safety against a bearing capacity failure is defined as the ratio of the net ultimate soil bearing capacity to the net applied foundation bearing pressures. The static factor of safety considered the total dead and live loads acting on the structure. A minimum safety factor of 3.0 was established as the design criterion. The ultimate bearing capacity was calculated using conventional bearing capacity equations for shallow strip footings and the appropriate bearing capacity factors for the soil parameters present (Reference 29). Bearing capacity for a wide footing is normally not critical unless the footing is subject to very heavy load and a high water table and/or very soft or loose soil conditions exist. The factor of safety against a bearing capacity failure calculated for the storage pad bearing on the stiff residual soil was significantly in excess of the required factor of 3.

Settlement was estimated by calculating the immediate elastic settlement and long-term consolidation settlement of the underlying residual soil. The elastic and consolidation settlement occur at different times but are additive. However, settlement calculations utilizing the classical consolidation theories which were developed for saturated sedimentary soils are generally not appropriate for the partially saturated residual soils. Consolidation theory considers the soils to be cohesive, homogeneous and isotropic. The residual soils encountered below the storage pads are only partially saturated, are highly variable and possess an interparticle bond related to the weathering of the parent rock, not the clay ion bond. Previous estimates of settlement of residual soils using consolidation theory have not agreed closely with the actual documented settlement which occurred at various structures onsite.

Therefore, settlement calculations were also performed using empirical equations developed by Schmertmann and others and utilizing results of correlations between STP and in-situ pressuremeter tests in residual soils (Reference 30). Based on results obtained from the two different methods, it is estimated that a total settlement of less than 1-1/2 inches will occur under full load. This estimate assumes that only 5 feet of overburden will be removed. Six and a half to ten feet (for pad 1) of overburden will be removed prior to construction of the storage pads, which would reduce the amount of settlement that would occur. This estimate assumes that the total load

will be placed on the soil in one increment, which is a very conservative assumption. The time rate of loading will decrease the actual effect of any settlement that does occur, since it will take over nine years after the initial SSSC is placed for the storage pads to be fully loaded. The settlement will occur in small increments as the SSSCs are placed on the storage pads.

2.5.2 Vibratory Ground Motion

This section of the report describes the principal bases of the seismologic studies for Units 1 and 2 of the North Anna Power Station, and provides the framework for which the design-basis earthquake and its associated vibratory ground motion were evaluated. Additional reference is made to studies to evaluate the engineering properties of materials and their effect on seismic wave propagation and soil structure interaction.

2.5.2.1 Engineering Properties of Materials

The static and dynamic engineering properties of the site are described in Section 2.5.1.11.

2.5.2.2 Seismic History

A complete description of the seismic history of the site areas, as well as a summary of all significant earthquakes to the establishment of the design basis earthquake for North Anna Power Station Units 1 and 2, are presented in Appendix 2B of the North Anna Power Station UFSAR. Table 2-5 and Figure 2-17 in this report provide an updated chronological listing (through January 1994) and a regional epicenter map, respectively, for an area of 200-mile radius around the site.

The eastern United States is generally divided into four basic geologic-tectonic provinces: the Valley and Ridge, the Blue-Ridge, the Piedmont and the Coastal Plain. All four of these provinces are characterized by a general northeast-southwest trend. The Valley and Ridge is dominated by a structural style of large anticline-syncline structures which are further complicated by faulting, igneous intrusions and the development of terrestrial sedimentary basins (Reference 1).

The Piedmont Province is a large northeasterly-trending elongated group of crystalline rocks extending for approximately 800 miles (1,288 km) from Alabama to New Jersey. This province is primarily characterized by metamorphosed sedimentary and volcanic rocks deformed into anticlinoria and synclinoria whose major axes parallel the dominant northeasterly trend of the province (Reference 1). The North Anna site is located in the north-central portion of Virginia within the Piedmont Province.

The historical record of earthquakes in the Appalachian region of the United States reveals significant differences in the seismic characteristics between the individual provinces. Generally, the activity occurs parallel to the regional structure and primarily in the Valley and Ridge and Blue Ridge Provinces northwest of the Piedmont Province (References 31, 32 & 33). Earthquakes are found to occur with less frequency in the Piedmont Province than in the adjacent provinces. Furthermore, none of the historical earthquakes in the Piedmont province in particular, or in the

Appalachian region in general, have been reported to have caused surface displacement. There are three principal geographic zones in the Piedmont and Coastal Plain Provinces where there is a tendency for epicenter clustering. One recognizable geographic cluster of activity is in the South Carolina-Georgia region (Piedmont-Coastal Plan), and another is in central Virginia (Piedmont Province). The third apparent cluster of activity is along the Fall Zone (Coastal Plain and Piedmont boundary) in the Delaware-New Jersey region.

The clustering of activity in Central Virginia is referred to as the Central Virginia Seismic Zone (Reference 31) and includes the North Anna site on its northern boundary. The principal activity in this zone is some 30 miles (48 km) south of North Anna, following an east-west trend. There have been 22 earthquakes of Modified Mercalli (M.M.) intensity V to VI reported within 100 miles (161 km) of the site since the end of the 18th century (Reference 34). The Central Virginia Seismic Zone has historically exhibited a low level of activity (2 to 10 shocks per decade), with most shocks having M.M. intensity levels of III to V.(31) Based on historical seismicity, the largest intensity shock that has occurred in the immediate site area (within 30 km) is approximately M.M. V (Figure 2-17).

The most significant earthquake in the region of the station affecting its design occurred near the Richmond Basin in 1774 (Intensity VI-VII), and near the Arvonia Syncline in 1875 (Intensity VII). These shocks and related zones of earthquake activity are both located within 50 miles of the site, and are believed to be associated with faulting in their respective basin-like structures. Additional earthquakes of epicentral intensity V occurred on December 11, 1969, near Richmond, Virginia (37.8°N 77.4°W) and on March 15, 1991, west of Richmond in Goochland County, some 37 km south-southwest of the site (Reference 35).

The 1875 shock was probably felt in the vicinity of the site, with an intensity approaching V. The 1774 shock cannot be accurately projected to the site area because of the lack of information, but it is believed that ground motion at the site did not exceed a few percent of gravity. The 1969 shock was perceptible over a 3,500 square-mile area. A study of the recent land forms in the site area does not reveal any adverse features such as faulting, slides, or areas of instability or brecciation that could have been caused by these shocks or from earlier earthquake shocks.

Additional details on seismic history are found in Appendix A to the North Anna Power Station Units 1 and 2 PSAR.

2.5.2.2.1 Microearthquake Monitoring

Dames & Moore's geologic investigation of the fault zone at the North Anna Power Station indicated that the zone had not experienced movement for the past 500,000 years, and was not in a critical state (Reference 1). None of the historic earthquakes in the Piedmont Province are known to have caused faulting at or near the surface. The fault zone underlying the reactor containment buildings and the fault zone underlying the North Anna dam appear to be of limited extent, and not structurally related to, or a continuation of, any known fault. No seismic activity, either

instrumentally recorded or historically determined, can be shown to have any direct tectonic relationship to these fault zones. The closest zone of activity is 30 miles (48 km) south of the lake (Central Virginia Seismic Zone). No topographic expression of recent faulting has been observed in the vicinity of the lake. Due to the absence of definite earthquake-tectonic correlations for the region, it is not surprising that no activity was found associated with the fault zone, nor associated with the impoundment of Lake Anna.

As a means of demonstrating this observation, the NRC required confirmatory microearthquake monitoring of the area around the site and Lake Anna. Phase I and Phase II (permanent) monitoring occurred at the site between January 21, 1974 through August 1, 1977. No microearthquake detected in the three and one-half years of monitoring was associated either with the fault onsite or related to the impoundment of Lake Anna. Four stations of the original 17-station monitoring network were incorporated into Virginia Tech's Central Virginia Monitoring Network for the specific purpose of monitoring any changes in seismicity in the region of the North Anna Power Station. To date, no changes have been observed that would contradict the conclusions reached in 1977 regarding the lack of association of microearthquakes with Lake Anna or with the fault at the North Anna Power Station (Reference 36).

2.5.2.3 **Design Basis Earthquake**

The North Anna Power Station Units 1 and 2 Preliminary Safety Analysis Report and design were completed prior to the promulgation of Appendix A to 10 CFR 100. Consequently, the term "design-basis earthquake," as used in this report, has the meaning it had prior to December 1973 when Appendix A to 10 CFR 100 became effective.

The design basis earthquake (DBE) for the North Anna Power Station Units 1 and 2 was established by assuming that an earthquake equivalent to the largest shock associated with the Arvonia Syncline might occur close to the North Anna site area. With the epicenter of a shock similar to the 1875 MM I-VII moved to the vicinity of the site, it was estimated that the maximum horizontal ground acceleration at rock surface would be less than 0.12g.

Accordingly, the design basis earthquake for Seismic Class I structures founded on rock was established as 0.12g for horizontal ground motion, and two-thirds (0.08g) that value for vertical ground motion.

For Seismic Class I structures founded on rock, analyses for earthquake motion were made using response spectra developed by enveloping the response spectra, for various degrees of damping, of the east-west and north-south components of the Helena (1935) earthquake and the southeast component of the Golden Gate record of the San Francisco (1957) earthquake, all normalized to 0.12g for the DBE. For Seismic Class I structures founded on saprolite more than 15 feet thick, these analyses for earthquake motion were normalized to 0.18g for the DBE to provide for calculated amplification through the overburden. The response spectra are shown on Figures 2.5-12 and 2.5-14 of the North Anna Power Station UFSAR.

The amplification of earthquake motion through the overburden was computed using a lumped-mass spring system with model superposition.

Based on the two-to-three pulses of strong ground motion for the San Francisco, California (1957), and Helena, Montana (1935), earthquakes, a conservative estimate of strong ground motion pulses to be experienced at the North Anna site is four to five pulses of strong ground motion for the operating-basis earthquake and eight to ten pulses of strong ground motion for the design-basis earthquake.

The results of the regional seismicity and structural geologic update for this report have not provided any basis for modifying the original seismic design basis for the site. Additionally, continued seismic monitoring in the region surrounding the site over the last 20 years has not provided any basis to associate the minor seismicity of the region with either Lake Anna or the fault at the North Anna Power Station. The North Anna Power Station seismic design provides adequate conservatism for seismic Class I Structures at the North Anna Power Station.

2.5.3 Surface Faulting

Surface faulting and capable faults are addressed in Section 2.5.2.2.

2.5.4 Stability of Subsurface Materials

The geologic features, seismicity, groundwater conditions, and soil and rock characteristics are addressed in Section 2.5.1 and Appendices 2A and 2B. The earthquake design basis is addressed in Section 2.5.2.

The storage pads and new portions of the transport route will be undercut a minimum of 18 inches and be brought up to grade with a compacted dense graded crushed aggregate fill. Random soils across the site will be used to construct leveling fills, slopes and berms. The soil fill will be placed in a controlled compacted manner.

Liquefiable soils consist primarily of loose sands at or below the water table which have low overburden or confining pressures, or highly sensitive clays. The fine grained soils encountered at the ISFSI site possess significant cohesion or inter-particle bond from the relic rock structure of the parent rock. Even the granular soils possess relatively high percentages (25% to 50%) of fine grained silt and clay size particles. The grains are also angular or sub-angular, not rounded or sub-rounded as deposited soils tend to be. Only one STP taken in the predominantly granular soils below the water table had a penetration resistance below 10 blows per foot, which would classify the soil as loose. Liquefaction at the Service Water Reservoir (SWR) was addressed in Section 3.6 of Appendix 3E of the North Anna Power Station UFSAR. It was concluded that liquefaction would not occur under the DBE of 0.18g. As stated, the soils encountered at the ISFSI site are similar to those encountered at the reactors, the Service Water Reservoir and the main dam. The soils encountered at the ISFSI site are a product of weathering of the same parent rock.

Dr. James Martin at Virginia Polytechnic Institute was retained by Virginia Power to evaluate the liquefaction potential for a horizontal earthquake acceleration of 0.30g at North Anna (Reference 38). This acceleration value is 2/3 higher than that generated by the DBE. His report concludes that liquefaction of the residual soils at the North Anna site will not occur under this horizontal earthquake loading.

2.5.5 Slope Stability

The ISFSI site will utilize both cut and fill to obtain final grade. A berm will be constructed across the front of the site. Soil fill will be utilized to construct portions of the transport route. Cut and fill slopes will not be steeper than two horizontal to one vertical (2H:lV). Proper compaction of onsite soils as required by specifications will ensure that the design parameters are achieved. The soils that comprise the cut or fill slopes are highly erodible, therefore, care will be taken to grade and seed the slopes to minimize the effects of erosion.

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16. American Society for Testing and Materials, ASTM, D422-63, *Particle Size Analysis of Soils.*

17. American Society for Testing and Materials, ASTM, D1140-54, *Amount of Material in Soil Finer Than the No. 200 (75 mm) sieve.*

18. American Society for Testing and Materials, ASTM, D4318-84, *Liquid Limit, Plastic Limit, and Plasticity Index of Soils.*

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22. American Society for Testing and Materials, ASTM, D2435-90, *One-Dimensional Consolidation Properties of Soil.*

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24. American Society for Testing and Materials, ASTM, D2166-91, *Unconfined Compression Strength of Cohesive Soil.*

25. American Society for Testing and Materials, ASTM, D2434-68, *Permeability of Granular Soils (Constant Head).*

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Table 2-1
DISPERSION FACTORS (χ/Q) IN ACCORDANCE WITH REGULATORY GUIDE 1.145

Sector	Distance (meters)	χ/Q (sec/m^3)
N	2033	6.61×10^{-5}
NNE	2113	6.85×10^{-5}
NE	2055	7.74×10^{-5}
ENE	1867	6.45×10^{-5}
E	1606	1.16×10^{-4}
ESE	1335	2.01×10^{-4}
SE	1100	3.15×10^{-4}
SSE	948	1.77×10^{-4}
S	847	1.10×10^{-4}
SSW	818	1.03×10^{-4}
SW	836	9.30×10^{-5}
WSW	919	8.43×10^{-5}
W	1067	8.53×10^{-5}
WNW	1281	7.04×10^{-5}
NW	1556	5.24×10^{-5}
NNW	1820	4.42×10^{-5}

Table 2-2
SUMMARY OF USGS GAUGING STATION RECORDS
AND ESTIMATED STREAM FLOW DATA FOR THE NORTH ANNA DAM

River Location	Drainage Area (sq.mi.)	Period of Record [a]	Discharge (cfs)		
			Average	Minimum	Maximum
USGS gauge at Doswell	439	1929-1971	382 [b]	1 [c]	24,800 [d]
USGS gauge at Doswell	439	1972-1992	399 [e]	35.5 [f]	23,300 [g]
North Anna Dam	343	1929-1971	300 [h]	1 [h]	19,500 [h]
North Anna Dam	343	1978-1993	288 [i]	25 [j]	11,700 [k]

a. Dam was closed January 1972.
b. Average discharge for 41-year period.
c. Date of discharge: September 30 to October 2, 1932.
d. Date of discharge: August 21, 1969.
e. Average discharge for 21 year-period since 1971.
f. Date of Discharge: October 8, 1991.
g. Date of Discharge: June 22, 1972.
h. Estimated.
i. Average Discharge since Partlow gauge has been in operation.
j. Date of Discharge: August 1, 1988.
k. Date of Discharge: February 26, 1979.

References 3, 4, and 5

Table 2-3
FLOODS ON THE NORTH ANNA RIVER

Flood Period	Peak Flow at Doswell (cfs)	Volume of Direct Runoff at Doswell (acre-feet)
August 12, 1928	18,400	—
April 24-29, 1937	18,300	81,400
October 17, 1943	11,600	—
August 12-25, 1955	12,400	54,700
August 20-23, 1969	24,800	141,000
June 20-22, 1972	23,300	107,200
Sept. 21-30, 1975	11,600	77,870
Feb. 22-March 3, 1979	11,700	73,131
March 27-April 3, 1984	11,700	78,229
Nov. 1-11, 1985	10,700	55,625
March 27-April 2, 1994	12,000	85,600
Sept. 5-13, 1996	11,600	61,380

References 3, 4, and 5

Table 2-4
RECOVERY AND RQD VALUES OF BORINGS

Boring No.	Run No.	From (Feet)	To (Feet)	Inches Recovered	Recovery Percent	Percent RQD
F-4	1	49.1	54.1	13	21.6	0
	2	54.1	59.1	47	78.3	40
F-5	1	64.5	69.5	0	0	0
	2	69.5	74.5	8	13.3	0
	3	74.5	79.5	2	3.3	0
	4	79.5	84.5	0	0	0
	5	84.5	89.5	4	6.6	0
	6	89.5	94.5	0	0	0
	7	94.5	99.5	0	0	0
	8	99.5	104.5	0	0	0
	9	104.5	109.5	30	50	0
	10	109.5	114.5	48	80	0
F-6	1	44.0	49.0	0	0	0
	2	49.0	54.0	0	0	0
	3	54.0	59.0	42	70	18.3
F-7	1	75.0	80.0	0	0	0
	2	80.0	85.0	0	0	0
	3	85.0	90.0	0	0	0
	4	90.0	95.0	2	3.3	0
	5	95.0	100.0	0	0	0
	6	100.0	105.0	38	63	0
F-8	1	64.2	69.2	48	80	0
F-9	1	59.1	64.1	0	0	0
	2	64.1	69.1	0	0	0
	3	69.1	74.1	7.5	12.5	0
	4	75.0	80.0	28.5	47	7.5
	5	80.0	85.0	12	20	6.6
	6	85.0	90.0	0	0	0
	7	90.0	95.0	8	13	0
	8	95.0	100.0	19	31	6.6
	9	100.0	105.0	36	60	17.5
F-10	1	69.0	74.0	57	95	35.8

Table 2-4 (continued)
RECOVERY AND RQD VALUES OF BORINGS

Boring No.	Run No.	From (Feet)	To (Feet)	Inches Recovered	Recovery Percent	Percent RQD
F-11	1	39.0	44.0	6	10	0
	2	44.0	49.0	8	13.3	0
	3	49.0	54.0	14	23	0
	4	54.0	59.0	42	70	0
	5	59.0	64.0	35	58	28
	6	64.0	69.0	42	70	22.5

Table 2-5
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude	Longitude	MMI	Magnitude
Apr 25, 1758	38.900 N	76.500 W	V	4.20
Feb 21, 1774	37.200 N	77.400 W	VI	4.54
Feb 22, 1774	37.200 N	77.400 W	IV	3.61
Mar 16, 1775	37.700 N	78.800 W	IV	3.61
Aug 30, 1775	37.700 N	78.800 W	III	
Nov 19, 1798	38.300 N	77.500 W	III	
Jan 13, 1791	37.700 N	78.800 W	IV	3.61
Jan 15, 1791	37.500 N	77.500 W	IV	3.61
Feb 11, 1795	37.800 N	77.300 W	III	
Feb 12, 1795	38.300 N	77.500 W	III	
Mar 29, 1800	39.800 N	75.200 W		3.00
Feb 11, 1801	37.400 N	79.200 W	III	
Aug 23, 1802	37.400 N	79.100 W	V	4.20
May 1, 1807	37.400 N	79.100 W	V	4.20
Nov 27, 1811	36.100 N	80.200 W	IV	3.61
Feb 2, 1812	37.600 N	77.400 W	IV	3.61
Apr 22, 1812	37.500 N	77.500 W	IV	3.61
Jan 8, 1817	36.000 N	80.200 W	V	5.04
Jul 15, 1824	39.700 N	80.500 W	IV	3.61
Mar 9, 1828	37.000 N	80.000 W	V	5.04
Aug 27, 1833	37.700 N	78.000 W	VI	5.04
Nov 11, 1840	39.800 N	75.200 W	V	4.20
Oct 19, 1846	39.300 N	77.900 W	III	
Mar 30, 1850	35.400 N	78.000 W	V	4.20
Oct 17, 1850	37.300 N	78.400 W	IV	3.61
Oct 18, 1850	37.400 N	78.400 W	IV	
Nov 2, 1852	37.500 N	78.600 W	VI	4.34
Jan 30, 1853	38.900 N	78.500 W	III	
May 2, 1853	38.500 N	79.500 W	V	4.64
Jan 3, 1855	39.200 N	77.500 W	V	
Feb 2, 1855	37.00 N	78.600 W	V	4.04
Jan 16, 1856	39.200 N	78.20 W	IV	3.61
Mar 21, 1856	37.700 N	78.900 W	III	
Apr 21, 1871	36.400 N	78.600 W	III	
Oct 9, 1871	39.700 N	75.500 W	VII	4.59
Mar 1, 1872	36.800 N	79.400 W	III	
Jun 5, 1872	37.700 N	78.000 W	IV	3.61

Table 2-5 (continued)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude	Longitude	MMI	Magnitude
Oct 3, 1873	37.200 N	78.200 W	IV	3.61
Dec 23, 1875	37.600 N	78.500 W	VII	4.54
Jan 3, 1876	37.600 N	77.900 W	III	
Apr 10, 1876	38.500 N	76.600 W	III	
Dec 23, 1876	37.400 N	77.500 W	IV	3.61
Sep 1, 1877	38.700 N	76.800 W	III	
Jan 3, 1878	37.900 N	77.700 W	III	
Mar 26, 1879	39.200 N	75.500 W	V	4.20
Apr 2, 1882	38.600 N	78.700 W	IV	
Mar 11, 1883	39.500 N	76.400 W	IV	3.61
Mar 12, 1883	39.500 N	76.400 W	IV	3.61
Sep 21, 1883	36.100 N	79.800 W	V	4.20
Jan 3, 1885	39.200 N	77.500 W	V	4.06
Jan 15, 1885	4.300 N	76.300 W	III	3.02
Feb 2, 1885	36.900 N	81.100 W	IV	3.61
Oct 10, 1885	37.700 N	78.800 W	VI	4.24
Mar 8, 1889	40.000 N	76.000 W	V	4.11
Oct 7, 1895	35.900 N	77.500 W	V	4.20
Feb 11, 1896	36.300 N	78.600 W	IV	3.61
May 3, 1897	37.100 N	80.700 W	VII	4.34
May 31, 1897	37.300 N	80.700 W	VII	5.84
Jun 28, 1897	37.300 N	80.700 W	V	4.04
Sep 3, 1897	37.300 N	80.700 W	IV	3.61
Oct 22, 1897	36.900 N	81.100 W	V	4.20
Nov 27, 1897	37.700 N	77.500 W	IV	3.61
Dec 18, 1897	37.700 N	77.500 W	V	4.04
Feb 5, 1898	37.000 N	81.000 W	VI	4.34
Nov 25, 1898	37.000 N	81.000 W	V	4.64
Feb 13, 1899	37.000 N	81.000 W	V	4.74
Mar 3, 1899	36.900 N	76.300 W	IV	3.61
Mar 11, 1902	39.600 N	77.100 W	III	
May 18, 1902	37.300 N	80.600 W	V	4.20
Jan 1, 1903	39.600 N	77.200 W	III	
Apr 29, 1905	37.300 N	79.500 W	III	
May 8, 1906	38.700 N	75.700 W	IV	3.40
Oct 13, 1906	39.200 N	76.700 W	III	
Feb 11, 1907	37.700 N	78.300 W	VI	4.79

Table 2-5 (continued)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude	Longitude	MMI	Magnitude
Aug 23, 1908	37.500 N	77.900 W	V	4.20
Apr 2, 1909	39.400 N	78.000 W	V	4.20
Feb 8, 1910	38.800 N	78.700 W	IV	3.64
Apr 24, 1910	39.200 N	76.700 W	III	
May 8, 1910	37.700 N	78.400 W	IV	3.61
Feb 10, 1911	36.600 N	79.400 W	IV	3.61
Apr 8, 1911	38.300 N	75.500 W	IV	3.61
Aug 7, 1912	37.700 N	78.400 W	IV	3.61
Aug 8, 1912	37.700 N	78.400 W	IV	3.61
Apr 10, 1918	38.700 N	78.400 W	VI	4.93
Apr 16, 1918	38.700 N	78.400 W	IV	3.61
Apr 19, 1918	36.800 N	76.300 W	III	
Sep 6, 1919	38.800 N	78.200 W	VI	4.79
Jul 24, 1920	38.700 N	78.400 W	IV	3.61
Aug 7, 1921	37.800 N	78.400 W	VI	4.79
Dec 31, 1923	39.200 N	78.000 W	V	
Jan 1, 1924	39.100 N	78.100 W	IV	
Jan 5, 1924	39.100 N	78.100 W	IV	3.61
Dec 26, 1924	37.300 N	79.900 W	V	4.20
May 16, 1925	37.300 N	77.500 W	V	4.20
Jul 14, 1925	37.600 N	77.500 W	IV	3.61
Jun 10, 1927	38.000 N	79.000 W	V	4.20
Oct 27, 1927	36.300 N	76.200 W	IV	3.61
Oct 15, 1928	38.300 N	75.100 W	IV	3.61
Oct 30, 1928	37.500 N	77.500 W	IV	3.61
Dec 26, 1929	38.100 N	78.500 W	VI	4.79
Sep 15, 1930	37.500 N	77.500 W	III	
Nov 1, 1930	39.100 N	76.500 W	IV	3.61
Oct 6, 1931	37.700 N	78.300 W	III	
Jan 5, 1932	37.600 N	78.400 W	IV	3.61
Jan 27, 1933	37.200 N	77.400 W	IV	3.61
Jul 23, 1933	37.700 N	78.300 W	III	
Apr 3, 1934	37.200 N	77.400 W	III	
Feb 10, 1935	37.200 N	77.400 W	IV	3.61
Nov 1, 1935	38.900 N	78.900 W	IV	3.61
Feb 3, 1937	37.700 N	78.700 W	IV	3.611
Mar 25, 1937	40.900 N	78.200 W	III	3.02

Table 2-5 (continued)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude	Longitude	MMI	Magnitude
Jul 15, 1938	40.680 N	78.430 W	VI	3.34
Nov 15, 1939	39.580 N	75.050 W	V	4.04
Nov 18, 1939	39.500 N	76.600 W	IV	3.61
Nov 26, 1939	39.500 N	76.600 W	V	4.20
Mar 26, 1940	38.800 N	78.500 W	V	4.20
Jan 3, 1942	37.400 N	79.100 W	III	
Oct 7, 1942	37.600 N	78.400 W	IV	3.61
Jan 8, 1944	39.800 N	75.500 W		4.25
Oct 10, 1945	37.700 N	78.300 W	III	
Oct 12, 1945	37.500 N	78.500 W	IV	3.61
Oct 30, 1945	37.500 N	78.500 W	IV	3.61
May 24, 1946	38.000 N	78.600 W	III	
Jan 4, 1948	37.600 N	78.600 W	IV	3.61
Jan 5, 1948	37.500 N	78.500 W	V	4.20
Mar 26, 1948	38.100 N	78.500 W	III	
May 8, 1949	37.600 N	77.600 W	V	4.20
Nov 26, 1950	37.700 N	78.300 W	V	4.20
Mar 9, 1951	37.600 N	77.600 W	V	4.20
Sep 11, 1952	38.100 N	78.500 W	IV	
Feb 7, 1953	37.700 N	78.100 W	IV	3.61
Jan 7, 1954	40.300 N	76.000 W	VI	4.79
Aug 11, 1954	40.30 N	76.000 W	IV	3.61
Jan 17, 1955	37.300 N	78.400 W	IV	3.61
Jan 20, 1955	40.300 N	76.000 W	IV	3.61
Apr 23, 1959	37.380 N	80.680 W	VI	3.84
Jul 7, 1959	37.300 N	80.700 W	IV	3.61
Aug 21, 1959	37.300 N	80.700 W	IV	3.61
Sep 4, 1960	37.400 N	79.300 W	IV	3.61
Sep 4, 1962	39.500 N	77.700 W	IV	3.61
Sep 7, 1962	39.700 N	78.200 W	IV	3.61
Jan 17, 1963	37.300 N	80.100 W	IV	3.61
Oct 10, 1963	39.800 N	78.200 W		3.60
Feb 13, 1964	40.380 N	77.960 W	VI	3.29
May 12, 1964	40.300 N	76.410 W	VI	3.19
Jul 15, 1965	37.310 N	74.390 W		5.30
Sep 16, 1965	37.250 N	74.360 W		5.00
Oct 8, 1965	40.080 N	79.750 W		3.60

Table 2-5 (continued)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude	Longitude	MMI	Magnitude
May 31, 1966	37.660 N	78.130 W	V	3.69
Sep 28, 1966	39.300 N	80.300 W	IV	3.61
Mar 8, 1968	37.280 N	80.770 W	IV	4.09
May 22, 1969	39.610 N	78.250 W		3.10
Nov 20, 1969	37.450 N	80.930 W	VI	4.69
Dec 11, 1969	37.840 N	77.670 W	V	3.39
May 27, 1970	39.620 N	78.280 W		3.20
Jul 14, 1971	39.700 N	75.600 W	IV	3.61
Sep 12, 1971	38.150 N	77.590 W	V	3.60
Dec 29, 1971	39.70 N	75.600 W	IV	3.61
Jan 2, 1972	39.700 N	75.600 W	IV	3.61
Jan 3, 1972	39.700 N	75.600 W	IV	3.61
Jan 7, 1972	39.700 N	75.600 W	IV	3.61
Jan 22, 1972	39.700 N	75.600 W	IV	3.61
Jan 23, 1972	39.700 N	75.600 W	IV	3.61
Feb 11, 1972	39.700 N	75.600 W	V	4.20
Aug 14, 1972	39.700 N	75.600 W	IV	3.61
Sep 5, 1972	37.600 N	77.700 W	IV	3.39
Sep 12, 1972	39.600 N	79.900 W	III	3.02
Dec 8, 1972	40.140 N	76.240 W	V	3.52
Feb 28, 1973	39.690 N	75.430 W	V	3.79
Apr 9, 1973	37.300 N	77.700 W	IV	3.61
Jul 10, 1973	39.700 N	75.700 W	IV	3.61
Mar 23, 1974	38.700 N	77.800 W		3.80
Apr 28, 1974	39.800 N	75.600 W	IV	3.61
May 30, 1974	37.460 N	80.540 W	V	3.59
May 31, 1974	37.400 N	80.400 W		3.80
Mar 7, 1975	37.320 N	80.480 W	II	3.04
Nov 11, 1975	37.220 N	80.890 W	IV	3.19
May 6, 1976	39.600 N	79.900 W	IV	3.61
Sep 13, 1976	36.620 N	80.770 W	VI	3.29
Apr 26, 1978	39.700 N	78.240 W		3.10
Jul 16, 1978	39.900 N	76.220 W	V	3.09
Oct 6, 1978	40.080 N	76.150 W		3.00
Aug 30, 1980	39.800 N	74.900 W		3.00
Nov 5, 1980	38.180 N	79.900 W		3.00
Feb 11, 1981	37.720 N	78.440 W	IV	3.39

Table 2-5 (continued)
EARTHQUAKES WITHIN 200 MILES OF NORTH ANNA SITE
EVENTS LISTED CHRONOLOGICALLY

Date	Latitude	Longitude	MMI	Magnitude
May 12, 1982	40.410 N	77.960 W		3.00
Apr 19, 1984	40.131 N	76.037 W		3.00
Apr 23, 1984	39.950 N	76.370 W	V	4.46
Aug 17, 1984	37.868 N	78.324 W		4.20
Jun 10, 1985	37.248 N	80.485 W		3.20
Mar 15, 1991	37.746 N	77.916 W	V	3.80
Apr 22, 1991	37.996 N	80.266 W		3.40
Jun 28, 1991	38.231 N	81.335 W		3.00
Aug 15, 1991	40.786 N	77.657 W	V	3.00
Mar 16, 1993	39.190 N	76.870 W	III	
Nov 17, 1993	39.190 N	76.870 W	III	
Jan 16, 1994	40.330 N	76.037 W	V	4.60

Figure 2-1
AREA MAP (0-10 MILES)

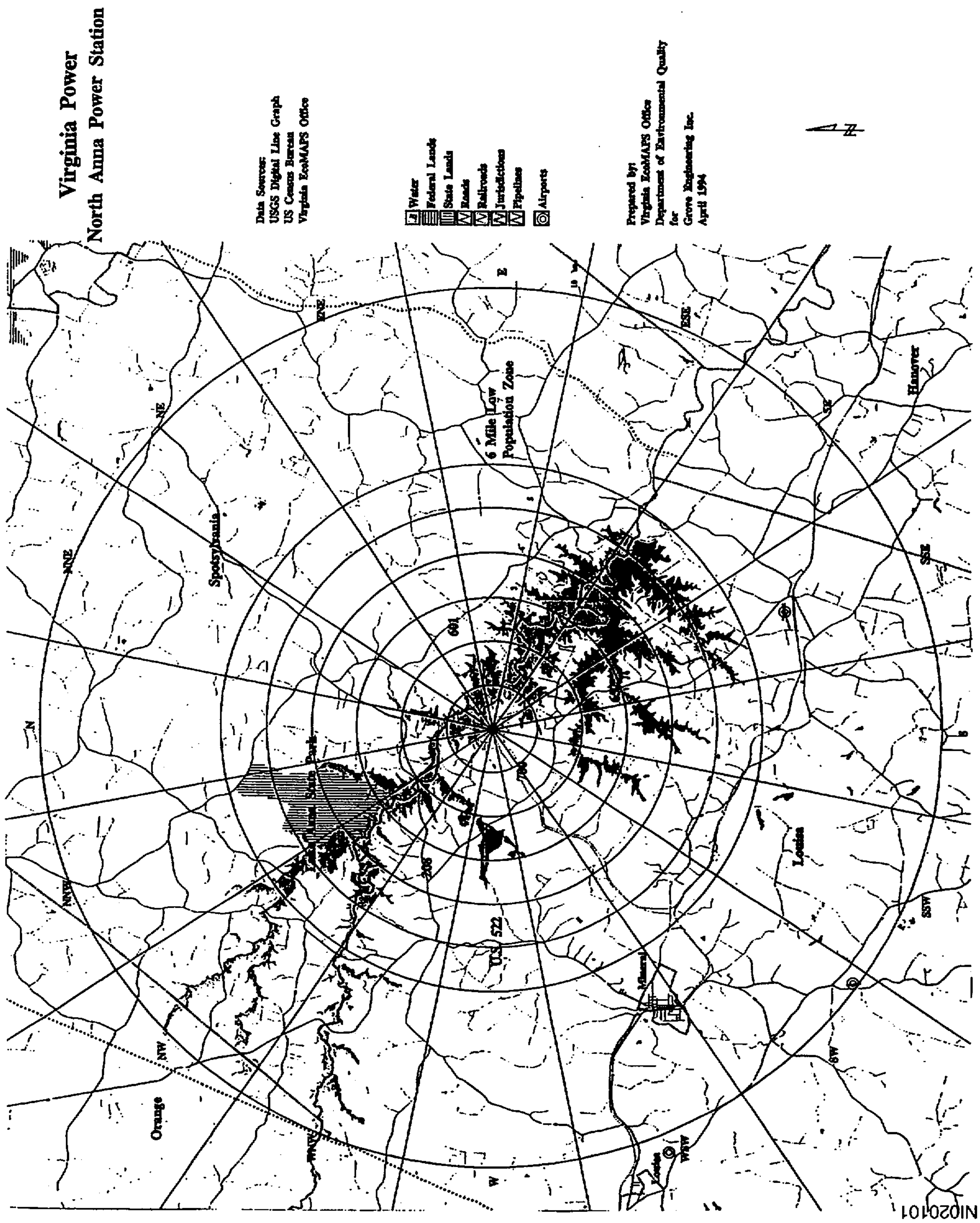


Figure 2-2
REGIONAL MAP (0-50 MILES)

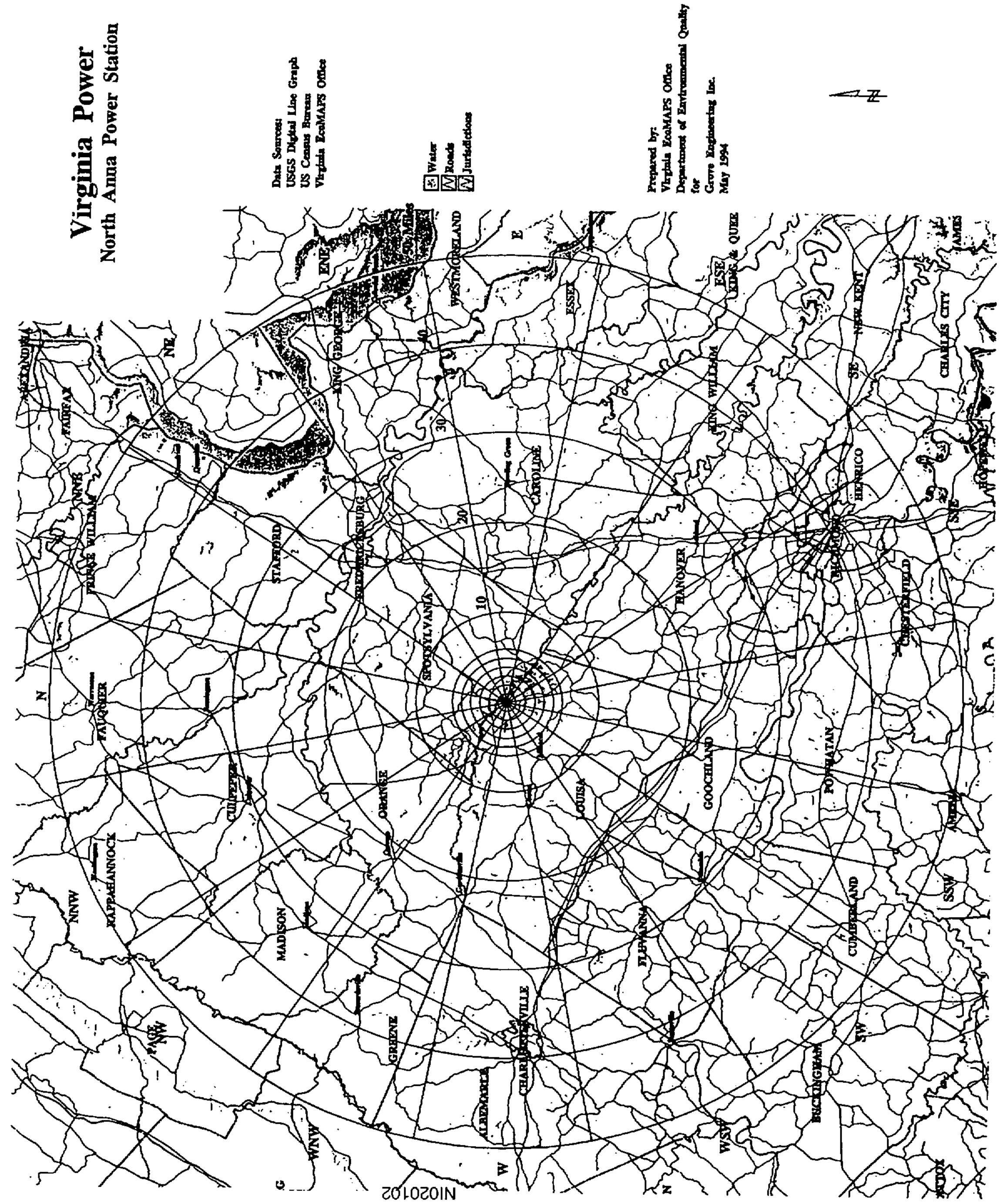


Figure 2-3
NORTH ANNA SITE BOUNDARY

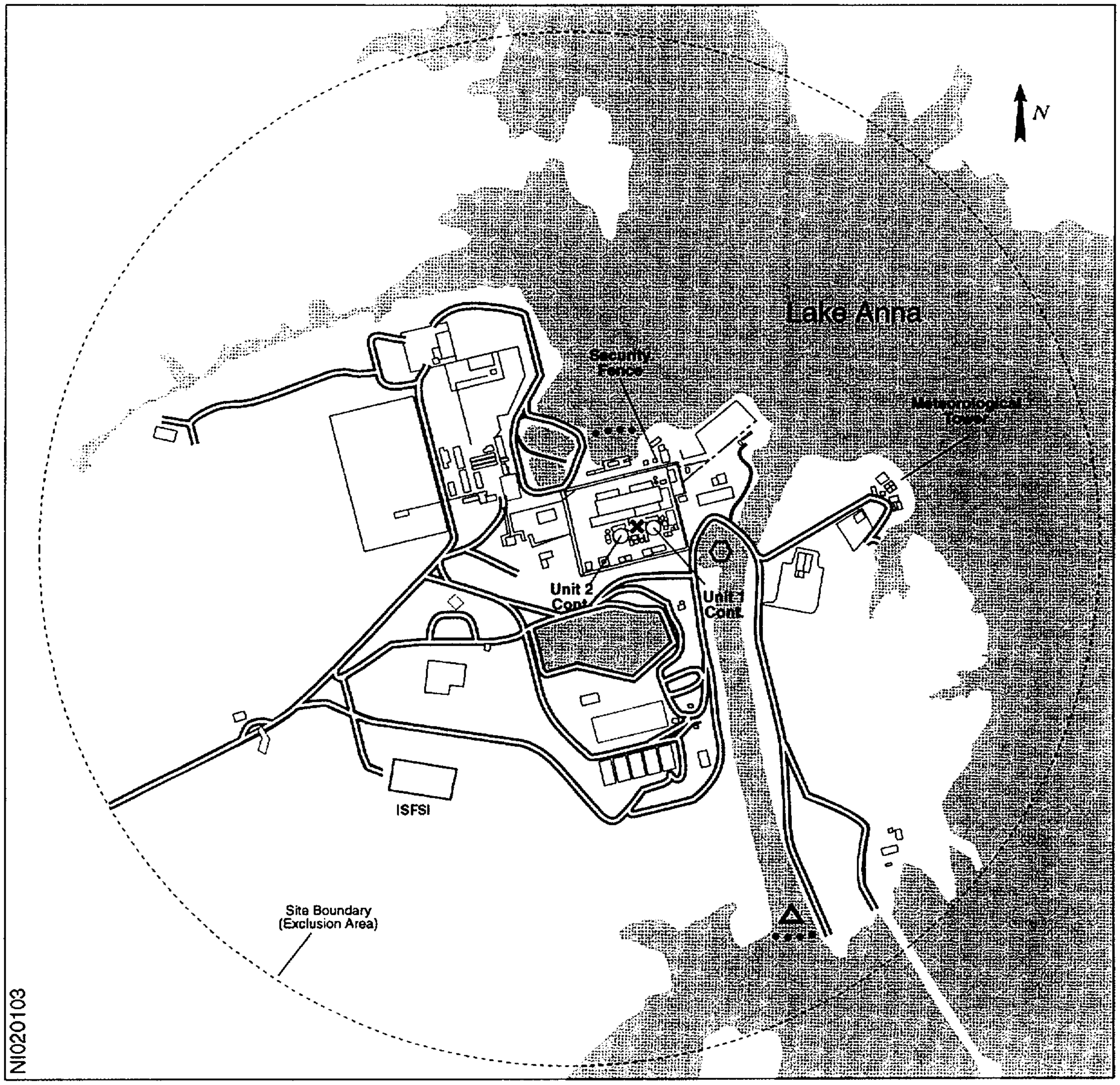
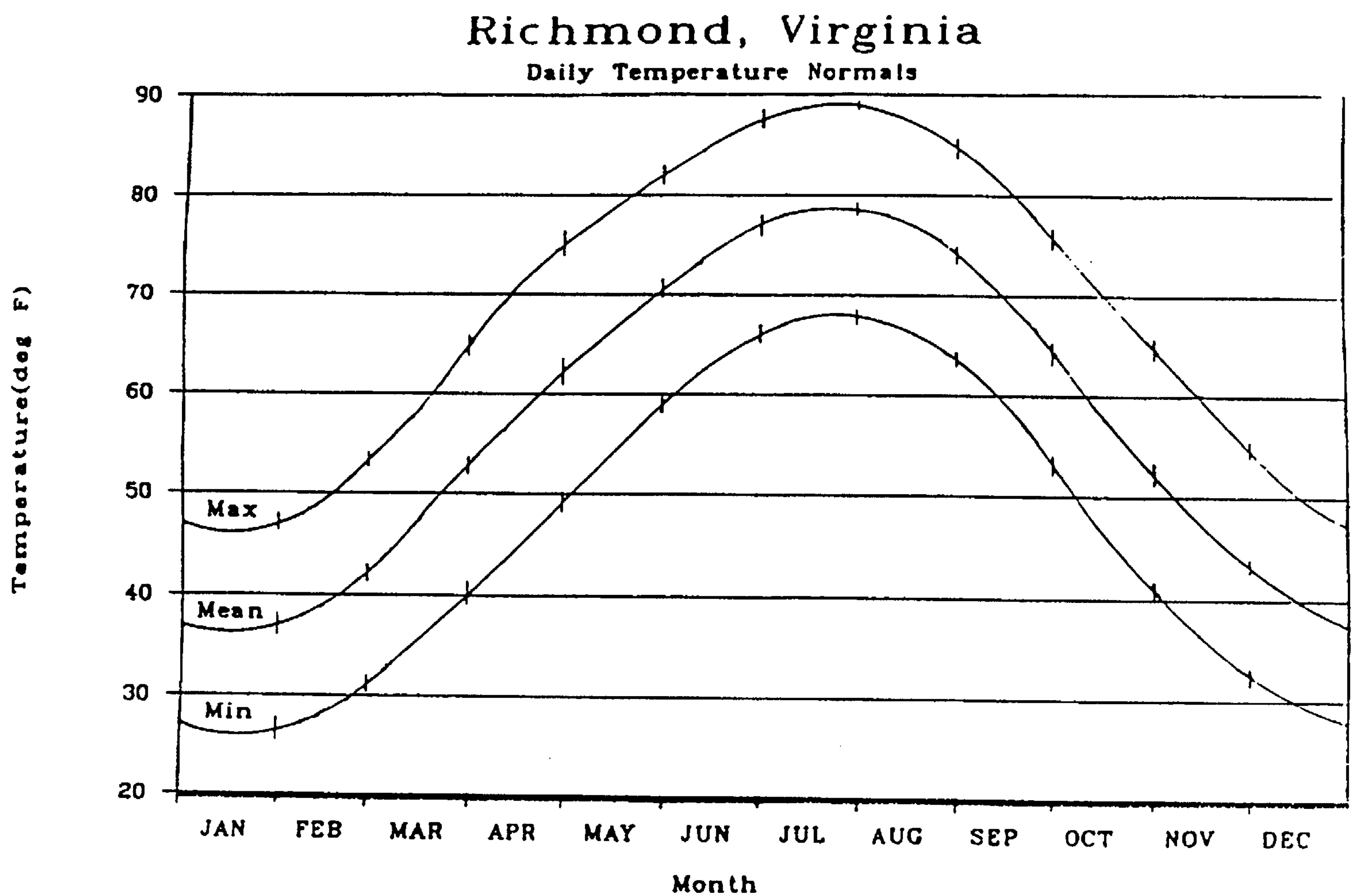
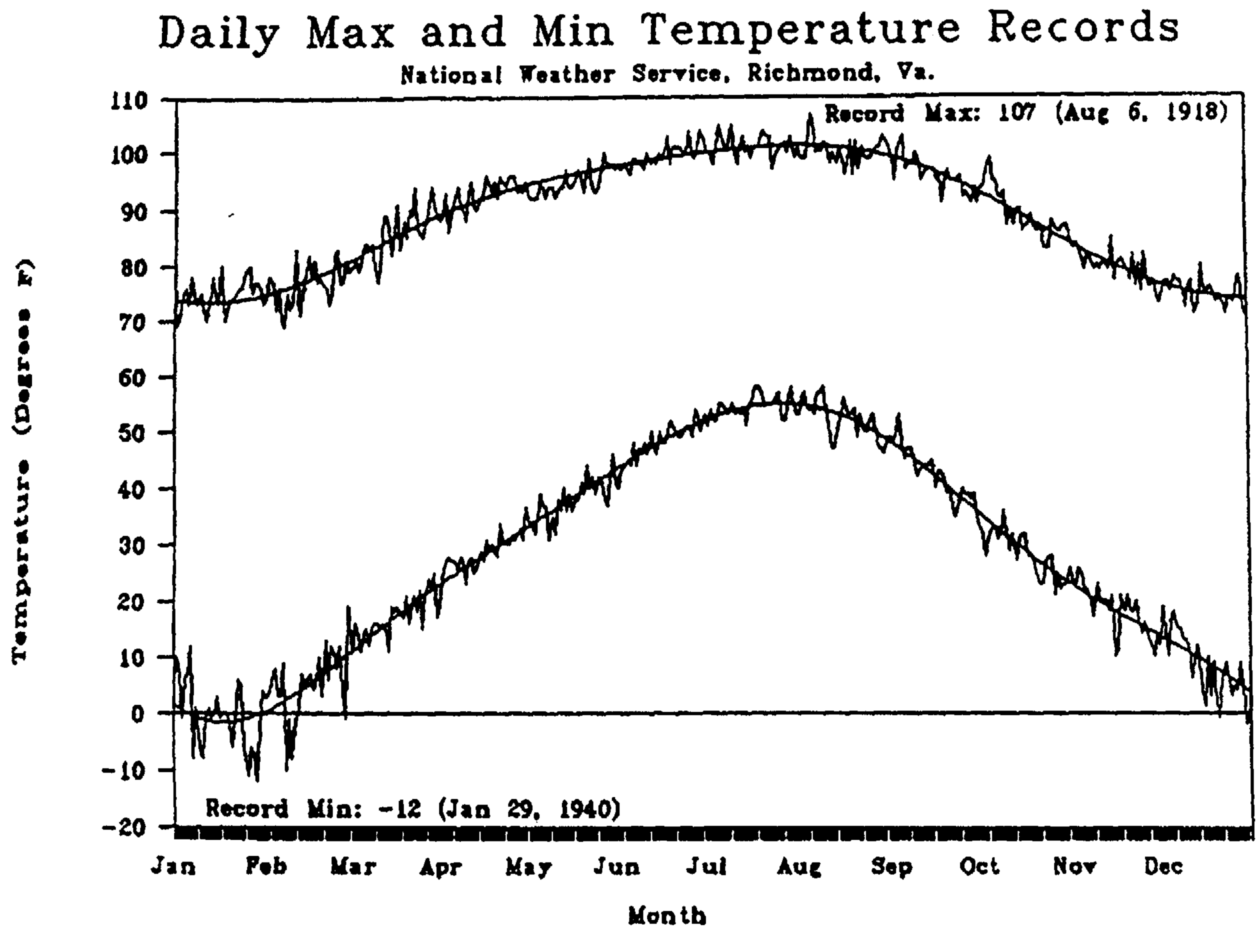


Figure 2-4
DAILY AVERAGE TEMPERATURES FOR RICHMOND, VIRGINIA (1951-1980)



NI020301

Figure 2-5
DAILY EXTREME TEMPERATURES FOR RICHMOND, VIRGINIA (1898-1991)



NI020302

Figure 2-6
EXTREME 1-MILE WIND PASSAGE AT RICHMOND, VIRGINIA

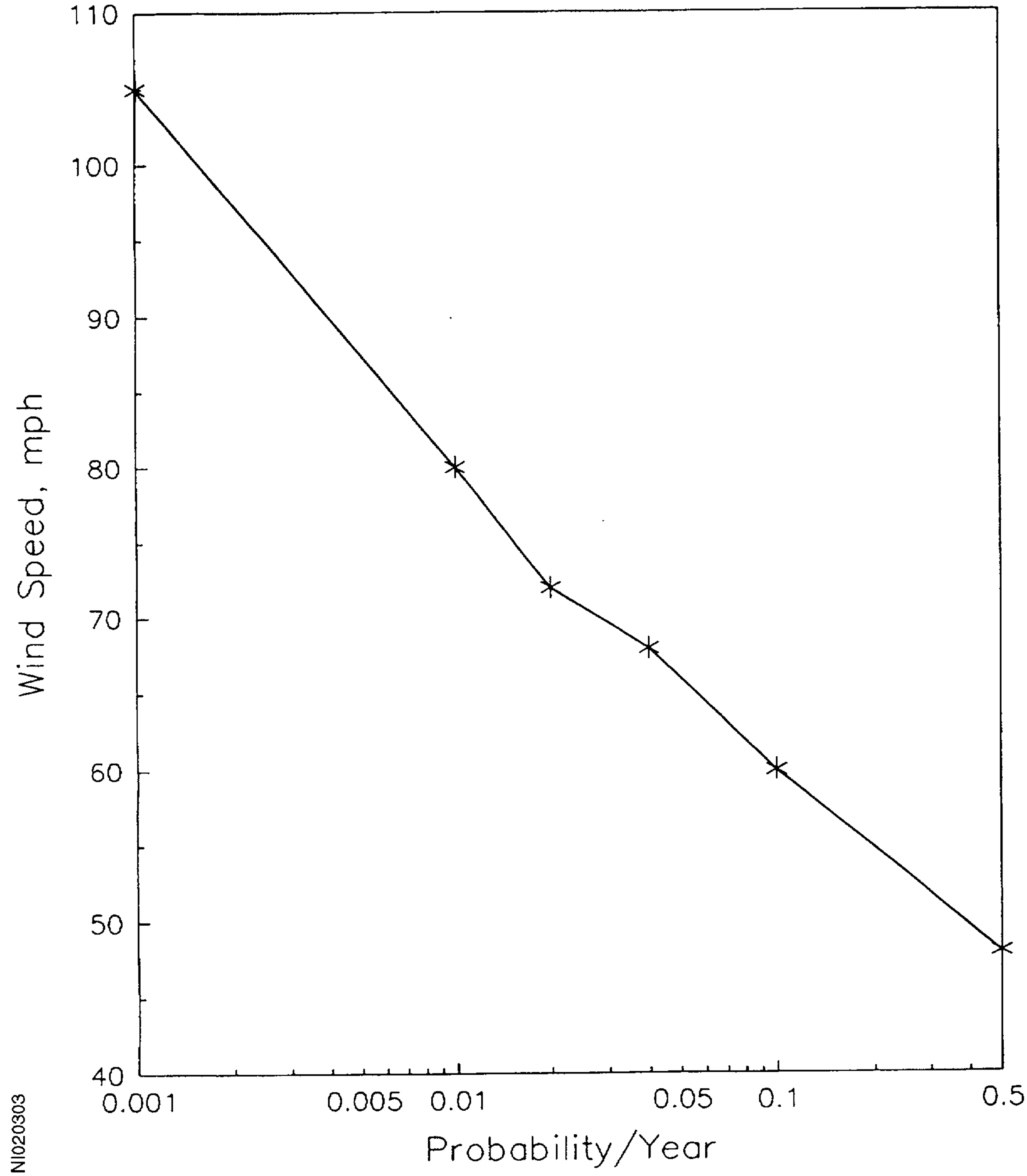
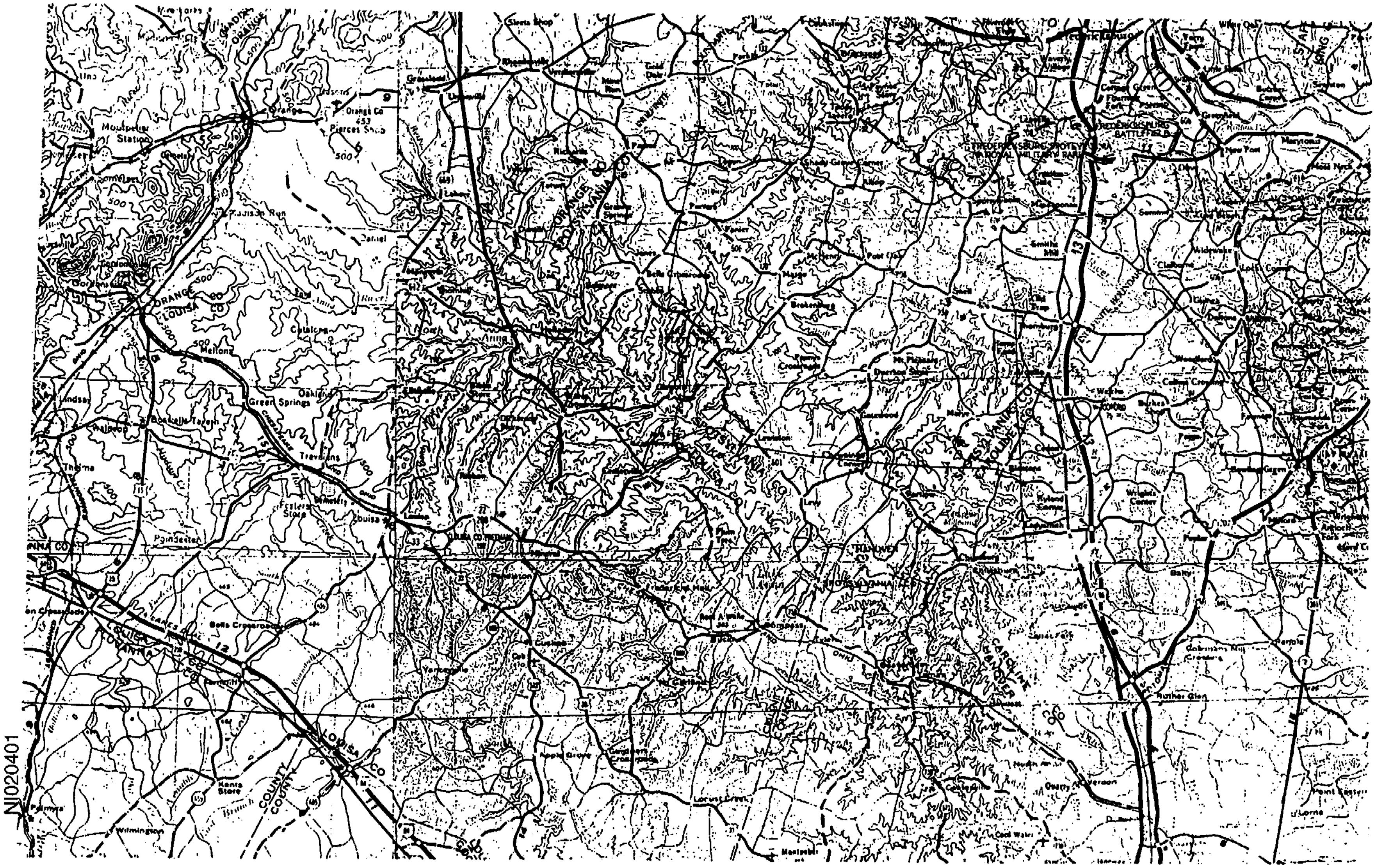


Figure 2-7
REGIONAL TOPOGRAPHY AND CHARACTERISTICS



NI020401

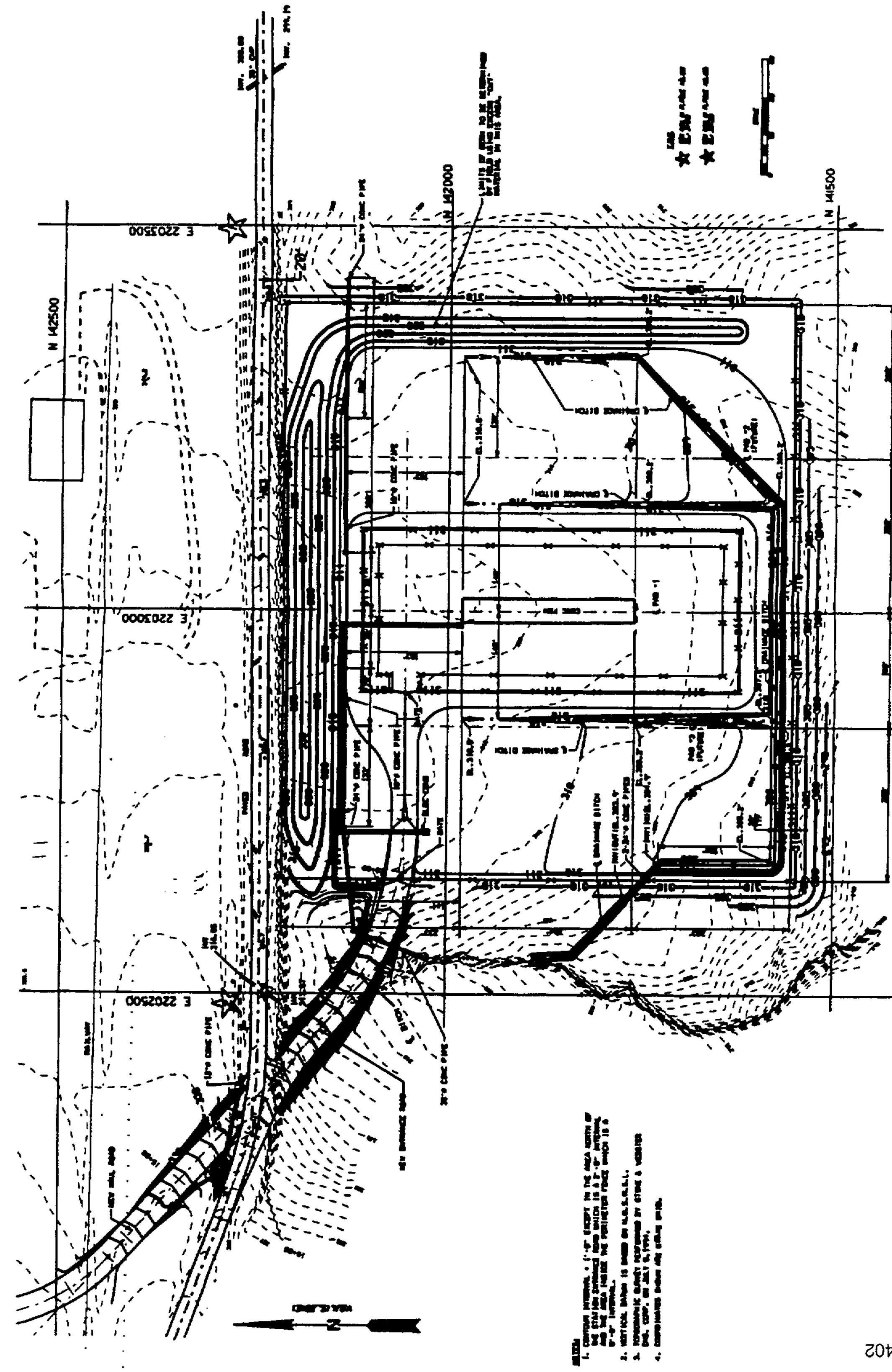
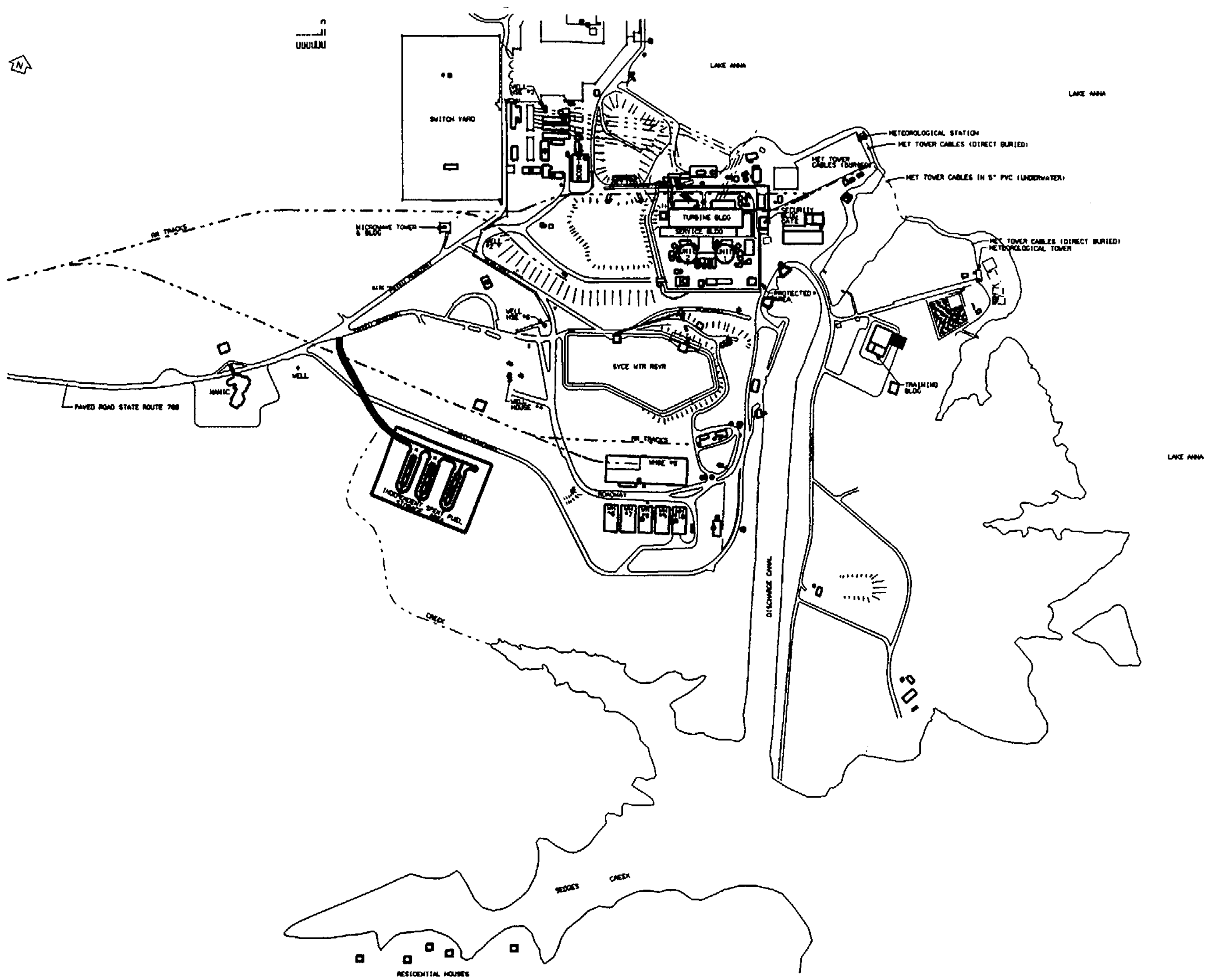


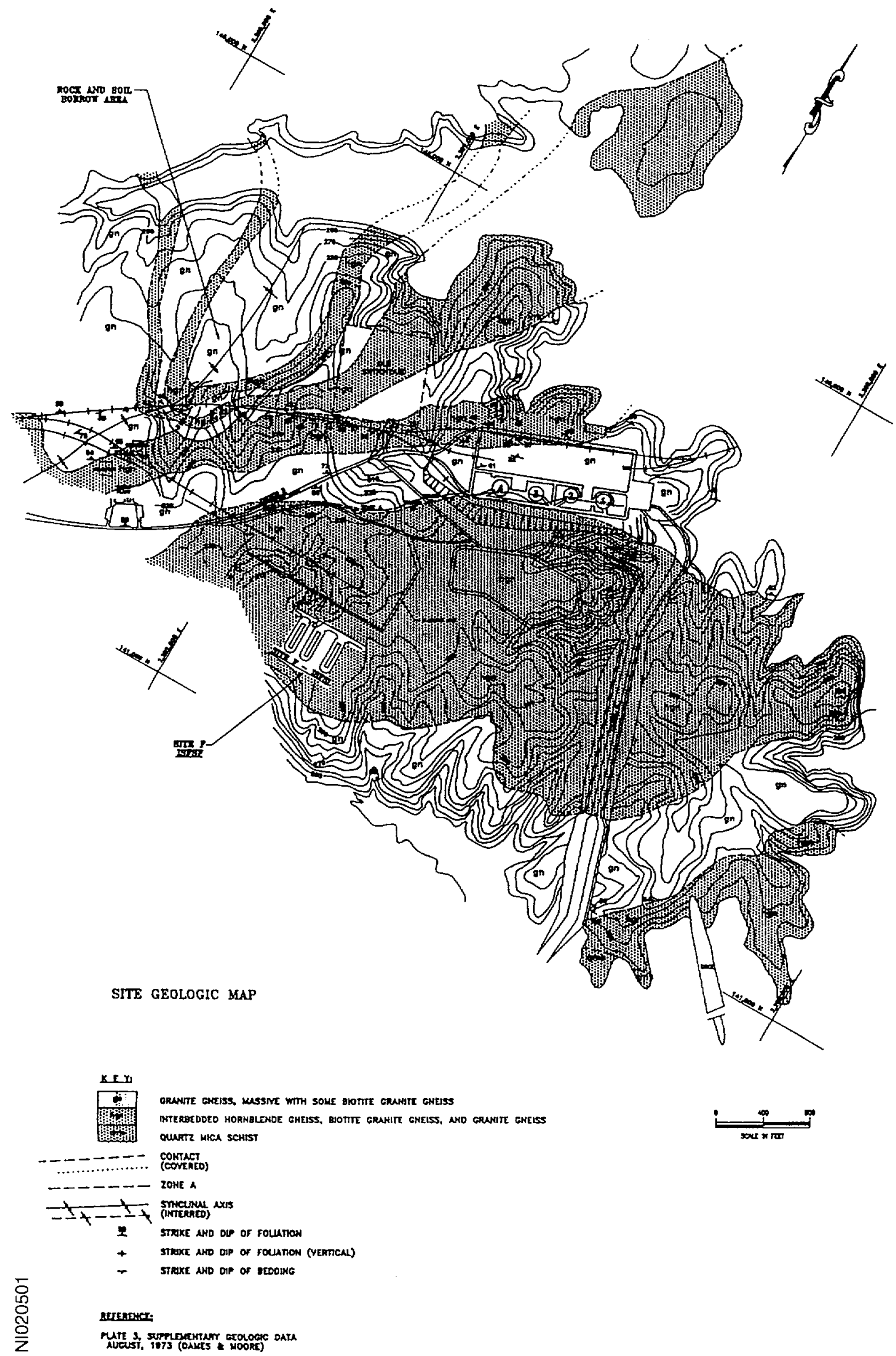
Figure 2-8
ISFSI LOCAL TOPOGRAPHY AND GRADING PLAN

Figure 2-9
HYDROLOGIC CHARACTERISTICS OF THE ISFSI SITE



NI020403

Figure 2-10
SITE GEOLOGICAL MAP



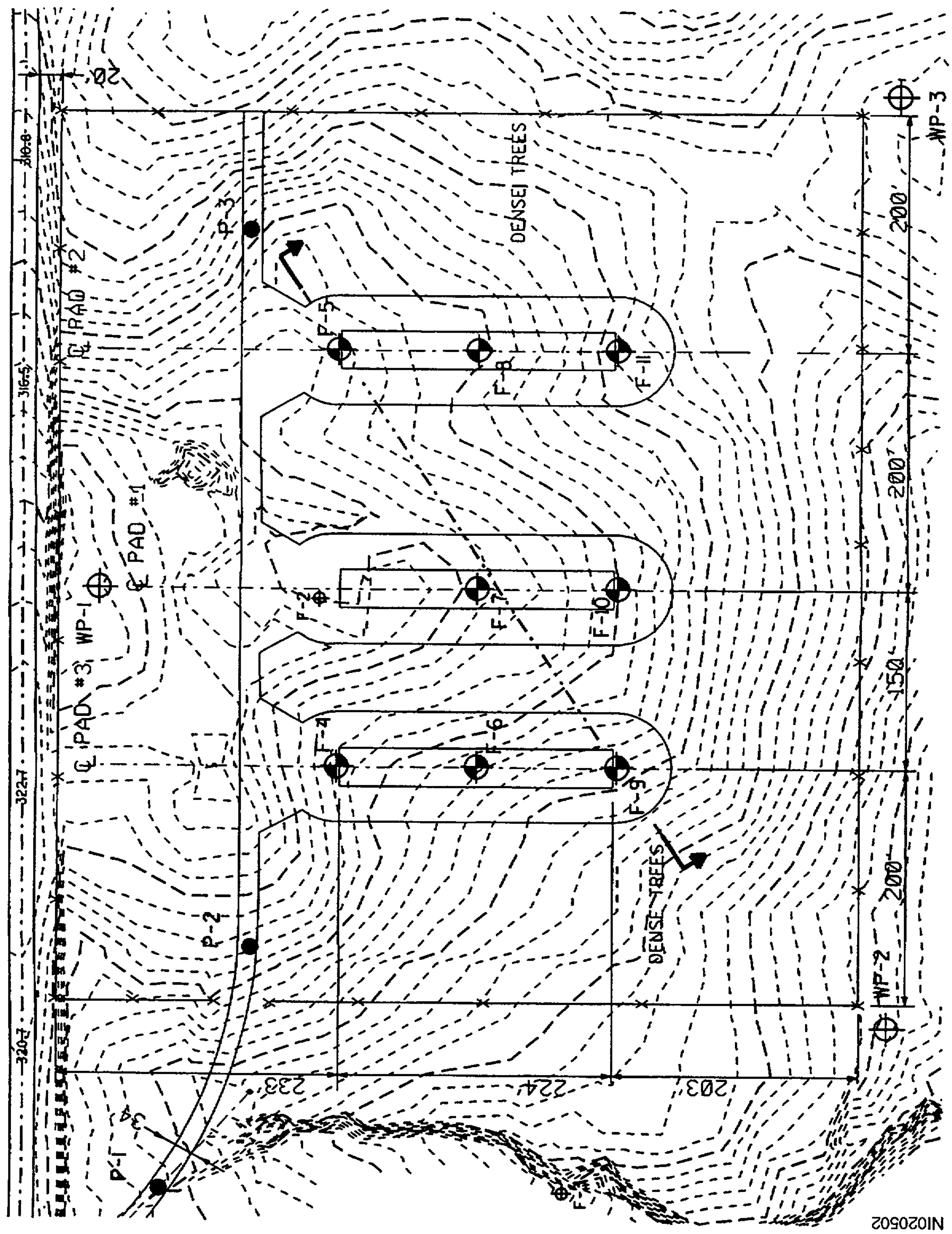
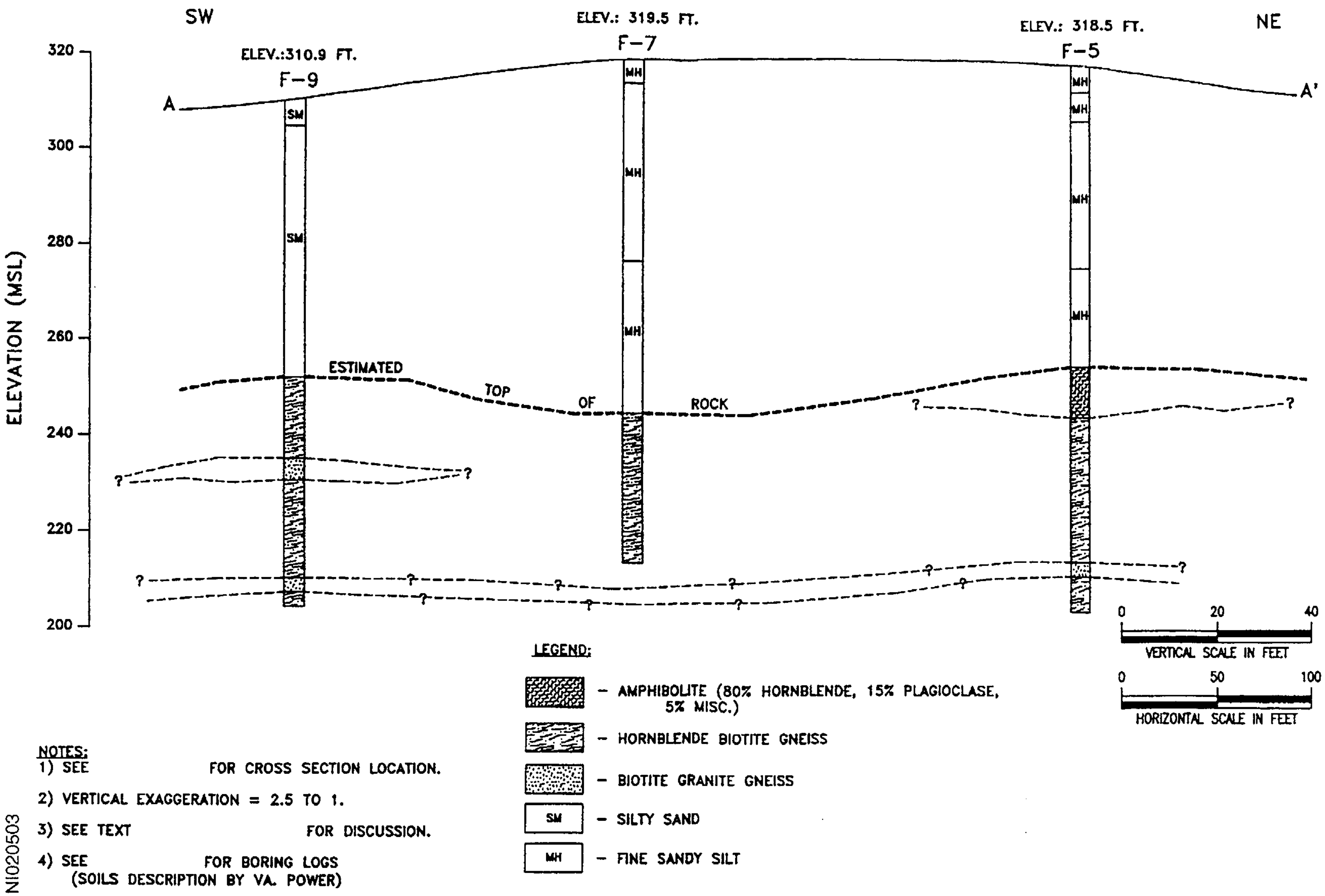


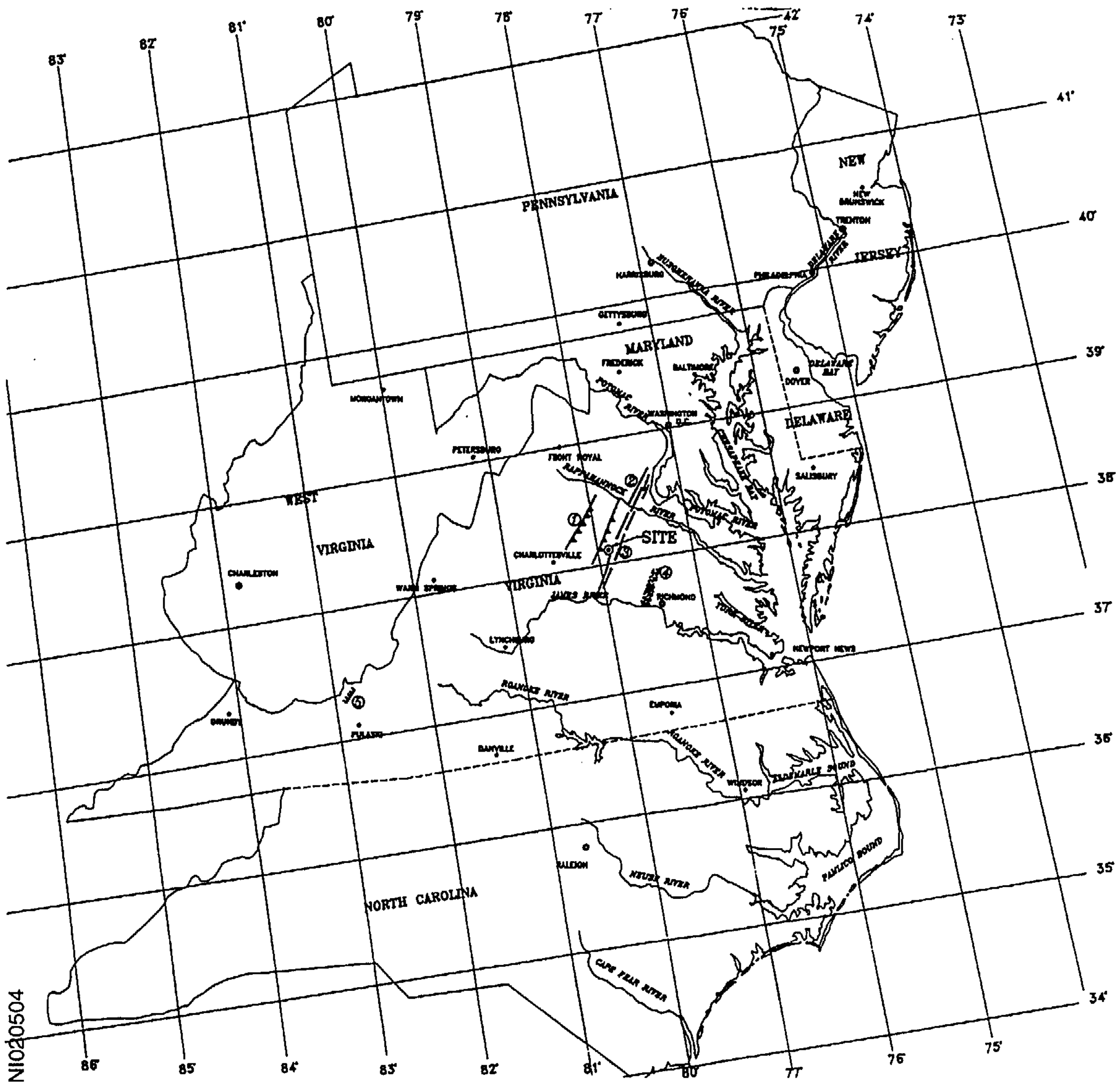
Figure 2-11
ISFSI BORING LOCATIONS

Figure 2-12
ISFSI SUBSURFACE CROSS SECTION



NOTES:
1) SEE FOR CROSS SECTION LOCATION.
2) VERTICAL EXAGGERATION = 2.5 TO 1.
3) SEE TEXT FOR DISCUSSION.
4) SEE FOR BORING LOGS (SOILS DESCRIPTION BY VA. POWER)

Figure 2-13
REGIONAL GEOLOGIC MAP



NOTES:

1. For a more detailed depiction of the fault systems of Virginia, please refer to "Geologic Map of Virginia – Expanded Explanation", 1993, Virginia-Division of Mineral Resources.

2. References for fault systems:

① MOUNTAIN RUN FAULT ZONE:
Lampshire, L.D., et al., 1994, crystal structures and the eastern extent of lower Paleogoic shelf strata within the central Appalachians: A seismic reflection interpretation: Geological Society of America Bulletin, v. 106, p 1–18.

② STAFFORD FAULT SYSTEM:
Mixon, R.B. and Newell, N.L., 1977, Stafford fault system: Structures documenting Cretaceous and Tertiary deformation along the Fall line in northeastern Virginia: Geology, v. 5, p. 437–440.

③ SPOTSYLVANIA MAGNETIC LINEAMENT:
Mixon, R.B., Powers, D.S. and Daniels, D.L., 1992, Nature and Timing of deformation of Upper Mesozoic and Cenozoic deposits in the Inner Atlantic Coastal Plain, Virginia and Maryland, editor Gregory S. Cohn, U.S. Geological Survey Circular 1059, p. 65–73.

④ HYLAS ZONE:
Bobyarchick, A.R. and Glover, Lynn III deformation and metamorphism in the Hylas Zone and adjacent parts of the Eastern Piedmont in Virginia: Geological Society of America Bulletin, PArt I, v. 90, p. 739–752.

⑤ GILES ZONE:
LAW, R.D., et. al., 1992; Geologically near surface folding and faulting in the Valley and Ridge Province: New exposures of extensional faults in alluvial sediments, Giles Co., SW Virginia IN proceedings, seismological society of America, 64th Ann. Meeting, Richmonmd, Va., October, 1992.

0 60 120 MILES

Figure 2-14
PAD #1 SURFACE PROFILE

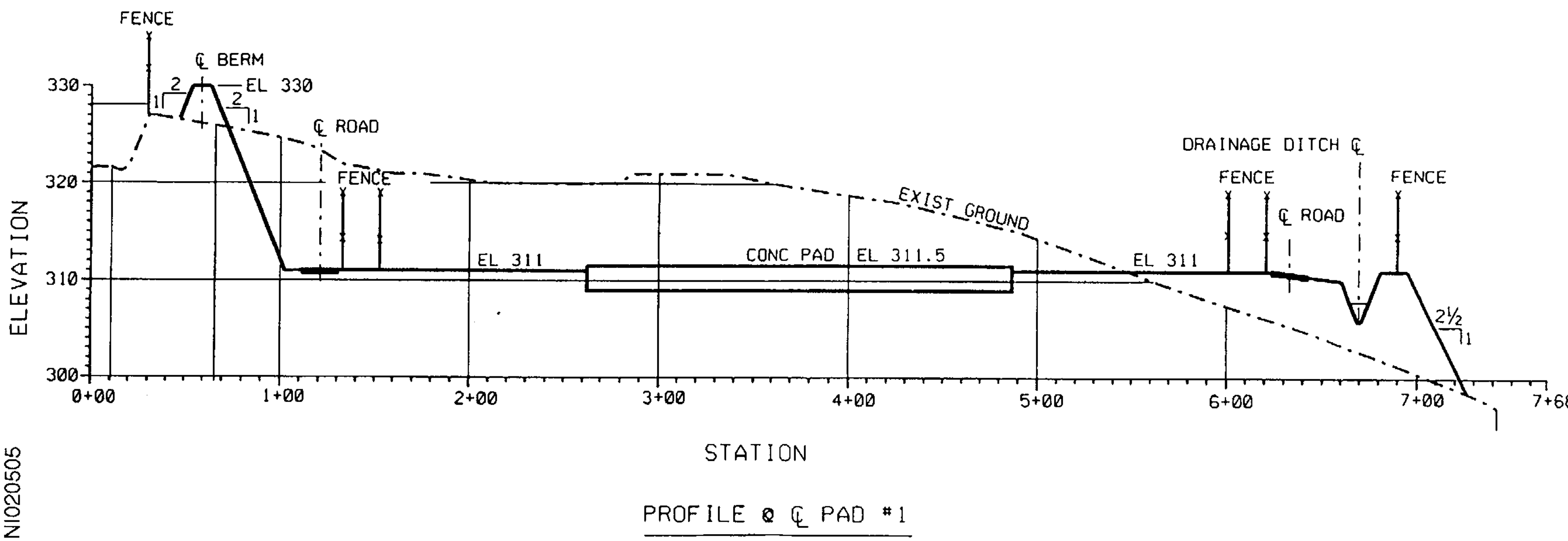
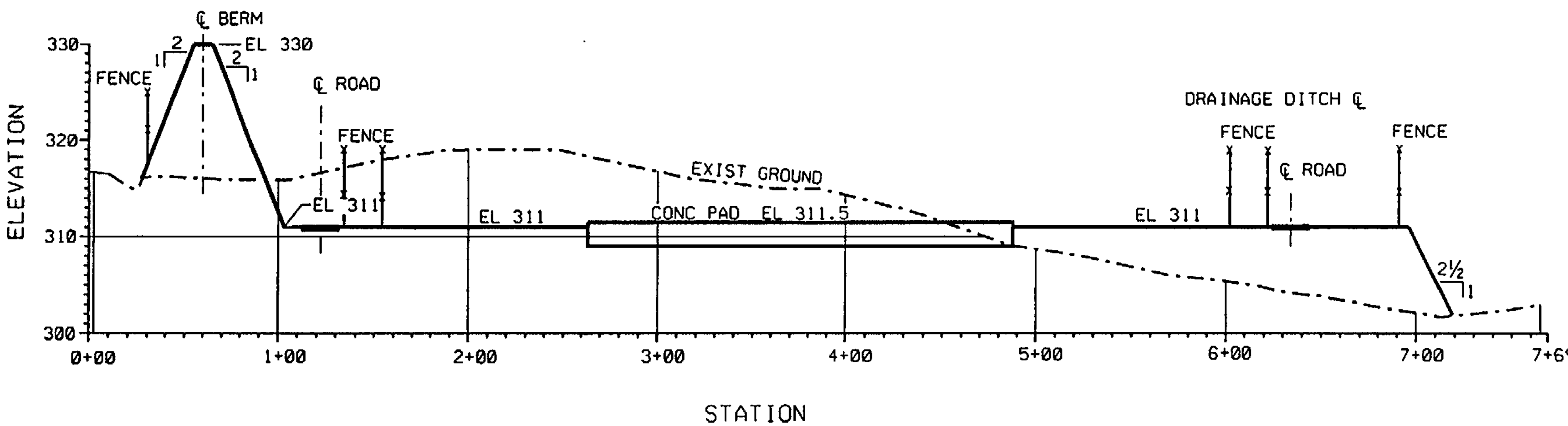


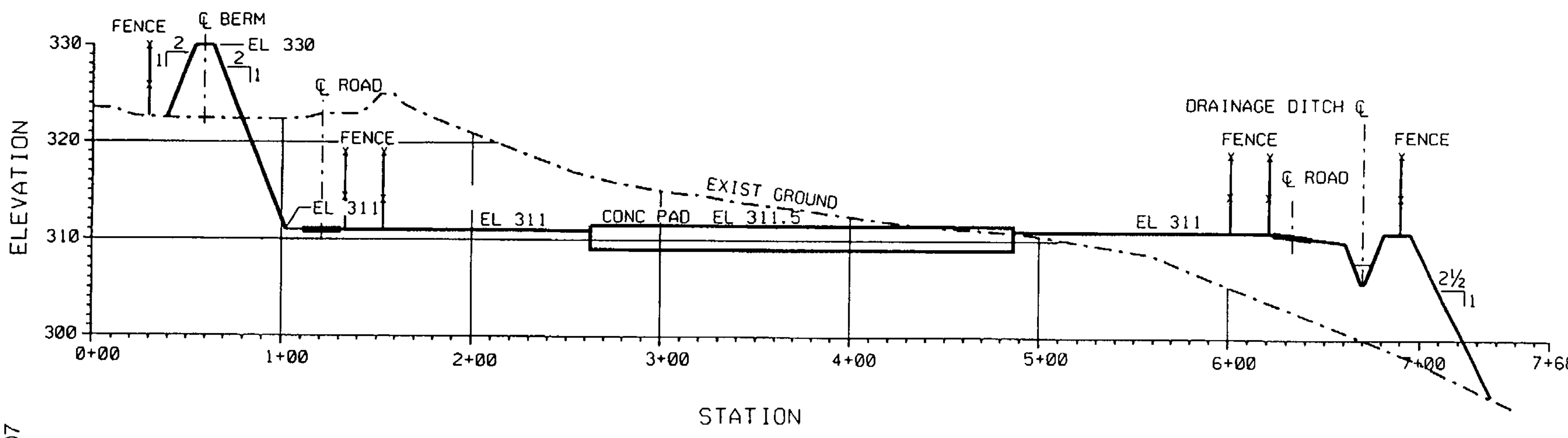
Figure 2-15
PAD #2 SURFACE PROFILE



PROFILE @ ℄ PAD #2

NI020506

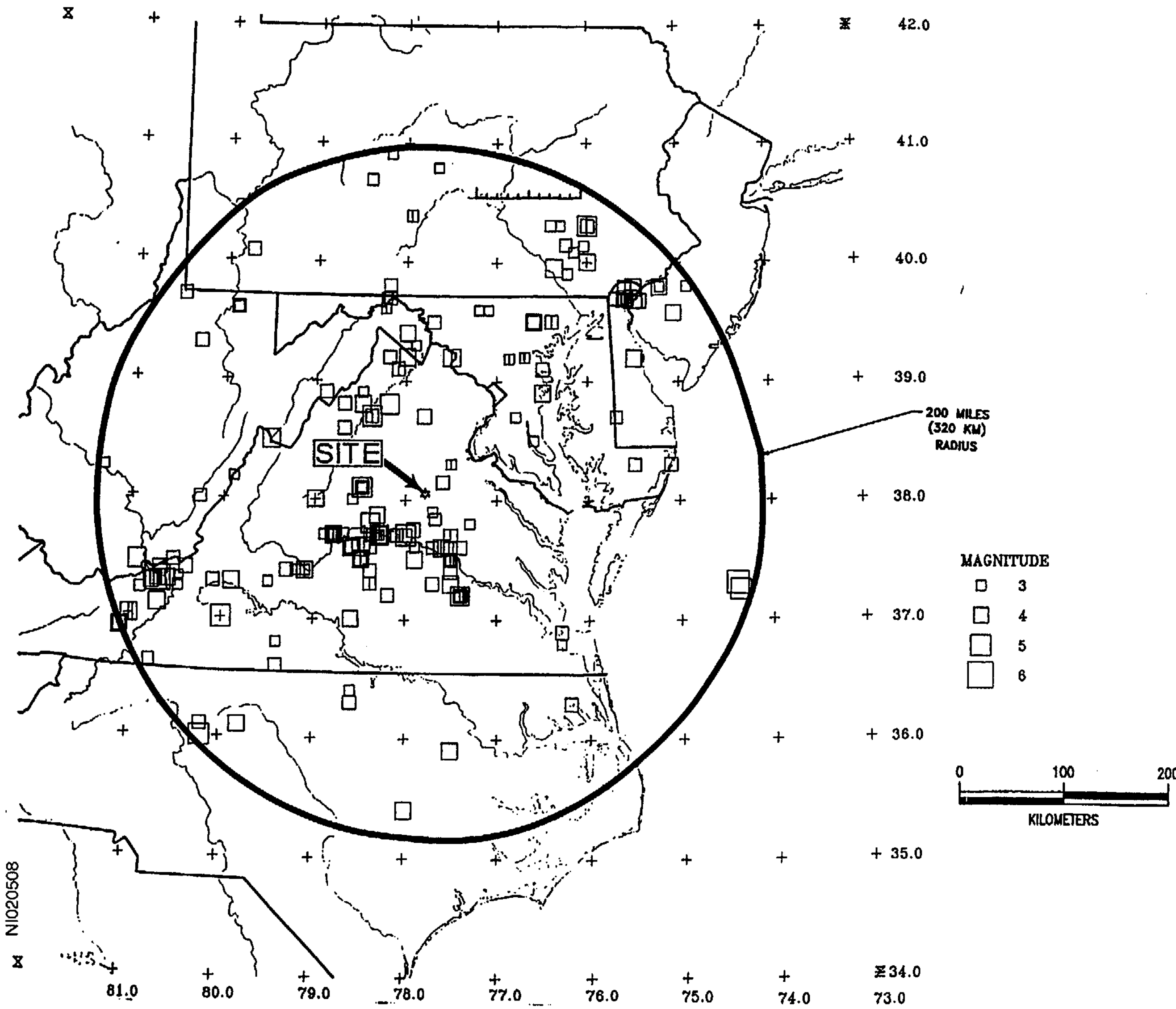
Figure 2-16
PAD #3 SURFACE PROFILE



PROFILE @ ℄ PAD #3

NI020507

Figure 2-17
EARTHQUAKE LOCATIONS



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Appendix 2A
Boring Logs

Appendix 2A
Boring Logs

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FIELD EXPLORATION PROCEDURES

Disturbed Sampling

Soil test borings were drilled and tested in accordance with ASTM D 1452 and ASTM D 1586 procedures with a CME-55 truck mounted drill rig, by mechanically advancing hollow stem auger flights into the ground. At regular intervals, the plug was removed from the auger head, and soil samples were obtained with a standard 1.4"I.D., 2"O.D., 20" long split tube sampler. The sampler was attached to the end of "A" size drill rods and lowered through the augers to sampling elevation. The sampler was first seated to penetration loose cuttings and disturbed soil, then driven an additional foot with blows of a 140 lb. hammer falling 30". The sampler was then extracted from the soil, the plug reinserted into the auger head, and the auger advanced to the next sampling elevation. The number of blows required to drive the sampler each 6" increment of penetration was recorded and is shown on the boring logs. The number of blows required to drive the sampler the final foot is termed the "penetration resistance". Penetration resistance, when properly evaluated, is an index to soil density, strength, and foundation support capacity.

Undisturbed Sampling

Split tube samples are suitable for visual examination and classification tests but are not sufficiently intact for quantitative laboratory testing. Relatively undisturbed samples were obtained by forcing sections of 3"O.D., 16 gauge, steel tubing into the soil at the desired sampling levels. This sampling procedure is described by ASTM Specification D-1587. Each tube, together with the encased soil, was carefully removed from the ground, made airtight, and transported to the laboratory. Locations and depths of undisturbed samples are shown on the test boring records.

ROCK CORING PROCEDURES

Rock coring procedures are used to evaluate subsurface conditions below the depth of auger refusal. Auger refusal typically reflects the presence of obstructions (e.g., boulders) or the presence of bedrock.

Water is used to drill a diamond studded drill bit through bedrock or obstructions. The drill pipe at the bottom of the boring contains a steel sleeve, or core barrel, that accepts the drill core as the bit is advanced. Typically, the core barrel can accommodate 5 or 10 feet of core. When bedrock is encountered, a run number is designated each time the core barrel is filled with sample and removed from the boring.

The percent of recovery is calculated for every run. Percent recovery is the ratio of the recovered length of core to the length of the core run.

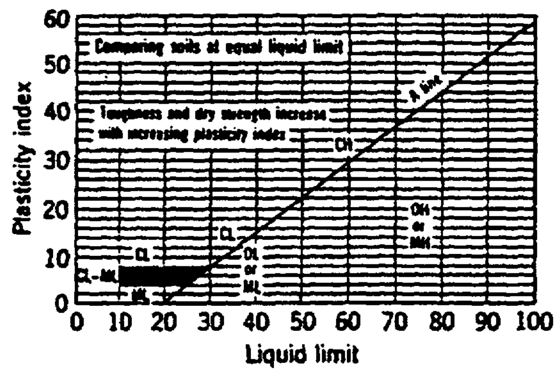
The Rock Quality Designation (RQD) is calculated for each core run when N-sized core sampling procedures are used. N-sized core is approximately 2-inches in diameter. The RQD is the ratio of the cumulative length of core greater than 4-inches long and the length of core run. The RQD is often used to evaluate the engineering properties of bedrock.

KEY TO BORING LOG SOIL CLASSIFICATIONS

Soils Identification

ASTM SOIL CLASSIFICATION IS BASED ON THE DISTRIBUTION OF THE SAND AND GRAVEL SIZED PARTICLES, THE PLASTICITY (e.g. ATTERBERG LIMITS) OF THE FINE SAND, SILT AND CLAY FRACTION, AND THE RELATIVE DENSITY/CONSISTENCY AS DETERMINED FROM THE STANDARD PENETRATION TEST N-VALUE.

Soil Type	Particle Size
Boulder	12 in.
Cobble	3 - 12 in.
Gravel-Coarse	3/4 - 3 in.
-Fine	#4 - 3/4 in.
Sand -Coarse	#10 - #4
-Medium	#40 - #10
-Fine	#200 - #40
Silt (non-cohesive)	<#200
Clay (cohesive)	<#200



Plasticity chart

NOTE: Particle Size is Designated by U. S. Standard Sieve Sizes.

Relative Density or Consistency

THE STANDARD PENETRATION TEST N-VALUES ARE USED TO EVALUATE THE RELATIVE DENSITY OF COARSE-GRAINED SOILS OR THE CONSISTENCY OF FINE-GRAINED SOILS.

RELATIVE DENSITY

Term	N-Value
Very Loose	0 - 4
Loose	5 - 9
Medium Dense	10 - 30
Dense	31 - 50
Very Dense	Over 50

CONSISTENCY

Term	N-Value
Very Soft	0 - 1
Soft	2 - 4
Firm	5 - 8
Stiff	9 - 16
Very Stiff	17 - 30
Hard	31 - 50
Very Hard	Over 50

NI02A003

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES • ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 | Date: April 19, 1994

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-2 (1 of 2) | Total Depth 70.0' | Elev: 319.9'± | Location:

Type of Boring: Hollow Stem Auger | Started: 4/5/94 | Completed: 4/5/94 | Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Stiff to Very Stiff, Reddish Brown Clayey SILT, Trace Fine Sand and Mica - Moist (ML)	4/6/7	0.0 1.5		Groundwater was Encountered at 24.0' During Drilling Groundwater was Observed at 20.0' Upon Removal of Auger Cave-in Depth at 6.5' on 4/7/94 Groundwater was not Observed on 4/7/94
			6/9/11	3.0 4.5		
			7/8/10	7.0 8.5		
			4/8/10	9.0 10.5		
308.9	11.0	Medium Dense, Pinkish Brown Silty Fine SAND - Moist (SM) (Relict Rock Structure Apparent)	3/6/8	14.0 15.5		
			6/8/10	19.0 20.5		
295.9	24.0	Medium Dense, Light Brown Silty Fine SAND - Moist (Micaceous) (SM)	6/8/10	24.0 25.5		
			6/10/12	29.0 30.5		
289.4	30.5	Medium Dense to Very Dense, Brown Silty Micaceous Fine SAND - Moist (SM) (Relict Rock Structure Apparent)	3/6/8	34.0 35.5		
			5/7/10	39.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

NI02A004

BORING LOG

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SINCE 1881

Report No.: V60-073 Date: April 19, 1994

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-2 (2 of 2) Total Depth 70.0' Elev: 319.9'± Location:

Type of Boring: Hollow Stem Auger Started: 4/5/94 Completed: 4/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Medium Dense to Very Dense, Brown Silty Micaceous Fine SAND - Moist (SM)		40.5		
		(Relict Rock Structure Apparent)	3/7/11	44.0 45.5		
			10/18/25	49.0 50.5		
			8/18/36	54.5 56.0		
			10/32/46	59.0 60.5		
254.9	65.0		*	65.0 65.3		*50/0.3' No Sample Recovery
		Driller Reported "Gray Schist"			0%/0%	Started Coring Rock at 65.3' with NX Dia. Bit No Sample Recovery
249.9	70.0			70.0		
		Boring Terminated at 70.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

NI02A005

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Report No.: V60-073
Date: August 11, 1994

Client: Virginia Power			
Project: Phase 2 - ISFSI North Anna Power Station			
Boring No.: F-4 (1 of 2)	Total Depth 59.1'	Elev: 316.6'	Location:
Type of Boring: Hollow Stem Auger	Started: 6/27/94	Completed: 6/27/94	Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
316.0	0.6	Driller Reported "Surficial Organic Soil"	8/11/14	0.0 – 1.5		Groundwater was Encountered at 25.0' During Drilling
		Very Stiff to Stiff, Red Clayey SILT with Fine Sand, Trace Mica and Organics (0.6'-3.0') - Moist (MH)	9/11/18	1.5 – 3.0		Groundwater was Observed at 20.5' Approximately 24 hrs. after Drilling
			7/8/11	3.0 – 4.5		Groundwater was observed at 20.5' on 7/12/94
			7/8/11	6.0 – 7.5		
309.6	7.0	Medium Dense to Very Dense, Brown to Gray Micaceous Silty Fine to Medium SAND - Moist (SM) (Relict Rock Structure Present)	7/7/8	9.0 – 10.5		
			7/9/12	14.0 – 15.5		
			6/7/9	19.0 – 20.5		
			6/8/15	24.0 – 25.5		
			15/*	29.0 – 29.9		*50/0.4'
282.6	34.0	Very Dense, Light Brown Silty Fine SAND, Trace Mica - Moist (SM) (Relict Rock Structure Present)	*	34.0 – 34.4		*50/0.4'
			*	39.0 – 39.4		*50/0.4'

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A006

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Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-4 (2 of 2) Total Depth 59.1' Elev: 316.6' Location:

Type of Boring: Hollow Stem Auger Started: 6/27/94 Completed: 6/27/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Very Dense, Light Brown Silty Fine SAND, Trace Mica - Moist (SM) (Relict Rock Structure Present)		44.0 44.3 49.0 49.1		*50/0.3'- No Sample Recovery *50/0.1 - No Sample Recovery
267.5	49.1	Extremely Weathered Gray Biotite Granite GNEISS - Foliation Dips Approximately 35 Degrees from Horizontal. Up to Four Fractures Per Foot of Core. Fractures Highly Weathered and Iron Stained.		54.1	21.6%/0%	Started Coring Rock at 49.1' with "NX" Dia. Bit
262.5	54.1	Moderately Weathered Gray Biotite Granite GNEISS - Foliation Dips Approximately 35 Degrees from Horizontal. Up to One Fracture Per Foot		59.1	78.3%/40%	
257.5	59.1	Boring Terminated at 59.1'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance. N.

NI02A007

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power			
Project: Phase 2 - ISFSI North Anna Power Station			
Boring No.: F-5 (1 of 3)	Total Depth 114.5'	Elev. 318.5'	Location:
Type of Boring: Hollow Stem Auger	Started: 6/30/94	Completed: 7/5/94	Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
318.0	0.5	Driller Reported "Surficial Organic Soil"	6/11/14	0.0		Groundwater was Encountered at 24.0' During Drilling
		Very Stiff, Red Clayey SILT, Trace to Some Fine Sand - Moist (MH)	11/14/11	1.5		Groundwater was Observed at 27.0' on 7/12/94
			6/8/10	3.0		Cave-in Depth at 16.0'
				4.5		
			8/10/11	6.0		
				7.5		
310.5	8.0	Stiff, Red Clayey SILT with Mica and Fine Sand - Moist (MH)	3/4/5	9.0		
				10.5		
304.5	14.0	Stiff to Hard, Brown Clayey Micaceous SILT, Trace to Some Fine Sand - Moist (MH) (Relict Rock Structure Present)	5/6/7	14.0		
				15.5		
			3/4/5	19.0		
				20.5		
			4/5/7	24.0		
				25.5		
			5/6/8	29.0		
				30.5		
			5/12/14	34.0		
				35.5		
			8/14/17	39.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A008

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"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073 Date:

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-5 (2 of 3) Total Depth: 114.5' Elev: 318.5' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 7/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
				40.5		
274.5	44.0	Stiff to Hard, Brown Clayey Micaceous SILT, Trace to Some Fine Sand - Moist (MH) (Relict Rock Structure Present)	5/11/16	44.0 / 45.5		
		Very Stiff to Hard, Grayish-Green Micaceous SILT, Trace Fine Sand - Moist (MH) (Relict Rock Structure Present)	8/20/24	49.0 / 50.5		
			7/12/15	54.0 / 55.5		
			10/16/24	59.0 / 60.5		
254.5	64.0			64.0		*50/0.3'
254.0	64.5	SEE NOTE (1)		64.3 / 64.5		Started Coring Rock at 64.5' with "NX" Dia. Bit
		Extremely Weathered AMPHIBOLITE			0%/0%	
249.0	69.5	Extremely Weathered Hornblende GNEISS		69.5	13.3%/0%	NOTE (1) Very Dense, Gray Silty Medium SAND with Rock Fragments - Moist (SM) "Weathered Rock"
				74.5	3.3%/0%	
				79.5		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments.

NI02A009

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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-5 (3 of 3) Total Depth 114.5' Elev: 318.5' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 7/5/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Extremely Weathered Hornblende GNEISS		84.5	0%/0%	Core is Saprolitic with Parent Structure Still Visible
				89.5	6.6%/0%	
				94.5	0%/0%	
				99.5	0%/0%	
				104.5	0%/0%	
209.0	109.5			109.5	50%/0%	
204.0	114.5	Moderately Weathered Biotite Hornblende GNEISS - Interlayered with Quartz Biotite Gneiss		114.5	80%/0%	
		Boring Terminated at 114.5'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

NI02A010

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"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073

DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-5A (1 of 1) | Total Depth 20.0' | Elev: | Location:

Type of Boring: Hollow Stem Auger | Started: 6/30/94 | Completed: 7/5/94 | Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
		AUGER PROBE TO OBTAIN SHELBY TUBE SAMPLE	UD-1	18.0 20.0		"UD" denotes Undisturbed Thin-Walled Shelby Tube Sample
	20.0	Boring Terminated at 20.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A011

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-6 (1 of 2) Total Depth 59.0' Elev: 316.0' Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
315.5	0.5	Driller Reported "Surficial Organic Soil"	6/8/11	0.0		Groundwater was Encountered at 22.0' During Drilling
		Very Stiff, Red Clayey SILT with Fine Sand, Trace Organics (0.5'-3.0') and Mica - Moist (MH)	8/12/14	1.5		Groundwater was Observed at 21.5' Approximately 24 hrs. After Drilling
			8/11/15	3.0		Groundwater was Observed at 21.5' on 7/12/94
				4.5		
			9/12/14	6.0		
309.0	7.0	Very Stiff, Reddish Brown Fine Sandy SILT with Clay, Some Mica - Moist (MH)		7.5		
			6/9/10	9.0		
				10.5		
304.0	12.0	Stiff, Brown to Gray Clayey SILT, Trace Fine Sand and Mica - Moist (MH)	7/7/7	14.0		
				15.5		
			5/6/7	19.0		
				20.5		
			5/6/7	24.0		
				25.5		
287.0	29.0	Medium Dense to Very Dense, Gray Micaceous Silty Fine to Medium SAND - Moist (SM) (Relict Rock Structure Present)	6/8/9	29.0		
				30.5		
			9/12/11	34.0		
				35.5		
			20/30/*	39.0		*50/0.3'

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A012

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-6 (2 of 2) Total Depth 59.0' Elev: 316.0' Location:

Type of Boring: Hollow Stem Auger Started: 6/28/94 Completed: 6/28/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Medium Dense to Very Dense, Gray Micaceous Silty Fine to Medium SAND - Moist (SM)		40.3		
272.0	44.0	(Relict Rock Structure Present)		44.0		
		Heavily Fractured and Extremely Weathered Light Gray Biotite Granite GNEISS - Foliation Dips Approximately 45 Degrees from Horizontal. Up to Three Fractures Per Foot of Rock Core			0%/0%	Started Coring Rock at 44.0' with "NX" Dia. Bit
				49.0	0%/0%	
				54.0	70%/18.3%	
257.0	59.0			59.0		
		Boring Terminated at 59.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

NI02A013

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073   Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-7 (1 of 3) | Total Depth 105.0' | Elev. 319.5' | Location:

Type of Boring: Hollow Stem Auger | Started: 7/12/94 | Completed: 7/12/94 | Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
319.0	0.5	Driller Reported "Surficial Organic Soil"	3/7/12	0.0 / 1.5		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Stiff to Hard, Reddish Brown Clayey SILT, Trace Fine Sand - Moist (MH)	18/20/21	1.5 / 3.0		
			12/18/18	3.0 / 4.5		
			8/11/16	6.0 / 7.5		
			3/7/8	9.0 / 10.5		
307.5	12.0	Stiff, Reddish Brown and Black Clayey Micaceous SILT and Fine SAND to Clayey Micaceous SILT with Some Fine Sand - Moist (MH) (Relict Rock Structure Present)	4/5/5	14.0 / 15.5		
			3/5/5	19.0 / 20.5		
			3/5/5	24.0 / 25.5		
			5/7/8	29.0 / 30.5		
			3/7/8	34.0 / 35.5		
			4/5/9	39.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A014

BORING LOG

FROEHLING & ROBERTSON, INC.
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FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
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Report No.: V60-073 Date:

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-7 (2 of 3) Total Depth 105.0' Elev: 319.5' Location:

Type of Boring: Hollow Stem Auger Started: 7/12/94 Completed: 7/12/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		SEE NOTE (1)		40.5		NOTE (1) Stiff, Reddish Brown and Black Clayey Micaceous SILT and Fine SAND to Clayey Micaceous SILT with Some Fine Sand - Moist (MH) (Relict Rock Structure Present)
275.5	44.0	Very Stiff to Hard, Brown and Gray SILT, Trace Fine Sand, Some Mica - Moist (MH) (Relict Rock Structure Present)	4/8/9	44.0		
				45.5		
			3/8/14	49.0		
				50.5		
			6/14/22	54.0		
				55.5		
			12/18/20	59.0		
				60.5		
255.5	64.0	Very Dense, Brown Micaceous Silty Fine SAND - Moist (SM) (Relict Rock Structure Present)	9/22/32	64.0		
				65.5		
			19/31/40	69.0		
				70.5		
			38/*	74.0		*50/0.3'
				74.8		
244.5	75.0	Extremely Weathered Hornblende GNEISS		75.0	0%/0%	Started Coring Rock at 75.0' with "NX" Dia. Bit
				80.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A015

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-7 (3 of 3) Total Depth 105.0' Elev: 319.5' Location:

Type of Boring: Hollow Stem Auger Started: 7/12/94 Completed: 7/12/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Extremely Weathered Hornblende GNEISS			0%/0%	Core Recovery is Saprolitic - Almost Soil-like
				85.0		
					0%/0%	
				90.0		
					3.3%/0%	
				95.0		
					0%/0%	
				100.0		
					63%/0%	
214.5	105.0	Some Joints Visible When They Cross Foliation		105.0		
		Boring Terminated at 105.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance. N.

NI02A016

BORING LOG

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Report No.: V60-073

DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-7A (1 of 1) Total Depth 22.0' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 7/12/94 Completed: 7/12/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
		AUGER PROBE TO OBTAIN SHELBY TUBE SAMPLES				
			UD-1	4.0		
				6.0		
						"UD" Denotes Undisturbed Thin Walled Shelby Tube Samples
			UD-2	16.0		
			UD-3	18.0		
			UD-4	20.0		
	22.0			22.0		
		Boring Terminated at 22.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A017

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073
Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-8 (1 of 2) | Total Depth 69.2' | Elev: 317.9' | Location:

Type of Boring: Hollow Stem Auger | Started: 7/6/94 | Completed: 7/6/94 | Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	REMARKS
		Medium Dense, Brown Silty Clayey SAND - Moist (SC)	5/8/10	0.0	Groundwater was Encountered at 42.0' During Drilling
316.4	1.5		10/15/18	1.5	
		Hard to Very Stiff Brown and Reddish Brown Silty CLAY, Trace Fine Sand - Moist (CL)		3.0	
			8/12/17	4.5	Groundwater was Observed at 40.0' Upon Removal of Auger
				6.0	
			11/16/20	7.5	
309.9	8.0	Very Stiff, Brown Clayey SILT, Trace Fine Sand - Moist (MH)		9.0	Groundwater was Observed at 26.5' on 7/12/94
			5/7/10	10.5	
				14.0	
			6/8/10	15.5	
298.9	19.0	Stiff to Very Hard, Gray and Green Fine Sandy SILT - Moist (ML) (Relict Rock Structure Present)		19.0	
			6/11/14	20.5	
				24.0	
			8/10/14	25.5	
				29.0	
			6/7/9	30.5	
				34.0	
			12/*	34.9	*50/0.4'
				39.0	
			*	39.5	*50/0.5'

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A018

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 Date:

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-8 (2 of 2) Total Depth 69.2' Elev: 317.9' Location:

Type of Boring: Hollow Stem Auger Started: 7/6/94 Completed: 7/6/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Stiff to Very Hard, Gray and Green Fine Sandy SILT - Moist (ML)				
		(Relict Rock Structure Present)		44.0 44.4		*50/0.4'
				49.0 49.3		*50/0.3'
				54.0 54.3		*50/0.3'
				59.0 59.4		*50/0.4'
253.7	64.2			64.0 64.2		*50/0.2'
		Heavily Fractured and Weathered PEGMATITE, Less Severely Weathered from 67.0'- 68.0'			80%/0%	Started Coring Rock at 64.2' with an "NX" Dia. Bit
248.7	69.2			69.2		
		Boring Terminated at 69.2'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A019

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 | Date: August 11, 1994

Client: Virginia Power			
Project: ISFSI - North Anna Power Station			
Boring No.: F-9 (1 of 3)	Total Depth 105.0'	Elev: 310.9'	Location:
Type of Boring: Hollow Stem Auger	Started: 6/28/94	Completed: 6/28/94	Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
310.3	0.6	Driller Reported "Surficial Organic Soil"	6/8/9	0.0		Groundwater was Encountered at 20.0' During Drilling
		Medium Dense, Red Clayey Silty Fine SAND - Moist (SM)	8/11/14	1.5		
			8/11/12	3.0		
				4.5		
304.4	6.5		9/11/13	6.0		
		Loose to Very Dense, Brown to Gray Micaceous Silty Fine SAND - Moist (SM)		7.5		
		(Relict Rock Structure Present)	6/8/8	9.0		
				10.5		
			5/6/8	14.0		
				15.5		
			3/4/8	19.0		
				20.5		
			3/3/4	24.0		
				25.5		
			5/6/8	29.0		
				30.5		
			7/9/12	34.0		
				35.5		
			8/12/14	39.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

NI02A020

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073　　Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-9 (2 of 3)　Total Depth: 105.0'　Elev: 310.9'　Location:

Type of Boring: Hollow Stem Auger　Started: 6/28/94　Completed: 6/28/94　Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Loose to Very Dense, Brown to Gray Micaceous Silty Fine SAND - Moist (SM)		40.5		
				44.0		
		(Relict Rock Structure Present)	10/22/30	45.5		
				49.0		
			20/22/34	50.5		
				54.0		
			*	54.4		*50/0.4' - No Sample Recovery
				59.0		*50/0.1' - No Sample Recovery
251.8	59.1	Hornblende GNEISS (Several Small Pieces of Hornblende Gneiss Obtained)	*	59.1	0%/0%	Started Coring Rock at 59.1' with an "NX" Dia. Bit
				64.1	0%/0%	
				69.1	12.5%/0%	
236.8	74.1	Biotite GNEISS with Some Hornblende GNEISS Interlayers. Foliation Dips Approximately 45 to 50 Degrees from Horizontal Up to Three Fractures Per Foot of Core		74.1		
				75.0	47%/7.5%	
230.9	80.0			80.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three (6") increments. The sum of the last two increments of penetration is termed the standard penetration resistance. N

NI02A021

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"
1881

Report No.: V60-073
Date:

Client: Virginia Power						
Project: ISFSI - North Anna Power Station						
Boring No.: F-9 (3 of 3)	Total Depth 105.0'	Elev: 310.9'		Location:		
Type of Boring: Hollow Stem Auger	Started: 6/28/94	Completed: 6/28/94		Driller: Ayers		

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Hornblende GNEISS			20%/6.6%	
				85.0	0%/0%	
				90.0	13%/0%	
216.9	94.0					
215.9	95.0	Quartz Granite GNEISS		95.0		
		Biotite Granite GNEISS, Light Gray, Foliation Dips Approximately 45 to 50 Degrees from Horizontal			31%/6.6%	
				100.0	60%/17.5%	
206.9	104.0					
205.9	105.0	Hornblende GNEISS		105.0		
		Boring Terminated at 105.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

NI02A022

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073

DATE: August 11, 1994

Client: Virginia Power						
Project: Phase 2 - ISFSI North Anna Power Station						
Boring No.: F-9A (1 of 1)	Total Depth 6.0'	Elev:		Location:		
Type of Boring: Hollow Stem Auger	Started: 6/28/94	Completed: 6/28/94		Driller: Ayers		
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	6.0	AUGER PROBE TO OBTAIN SHELBY TUBE SAMPLE	UD-1	4.0 6.0		"UD" Denotes Undisturbed Thin Walled Shelby Tube Sample
		Boring Terminated at 6.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A023

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 | Date: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: F-10 (1 of 2) | Total Depth: 74.0' | Elev: 315.1' | Location:

Type of Boring: Hollow Stem Auger | Started: 7/11/94 | Completed: 7/11/94 | Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
314.6	0.5	Driller Reported "Surficial Organic Soil"	8/9/14	0.0		Groundwater was Encountered at 36.0' During Drilling
		Medium Dense, Brown Silty Clayey SAND - Moist (SC)		1.5		
			13/14/16	3.0		
			10/14/14	4.5		
				6.0		
			11/12/15	7.5		
				9.0		
			8/10/10	10.5		
303.1	12.0	Medium Dense to Very Dense, Brown Silty Fine SAND to Fine SAND with Some Silt - Moist (SM) (Relict Rock Structure Present)		14.0		
			10/12/12	15.5		
				19.0		
			12/16/16	20.5		
				24.0		
			9/10/12	25.5		
				29.0		
			9/20/28	30.5		
				34.0		
			14/30/31	35.5		No Sample Recovery
				39.0		
			12/30/50			No Sample Recovery

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A024

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No.: F-10 (2 of 2) Total Depth 74.0' Elev: 315.1' Location:

Type of Boring: Hollow Stem Auger Started: 7/11/94 Completed: 7/11/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Medium Dense to Very Dense, Brown Silty Fine SAND to Fine SAND with Some Silt - Moist (SM) (Relict Rock Structure Present)		40.5		
			6/10/16	44.0 45.5		
				49.0 49.4		*50/0.4'
				54.0 54.4		*50/0.4'
				59.0 59.3		*50/0.3'
				64.0 64.2		*50/0.2' - No Sample Recovery
						*50/0.0' - No Sample Recovery
246.1	69.0	Coarse PEGMATITE - Near Horizontal Fractures - Iron Stained		69.0	95%/35.8%	Started Coring Rock at 69.0' with an "NX" Dia. Bit
241.1	74.0	Boring Terminated at 74.0'		74.0		

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

N102A025

BORING LOG

FROEHLING & ROBERTSON, INC.
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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 | Date: August 11, 1994

Client: Virginia Power			
Project: ISFSI - North Anna Power Station			
Boring No.: F-11 (1 of 2)	Total Depth 69.0'	Elev: 308.8'	Location:
Type of Boring: Hollow Stem Auger	Started: 7/6/94	Completed: 7/6/94	Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Hard to Very Hard, Brown Clayey SILT, Trace Fine Sand - Moist (MH)	8/19/24	0.0 1.5		Groundwater was Encountered at 26.0' During Drilling
			29/30/32	3.0		
			12/18/23	4.5		Groundwater was Observed at 19.0' on 7/12/94
				6.0		
			11/14/18	7.5		
				9.0		
			10/14/24	10.5		
				14.0		
293.8	15.0		34/*	14.8		*50/0.3'
		Hard, Gray and Green Micaceous SILT, Trace Fine Sand - Moist (ML) (Relict Rock Structure Present)		19.0		
			11/18/21	20.5		
284.8	24.0			24.0		NOTE (1) Mafic Zone from 39 to 40 ft. Heavily Weathered PEGMATITE
		Very Dense, Brown Micaceous Silty Fine SAND - Moist (SM) (Relict Rock Structure Present)	12/20/41	25.5		
279.8	29.0			29.0		
		Very Dense, Gray and Green Silty Fine SAND, Trace Clay - Moist (SM) (Relict Rock Structure Present)	*	29.4		*50/0.4'
				34.0		*50/0.3'- No Sample Recovery
			*	34.3		From 39.0 - 39.3' - 50/0.3' No Sample Recovery
269.8	39.0			39.0		Started Coring Rock at 39.0 with an "NX" Dia. Bit
		SEE NOTE (1)				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

NI02A026

NI02A027

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No: V60-073 Date:

Client: Virginia Power

Project: ISFSI - North Anna Power Station

Boring No: F-11 (2 of 2) Total Depth 69.0' Elev: 308.8' Location:

Type of Boring: Hollow Stem Auger Started: 7/6/94 Completed: 7/6/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	*Sample Blows	Sample Depth (Feet)	% CORE REC/RQD	REMARKS
		Mafic Zone from 39 to 40 ft.			10%/0%	
		Heavily Weathered PEGMATITE		44.0		
					13.3%/0%	
259.8	49.0			49.0		
		Medium Weathered Hornblende GNEISS with Predominantly Vertical Fractures. Fractures are Infilled with Weathered Zeolites or Orthoclase			23%/0%	
				54.0		
					70%/0%	
				59.0		
					58%/28%	
				64.0		
					70%/22.5%	
239.8	69.0			69.0		
		Boring Terminated at 69.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

BORING LOG

FROEHLING & ROBERTSON, INC.
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FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073

DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-1 (1 of 1) | Total Depth 5.0' | Elev: 311.3' | Location:

Type of Boring: Hollow Stem Auger | Started: 6/30/94 | Completed: 6/30/94 | Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
309.8	1.5	Loose, Dark Brown Clayey Fine SAND, Trace Micaceous Silt and Organics - Moist (SC)	2/3/4	0.0 - 1.5		No Groundwater was Encountered During Drilling or Upon Removal of Auger
307.8	3.5	Firm, Brown and Gray Silty CLAY, Trace Sand and Mica - Moist (CH)	2/3/4	3.0 - 3.5		
306.3	5.0	Stiff, Gray Fine Sandy Micaceous SILT with Clay - Moist (MH)	4/6/7	3.5 - 5.0		Cave-in Depth at 4.0'

Boring Terminated at 5.0'

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

N102A028

BORING LOG

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES ENGINEERS & CHEMISTS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-2 (1 of 1) Total Depth 5.0' Elev. 317.0' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 6/30/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
316.4	0.6	Driller Reported "Surficial Organic Soil"	10/10/10	0.0		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Medium Dense to Dense, Brown Clayey Fine SAND with Silt - Moist (SC)		1.5		
			10/20/21	3.0		
				3.5		
312.0	5.0		6/10/12	5.0		Cave-in Depth at 4.0'
		Boring Terminated at 5.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A029

BORING LOG

SINCE 1881 **FROEHLING & ROBERTSON, INC.**
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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-3 (1 of 1) Total Depth 5.0' Elev. 312.6' Location:

Type of Boring: Hollow Stem Auger Started: 6/30/94 Completed: 6/30/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
312.0	0.6	Driller Reported "Surficial Organic Soil"	6/8/12	0.0 1.5		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Very Stiff, Brown Silty CLAY/Clayey SILT with Fine Sand - Moist (CH-MH)	8/12/16	3.0		
			8/14/15	3.5 5.0		
307.6	5.0					Cave-in Depth at 4.0
		Boring Terminated at 5.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A030

BORING LOG

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Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-4 (1 of 1) Total Depth 1.8' Elev: Location:

Type of Boring: Hollow Stem Auger Started: 7/13/94 Completed: 7/13/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.3	Driller Reported "Bituminous Concrete - Asphalt	24/12/8	0.3 1.8		
	0.8	Gray Crushed Stone Base (21A)				No Groundwater was Encountered During Drilling or Upon Removal of Auger
	1.8	Very Stiff, Reddish Brown Fine Sandy SILT, Trace Clay - Moist (ML)				0 - 4" Base Course Bituminous Concrete 4"- 10" Gray Crushed Stone Base (21A) 10"- 22" Reddish Brown Silty CLAY, Trace Fine Sand
		Boring Terminated at 1.8'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A031

BORING LOG

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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073

DATE: August 11, 1994

Client: Virginia Power			
Project: Phase 2 - ISFSI North Anna Power Station			
Boring No.: P-5 (1 of 1)	Total Depth 5.0'	Elev:	Location:
Type of Boring: Hollow Stem Auger	Started: 7/13/94	Completed: 7/13/94	Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.5	Driller Reported "Surficial Organic Soil"	8/12/15	0.0 1.5		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Stiff to Very Stiff, Brown Fine Sandy SILT - Moist (ML)	8/11/11	3.0		
			6/8/8	3.5 5.0		Cave-in Depth at 4.0'.
	5.0	Boring Terminated at 5.0'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A032

BORING LOG

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Report No.: V60-073

DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-6 (1 of 1) | Total Depth: 0.9' | Elev: | Location:

Type of Boring: Hollow Stem Auger | Started: 7/13/94 | Completed: 7/13/94 | Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.3	Driller Reported "Bituminous Concrete - Asphalt	40/*	0.3		*50/0.1'
	0.9	Very Dense, Brown SAND and Gray GRAVEL		0.9		No Groundwater was Encountered During Drilling or Upon Removal of Auger
		Boring Terminated at 0.9'				0 - 3.5" Base Course Bituminous Concrete
						3.5"- 7" Brown SAND and Gray GRAVEL

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A033

BORING LOG

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"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No.: V60-073 DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: P-7 (1 of 1) Total Depth 3.2' Elev: ± Location:

Type of Boring: Hollow Stem Auger Started: 7/13/94 Completed: 7/13/94 Driller: Ayers

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
	0.2	Driller Reported "Asphaltic Concrete"	12/18/22	0.2		
	0.6	Gravel Base (21A Stone)		1.7		
	1.8	Dense, Brown SAND and GRAVEL	6/26/31	3.2		
	3.2	Very Hard, Brown and Gray Silty CLAY, Trace Fine Sand				No Groundwater was Encountered During Drilling or Upon Removal of Auger 0 - 2.5" Base Course Bituminous Concrete 2.5"- 7.5" Gravel Base (21A Stone) 7.5"- 21" Brown SAND and GRAVEL 21"- 36" Brown and Gray Silty CLAY, Trace Fine Sand
		Boring Terminated at 3.2'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

N102A034

BORING LOG

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"OVER ONE HUNDRED YEARS OF SERVICE"

Report No.: V60-073

DATE: August 11, 1994

Client: Virginia Power

Project: Phase 2 - ISFSI North Anna Power Station

Boring No.: WP-2 (1 of 1) | Total Depth: 34.3' | Elev: 298.2' | Location:

Type of Boring: Hollow Stem Auger | Started: 6/30/94 | Completed: 6/30/94 | Driller: Ayers

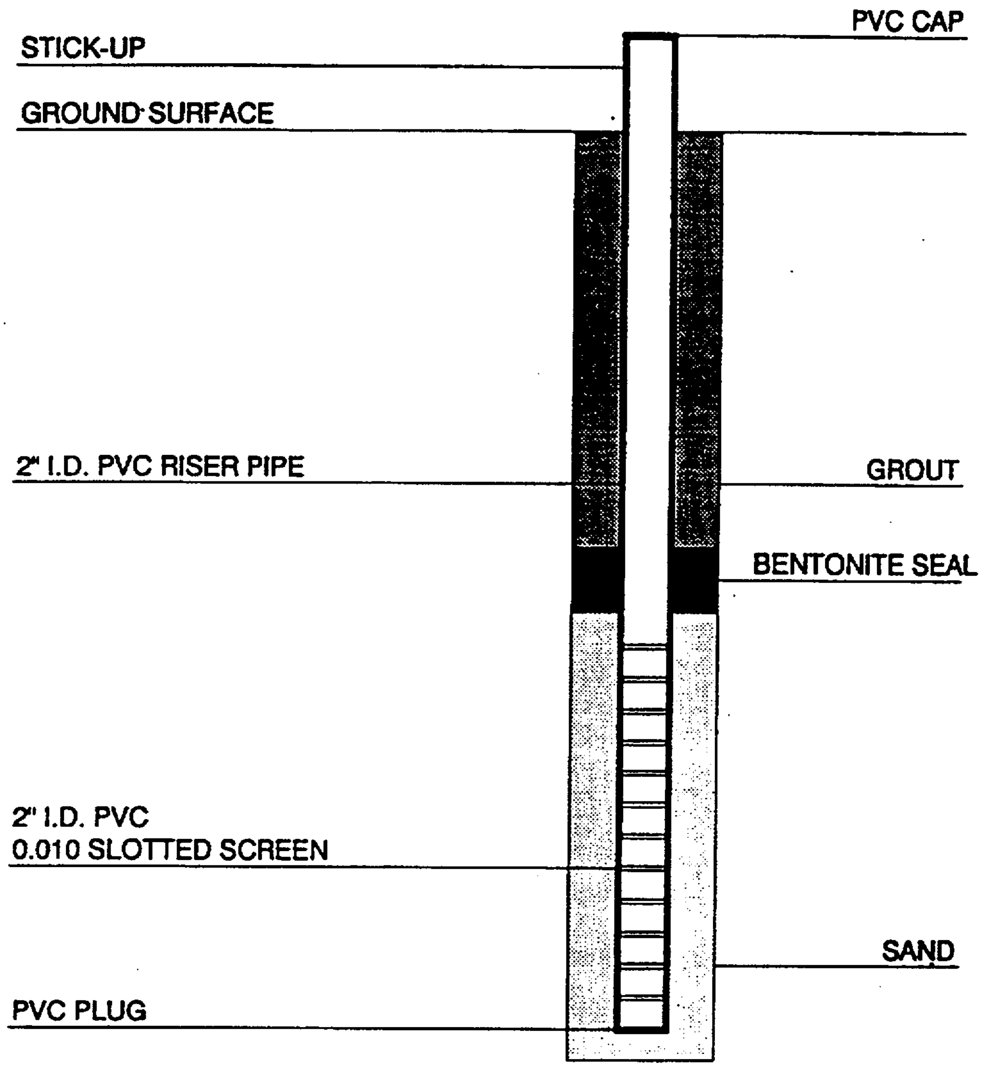
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (Feet)		REMARKS
		Very Stiff to Stiff, Brown and Gray Fine Sandy CLAY, Trace Silt and Mica - Moist (CL)	6/10/12	0.0		Groundwater was Encountered at 14.0' During Drilling
				1.5		
			6/10/11	3.0		
			6/8/8	4.5		
292.2	6.0			6.0		
		Medium Dense, Brown and Gray Clayey Fine SAND, Trace Silt and Mica - Moist (SC)	7/8/9	7.5		
289.2	9.0			9.0		
		Medium Dense, Brown Silty Fine SAND, Trace Clay and Mica - Moist (SM) (Relict Rock Structure Present)	6/12/16	10.5		
				14.0		
			8/11/16	15.5		
279.2	19.0			19.0		
		Medium Dense to Very Dense, Brown and Green Clayey Fine SAND, Trace Silt and Mica - Moist (SC) (Relict Rock Structure Present)	6/12/14	20.5		
				24.0		
			30/*	24.8		*50/0.3'
				29.0		
			8/*	29.9		*50/0.4'
				34.0		
263.9	34.3		*	34.3		*50/0.3'
		Boring Terminated at 34.3'				

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler in 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration resistance, N.

NI02A035

MONITOR WELL DIAGRAM

WELL WP-1



GROUT	26.5 ft.	CASING TOP EL	323.22
BENTONITE	2.0 ft.	RISER PIPE	33.1 ft.
SAND	7.0 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	35.5 ft.	STICK-UP	2.6 ft.

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DATE: August, 1994
SCALE: NONE
DRWN: TMM
V60-073

MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

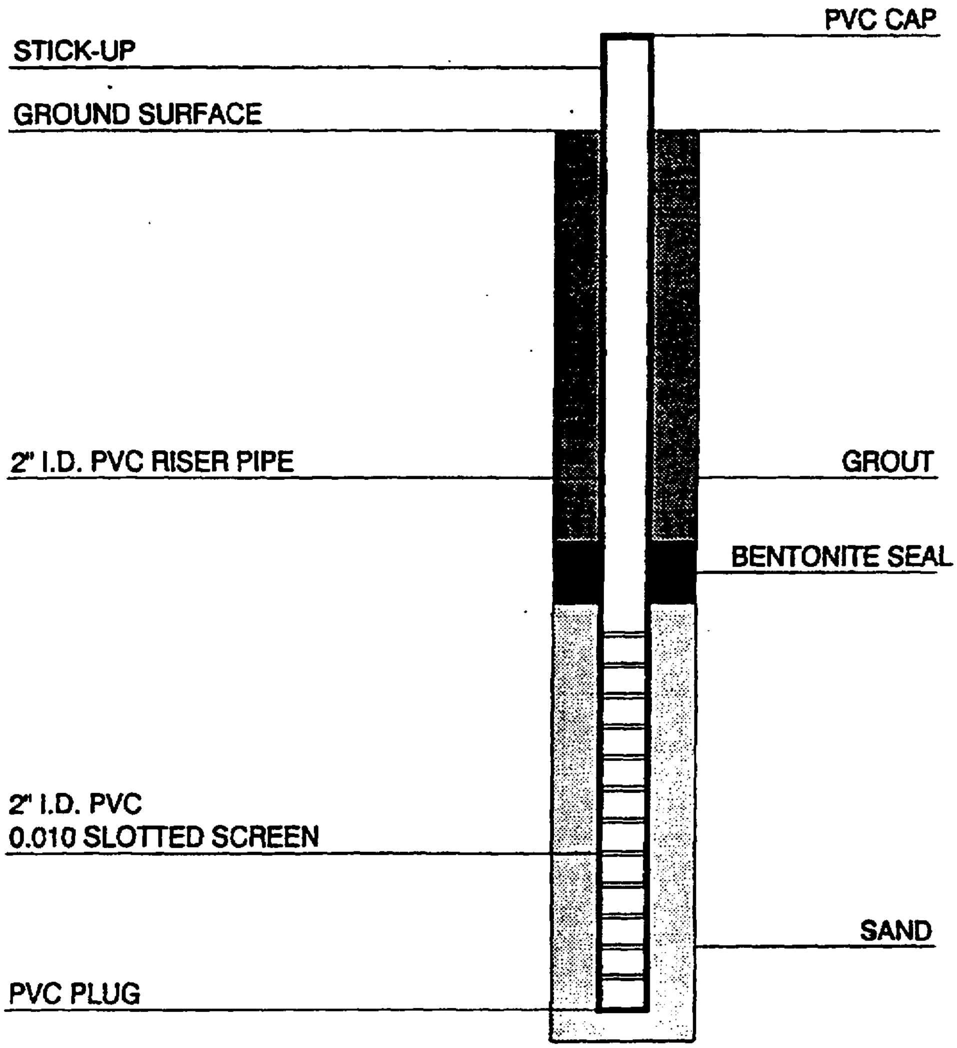
DWG. NO.
WP-1

Form No 103

NI02A036

MONITOR WELL DIAGRAM

WELL WP-2



GROUT	24.0 ft.	CASING TOP EL	298.20
BENTONITE	2.0 ft.	RISER PIPE	31.7 ft.
SAND	8.3 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	34.3 ft.	STICK-UP	2.4 ft.

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"OVER ONE HUNDRED YEARS OF SERVICE"

DATE: August, 1994
SCALE: NONE
DRWN: TMM | V60-073

MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA   VIRGINIA POWER

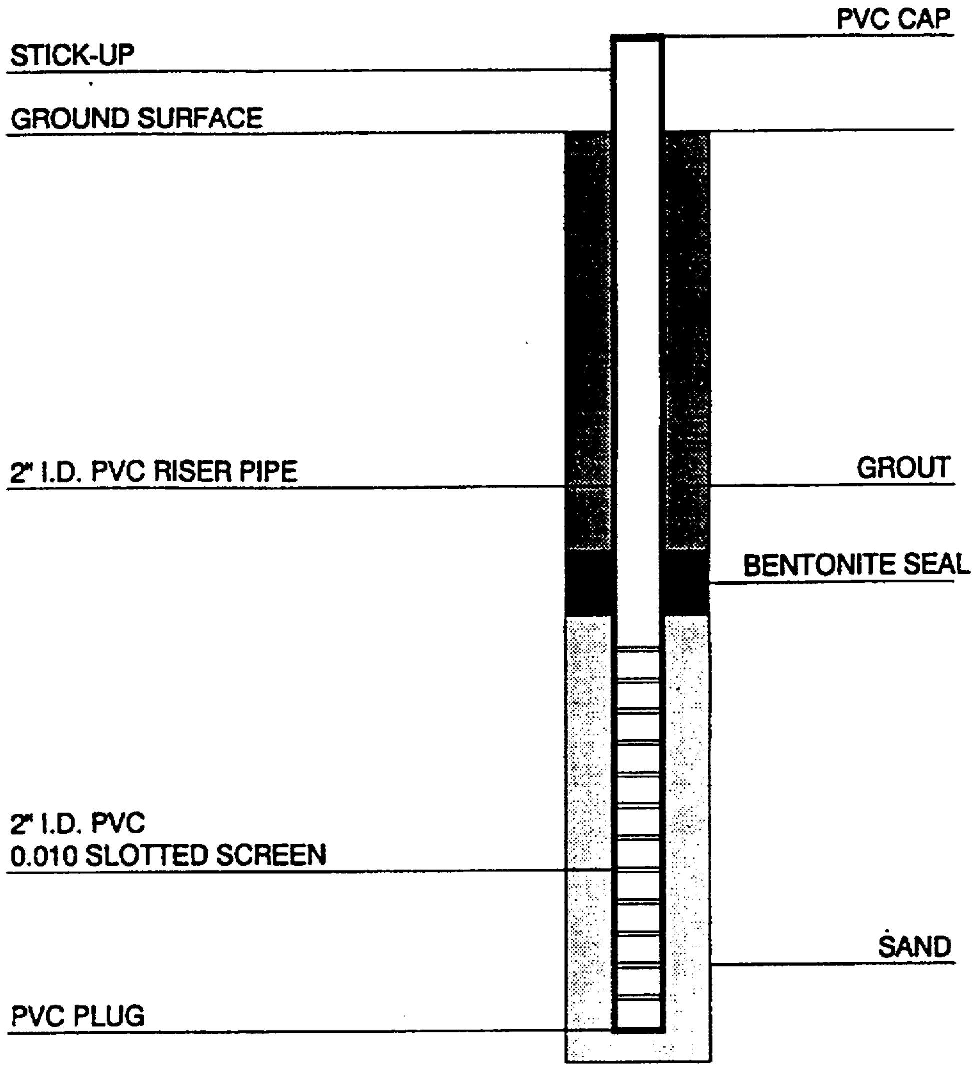
DWG. NO. WP-2

Form No 103

NI02A037

MONITOR WELL DIAGRAM

WELL WP-3



GROUT	30.0 ft.	CASING TOP EL	311.32
BENTONITE	2.0 ft.	RISER PIPE	36.5 ft.
SAND	7.0 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	39.0 ft.	STICK-UP	2.5 ft.

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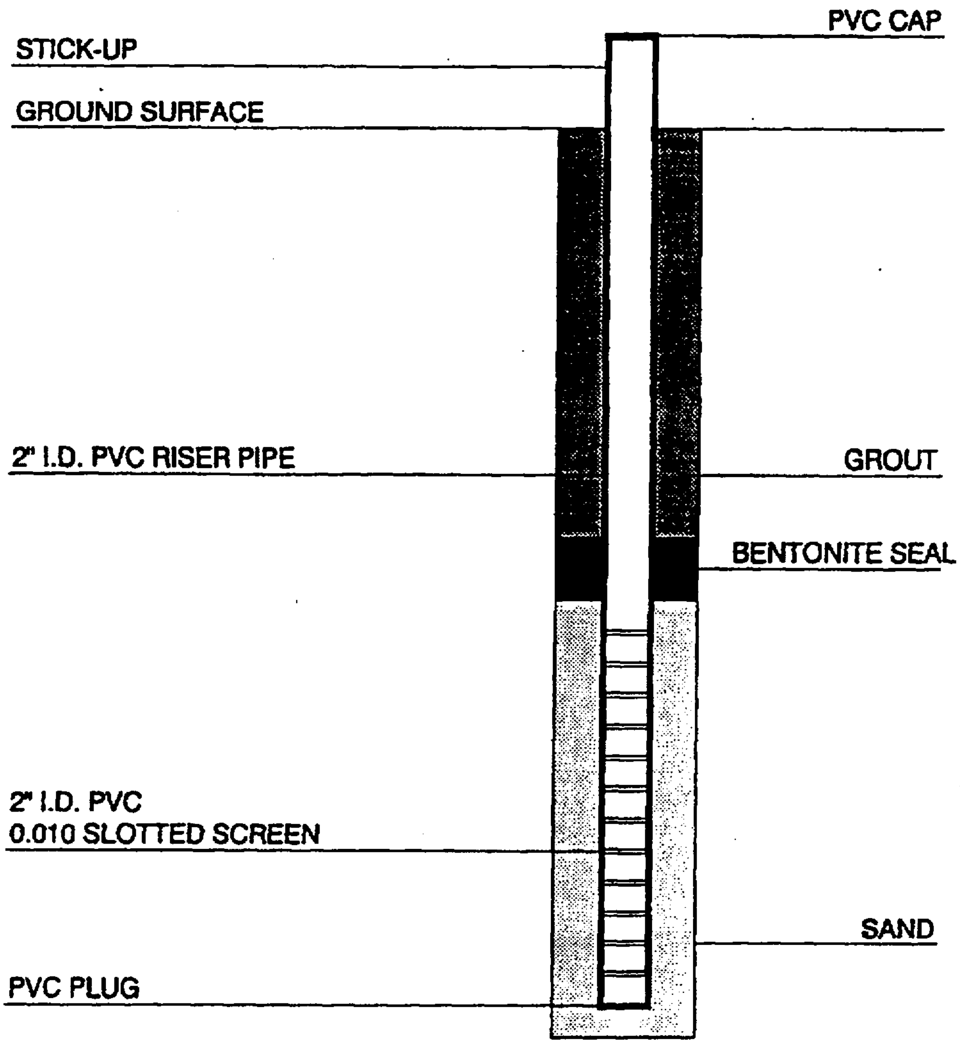
DATE:	August, 1994
SCALE:	NONE
DRWN: TMM	V60-073

MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

DWG. NO.
WP-3

MONITOR WELL DIAGRAM

WELL F-6



GROUT	35.0 ft.	CASING TOP EL	315.98
BENTONITE	2.0 ft.	RISER PIPE	41.6 ft.
SAND	7.0 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	44.0 ft.	STICK-UP	2.6 ft.

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DATE:	August, 1994
SCALE:	NONE
DRWN: TMM	V60-073

MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

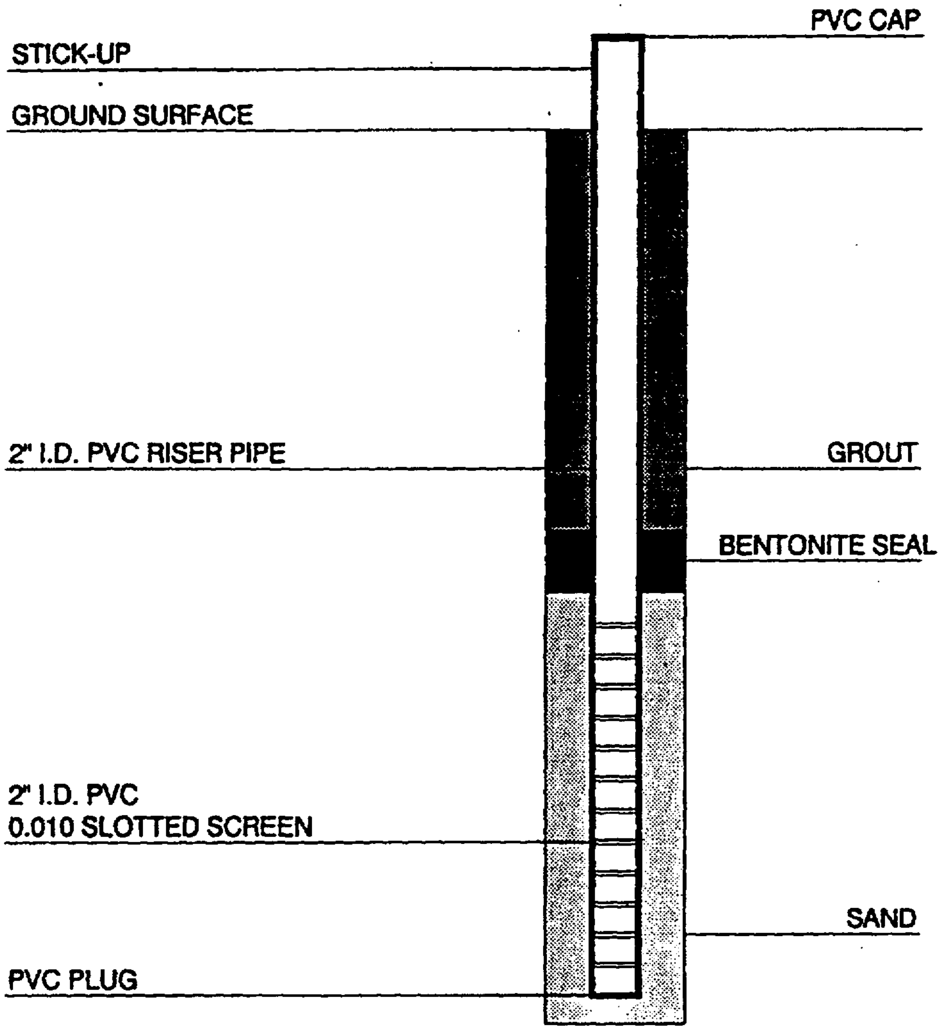
DWG. NO. F-6

Form No 103

NI02A039

MONITOR WELL DIAGRAM

WELL F-8



GROUT	50.1 ft.	CASING TOP EL	317.92
BENTONITE	2.0 ft.	RISER PIPE	56.4 ft.
SAND	7.0 ft.	SCREEN	5.0 ft.
TOTAL DEPTH	59.1 ft.	STICK-UP	2.3 ft.

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"OVER ONE HUNDRED YEARS OF SERVICE"

DATE: August, 1994
SCALE: NONE
DRWN: TMM V60-073

MONITOR WELL DIAGRAM
PHASE 2 - ISFSI - NORTH ANNA POWER STATION
MINERAL, VIRGINIA VIRGINIA POWER

DWG. NO. F-8

Form No 103

Appendix 2B
Laboratory Tests

Appendix 2B
Laboratory Tests

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PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

LABORATORY TEST RESULTS

Boring	F-5A	F-5	F-6	F-6	F-6	F-7A	F-7A
Sample No.	UD-1	S-7	S-2	S-5	S-9	UD-1	UD-2
Depth (ft.)	18.0-20.0	19.0.20.5	1.5-3.0	9.0-10.5	29.0-30.5	4.0-6.0	16.0-18.0
Gradation % Passing Sieve							
No. 4	---	---	---	100	100	---	100
No. 10	100	100	100	97.9	99.9	100	99.8
No. 40	92.5	96.1	96.6	84.4	77.8	96.8	83.1
No. 100	67.7	79.5	90.3	61.7	35.9	77.9	50.8
No. 200	53.9	70.2	87.9	54.3	24.8	72.0	38.0
Liquid Limit (%)	---	65	85	62	---	84	---
Plasticity Index	---	19	31	19	---	30	---
Natural Moisture (%)	53.3	55.7	37.4	29.0	29.3	34.1	31.8
ASTM Classification	---	MH	MH	MH	---	MH	---

NI02B001

PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

LABORATORY TEST RESULTS

Boring	F-7	F-7	F-8	F-8	F-9A	F-9	F-10
Sample No.	S-7	S-18	S-4	S-7	UD-1	S-13	S-3
Depth (ft.)	19.0-20.5	74.0-74.8	9.0-10.5	19.0.20.5	4.0-6.0	49.0-50.5	3.0-4.5
Gradation % Passing Sieve							
3/8 inch	---	---	---	---	---	---	---
No. 4	100	100	100	100	100	100	100
No. 10	98.6	97.6	99.9	99.9	99.8	97.7	99.7
No. 40	80.7	70.7	93.1	84.9	84.3	78.8	69.0
No. 100	60.8	47.2	81.3	64.4	52.3	39.3	44.5
No. 200	53.1	34.2	76.3	51.2	44.9	26.2	36.8
Liquid Limit (%)	60	40	58	---	64	---	46
Plasticity Index	16	6	26	---	18	---	15
Natural Moisture (%)	30.3	25.4	34.7	27.0	27.1	22.7	13.6
ASTM Classification	MH	SM	MH	---	SM	---	SM

NI02B002

PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

LABORATORY TEST RESULTS

Boring	F-10	F-10	P-2	P-3	P-4
Sample No.	S-5	S-10	BAG	BAG	BAG
Depth (ft.)	9.0-10.5	34.0-35.5	0.0-5.0	0.0-5.0	0.0-5.0
Gradation % Passing Sieve					
3/8 inch	---	100	100	---	---
No. 4	100	99.2	98.7	100	100
No. 10	99.4	90.9	94.8	99.4	99.1
No. 40	65.4	55.4	81.1	83.5	90.9
No. 100	41.5	33.9	57.8	67.7	64.9
No. 200	31.6	24.8	49.5	62.1	55.7
Liquid Limit (%)	41	---	41	60	48
Plasticity Index	12	---	20	30	19
Natural Moisture (%)	14.9	22.1	8.5	15.0	8.5
ASTM Classification	SM	---	SC	CH	ML

NI02B003

PHASE 2 - ISFSI
NORTH ANNA POWER STATION - MINERAL, VIRGINIA
VIRGINIA POWER
F&R #V60-073

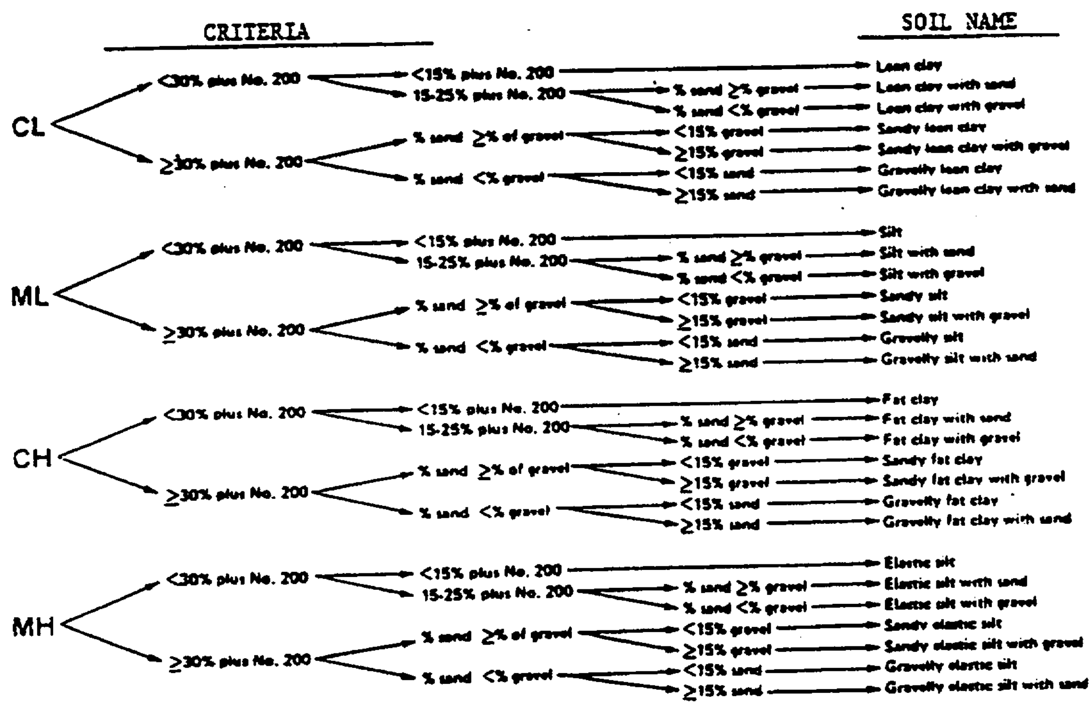
CBR TEST RESULTS

Boring	P-2	P-3	F-7A
Sample No.	Bulk	Bulk	Composite
Depth (ft.)	0.0-5.0	0.0-5.0	16.0-22.0
ASTM Classification	SC	CH	SM
Moisture-Density Relationship Test			
Maximum Dry Density (pcf)	117.5	111.2	109.0*
Optimum Moisture (%)	12.4	16.6	35.0*
CBR (Unsoaked)	39.2	38.9	6.4
CBR (Soaked)	7.6	7.3	NA

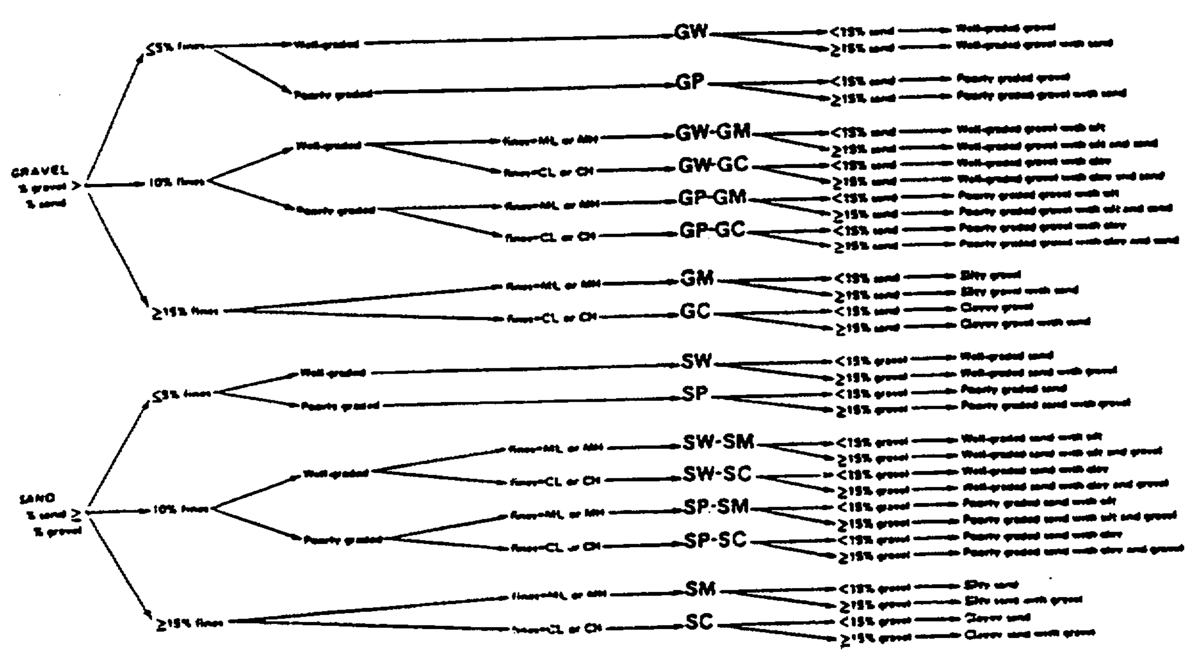
*Sample was molded at natural moisture content and unit weight.

NI02B004

ASTM SOIL CLASSIFICATION



Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

NI02B005

PARTICLE SIZE ANALYSIS TEST

Objective: The grain size data are used to aid in the classification of soils and in the estimation of soil behavior.

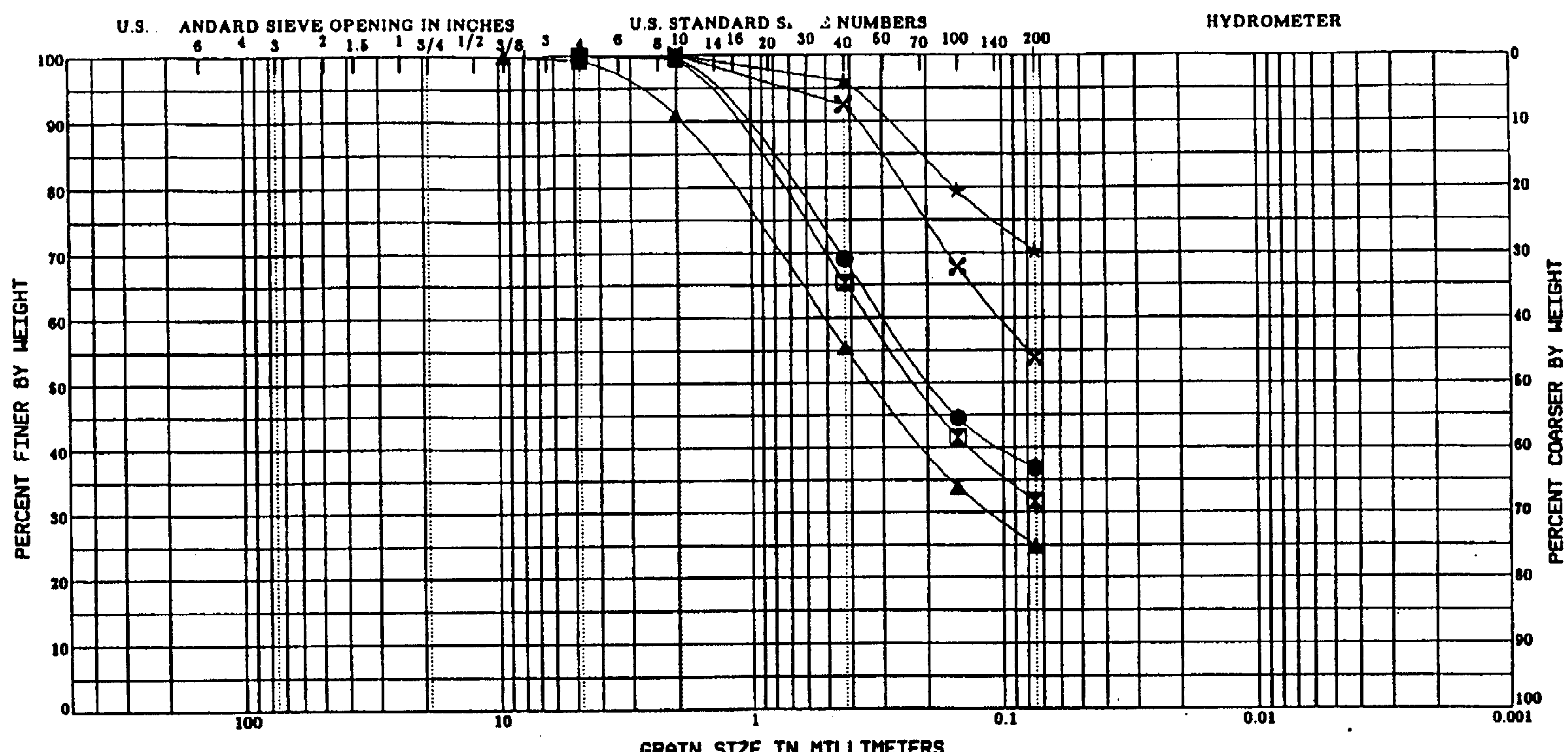
Procedure: The test can be divided into two parts, the determination of the size and distribution of the coarse fraction and the determination of the size and distribution of the fine fraction. The division between the coarse and fine fraction is the No. 200 sieve. The coarse fraction is tested using the sieve method; the fine fraction is tested using the hydrometer method. If both tests are performed, the test is referred to as the combined analysis.

For the analysis of the coarse fraction, the dried soil is soaked and then washed through a #200 sieve. The sand and gravel remaining on the sieve is oven dried. The dried sand and gravel is then passed through a series of sieves, and the weight retained on each sieve is determined. The distribution of weights is then computed and the percent passing each sieve is plotted as a curve.

In the hydrometer method, the particle size is determined by Stoke's equation. The soil is mixed with water to form a heavy slurry. The rate of sedimentation is measured using a hydrometer. Hydrometer data can be reduced to develop the weight percent distribution curve for the fine grained soil fraction.

References: ASTM Specification D-422, "Particle Size Analysis of Soils".

Laboratory Soils Testing, EM 1110-2-1906 by The Department of the Army, Appendix V.



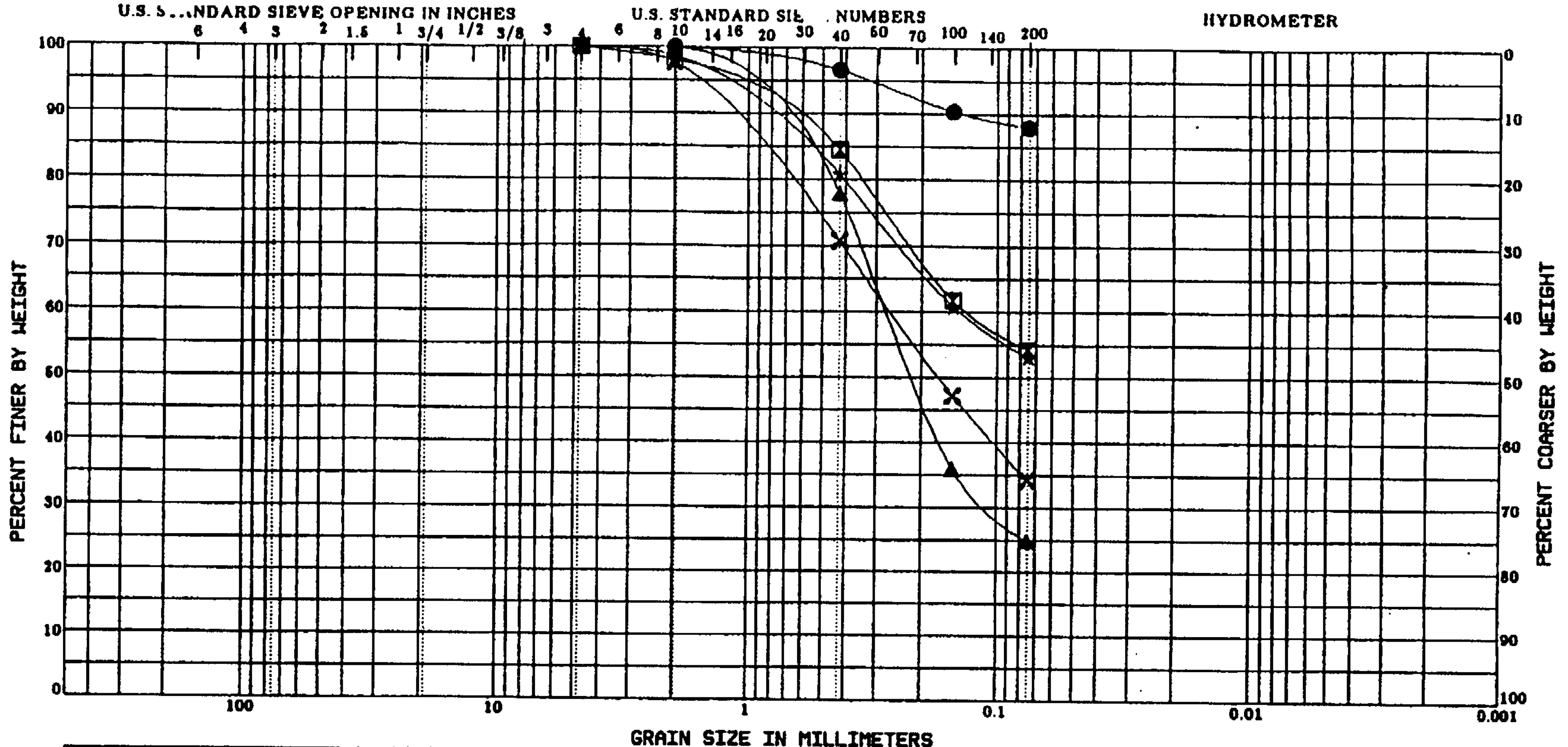
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-10 at 3.0 ft.	Silty Sand (SM)	13.6	46	31	15		
⊠	F-10 at 9.0 ft.	Silty Sand (SM)	14.9	41	29	12		
▲	F-10 at 34.0 ft.	()	22.1					
★	F-5 at 19.0 ft.	Sandy Elastic Silt (MH)	55.7	65	46	19		
✕	F-5A at 18.0 ft.	()	46.0					

	Specimen Identification	D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-10 at 3.0 ft.	4.75	0.29			0.0	63.2	36.8	
⊠	F-10 at 9.0 ft.	4.75	0.34			0.0	68.4	31.6	
▲	F-10 at 34.0 ft.	9.50	0.52	0.112		0.8	74.4	24.8	
★	F-5 at 19.0 ft.	2.00				0.0	29.8	70.2	
✕	F-5A at 18.0 ft.	2.00	0.10			0.0	46.1	53.9	

F&R Richmond Virginia	Project: Phase 2 - ISFSI North Anna Power Station	Location: Mineral, Virginia
	Client: Virginia Power	F+R No: V60-073
	Date: September 1994	GRADATION CURVES

NI02B007



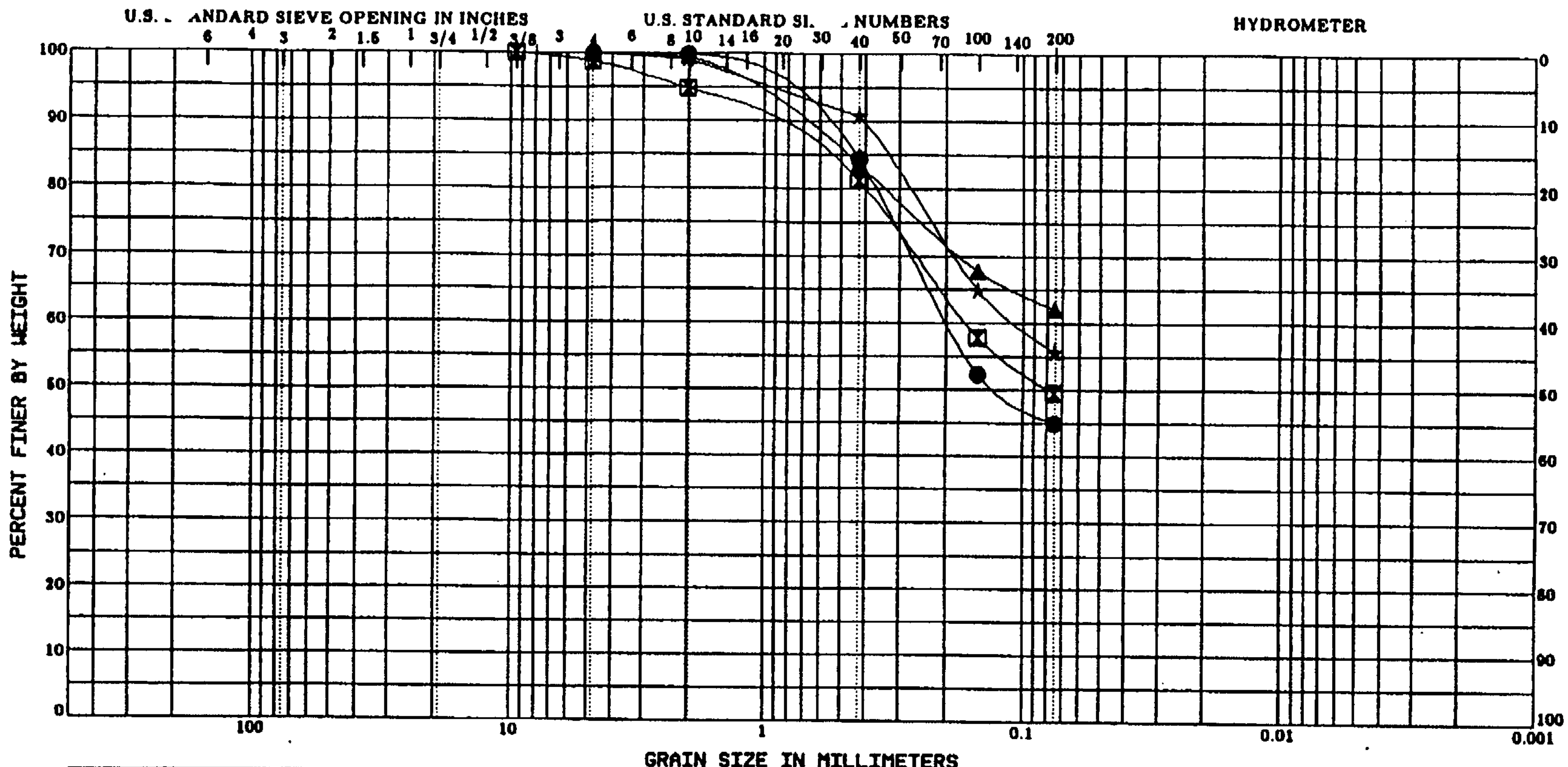
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification	Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-6 at 1.5 ft.	Elastic Silt (MH)	37.4	85	54	31		
⊠	F-6 at 9.0 ft.	Sandy Elastic Silt (MH)	29.0	62	43	19		
▲	F-6 at 29.0 ft.	()	29.3					
✱	F-7 at 19.0 ft.	Sandy Elastic Silt (MH)	30.3	60	44	16		
×	F-7 at 74.0 ft.	Silty Sand (SM)	25.4	40	34	6		

	Specimen Identification	D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-6 at 1.5 ft.	2.00				0.0	12.1	87.9	
⊠	F-6 at 9.0 ft.	4.75	0.13			0.0	45.7	54.3	
▲	F-6 at 29.0 ft.	4.75	0.27	0.104		0.0	75.2	24.8	
✱	F-7 at 19.0 ft.	4.75	0.14			0.0	46.9	53.1	
×	F-7 at 74.0 ft.	4.75	0.26			0.0	65.8	34.2	

F&R Richmond Virginia	Project: Phase 2 - ISFSI North Anna Power Station	Location: Mineral, Virginia
	Client: Virginia Power	F+R No: V60-073
	Date: September 1994	GRADATION CURVES

NI02B008



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification				Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-9A	at	4.0	ft.	Silty Sand (SM)	27.1	64	46	18		
⊠	P-2	at	0.0	ft.	Clayey Sand (SC)	8.5	41	21	20		
▲	P-3	at	0.0	ft.	Sandy Fat Clay (CH)	15.0	60	30	30		
★	P-4	at	0.0	ft.	Sandy Silt (ML)	8.5	48	29	19		
		at		ft.							

	Specimen Identification				D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-9A	at	4.0	ft.	4.75	0.19			0.0	55.1	44.9	
⊠	P-2	at	0.0	ft.	9.50	0.17			1.3	49.2	49.5	
▲	P-3	at	0.0	ft.	4.75				0.0	37.9	62.1	
★	P-4	at	0.0	ft.	4.75	0.10			0.0	44.3	55.7	
		at		ft.								

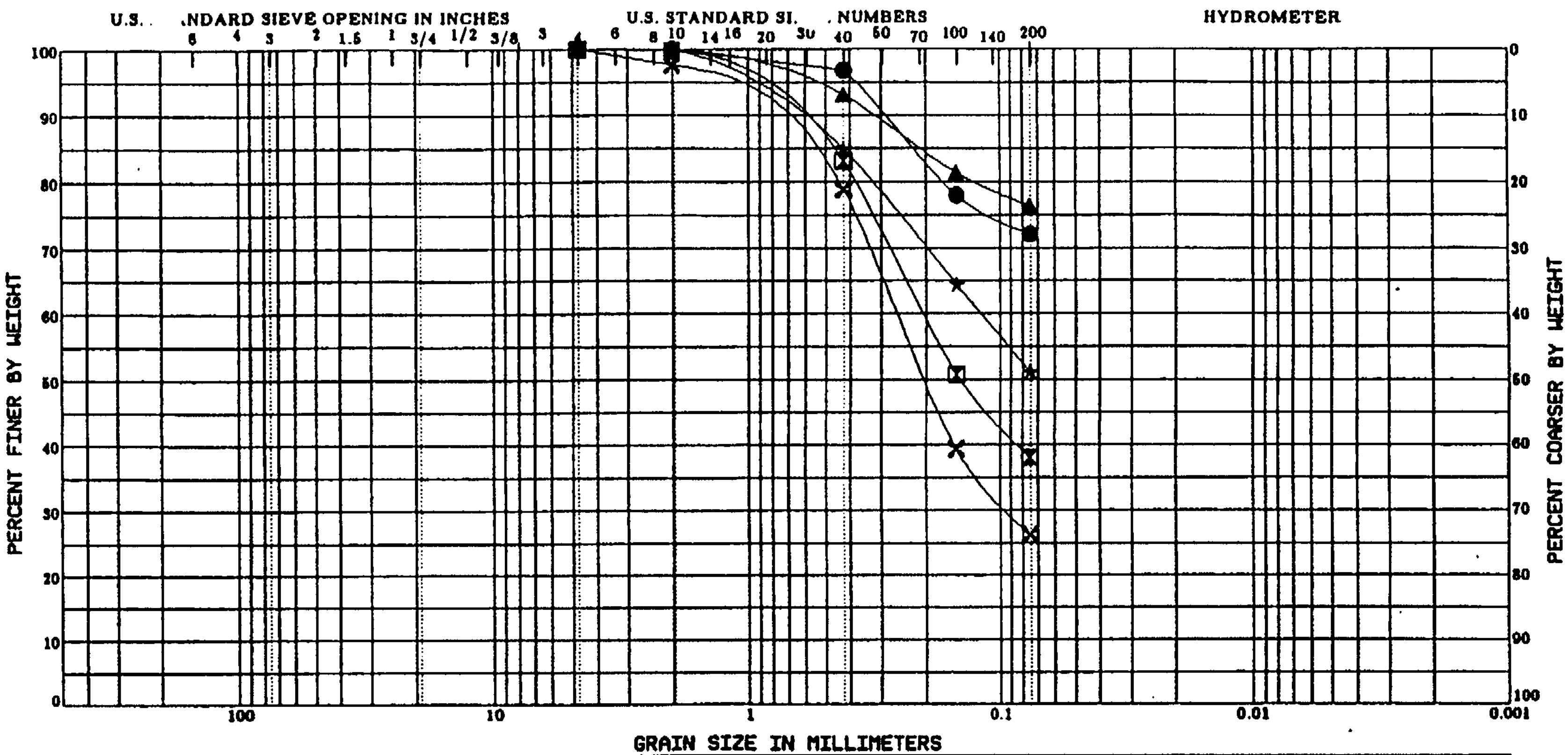
F&R Richmond Virginia

Project: Phase 2 - ISFSI North Anna Power Station
Client: Virginia Power
Date: September 1994

Location: Mineral, Virginia
F+R No: V60-073

GRADATION CURVES

NI02B009



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification				Classification (ASTM)	WC%	LL	PL	PI	Cc	Cu
●	F-7A	at	4.0	ft.	Elastic Silt with Sand (MH)	34.1	84	54	30		
⊠	F-7A	at	16.0	ft.	()	31.8					
▲	F-8	at	9.0	ft.	Elastic Silt with Sand (MH)	34.7	58	32	26		
★	F-8	at	19.0	ft.	()	27.0					
✕	F-9	at	49.0	ft.	()	22.7					

	Specimen Identification				D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Silt	%Clay
●	F-7A	at	4.0	ft.	2.00				0.0	28.0	72.0	
⊠	F-7A	at	16.0	ft.	4.75	0.20			0.0	62.0	38.0	
▲	F-8	at	9.0	ft.	4.75				0.0	23.7	76.3	
★	F-8	at	19.0	ft.	4.75	0.12			0.0	48.8	51.2	
✕	F-9	at	49.0	ft.	4.75	0.26	0.092		0.0	73.8	26.2	

F&R Richmond Virginia

Project: Phase 2 - ISFSI North Anna Power Station	Location: Mineral, Virginia
Client: Virginia Power	F+R No: V60-073
Date: September 1994	**GRADATION CURVES**

NI02B010

ATTERBERG LIMITS

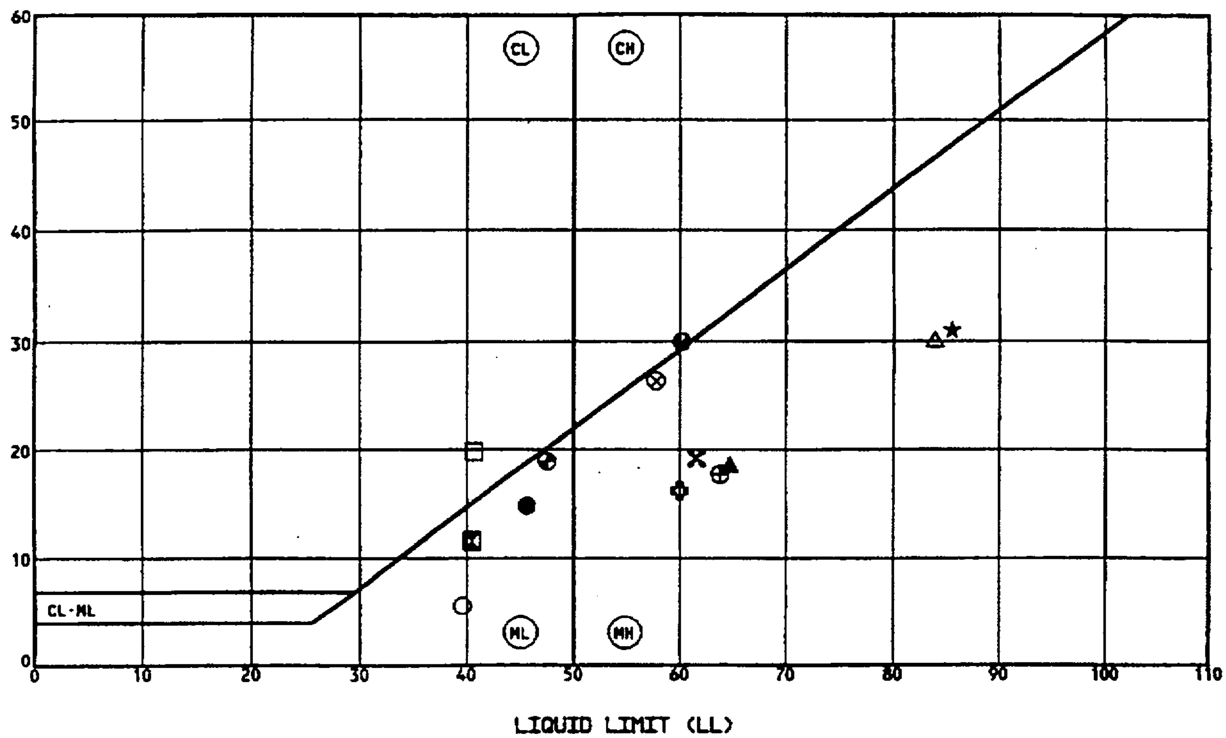
Purpose: Dr. Atterberg (1911) defined the liquid limit of a soil as the water content, expressed as a percentage of the dry weight of the soil, at the boundary between the liquid and plastic states. The plastic limit is the water content expressed as a percentage of the dry weight of the soil, at the boundary between the plastic and semisolid states. The difference between these two values is the Plasticity Index (PI).

Liquid and Plastic limits are performed to determine the soil classification and plasticity properties of the soil specimen. Atterberg limits can be correlated with approximate values for compressibility and strength.

Procedure: The liquid limit is the water content when a soil will flow under a specific dynamic force. The soil is wetted, placed in a special liquid limit device, and grooved into two halves. The water content is measured when the two halves flow together over a specified distance.

The plastic limit is determined, as described by ASTM Specification D-4318, by obtaining the water content when a soil can be rolled by hand into thin threads on a surface of ground glass. The plastic limit is defined as the moisture content at which the soil can not be rolled into threads smaller than 1/8 inch in diameter.

References: ASTM Specification D-4318 "Standard Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils."



	BORING	DEPTH	LL	PL	PI	FINES	CLASSIFICATION
●	F-10	3.0	46	31	15	37	SM
⊠	F-10	9.0	41	29	12	32	SM
▲	F-5	19.0	65	46	19	70	MH
★	F-6	1.5	85	54	31	88	MH
✕	F-6	9.0	62	43	19	54	MH
✤	F-7	19.0	60	44	16	53	MH
○	F-7	74.0	40	34	6	34	SM
△	F-7A	4.0	84	54	30	72	MH
⊗	F-8	9.0	58	32	26	76	MH
⊕	F-9A	4.0	64	46	18	45	SM
□	P-2	0.0	41	21	20	50	SC
⊖	P-3	0.0	60	30	30	62	CH
◕	P-4	0.0	48	29	19	56	ML

F+R No. V60-073 September 1994

Phase 2 - ISFSI North Anna Power Station

Mineral, Virginia

ATTERBERG LIMITS' RESULTS

Froehling & Robertson, Inc. Richmond, Virginia FIGURE 1

NI02B012

MOISTURE CONTENT TEST

Objective: To determine the ratio between the moisture contained in the soil and the weight of the solid soil grains, expressed as a percentage. The in-situ moisture content with other index properties are used to evaluate anticipated soil behavior. For controlled fill placement, the moisture content is critical in achieving maximum compaction.

Procedure: A moist sample is weighed and then oven dried. The dry sample is then weighed. The moist sample weight minus the dry sample weight is used to determine the weight of water removed. The weight of the sample remaining after oven-drying is used as the weight of the solid soil grains. The moisture content, in percent, is the ratio of the weight of moisture to the weight of dry soil multiplied by 100.

References: ASTM Specification D-2216, "Standard Method of Laboratory Determination of Moisture Content of Soil."

Laboratory Soils Testing, EM 1110-2-1906 by The Department of the Army, Appendix, I.

UNIT WEIGHT TEST.

Objective: The unit weight test is performed to determine the density of moist soil, expressed in terms of weight per volume. The dry unit weight is calculated from the moist unit weight and the natural moisture content. The unit weight is used in soils engineering calculations.

Procedure: The volumetric method consists of computing the total volume of a regular-shaped sample. The weight and volume of the sample is measured. The moist unit weight equals the weight of sample divided by the volume of the sample. To determine the dry unit weight, the moisture content of the sample needs to be determined. The moist unit weight divided by the moisture content plus one equals the dry unit weight.

The displacement method consists of determining the total volume of a soil by measuring the volume or weight of water displaced by the soil mass. The sample is placed in a wire cage and submerged in water. The volume of the displaced water is measured. The weight of the sample is determined. The moist unit weight is estimated by dividing the sample weight by the volume of water displaced.

Reference: Laboratory Soils Testing, EM 1110-2-1906, by The Department of the Army, Appendix II.

MOISTURE-DENSITY (MODIFIED)

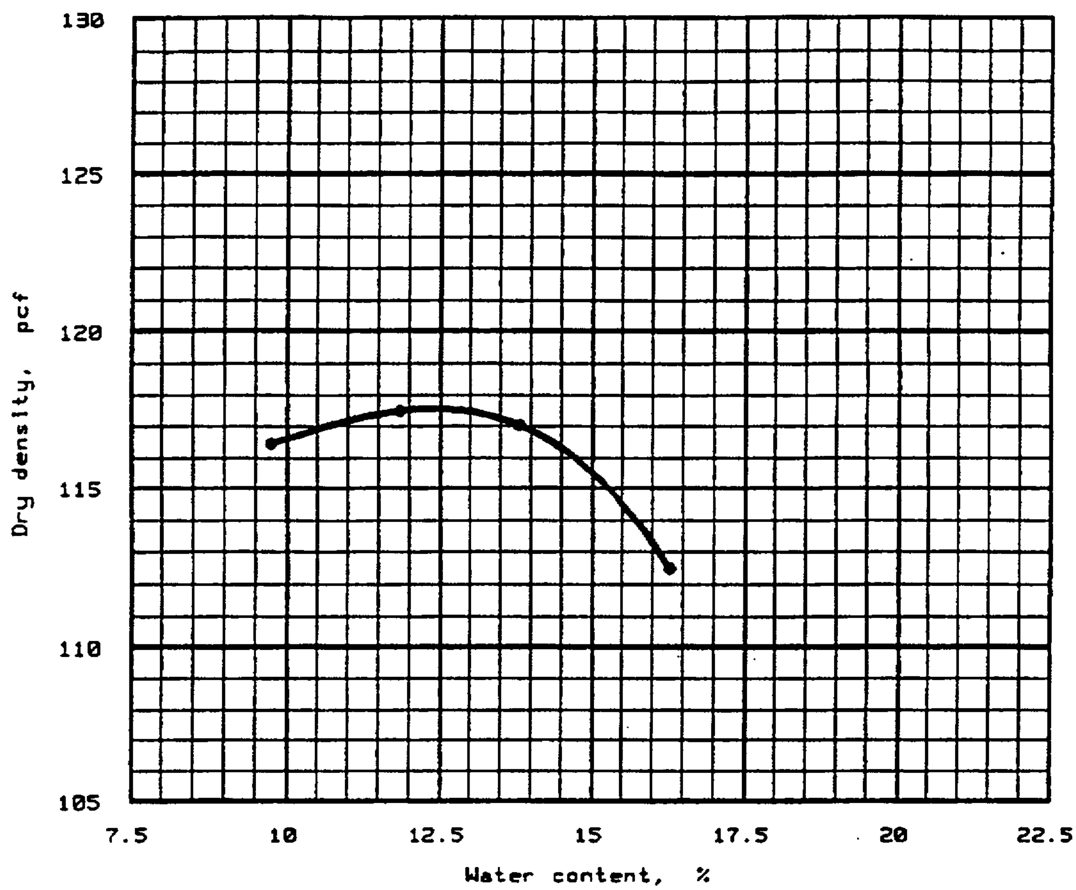
Purpose: The moisture-density relationship of a given soil is determined to provide an index unit weight that can be compared to the field compacted unit weight. The maximum dry unit weight determined using this test method is termed 100 percent of Modified Proctor.

Procedure: The Modified Proctor Test is performed on a bulk soil sample. Gravel (plus No. 4 or plus 3/4 inch, depending on the test method) is removed from the bulk sample. The prepared bulk sample is split to form four to five test specimens. The moisture content of each prepared specimen is adjusted in the laboratory to vary by 1-1/2 to 2 percent from the other prepared specimens.

The prepared soil specimens are compacted in a cylindrical mold in five equal layers to give a total compacted depth of about 5 inches. Each layer is compacted by uniformly distributed blows using a 10 pound, sliding weight hammer and a 18-inch drop. The number of blows used for compaction (25 or 56) depends on the test method. The dry density and compaction moisture content is determined for each compacted test specimen and plotted to provide the moisture-density curve. The maximum dry density and the optimum compaction moisture content for the sample with the gravel removed is determined from the moisture-density curve. The maximum dry density for the bulk sample with gravel is determined using the gravel correction factor as outlined in ASTM Procedures D-4718.

Reference: ASTM Specification D-1557, "Standard Methods of Test for Moisture-Density Relations of Soils using 10.0 lb. (4.5 Kg) Rammer and 18-inch (457 mm) Drop".

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 1557-91 Method A, Modified

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
0-5'								

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 117.5 pcf Optimum moisture = 12.4 %	Tan sandy silt P-2

Project No.: V60-073

Project: Soil Borings & Lab Testing

Location: Mineral, Virginia

Control No. 36791

Date: 7-25-1994

Remarks:

Virginia Power

5000 Dominion Boulevard

Glen Allen, VA 23060

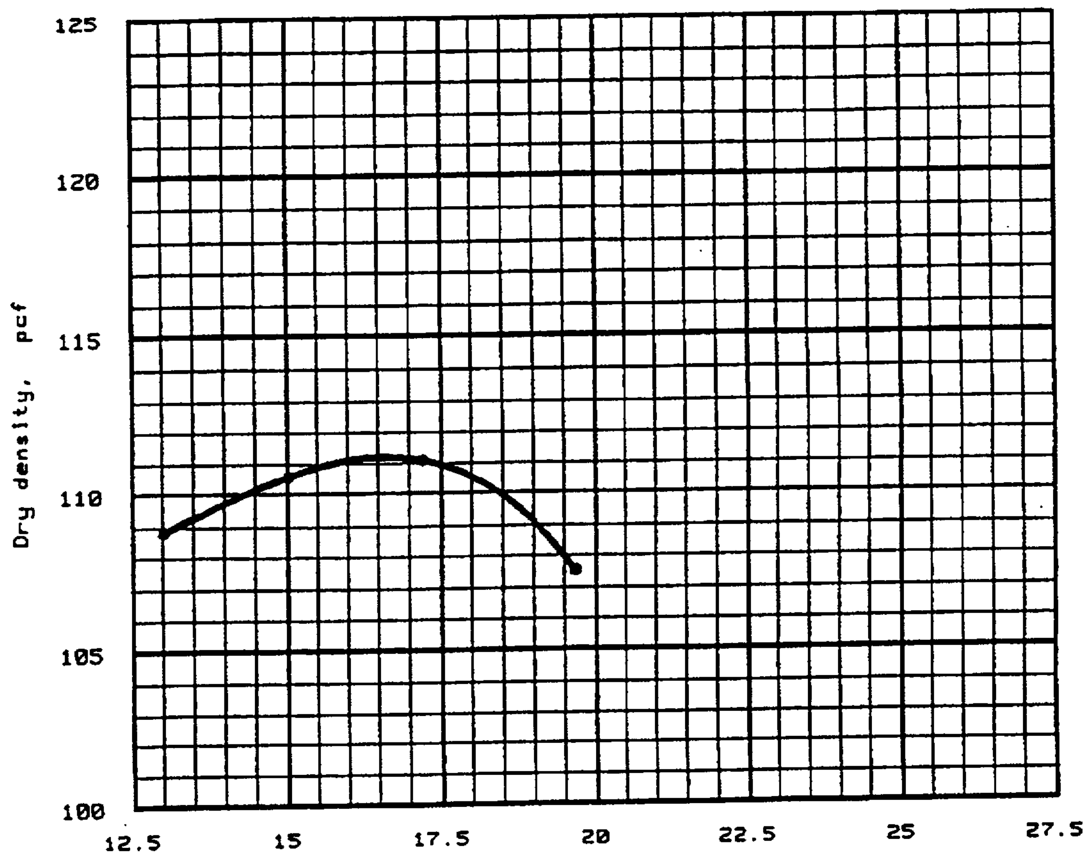
MOISTURE-DENSITY RELATIONSHIP TEST

FROEHLING & ROBERTSON, INC.

Fig. No. ______

NI02B016

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 1557-91 Method A, Modified

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
0-5'								

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 111.2 pcf Optimum moisture = 16.6 %	Red sandy clay P-3

Project No.: V60-073
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia
Control No. 36781
Date: 7-25-1994

Remarks:
Virginia Power
5000 Dominion Boulevard
Glen Allen, VA 23060

MOISTURE-DENSITY RELATIONSHIP TEST
FROEHLING & ROBERTSON, INC.

Fig. No. ______

NI02B017

CALIFORNIA BEARING RATIO

Purpose: The California Bearing Ratio test is performed on subgrade, subbase and base course materials to provide supporting values of various roadway materials which can be used as a basis for pavement design.

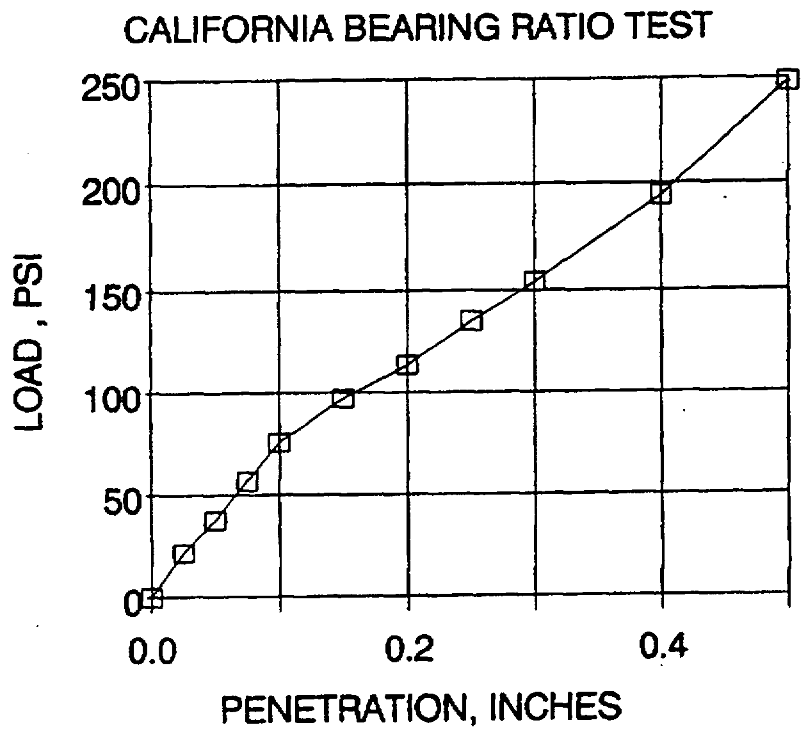
Procedure: A sample of the subgrade soil is compacted in a cylindrical mold to the density and moisture anticipated in actual construction. Cohesive soils are allowed to soak, immersed in water for 96 hours. By means of a hydraulic jack, a penetration "needle" is forced into sample at a controlled rate. Load values and corresponding strain or deformation are noted. The ratios of the load values in pounds per square inch at 0.1 inch and 0.2 inch penetration, respectively, are compared to the standard loads of 1000 and 1500 pounds per square inch respectively. (The latter are those loads required to produce the same penetration in a compacted limestone sample.) The CBR in percent is the ratio of the loads at 0.1 penetration multiplied by 100.

Reference: ASTM Specification D-1883-67, "Standard Method of Test for Bearing Ratio of Laboratory-Compacted Soils."

CALIFORNIA BEARING RATIO TEST

Record No.:	V60-073
Client:	Virginia Power
Project:	Soil Borings & Lab Testing
Location:	Mineral, Virginia

Date:	August 3, 1994
Date Tested:	August 2, 1994



CBR (Soaked):	7.6
Swell (%):	0.08
Dry Density Before Soaking:	115.3
% Moisture Before Soaking:	13.3
% Moisture (top 1 in.):	19.1

Sample: P-2 (0-5')
Control No. 36791
Molded in accordance with D-1557

FROEHLING & ROBERTSON, INC.

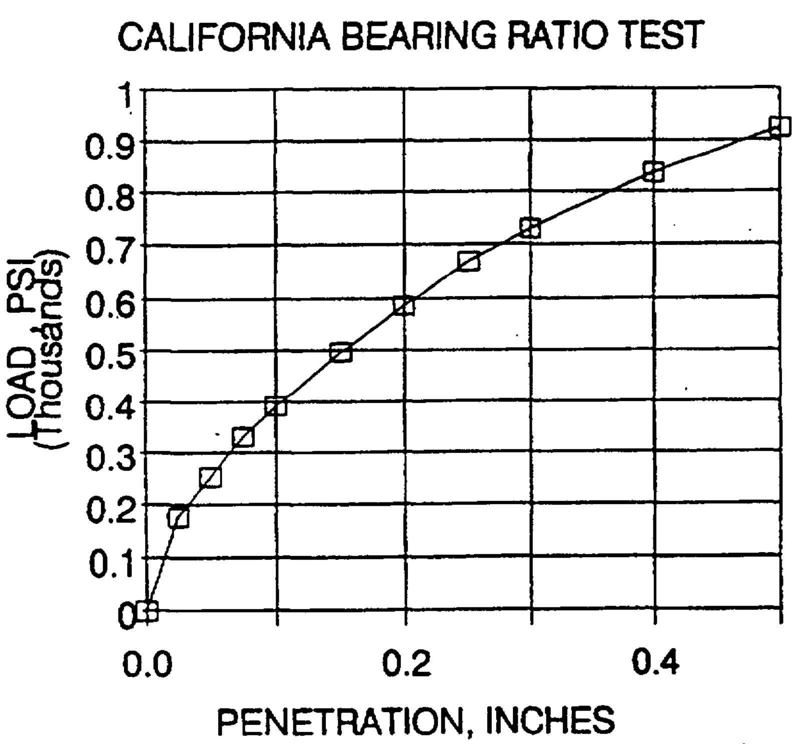
By: Clyde Mallory
Manager - Soil's Department

Reviewed by: [signature]

NI02B019

CALIFORNIA BEARING RATIO TEST

Record No.:	V60-073	**Date:**	August 16, 1994
Client:	Virginia Power	**Date Tested:**	August 15, 1994
Project:	Soil Borings & Lab Testing		
Location:	Mineral, Virginia		



CBR (DRY)	39.2
Dry Density Before Soaking:	115.5
% Moisture Before Soaking:	13.3

Sample: P-2 (0-5')
Control No. 50055
Molded in accordance with D-1557(dry break)

FROEHLING & ROBERTSON, INC.

Reviewed by:

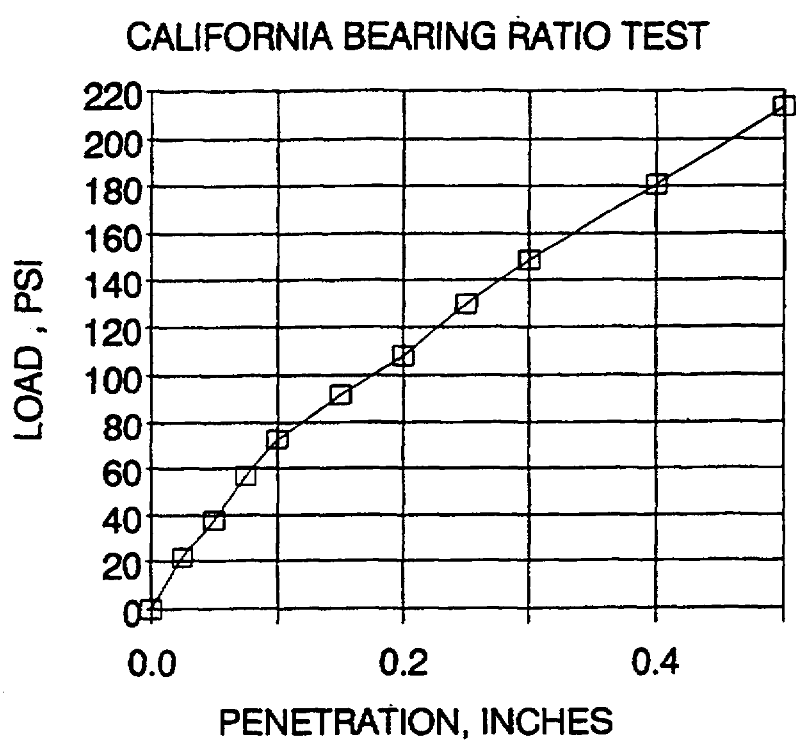
By: Clyde Mallory
Manager - Soil's Department

NI02B020

CALIFORNIA BEARING RATIO TEST

Record No.: V60-073
Client: Virginia Power
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia

Date: August 3, 1994
Date Tested: August 2, 1994



CBR (Soaked):	7.3
Swell (%):	1.62
Dry Density Before Soaking:	108.7
% Moisture Before Soaking:	17.5
% Moisture (top 1 In.):	24.2

Sample: P-3 (0-5')
Control No. 36781
Molded in accordance with D-1557

FROEHLING & ROBERTSON, INC.

Reviewed by: [signature]

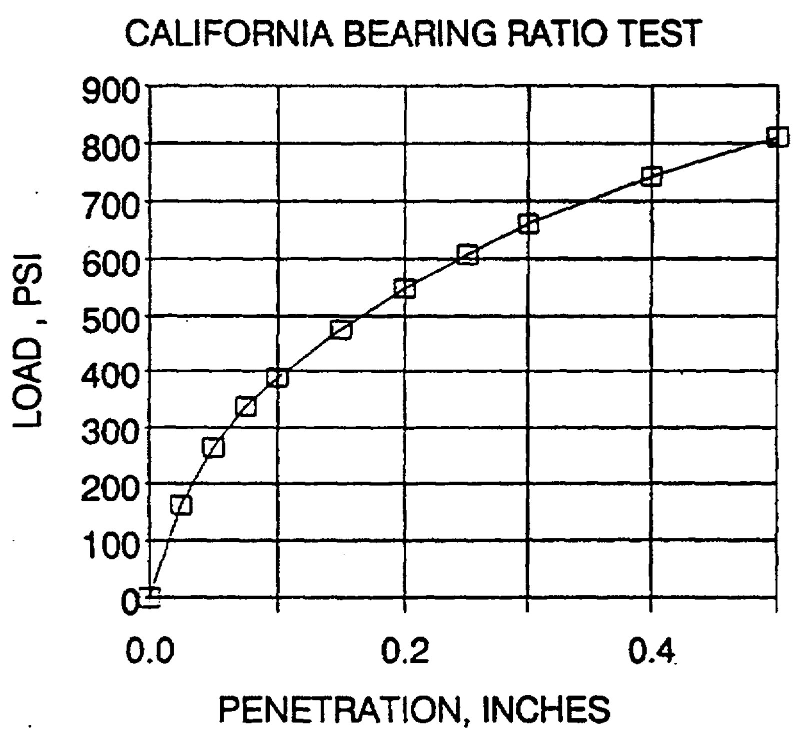
By: Clyde Mallory
Manager - Soil's Department

NI02B021

CALIFORNIA BEARING RATIO TEST

Record No.: V60-073
Client: Virginia Power
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia

Date: August 16, 1994
Date Tested: August 15, 1994



CBR (DRY) 38.9
Dry Density Before Soaking: 108.4
% Moisture Before Soaking: 17.1

Sample: P-3 (0-5')
Control No. 50054
Molded in accordance with D-1557(dry break)

FROEHLING & ROBERTSON, INC.

Reviewed by: [signature]

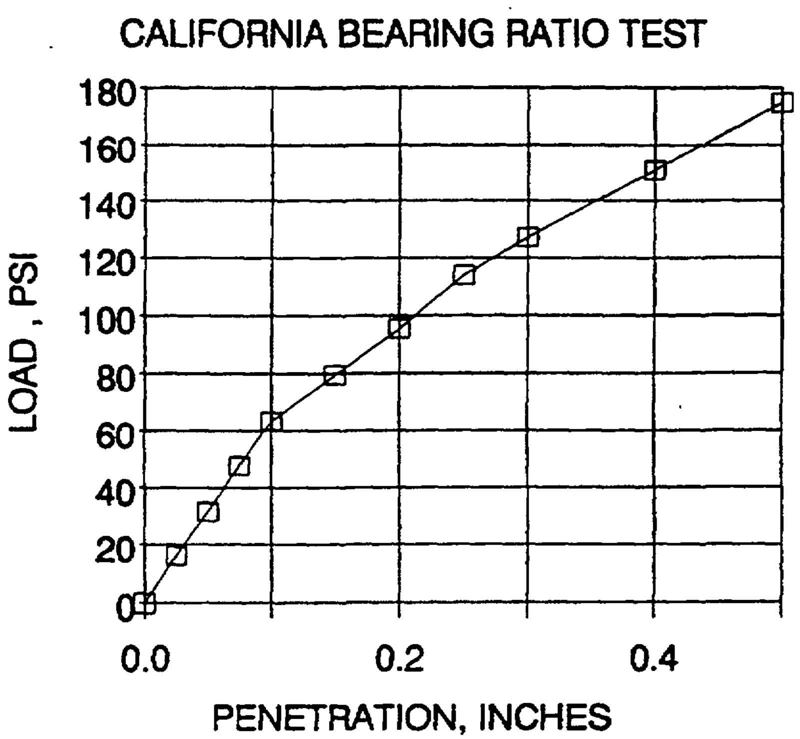
By: Clyde Mallory
Manager - Soil's Department

NI02B022

CALIFORNIA BEARING RATIO TEST

Record No.: V60-073
Client: Virginia Power
Project: Soil Borings & Lab Testing
Location: Mineral, Virginia

Date: September 15, 1994
Date Tested: September 15, 1994



CBR (DRY)	6.4
Dry Density	79.5
% Moisture	37.1

Sample: *
Control No. 49752

FROEHLING & ROBERTSON, INC.

Reviewed by: [signature]

By: Clyde Mallory
Manager - Soil's Department

* Composite Sample: F-7A UD-2 16.0'-18.0'
UD-3 18.0'-20.0'
UD-4 20.0'-22.0'

NI02B023

CONSOLIDATION TEST

Objective: Consolidation tests are performed on undisturbed soil samples in order to estimate the settlement resulting from imposed loads. The time required for consolidation and the amount of consolidation settlement can be predicted from this test data.

Procedure: An undisturbed sample is trimmed to fit a consolidometer ring. The trimmed sample has a diameter of 2.5 inches and a height of 1.0 inch. The soil sample is sandwiched between porous stones. A seating pressure is applied and the micrometer dial gauge is adjusted to zero. Load increments are placed on the soil sample at regular intervals (e.g. every 24 hours.) Load increments are determined from anticipated field loading conditions and project requirements. The test results are presented in the form of a void ratio, or an axial strain versus applied pressure curve on a semilogrithmitic graph.

References: ASTM Specification D-2435, "One-Dimensional Consolidation Properties of Soils".

Engineering Properties of Soils & Their Measurements by Joseph E. Bowles, McGraw-Hill, Inc., "Consolidation Test".

Laboratory Soils Testing, EM-1110-2-1906 by The Department of the Army, Appendix VIII.

Froehling & Robertson, Inc.

CONSOLIDATION TEST

ASTM 2435

CLIENT: Virgina Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

DATE: August 24, 1994

BORING NO: F-7A SAMPLE NO: UD-1 DEPTH (ft.): 4.0-6.0

DESCRIPTION OF SAMPLE: Reddish Brown Clayey Silt

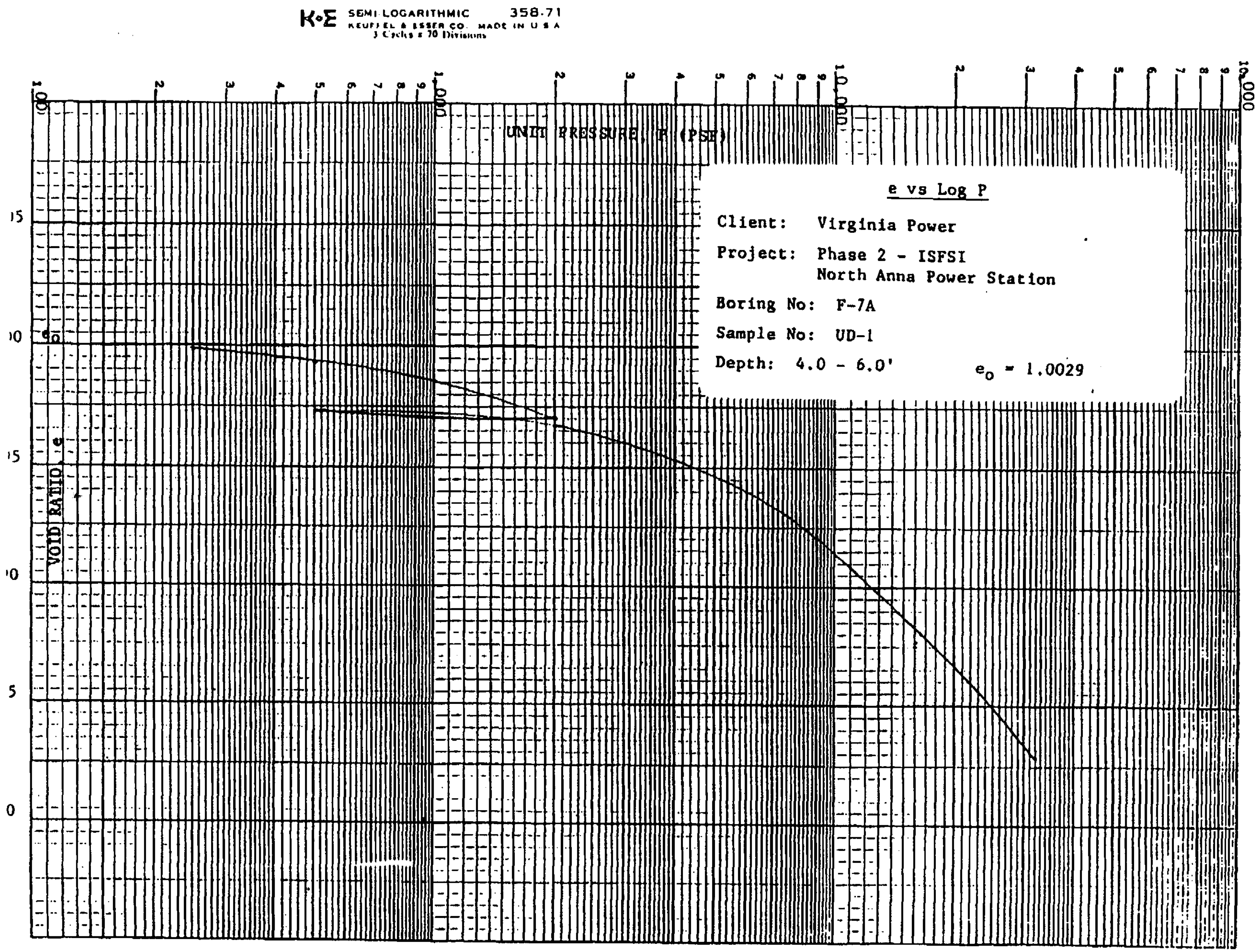
SAMPLE HT: 1.0 in. Specific Gravity: 2.64

RING AREA: 4.909 in^2

Initial Conditions		Final Conditions	
Wt. Cup + Soil Wet	31.20 g	Wt. Ring + Soil Wet	614.70 g
Wt. Cup + Soil Dry	23.40 g	Wt. Ring + Soil Dry	576.30 g
Wt. Water	7.80 g	Wt. Water	38.40 g
Wt. Cup + Soil Dry	23.40 g	Wt. Ring + Soil Dry	576.30 g
Wt. of Cup	1.39 g	Wt. of Ring	473.00 g
Wt. Dry Soil	22.01 g	Wt. Dry Soil	103.30 g
Initial Moisture	35.44 %	Final Moisture	37.17 %

Wt. Ring + Soil Wet	616.60 g
Wt. Ring	473.00 g
Wt. Soil, Wet	143.60 g
Wt. Water	37.57 g
Wt. Dry Soil	0.2337 lbs
Ht. Solids	0.4993 in.
Void Ratio	1.0029
Wet Unit Wt.	111.44 pcf

LOAD INCR. (TSF)	UNIT PRESSURE P (PSF)	INITIAL DIAL READING D_0 (IN.)	FINAL DIAL READING D_{100} (IN.)	RD HS	VOID RATIO e	H (IN.)	T_{50} (MIN.)	CV (IN^2/MIN.)
0.125	250	0.0016	0.0020	0.0040	0.9988	0.9982	0.20	1.0431
0.250	500	0.0033	0.0041	0.0082	0.9946	0.9963	0.49	0.4295
0.500	1000	0.0076	0.0086	0.0172	0.9856	0.9919	0.42	0.4937
1.000	2000	0.0148	0.0164	0.0328	0.9700	0.9844	0.42	0.4862
0.500	1000	0.0161	0.0157	0.0314	0.9714	0.9841	0.16	1.2832
0.250	500	0.0150	0.0146	0.0292	0.9736	0.9852	0.25	0.8231
0.500	1000	0.0148	0.0152	0.0304	0.9724	0.9850	0.25	0.8228
1.000	2000	0.0164	0.0171	0.0342	0.9686	0.9833	0.25	0.8198
2.000	4000	0.0233	0.0250	0.0501	0.9528	0.9759	0.42	0.4778
4.000	8000	0.0392	0.0413	0.0827	0.9201	0.9598	0.36	0.5424
8.000	16000	0.0601	0.0633	0.1266	0.8761	0.9383	0.42	0.4418
16.000	32000	0.0803	0.0864	0.1730	0.8298	0.9167	0.56	0.3167


K•E SEMI-LOGARITHMIC 358-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 Cycles x 70 Divisions
UNIT PRESSURE, P (PSF)
VOID RATIO, e
e_o
e vs Log P
Client: Virginia Power
Project: Phase 2 - ISFSI
North Anna Power Station
Boring No: F-7A
Sample No: UD-1
Depth: 4.0 - 6.0'
e_o = 1.0029

NI02B026

Froehling & Robertson, Inc.

CONSOLIDATION TEST

ASTM 2435

CLIENT: Virgina Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

DATE: August 24, 1994

BORING NO: F-7A SAMPLE NO: UD-2 DEPTH (ft.): 16.0-18.0

DESCRIPTION OF SAMPLE: Red and Brown Silty Fine Sand

SAMPLE HT: 1.0 in. Specific Gravity: 2.64

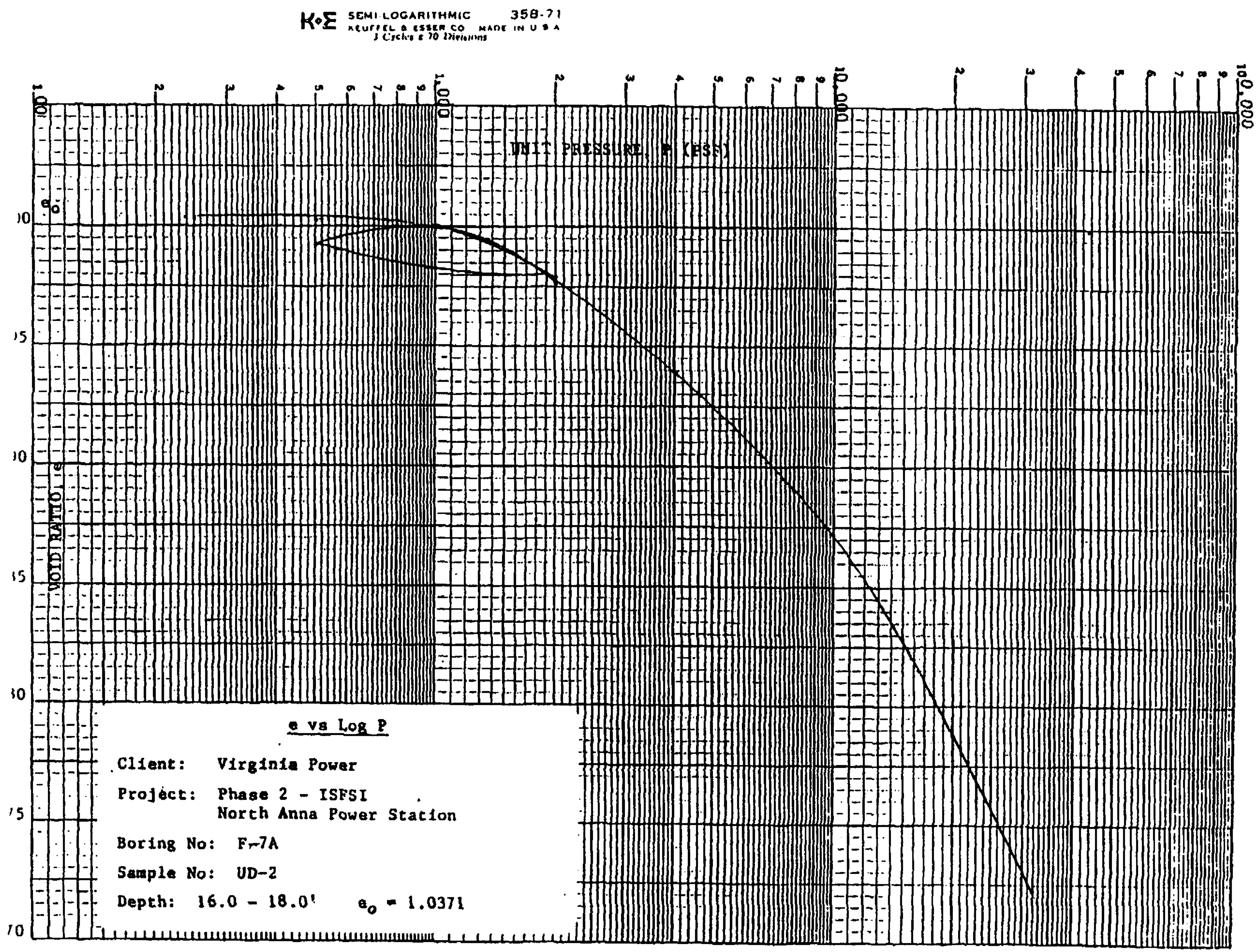
RING AREA: 4.909 in^2

Initial Conditions		Final Conditions	
Wt. Cup + Soil Wet	13.98 g	Wt. Ring + Soil Wet	795.50 g
Wt. Cup + Soil Dry	10.93 g	Wt. Ring + Soil Dry	761.80 g
Wt. Water	3.05 g	Wt. Water	33.70 g
Wt. Cup + Soil Dry	10.93 g	Wt. Ring + Soil Dry	761.80 g
Wt. of Cup	1.34 g	Wt. of Ring	657.80 g
Wt. Dry Soil	9.59 g	Wt. Dry Soil	104.00 g
Initial Moisture	31.80 %	Final Moisture	32.40 %

Wt. Ring + Soil Wet	795.20 g
Wt. Ring	657.80 g
Wt. Soil, Wet	137.40 g
Wt. Water	33.15 g
Wt. Dry Soil	0.2298 lbs
Ht. Solids	0.4909 in.
Void Ratio	1.0371
Wet Unit Wt.	106.63 pcf

LOAD INCR. (TSF)	UNIT PRESSURE P (PSF)	INITIAL DIAL READING D_0 (IN.)	FINAL DIAL READING D_{100} (IN.)	RD HS	VOID RATIO e	H (IN.)	T_{90} (MIN.)	CV (IN^2/MIN.)
0.125	250	0.0015	0.0022	0.0045	1.0326	0.9982	0.30	0.6982
0.250	500	0.0053	0.0063	0.0128	1.0242	0.9942	0.42	0.4960
0.500	1000	0.0126	0.0144	0.0293	1.0077	0.9865	0.36	0.5731
1.000	2000	0.0254	0.0288	0.0587	0.9784	0.9729	0.36	0.5574
0.500	1000	0.0273	0.0265	0.0540	0.9831	0.9731	0.42	0.4751
0.250	500	0.0237	0.0221	0.0450	0.9920	0.9771	0.49	0.4131
0.500	1000	0.0134	0.0141	0.0287	1.0083	0.9863	0.36	0.5728
1.000	2000	0.0285	0.0297	0.0605	0.9766	0.9709	0.42	0.4730
2.000	4000	0.0441	0.0477	0.0972	0.9399	0.9541	0.42	0.4568
4.000	8000	0.0674	0.0720	0.1467	0.8904	0.9303	0.36	0.5097
8.000	16000	0.1166	0.1226	0.2497	0.7873	0.8804	0.30	0.5432
16.000	32000	0.1466	0.1545	0.3147	0.7223	0.8495	0.56	0.2719

NI02B027


K+E SEMI-LOGARITHMIC 358-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 Cycles x 70 Divisions
UNIT PRESSURE, P (PSF)
VOID RATIO, e
e_o
1,000
10,000
100,000
e vs Log P
Client: Virginia Power
Project: Phase 2 - ISFSI
North Anna Power Station
Boring No: F-7A
Sample No: UD-2
Depth: 16.0 - 18.0' e_o = 1.0371

NI02B028

Froehling & Robertson, Inc.

CONSOLIDATION TEST

ASTM 2435.

CLIENT: Virgina Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

DATE: August 24, 1994

BORING NO: F-9A SAMPLE NO: UD-1 DEPTH (ft.): 4.0-6.0

DESCRIPTION OF SAMPLE: Red & Brown Silty Fine Sand

SAMPLE HT: 1.0 in. Specific Gravity: 2.64

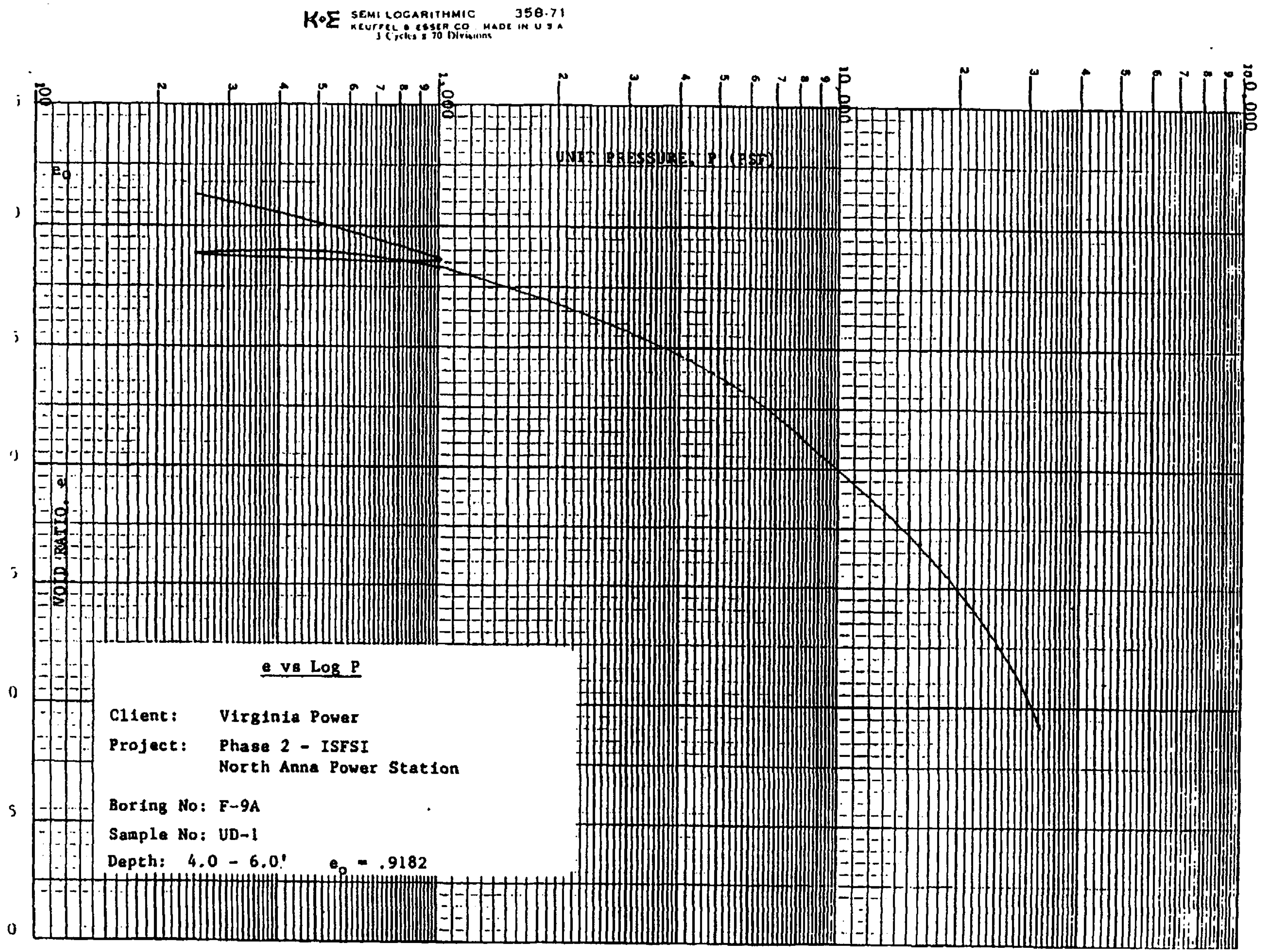
RING AREA: 4.909 in^2

Initial Conditions		Final Conditions	
Wt. Cup + Soil Wet	24.52 g	Wt. Ring + Soil Wet	615.80 g
Wt. Cup + Soil Dry	19.49 g	Wt. Ring + Soil Dry	579.20 g
Wt. Water	5.03 g	Wt. Water	36.60 g
Wt. Cup + Soil Dry	19.49 g	Wt. Ring + Soil Dry	579.20 g
Wt. of Cup	1.35 g	Wt. of Ring	471.60 g
Wt. Dry Soil	18.14 g	Wt. Dry Soil	107.60 g
Initial Moisture	27.73 %	Final Moisture	34.01 %

Wt. Ring + Soil Wet	613.00 g
Wt. Ring	471.60 g
Wt. Soil, Wet	141.40 g
Wt. Water	30.70 g
Wt. Dry Soil	0.2441 lbs
Ht. Solids	0.5213 in.
Void Ratio	0.9182
Wet Unit Wt.	109.74 pcf

LOAD INCR. (TSF)	UNIT PRESSURE P (PSF)	INITIAL DIAL READING D_0 (IN.)	FINAL DIAL READING D_{100} (IN.)	RD HS	VOID RATIO e	H (IN.)	T_{50} (MIN.)	CV (IN^2/MIN.)
0.125	250	0.0013	0.0023	0.0044	0.9136	0.9982	0.36	0.5868
0.250	500	0.0080	0.0092	0.0176	0.9006	0.9914	0.81	0.2572
0.500	1000	0.0153	0.0166	0.0318	0.8864	0.9841	0.30	0.6786
0.250	500	0.0173	0.0166	0.0318	0.8864	0.9831	0.25	0.8195
0.125	250	0.0158	0.0155	0.0297	0.8885	0.9844	0.09	2.2824
0.250	500	0.0157	0.0161	0.0309	0.8873	0.9841	0.25	0.8212
0.500	1000	0.0171	0.0178	0.0341	0.8841	0.9826	0.16	1.2792
1.000	2000	0.0248	0.0262	0.0503	0.8680	0.9745	0.42	0.4765
2.000	4000	0.0358	0.0371	0.0712	0.8471	0.9636	0.36	0.5467
4.000	8000	0.0520	0.0539	0.1034	0.8148	0.9471	0.30	0.6286
8.000	16000	0.0732	0.0778	0.1492	0.7690	0.9245	0.25	0.7248
16.000	32000	0.1090	0.1166	0.2237	0.6946	0.8872	0.56	0.2967

NI02B029


K+E SEMI LOGARITHMIC 358-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 Cycles x 70 Divisions
UNIT PRESSURE, P (PSF)
VOID RATIO, e
e_o
100
1,000
10,000
10,000
e vs Log P
Client: Virginia Power
Project: Phase 2 - ISFSI
North Anna Power Station
Boring No: F-9A
Sample No: UD-1
Depth: 4.0 - 6.0' e_o = .9182

NI02B030

TRIAXIAL COMPRESSION TEST

Objective: The triaxial compression test is performed to estimate the shear strength of a soil under controlled drainage conditions. Sheer strength is expressed in terms of the angle of internal friction (O) and the cohesion intercept (c).

Procedure: Triaxial tests on undisturbed soil samples may be: (1) unconsolidated undrained, "UU"; (2) consolidated undrained, "CU"; or (3) consolidated drained, "CD". The type of test is selected to best represent the field and loading conditions. Back pressure is often applied to facilitate complete saturation. Pore water pressure readings may also be taken to determine the effective stresses and effective angle of internal friction.

In the triaxial test, a cylindrical specimen of soil, encased in a rubber membrane, is placed in a compression chamber, subjected to a confining fluid pressure and then loaded axially to failure. Connections at the ends of the specimen permit controlled drainage of pore water from the specimen. Also, pore pressure readings can be recorded as the axial load is applied. In general, a minimum of three specimens, each under a different confining pressure, are tested to establish the relation between shear stress and normal stress. The test results are represented by a plot of shear versus axial stress (Mohr Circle Diagram).

References: ASTM Specification D-2850, "Standard Method of Test for Unconsolidated Undrained Strength of Cohesive Soils in Triaxial Compression."

Laboratory Soils Testing, EM 1110-2-1906, by The Department of the Army, Appendixes X, XA, & XB

Engineering Properties of Soils & Their Measurements, by Joseph E. Bowles, McGraw-Hill Book Company

The Measurement of Soil Properties in the Triaxial Test, by Bishop & Henkel, 2nd Edition 1962, Edward Arnold Publishers, LTD.

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: August 26, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V80-073

BORING NO: F-7A   DEPTH (FT.): 18.0-20.0   SAMPLE NO: UD-3

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1055.1 GRAMS
MOISTURE CONTENT	39.0 %
UNIT WEIGHT (WET)	108.0 PCF
UNIT WEIGHT (DRY)	77.7 PCF

CHAMBER PRESSURE	65.0 PSI
BACKPRESSURE	60.0 PSI
CONFINING PRESSURE	5.0 PSI
B CHECK	
PISTON FRICTION	259 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

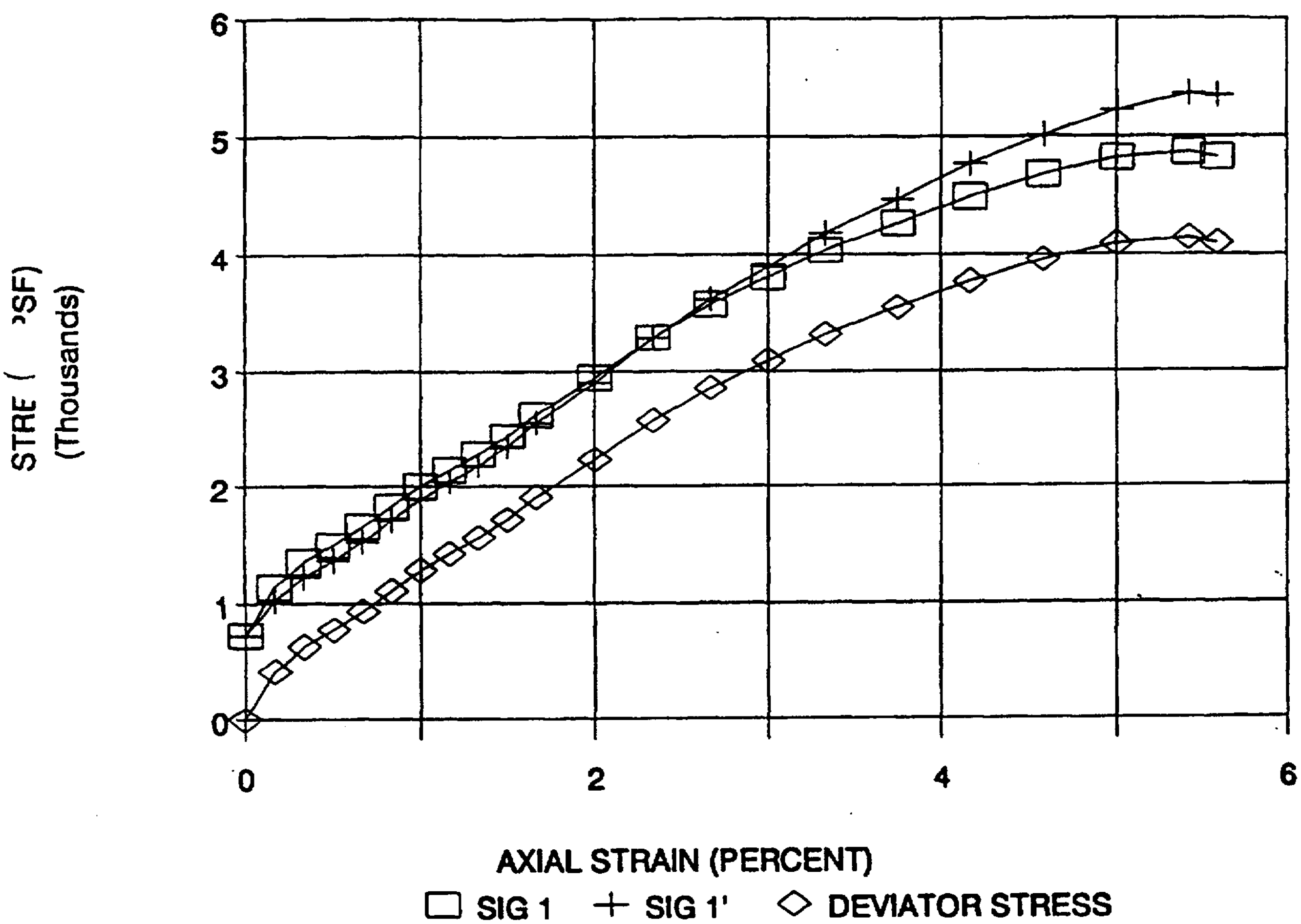
ADING MBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	259.0	60.0	0.000	0.00	0.0	6.20	720.0	720.0	720.0	720.0	0.0	1.0	0.0
1	281.0	60.8	0.010	0.17	17.9	6.21	1134.9	720.0	1019.7	604.8	414.9	1.7	0.3
2	293.0	60.9	0.020	0.33	27.1	6.22	1348.0	720.0	1218.4	590.4	628.0	2.1	0.1
3	301.0	60.8	0.030	0.50	33.3	6.23	1489.3	720.0	1359.7	590.4	769.3	2.3	0.0
4	310.0	60.9	0.040	0.67	40.2	6.24	1647.6	720.0	1518.2	590.4	927.6	2.6	0.0
5	320.0	60.8	0.050	0.83	47.9	6.25	1823.6	720.0	1708.4	604.8	1103.6	2.8	-0.1
6	330.0	60.8	0.060	1.00	55.6	6.26	1998.7	720.0	1883.5	604.8	1278.7	3.1	0.0
7	338.0	60.7	0.070	1.17	61.8	6.27	2138.0	720.0	2037.2	619.2	1418.0	3.3	-0.1
8	346.0	60.7	0.080	1.33	67.9	6.29	2278.7	720.0	2175.9	619.2	1558.7	3.5	0.0
9	355.0	60.8	0.090	1.50	74.9	6.30	2432.6	720.0	2348.2	633.6	1712.6	3.7	-0.1
10	366.0	60.5	0.100	1.67	83.3	6.31	2623.1	720.0	2551.1	648.0	1903.1	3.9	-0.1
11	385.0	60.3	0.120	2.00	98.0	6.33	2949.5	720.0	2906.3	676.8	2229.5	4.3	-0.1
12	405.0	60.0	0.140	2.33	113.4	6.35	3291.2	720.0	3291.2	720.0	2571.2	4.6	-0.1
13	422.0	59.7	0.160	2.67	126.5	6.37	3578.3	720.0	3621.5	763.2	2858.3	4.7	-0.2
14	436.0	59.4	0.180	3.00	137.2	6.39	3811.3	720.0	3897.7	806.4	3091.3	4.8	-0.2
15	450.0	59.0	0.200	3.33	148.0	6.42	4042.7	720.0	4186.7	864.0	3322.7	4.8	-0.2
16	464.0	58.6	0.225	3.75	158.8	6.44	4269.3	720.0	4470.9	921.6	3549.3	4.9	-0.3
17	478.0	58.1	0.250	4.17	169.6	6.47	4493.8	720.0	4787.4	993.6	3773.8	4.8	-0.3
18	490.0	57.7	0.275	4.58	178.9	6.50	4682.1	720.0	5013.3	1051.2	3962.1	4.8	-0.3
19	498.0	57.2	0.300	5.00	185.6	6.53	4817.7	720.0	5220.9	1123.2	4097.7	4.6	-0.5
20	503.0	56.6	0.325	5.42	188.8	6.56	4867.3	770.0	5356.8	1209.6	4147.3	4.4	-1.7
21	501.0	56.4	0.335	5.58	187.3	6.57	4826.3	720.0	5344.7	1238.4	4106.3	4.3	0.7

MAX. DEVIATOR STRESS: 4147.3 PSF
MAX. STRESS RATIO: 4.9

NI02B032

STRESS VS STRAIN

CONFINING PRESSURE, 5 psi



NI02B033

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: August 28, 1984

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V80-073

BORING NO: F-7A DEPTH (FT.): 18.0-20.0 SAMPLE NO: UD-3

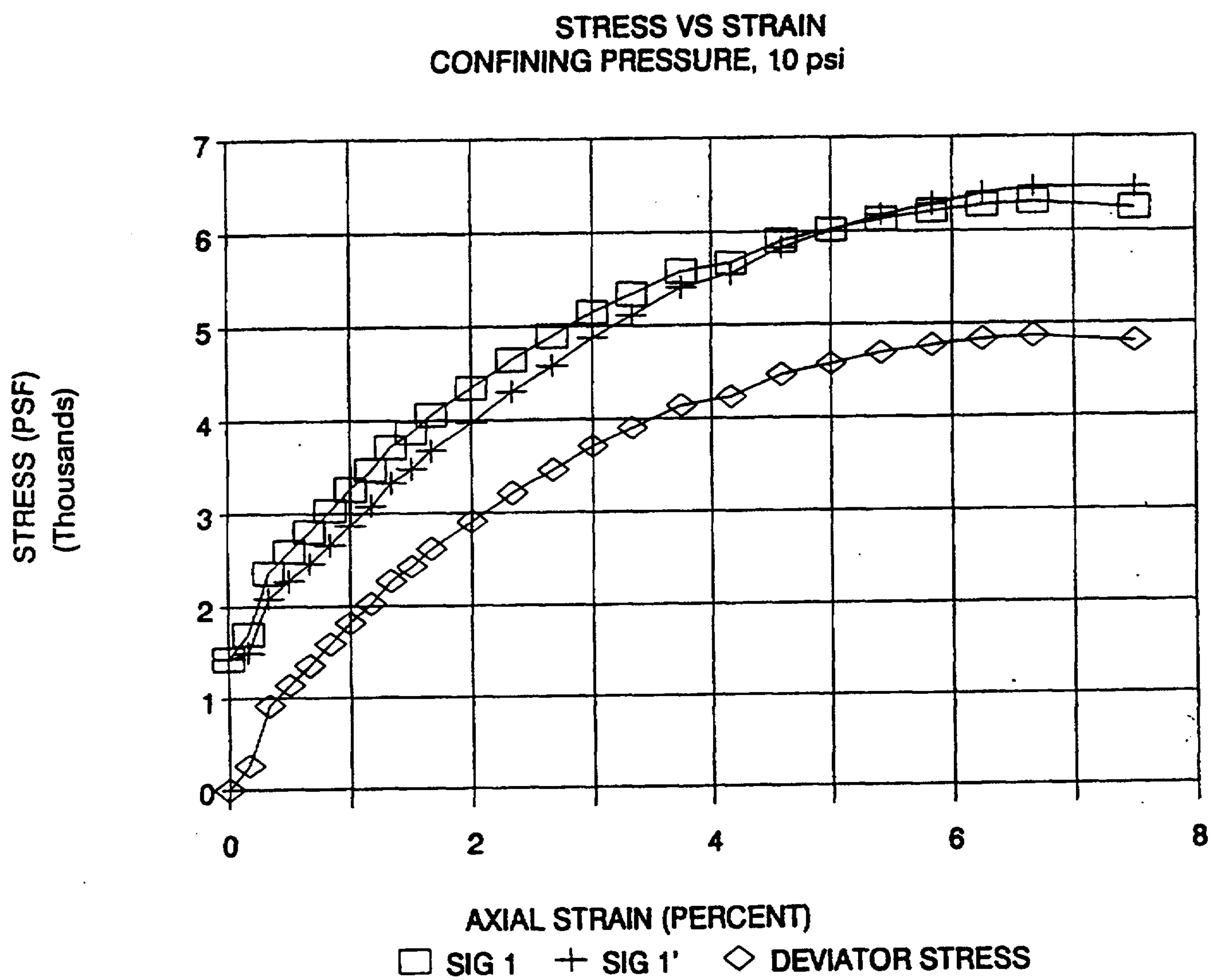
SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1065.6 GRAMS
MOISTURE CONTENT	32.8 %
UNIT WEIGHT (WET)	109.1 PCF
UNIT WEIGHT (DRY)	82.3 PCF

CHAMBER PRESSURE	80.0 PSI
BACKPRESSURE	70.0 PSI
CONFINING PRESSURE	10.0 PSI
B CHECK	
PISTON FRICTION	270 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

ADING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMA-TION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	270.0	70.0	0.000	0.00	5.2	6.20	1440.0	1440.0	1440.0	1440.0	0.0	1.0	0.0
1	278.0	71.4	0.010	0.17	11.4	6.21	1704.4	1440.0	1502.6	1238.4	264.4	1.2	0.8
2	315.0	71.9	0.020	0.33	39.8	6.22	2363.3	1440.0	2069.7	1196.4	923.3	1.8	0.1
3	326.0	72.2	0.030	0.50	49.8	6.23	2593.0	1440.0	2276.2	1123.2	1153.0	2.0	0.2
4	340.0	72.4	0.040	0.67	58.1	6.24	2804.2	1440.0	2458.8	1094.4	1364.2	2.2	0.1
5	353.0	72.6	0.050	0.83	68.2	6.25	3032.4	1440.0	2658.0	1065.6	1592.4	2.5	0.1
6	366.0	72.7	0.060	1.00	78.2	6.26	3259.8	1440.0	2871.0	1051.2	1819.8	2.7	0.1
7	376.0	72.7	0.070	1.17	88.4	6.27	3468.8	1440.0	3080.0	1051.2	2028.8	2.9	0.0
8	392.0	72.7	0.080	1.33	98.2	6.29	3712.4	1440.0	3323.6	1051.2	2272.4	3.2	0.0
9	401.0	72.7	0.090	1.50	108.1	6.30	3867.0	1440.0	3478.2	1051.2	2427.0	3.3	0.0
10	412.0	72.7	0.100	1.67	114.8	6.31	4058.3	1440.0	3667.5	1051.2	2618.3	3.5	0.0
11	429.0	72.6	0.120	2.00	127.7	6.33	4345.3	1440.0	3970.9	1065.6	2905.3	3.7	0.0
12	447.0	72.4	0.140	2.33	141.5	6.35	4649.6	1440.0	4304.2	1094.4	3209.6	3.8	-0.1
13	462.0	72.2	0.160	2.67	153.1	6.37	4899.9	1440.0	4583.1	1123.2	3459.9	4.1	-0.1
14	477.0	71.9	0.180	3.00	164.6	6.39	5148.2	1440.0	4874.6	1166.4	3708.2	4.2	-0.2
15	489.0	71.6	0.200	3.33	173.9	6.42	5342.8	1440.0	5112.4	1209.6	3902.8	4.2	-0.2
16	504.0	71.2	0.225	3.75	185.4	6.44	5584.2	1440.0	5411.4	1267.2	4144.2	4.3	-0.2
17	510.0	70.8	0.250	4.17	190.0	6.47	5669.0	1440.0	5553.8	1324.8	4229.0	4.2	-0.7
18	525.0	70.5	0.275	4.58	201.6	6.50	5906.5	1440.0	5834.5	1368.0	4466.5	4.3	-0.2
19	533.0	70.1	0.300	5.00	207.8	6.53	6022.9	1440.0	6008.5	1425.6	4582.9	4.2	-0.5
20	541.0	69.7	0.325	5.42	213.9	6.56	6136.1	1440.0	6181.3	1483.2	4696.1	4.2	-0.5
21	547.0	69.5	0.350	5.83	218.5	6.59	6218.4	1440.0	6290.4	1512.0	4778.4	4.2	-0.4
22	552.0	69.2	0.375	6.25	222.4	6.62	6281.1	1440.0	6386.3	1555.2	4841.1	4.1	-0.7
23	555.0	68.9	0.400	6.67	224.7	6.64	6308.7	1440.0	6466.1	1598.4	4868.7	4.0	-1.5
24	554.0	68.5	0.450	7.50	223.9	6.70	6249.6	1440.0	6465.6	1656.0	4809.6	3.9	1.0

X. DEVIATOR STRESS: 4868.7 PSF
. STRESS RATIO: 4.3

NI02B034



STRESS VS STRAIN
CONFINING PRESSURE, 10 psi
STRESS (PSF)
(Thousands)
0
1
2
3
4
5
6
7
0
2
4
6
8
AXIAL STRAIN (PERCENT)
SIG 1
SIG 1'
DEVIATOR STRESS

NI02B035

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: August 24, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V80-073

BORING NO: F-7A DEPTH (FT.): 16.0-18.0 SAMPLE NO: UD-2

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1039.9 GRAMS
MOISTURE CONTENT	38.6 %
UNIT WEIGHT (WET)	106.5 PCF
UNIT WEIGHT (DRY)	76.7 PCF

CHAMBER PRESSURE	45.0 PSI
BACKPRESSURE	30.0 PSI
CONFINING PRESSURE	15.0 PSI
B CHECK	
PISTON FRICTION	173 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

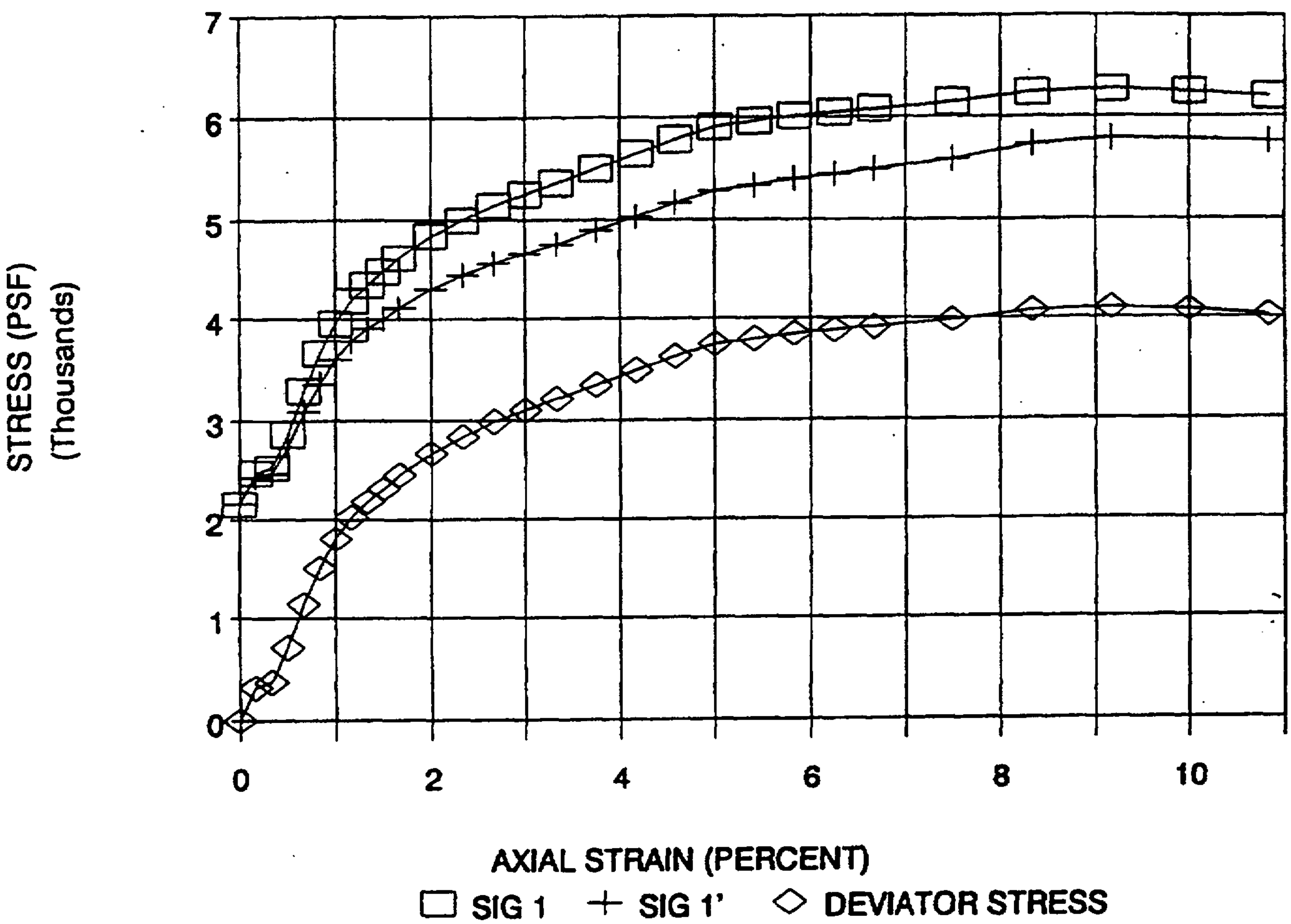
READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	173.0	30.0	0.000	0.00	0.0	6.20	2160.0	2160.0	2160.0	2160.0	0.0	1.0	0.0
1	209.0	30.3	0.010	0.17	13.7	6.21	2477.3	2160.0	2434.1	2116.8	317.3	1.1	0.1
2	215.0	30.4	0.020	0.33	16.0	6.22	2529.6	2160.0	2472.0	2102.4	369.6	1.2	0.3
3	253.0	30.9	0.030	0.50	30.4	6.23	2862.8	2160.0	2733.2	2030.4	702.8	1.3	0.2
4	279.0	31.4	0.040	0.67	49.1	6.24	3291.5	2160.0	3089.9	1958.4	1131.5	1.6	0.2
5	300.0	32.1	0.050	0.83	65.2	6.25	3661.9	2160.0	3359.5	1857.6	1501.9	1.8	0.3
6	317.0	32.5	0.060	1.00	78.3	6.26	3960.3	2160.0	3600.3	1800.0	1800.3	2.0	0.2
7	330.0	32.8	0.070	1.17	88.3	6.27	4187.0	2160.0	3783.8	1756.8	2027.0	2.2	0.2
8	338.0	33.0	0.080	1.33	95.3	6.29	4342.4	2160.0	3910.4	1728.0	2182.4	2.3	0.2
9	347.0	33.3	0.090	1.50	101.4	6.30	4479.6	2160.0	4004.4	1684.8	2319.6	2.4	0.3
10	355.0	33.5	0.100	1.67	107.6	6.31	4616.3	2160.0	4112.3	1656.0	2456.3	2.5	0.2
11	368.0	33.7	0.120	2.00	117.6	6.33	4835.8	2160.0	4303.0	1627.2	2675.8	2.6	0.1
12	376.0	33.9	0.140	2.33	125.3	6.35	5001.3	2160.0	4439.7	1598.4	2841.3	2.8	0.2
13	387.0	34.1	0.160	2.67	132.2	6.37	5148.2	2160.0	4557.8	1569.6	2988.2	2.9	0.2
14	394.0	34.2	0.180	3.00	137.6	6.39	5259.4	2160.0	4654.6	1555.2	3099.4	3.0	0.1
15	401.0	34.3	0.200	3.33	143.0	6.42	5369.7	2160.0	4750.5	1540.8	3209.7	3.1	0.1
16	410.0	34.3	0.225	3.75	149.9	6.44	5510.8	2160.0	4891.6	1540.8	3350.8	3.2	0.0
17	419.0	34.3	0.250	4.17	156.9	6.47	5650.5	2160.0	5031.3	1540.8	3490.5	3.3	0.0
18	428.0	34.3	0.275	4.58	163.8	6.50	5788.8	2160.0	5169.6	1540.8	3628.8	3.4	0.0
19	436.0	34.3	0.300	5.00	169.9	6.53	5908.9	2160.0	5289.7	1540.8	3748.9	3.4	0.0
20	440.0	34.3	0.325	5.42	173.0	6.56	5960.1	2160.0	5340.9	1540.8	3800.1	3.5	0.0
21	444.0	34.2	0.350	5.83	176.1	6.58	6010.7	2160.0	5405.9	1555.2	3850.7	3.5	-0.3
22	447.0	34.1	0.375	6.25	178.4	6.62	6043.9	2160.0	5453.5	1569.6	3883.9	3.5	-0.4
23	450.0	34.0	0.400	6.67	180.7	6.64	6078.7	2160.0	5500.7	1584.0	3918.7	3.5	-0.4
24	456.0	33.8	0.450	7.50	185.3	6.70	6141.0	2160.0	5593.8	1612.8	3981.0	3.5	-0.4
25	464.0	33.5	0.500	8.33	191.5	6.77	6236.3	2160.0	5732.3	1656.0	4076.3	3.5	-0.5
26	466.0	33.3	0.550	9.17	194.6	6.83	6264.2	2160.0	5789.0	1684.8	4104.2	3.4	-1.0
27	469.0	33.2	0.600	10.00	196.4	6.89	6242.6	2160.0	5781.8	1699.2	4082.6	3.4	0.7
28	468.0	33.0	0.650	10.83	194.6	6.96	6188.9	2160.0	5756.9	1728.0	4028.9	3.3	0.5

MAX. DEVIATOR STRESS: 4104.2 PSF
MAX. STRESS RATIO: 3.5

NI02B036

STRESS VS STRAIN

CONFINING PRESSURE, 15 psi



NI02B037

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: September 7, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V90-073

BORING NO: F-7A DEPTH (FT.): 18.0-20.0 SAMPLE NO: UD-3

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1084.9 GRAMS
MOISTURE CONTENT	39.0 %
UNIT WEIGHT (WET)	111.1 PCF
UNIT WEIGHT (DRY)	79.9 PCF

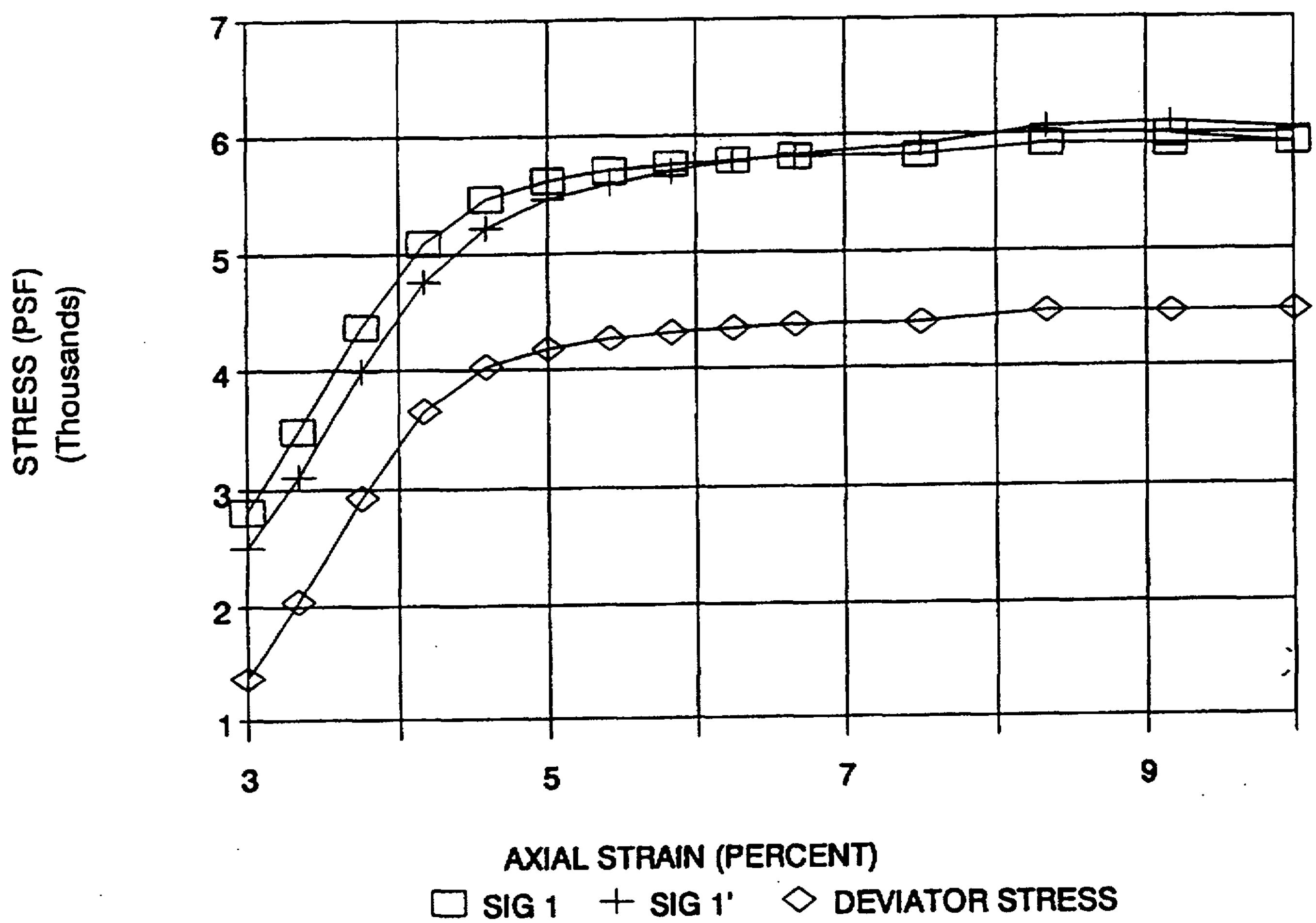
CHAMBER PRESSURE	65.0 PSI
BACKPRESSURE	55.0 PSI
CONFINING PRESSURE	10.0 PSI
B CHECK	
PISTON FRICTION	227 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
1	321.0	57.1	0.180	3.00	80.9	6.39	2810.9	1440.0	2508.5	1137.6	1370.9	2.2	0.0
2	360.0	57.6	0.200	3.33	90.8	6.42	3480.2	1440.0	3106.8	1065.6	2040.2	2.9	0.1
3	412.0	57.8	0.225	3.75	130.9	6.44	4366.3	1440.0	3981.9	1068.8	2926.3	3.7	0.0
4	455.0	57.3	0.250	4.17	164.0	6.47	5090.4	1440.0	4759.2	1108.8	3650.4	4.3	-0.1
5	478.0	56.7	0.275	4.58	181.8	6.50	5467.0	1440.0	5222.2	1195.2	4027.0	4.4	-0.2
6	488.0	56.1	0.300	5.00	189.5	6.53	5619.2	1440.0	5460.8	1281.6	4179.2	4.3	-0.8
7	494.0	55.8	0.325	5.42	194.1	6.56	5702.4	1440.0	5587.2	1324.8	4262.4	4.2	-0.5
8	498.0	55.4	0.350	5.83	197.2	6.59	5750.9	1440.0	5693.3	1382.4	4310.9	4.1	-1.2
9	501.0	55.1	0.375	6.25	199.5	6.62	5782.1	1440.0	5767.7	1425.6	4342.1	4.0	-1.4
10	504.0	54.9	0.400	6.67	201.8	6.64	5812.9	1440.0	5827.3	1454.4	4372.9	4.0	-0.9
11	507.0	54.4	0.450	7.50	204.1	6.70	5823.5	1440.0	5909.9	1526.4	4383.5	3.9	-6.8
12	515.0	54.0	0.500	8.33	210.2	6.77	5915.1	1440.0	6056.1	1584.0	4475.1	3.8	-0.8
13	517.0	53.7	0.550	9.17	211.8	6.83	5906.9	1440.0	6084.1	1627.2	4466.9	3.7	5.3
14	520.0	54.1	0.600	10.00	214.1	6.89	5914.2	1440.0	6043.8	1569.6	4474.2	3.9	7.9
15	522.0	53.4	0.550	9.17	213.6	6.83	5988.1	1440.0	6218.5	1670.4	4548.1	3.7	-1.4

MAX. DEVIATOR STRESS: 4548.1 PSF
MAX. STRESS RATIO: 4.4

NI02B038

STRESS VS STRAIN
CONFINING PRESSURE, 10 psi



NI02B039

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: September 7, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V80-073

BORING NO: F-7A DEPTH (FT.): 20.0-22.0 SAMPLE NO: UD-4

SAMPLE DIAMETER	2.81 IN.
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.20 SQ. IN.
SAMPLE VOLUME	37.21 CU. IN.
SAMPLE WEIGHT	1043.7 GRAMS
MOISTURE CONTENT	40.9 %
UNIT WEIGHT (WET)	108.8 PCF
UNIT WEIGHT (DRY)	75.6 PCF

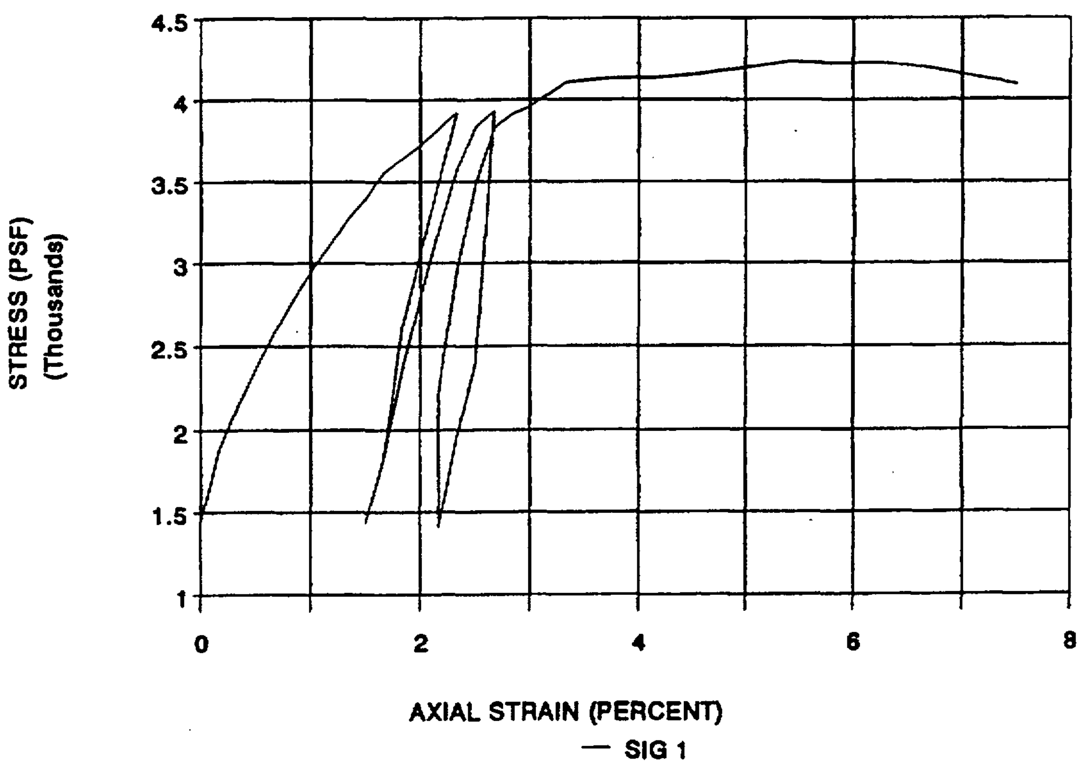
CHAMBER PRESSURE	55.0 PSI
BACKPRESSURE	45.0 PSI
CONFINING PRESSURE	10.0 PSI
B CHECK	
PISTON FRICTION	259 IN.x10-4
LOADING RATE	0.08 IN./MIN.
VOLUME CHANGE	ML
CORRECTED AREA	6.20 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR. (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	Ā
0	259.0	45.0	0.000	0.00	0.0	6.20	1440.0	1440.0	1440.0	1440.0	0.0	1.0	0.0
1	283.0	49.0	0.010	0.17	18.4	6.21	1890.8	1440.0	1314.8	864.0	450.8	1.5	1.3
2	297.0	49.4	0.020	0.33	30.2	6.22	2138.3	1440.0	1605.7	808.4	698.3	1.9	0.2
3	310.0	49.7	0.030	0.50	40.2	6.23	2369.4	1440.0	1662.8	763.2	929.4	2.2	0.2
4	322.0	49.8	0.040	0.67	48.5	6.24	2581.0	1440.0	1875.4	734.4	1141.0	2.6	0.1
5	333.0	50.0	0.050	0.83	57.9	6.25	2774.1	1440.0	2054.1	720.0	1334.1	2.9	0.1
6	343.0	50.1	0.060	1.00	65.8	6.26	2948.9	1440.0	2214.5	705.6	1508.9	3.1	0.1
7	352.0	50.1	0.070	1.17	72.8	6.27	3105.4	1440.0	2371.0	705.6	1665.4	3.4	0.0
8	361.0	50.2	0.080	1.33	78.5	6.28	3261.3	1440.0	2512.5	691.2	1821.3	3.6	0.1
9	369.0	50.1	0.090	1.50	85.7	6.30	3398.1	1440.0	2664.7	705.6	1958.1	3.8	-0.1
10	378.0	50.1	0.100	1.67	92.8	6.31	3554.1	1440.0	2819.7	705.6	2114.1	4.0	0.0
11	388.0	50.1	0.120	2.00	100.3	6.33	3722.1	1440.0	2987.7	705.6	2282.1	4.2	0.0
12	400.0	50.0	0.140	2.33	108.5	6.35	3923.9	1440.0	3203.9	720.0	2483.9	4.4	-0.1
13	373.0	48.8	0.130	2.17	80.3	6.34	3490.8	1440.0	2822.2	878.4	2050.8	3.3	0.4
14	350.0	48.7	0.120	2.00	71.0	6.33	3058.3	1440.0	2250.5	907.2	1618.3	2.8	0.1
15	325.0	48.6	0.110	1.83	51.8	6.32	2620.2	1440.0	2101.8	921.6	1180.2	2.3	0.0
16	280.0	48.5	0.100	1.67	17.1	6.31	1831.1	1440.0	1327.1	936.0	391.1	1.4	0.0
17	259.0	48.4	0.080	1.50	0.0	6.30	1440.0	1440.0	950.4	950.4	0.0	1.0	0.0
18	280.0	49.0	0.100	1.67	17.1	6.31	1831.1	1440.0	1255.1	864.0	391.1	1.5	0.2
19	310.0	50.0	0.110	1.83	40.2	6.32	2356.9	1440.0	1636.9	720.0	916.9	2.3	0.3
20	335.0	50.2	0.120	2.00	59.6	6.33	2793.4	1440.0	2044.6	691.2	1353.4	3.0	0.1
21	358.0	50.3	0.130	2.17	77.2	6.34	3193.5	1440.0	2430.3	676.8	1753.5	3.6	0.0
22	380.0	50.3	0.140	2.33	94.1	6.35	3574.7	1440.0	2811.5	676.8	2134.7	4.2	0.0
23	395.0	50.2	0.150	2.50	105.7	6.36	3832.5	1440.0	3080.7	691.2	2392.5	4.5	-0.1
24	401.0	50.1	0.160	2.67	110.3	6.37	3932.8	1440.0	3198.4	705.6	2492.8	4.5	-0.1
25	312.0	48.4	0.150	2.50	41.8	6.36	2385.6	1440.0	1752.0	806.4	945.6	2.2	0.1
26	288.0	49.0	0.140	2.33	23.3	6.35	1968.1	1440.0	1392.1	864.0	528.1	1.6	0.1
27	256.0	48.8	0.130	2.17	-1.5	6.34	1405.4	1440.0	843.8	878.4	-34.6	1.0	0.0
28	302.0	50.2	0.130	2.17	34.1	6.34	2213.9	1440.0	1465.1	691.2	773.9	2.1	0.2
29	345.0	50.1	0.140	2.33	67.2	6.35	2963.5	1440.0	2229.1	705.6	1523.5	3.2	0.0
30	375.0	50.3	0.150	2.50	90.3	6.36	3483.8	1440.0	2720.6	676.8	2043.8	4.0	0.1
31	395.0	50.3	0.160	2.67	105.7	6.37	3809.4	1440.0	3085.2	676.8	2369.4	4.6	0.0
32	400.0	50.1	0.170	2.83	108.5	6.38	3911.2	1440.0	3176.8	705.6	2471.2	4.6	-0.3
33	403.0	50.0	0.180	3.00	111.8	6.39	3958.0	1440.0	3238.0	720.0	2518.0	4.5	-0.3
34	412.0	48.8	0.200	3.33	118.8	6.42	4105.9	1440.0	3400.3	734.4	2665.9	4.6	-0.1
35	414.0	48.7	0.225	3.75	120.3	6.44	4128.8	1440.0	3462.0	763.2	2688.8	4.5	-1.3
36	418.0	48.6	0.250	4.17	121.1	6.47	4134.3	1440.0	3488.3	792.0	2694.3	4.4	-0.2
37	417.0	48.5	0.275	4.58	122.8	6.50	4156.7	1440.0	3508.7	792.0	2716.7	4.4	0.0
38	420.0	48.4	0.300	5.00	124.9	6.53	4195.9	1440.0	3562.2	806.4	2755.9	4.4	-0.4
39	423.0	48.3	0.325	5.42	127.2	6.56	4224.4	1440.0	3618.2	820.8	2784.4	4.4	-0.4
40	423.0	48.2	0.350	5.83	127.2	6.59	4222.1	1440.0	3617.3	835.2	2782.1	4.3	1.2
41	424.0	48.1	0.375	6.25	128.0	6.62	4228.6	1440.0	3636.2	849.6	2788.6	4.3	-3.2
42	423.0	48.1	0.400	6.67	127.2	6.64	4197.5	1440.0	3607.1	849.6	2757.5	4.2	0.0
43	416.0	48.6	0.450	7.50	123.4	6.70	4080.2	1440.0	3543.0	892.8	2640.2	4.0	0.4

MAX. DEVIATOR STRESS: 2784.4 PSF
MAX. STRESS RATIO: 4.6

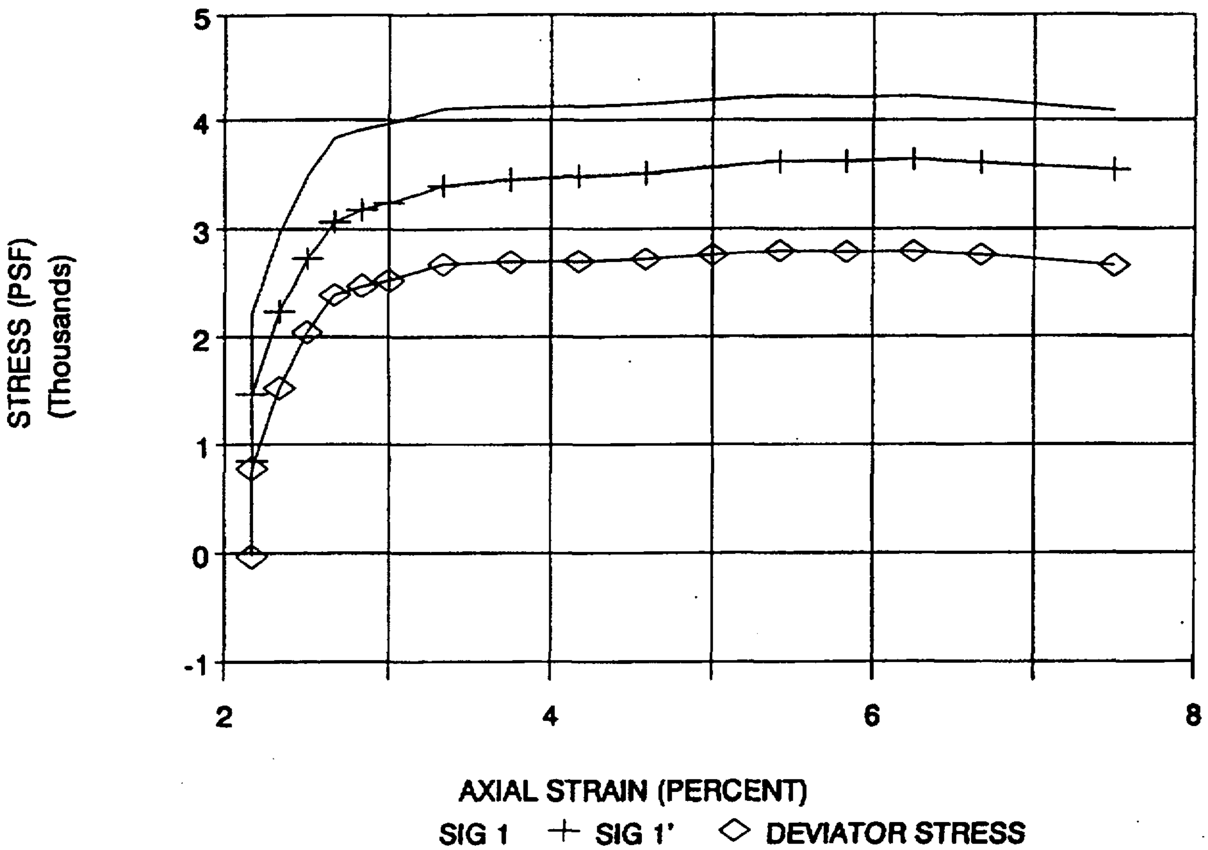
NI02B040

STRESS VS STRAIN
CONFINING PRESSURE, 10 psi



NI02B041

STRESS VS STRAIN
CONFINING PRESSURE, 10 psi



NI02B042

SINCE F&R 1881

FROEHLING & ROBERTSON, INC.

TRIAXIAL COMPRESSION TEST

Date: September 7, 1994

TEST TYPE: Consolidated Undrained with Pore Pressure Readings
CLIENT: Virginia Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V66-073

BORING NO: F-7A DEPTH (FT.): 20.0-22.0 SAMPLE NO: UD-4

SAMPLE DIAMETER	2.84 IN
SAMPLE HEIGHT	6.00 IN.
SAMPLE AREA	6.33 SQ. IN.
SAMPLE VOLUME	38.01 CU. IN.
SAMPLE WEIGHT	962.9 GRAMS
MOISTURE CONTENT	36.0 %
UNIT WEIGHT (WET)	99.0 PCF
UNIT WEIGHT (DRY)	72.8 PCF

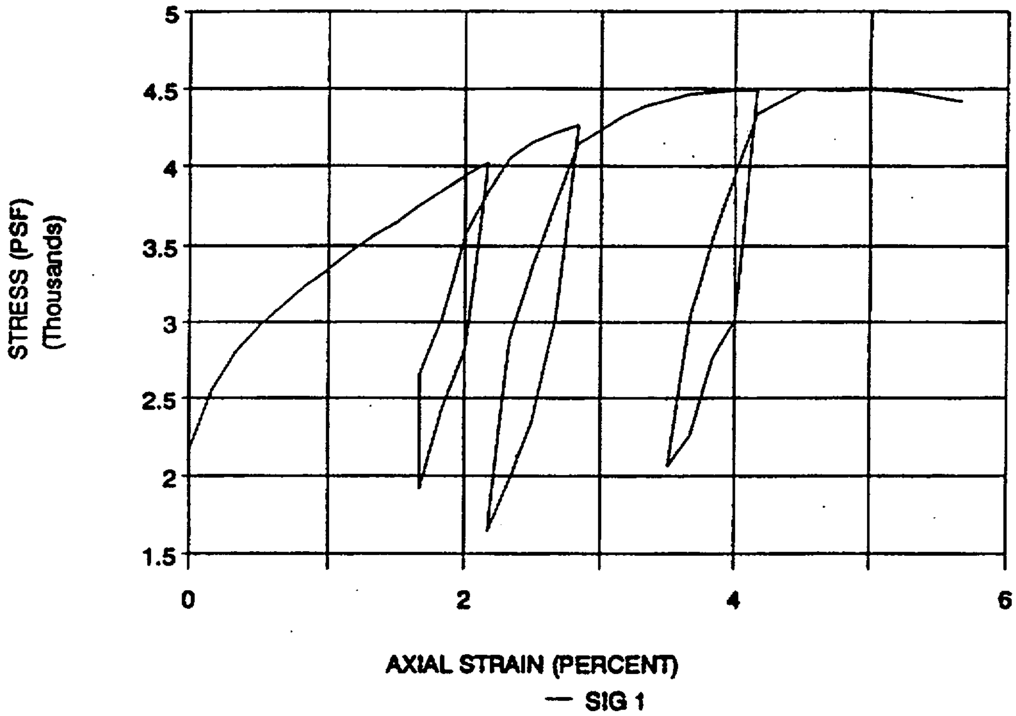
CHAMBER PRESSURE	95.0 PSI
BACKPRESSURE	80.0 PSI
CONFINING PRESSURE	15.0 PSI
B CHECK	
PISTON FRICTION	300 IN.x10-4
LOADING RATE	0.06 IN./MIN.
VOLUME CHANGE	ML.
CORRECTED AREA	6.33 SQ. IN.
CORRECTED HEIGHT	6.00 IN.

READING NUMBER	LOAD DIAL (IN.-4)	PORE PRESSURE (PSI)	DEFORMATION (IN.)	UNIT STRAIN (%)	AXIAL LOAD (LBS)	AREA CORR (in.²)	SIG 1 (PSF)	SIG 3 (PSF)	SIG 1' (PSF)	SIG 3' (PSF)	DEVIATOR STRESS (PSF)	STRESS RATIO	A
0	262.0	80.0	0.000	0.00	0.0	6.33	2160.0	2160.0	2160.0	2160.0	0.0	1.0	0.0
1	282.0	81.8	0.010	0.17	17.6	6.36	2467.7	2160.0	2241.7	1944.0	307.7	1.2	0.8
2	290.0	83.0	0.020	0.33	25.2	6.36	2601.3	2160.0	2013.2	1872.0	441.3	1.2	0.8
3	300.0	83.8	0.030	0.50	34.8	6.37	2974.4	2160.0	2020.8	1706.4	814.4	1.5	0.5
4	314.0	83.8	0.040	0.67	43.2	6.38	3112.1	2160.0	2006.1	1700.0	952.1	1.6	0.4
5	322.0	83.5	0.050	0.83	46.3	6.39	3249.4	2160.0	2748.4	1656.0	1088.4	1.7	0.5
6	329.0	83.5	0.060	1.00	58.0	6.40	3261.8	2160.0	2804.3	1612.8	1101.8	1.7	0.4
7	330.0	84.0	0.070	1.17	60.2	6.41	3476.0	2160.0	2804.8	1584.0	1316.0	1.9	0.3
8	341.0	84.3	0.080	1.33	63.8	6.42	3572.1	2160.0	2880.0	1540.8	1412.1	1.9	0.4
9	340.0	84.5	0.090	1.50	66.8	6.43	3566.8	2160.0	2907.6	1512.0	1406.8	2.0	0.3
10	362.0	84.8	0.100	1.67	71.4	6.44	3760.0	2160.0	3004.2	1497.6	1600.0	2.1	0.1
11	363.0	84.8	0.120	2.00	75.0	6.46	3939.6	2160.0	3048.7	1468.8	1779.6	2.2	0.2
12	386.0	84.8	0.130	2.17	83.7	6.46	4022.8	2160.0	3331.2	1468.8	1862.8	2.3	0.0
13	290.0	83.8	0.120	2.00	20.0	6.46	2624.8	2160.0	2077.7	1612.8	464.8	1.4	0.1
14	270.0	84.8	0.110	1.83	13.1	6.45	2430.8	2160.0	1864.8	1584.0	270.8	1.2	-0.1
15	233.0	84.8	0.100	1.67	-11.8	6.44	1813.6	2160.0	1237.6	1584.0	-346.8	0.8	0.8
16	290.0	84.2	0.100	1.67	22.1	6.44	2668.0	2160.0	2080.2	1566.2	408.0	1.3	0.0
17	310.0	84.7	0.110	1.83	30.1	6.45	2832.2	2160.0	2260.4	1463.2	672.2	1.6	0.2
18	342.0	86.8	0.120	2.00	63.7	6.46	3570.7	2160.0	2660.7	1440.0	1410.7	2.0	0.1
19	357.0	86.1	0.130	2.17	70.3	6.46	3634.1	2160.0	2800.7	1425.6	1574.1	2.2	0.1
20	370.0	86.2	0.140	2.33	86.3	6.48	4068.8	2160.0	2804.7	1411.2	1908.8	2.3	0.1
21	374.0	86.2	0.150	2.50	90.8	6.50	4168.7	2160.0	3408.8	1411.2	1998.7	2.4	0.0
22	380.0	86.3	0.160	2.67	96.0	6.51	4317.4	2160.0	3464.8	1396.8	2057.4	2.5	0.0
23	383.0	86.3	0.170	2.83	98.3	6.52	4264.8	2160.0	3461.7	1396.8	2104.8	2.5	0.0
24	310.0	84.4	0.180	3.07	30.1	6.51	3024.8	2160.0	2361.8	1699.4	864.8	1.5	0.1
25	270.0	84.8	0.150	2.50	8.3	6.50	2342.8	2160.0	1787.8	1684.8	182.8	1.1	0.1
26	240.0	83.7	0.140	2.33	-8.4	6.49	1974.3	2160.0	1441.8	1627.2	-185.7	0.9	0.1
27	200.0	83.8	0.130	2.17	-83.6	6.46	1836.7	2160.0	1080.8	1612.8	-324.3	0.7	0.0
28	302.0	84.8	0.140	2.33	30.0	6.48	2891.0	2160.0	2160.8	1468.8	731.0	1.5	0.1
29	330.0	86.2	0.150	2.50	54.6	6.50	3307.6	2160.0	3010.8	1411.2	1287.6	1.9	0.1
30	364.0	86.4	0.160	2.67	73.0	6.51	3774.8	2160.0	2806.8	1382.4	1614.8	2.2	0.1
31	379.0	86.5	0.170	2.83	86.8	6.52	4146.9	2160.0	3362.9	1380.8	1986.9	2.5	0.0
32	387.0	86.4	0.180	3.17	88.4	6.54	4266.8	2160.0	3647.8	1382.4	2106.8	2.5	-0.1
33	391.0	86.8	0.200	3.33	101.6	6.56	4360.0	2160.0	3607.8	1368.0	2200.0	2.6	0.0
34	398.0	86.4	0.220	3.67	105.3	6.58	4460.1	2160.0	3660.8	1382.4	2300.1	2.7	-0.2
35	398.0	86.4	0.240	4.00	105.0	6.60	4461.7	2160.0	3714.1	1382.4	2301.7	2.7	0.0
36	398.0	86.4	0.260	4.17	105.5	6.61	4467.7	2160.0	3716.1	1382.4	2307.7	2.7	0.0
37	310.0	84.8	0.240	4.00	30.1	6.60	3013.8	2160.0	2280.6	1497.6	853.8	1.6	0.1
38	298.0	84.4	0.230	3.83	27.5	6.58	2768.8	2160.0	2120.4	1598.4	608.8	1.4	0.1
39	266.0	84.2	0.220	3.67	4.4	6.56	2267.1	2160.0	1662.3	1555.2	97.1	1.1	0.1
40	260.0	84.1	0.210	3.50	-4.0	6.56	2060.8	2160.0	1400.8	1560.0	-100.1	0.9	0.1
41	312.0	86.2	0.200	3.67	40.0	6.56	3048.7	2160.0	2660.8	1411.2	880.7	1.6	0.0
42	347.0	86.6	0.230	3.83	68.7	6.58	3663.1	2160.0	2740.7	1368.0	1500.1	2.0	0.1
43	398.0	86.7	0.250	4.17	98.8	6.61	4336.7	2160.0	3615.8	1380.2	2176.7	2.6	0.0
44	398.0	86.8	0.270	4.50	107.8	6.63	4460.3	2160.0	3704.2	1368.8	2300.2	2.7	-0.2
45	398.0	86.8	0.290	4.83	107.8	6.65	4460.1	2160.0	3660.1	1368.0	2300.1	2.7	0.0
46	408.0	86.4	0.300	5.00	108.4	6.67	4500.7	2160.0	3723.1	1382.4	2340.7	2.7	-0.1
47	398.0	86.3	0.320	5.33	107.8	6.68	4478.8	2160.0	3712.7	1396.8	2318.8	2.7	0.0
48	396.0	86.2	0.340	5.67	106.3	6.72	4416.2	2160.0	3660.4	1411.2	2256.2	2.6	0.2

MAX. DEVIATOR STRESS: 2340.7 PSF
MAX. STRESS RATIO: 2.7

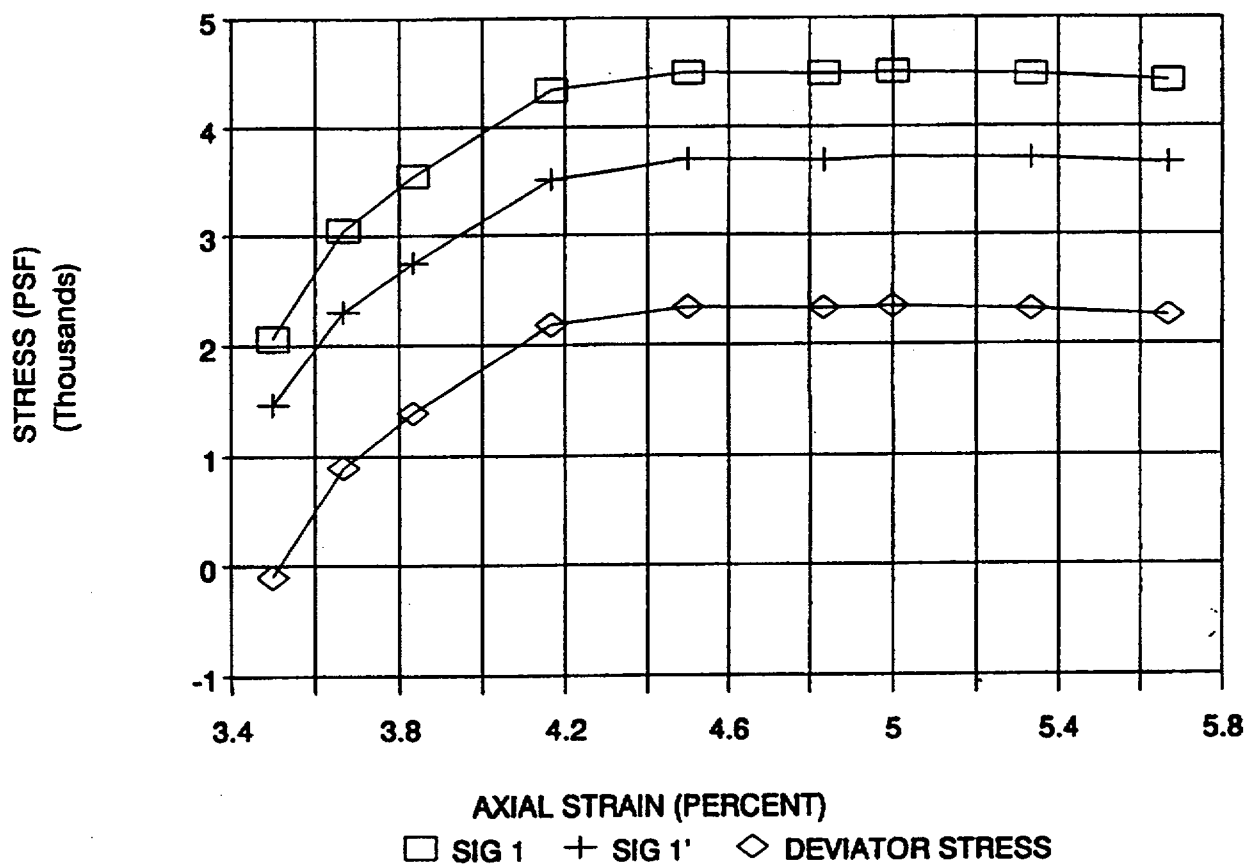
NI02B043

STRESS VS STRAIN
CONFINING PRESSURE, 15 psi



NI02B044

STRESS VS STRAIN
CONFINING PRESSURE, 15 psi



NI02B045

TRAIXIAL COMPRESSION TEST

UNCONSOLIDATED UNDRAINED

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Red and Brown Silty Clay
Boring: 7B2
Sample No.: UD-1
Sample Depth (ft): 1.5-3.0

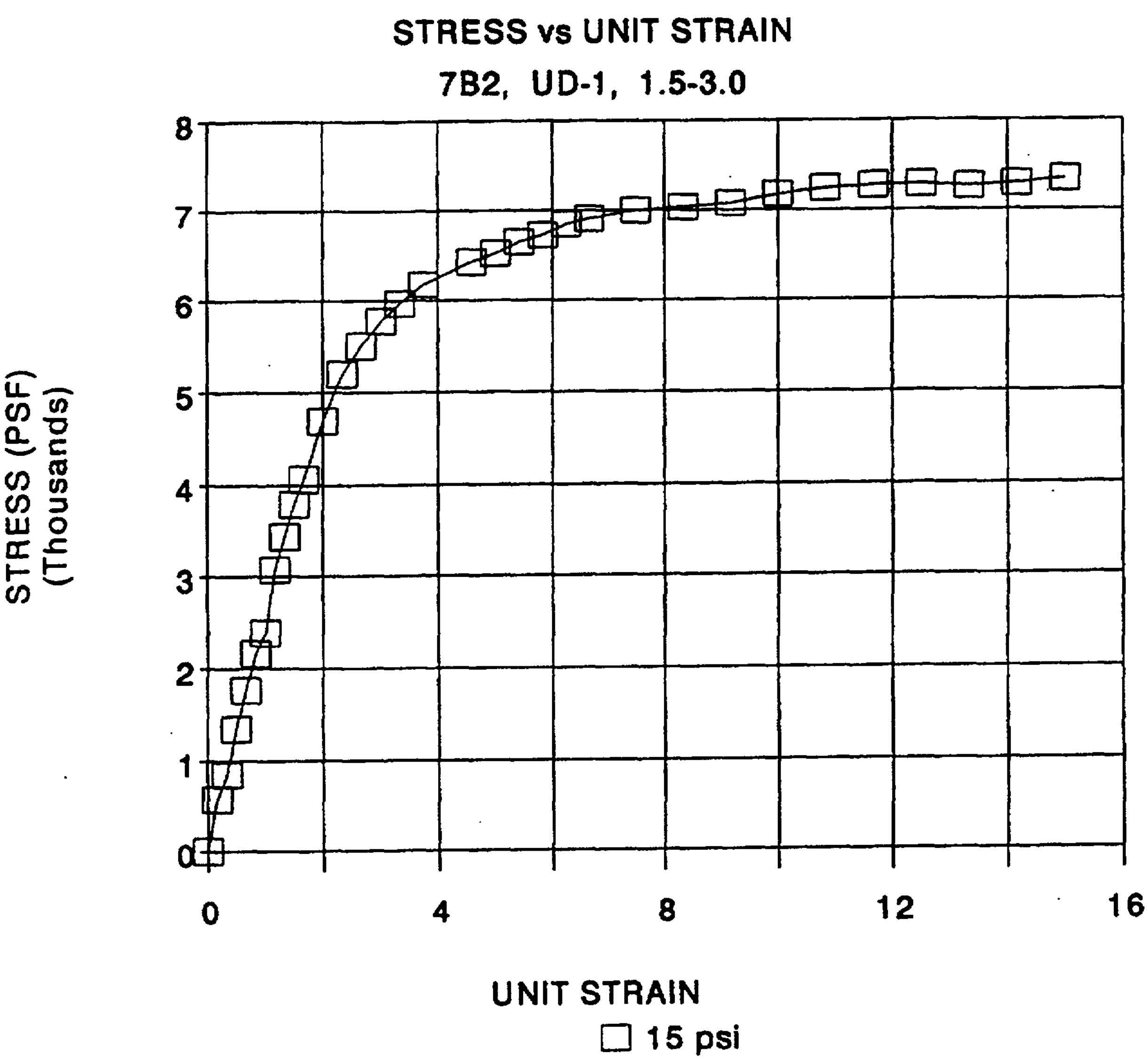
Sample Data: Confining Pressure: 15.0 psi
Diameter 2.81 Inches
Length: 6.0 Inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	68	0.010	24.75	0.167	6.21	573.78
2	100	0.020	36.40	0.333	6.22	842.38
3	160	0.030	58.24	0.500	6.23	1345.56
4	210	0.040	76.44	0.667	6.24	1763.09
5	258	0.050	93.91	0.833	6.25	2162.45
6	285	0.060	103.74	1.000	6.26	2384.74
7	305	0.070	134.00	1.167	6.27	3075.16
8	325	0.080	150.00	1.333	6.29	3436.53
9	345	0.090	166.00	1.500	6.30	3796.67
10	360	0.100	178.00	1.667	6.31	4064.24
11	395	0.120	206.00	2.000	6.33	4687.62
12	424	0.140	229.20	2.333	6.35	5197.80
13	442	0.160	243.60	2.667	6.37	5505.51
14	458	0.180	256.40	3.000	6.39	5774.96
15	470	0.200	266.00	3.333	6.42	5970.59
16	483	0.225	276.40	3.750	6.44	6177.29
17	500	0.275	290.00	4.583	6.50	6425.12
18	507	0.300	295.60	5.000	6.53	6520.59
19	516	0.325	302.80	5.417	6.56	6650.12
20	522	0.350	307.60	5.833	6.59	6725.78
21	531	0.375	314.80	6.250	6.62	6852.75
22	536	0.400	318.80	6.667	6.64	6908.98
23	545	0.450	326.00	7.500	6.70	7001.94
24	551	0.500	330.80	8.333	6.77	7041.03
25	557	0.550	335.60	9.167	6.83	7078.25
26	567	0.600	343.60	10.000	6.89	7180.50
27	575	0.650	350.00	10.833	6.96	7246.52
28	581	0.700	354.80	11.667	7.02	7277.25
29	586	0.750	358.80	12.500	7.09	7289.86
30	589	0.800	361.20	13.333	7.16	7268.73
31	595	0.850	366.00	14.167	7.23	7294.51
32	603	0.900	372.40	15.000	7.30	7350.00

MAX AXIAL STRESS: 7350.00

* Shelby tube secured with backhoe

NI02B046


STRESS vs UNIT STRAIN
7B2, UD-1, 1.5-3.0
STRESS (PSF)
(Thousands)
0
1
2
3
4
5
6
7
8
0
4
8
12
16
UNIT STRAIN
15 psi

NI02B047

TRIAXIAL COMPRESSION TEST

UNCONSOLIDATED UNDRAINED

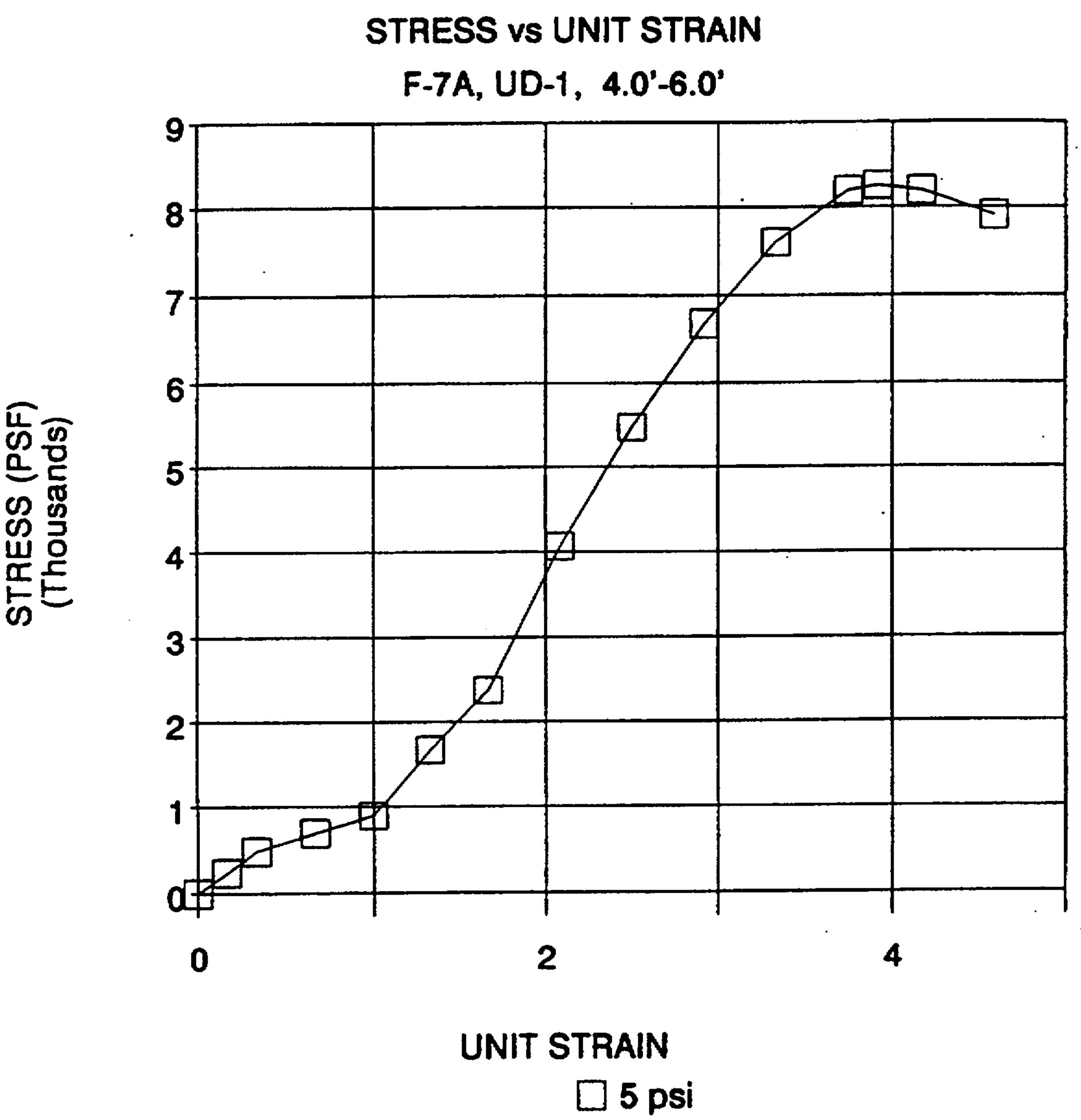
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Reddish Brown Clayey Silt
Boring: F-7A
Sample No.: UD-1
Sample Depth (ft): 4.0-6.0

Sample Data: Confining Pressure: 5.0 psi
Diameter 2.81 inches
Length: 6.0 inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	28	0.010	10.19	0.167	6.21	236.26
2	57	0.020	20.75	0.333	6.22	480.16
3	82	0.040	29.85	0.667	6.24	688.44
4	107	0.060	38.95	1.000	6.26	895.32
5	201	0.080	73.16	1.333	6.29	1676.20
6	286	0.100	104.10	1.667	6.31	2376.99
7	361	0.125	178.80	2.083	6.33	4065.21
8	440	0.150	242.00	2.500	6.36	5478.72
9	508	0.175	296.40	2.917	6.39	6681.62
10	561	0.200	338.80	3.333	6.42	7604.65
11	596	0.225	366.80	3.750	6.44	8197.64
12	600	0.235	370.00	3.917	6.45	8254.84
13	598	0.250	368.40	4.167	6.47	8197.76
14	584	0.275	357.20	4.583	6.50	7913.97

MAX AXIAL STRESS: 8254.84

NI02B048



STRESS vs UNIT STRAIN
F-7A, UD-1, 4.0'-6.0'
STRESS (PSF)
(Thousands)
0
1
2
3
4
5
6
7
8
9
0
2
4
UNIT STRAIN
5 psi

NI02B049

TRIAXIAL COMPRESSION TEST

UNCONSOLIDATED UNDRAINED

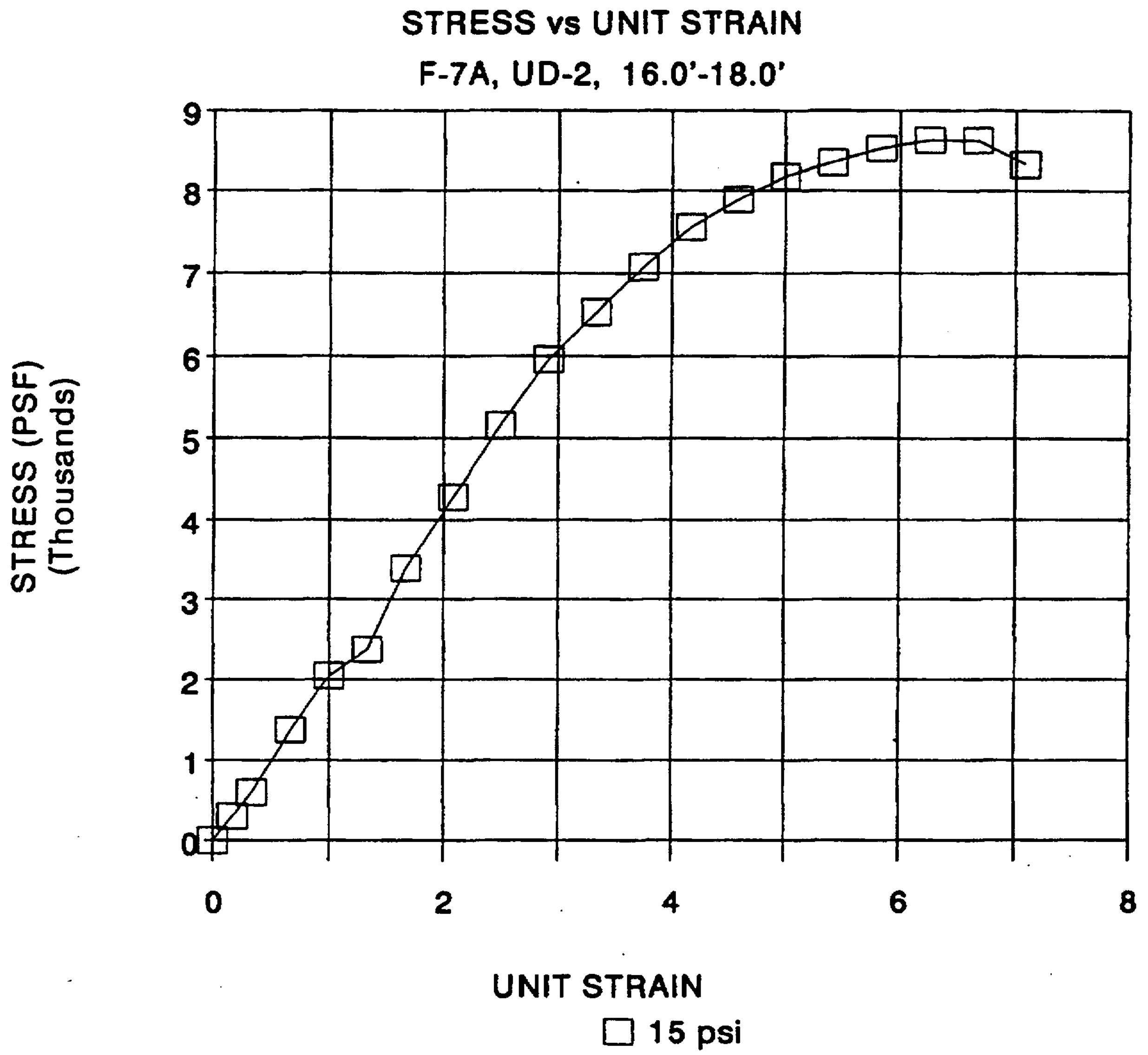
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Red and Brown Clayey Silt
Boring: F-7A
Sample No.: UD-2
Sample Depth (ft): 16.0-18.0

Sample Data:
Confining Pressure: 15.0 psi
Diameter 2.81 inches
Length: 6.0 inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	35	0.010	12.74	0.167	6.21	295.33
2	70	0.020	25.48	0.333	6.22	589.67
3	165	0.040	60.06	0.667	6.24	1385.29
4	245	0.060	89.18	1.000	6.26	2050.04
5	285	0.080	103.74	1.333	6.29	2376.71
6	323	0.100	148.40	1.667	6.31	3388.39
7	373	0.125	188.40	2.083	6.33	4283.48
8	422	0.150	227.60	2.500	6.36	5152.71
9	468	0.175	264.40	2.917	6.39	5960.26
10	501	0.200	290.80	3.333	6.42	6527.25
11	533	0.225	316.40	3.750	6.44	7071.25
12	562	0.250	339.60	4.167	6.47	7556.89
13	583	0.275	356.40	4.583	6.50	7896.25
14	601	0.300	370.80	5.000	6.53	8179.42
15	613	0.325	380.40	5.417	6.56	8354.38
16	625	0.350	390.00	5.833	6.59	8527.48
17	633	0.375	396.40	6.250	6.62	8629.07
18	635	0.400	398.00	6.667	6.64	8625.39
19	620	0.425	386.00	7.083	6.67	8327.98

MAX AXIAL STRESS: 8629.07

NI02B050


STRESS vs UNIT STRAIN
F-7A, UD-2, 16.0'-18.0'
STRESS (PSF)
(Thousands)
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
UNIT STRAIN
15 psi

NI02B051

TRIAXIAL COMPRESSION TEST

UNCONSOLIDATED UNDRAINED

Client:	Virginia Power
Project:	Phase 2 - ISFSI North Anna Power Station
Soil Description:	Reddish Brown Silty Sand
Boring:	F-9A
Sample No.:	UD-1
Sample Depth (ft):	4.0-6.0

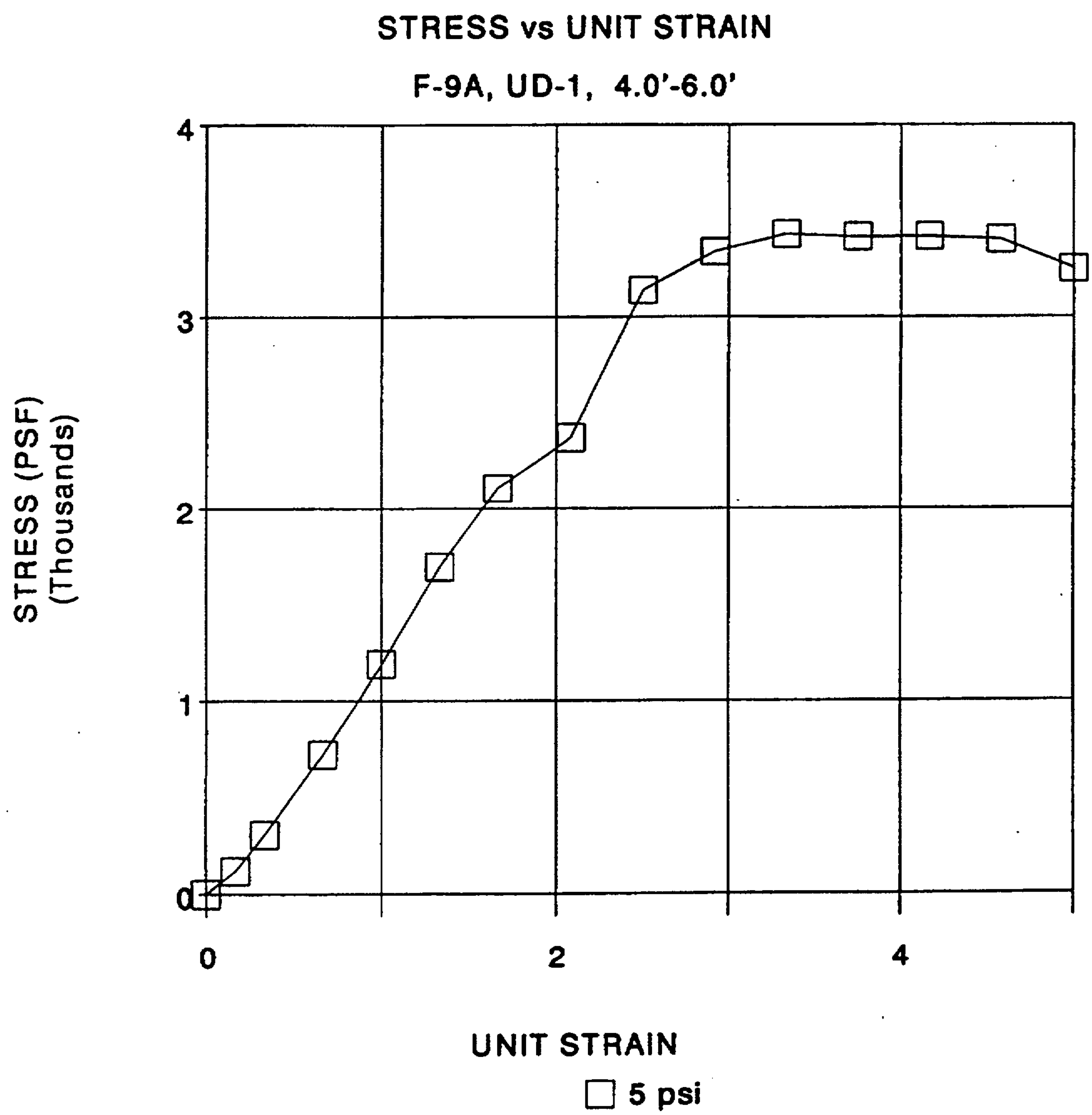
Sample Data:

Confining Pressure:	5.0	psi
Diameter	2.810	inches
Length:	6.0	inches

READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	14	0.010	5.10	0.167	6.21	118.13
2	36	0.020	13.10	0.333	6.22	303.26
3	85	0.040	30.94	0.667	6.24	713.63
4	142	0.060	51.69	1.000	6.26	1188.18
5	203	0.080	73.89	1.333	6.29	1692.88
6	254	0.100	92.46	1.667	6.31	2111.03
7	287	0.125	104.47	2.083	6.33	2375.19
8	311	0.150	138.80	2.500	6.36	3142.34
9	323	0.175	148.40	2.917	6.39	3345.32
10	329	0.200	153.20	3.333	6.42	3438.70
11	329	0.225	153.20	3.750	6.44	3423.88
12	330	0.250	154.00	4.167	6.47	3426.86
13	330	0.275	154.00	4.583	6.50	3411.96
14	322	0.300	147.60	5.000	6.53	3255.88

MAX AXIAL STRESS: 3438.70

NI02B052


STRESS vs UNIT STRAIN
F-9A, UD-1, 4.0'-6.0'
STRESS (PSF)
(Thousands)
0
1
2
3
4
0
2
4
UNIT STRAIN
5 psi

NI02B053

TRIAXIAL COMPRESSION TEST

UNCONSOLIDATED UNDRAINED

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Soil Description: Reddish Brown Silty Sand
Boring: F-9A
Sample No.: UD-1
Sample Depth (ft): 4.0-6.0

Sample Data: Confining Pressure: 10.0 psi
Diameter 2.810 inches
Length: 6.0 inches

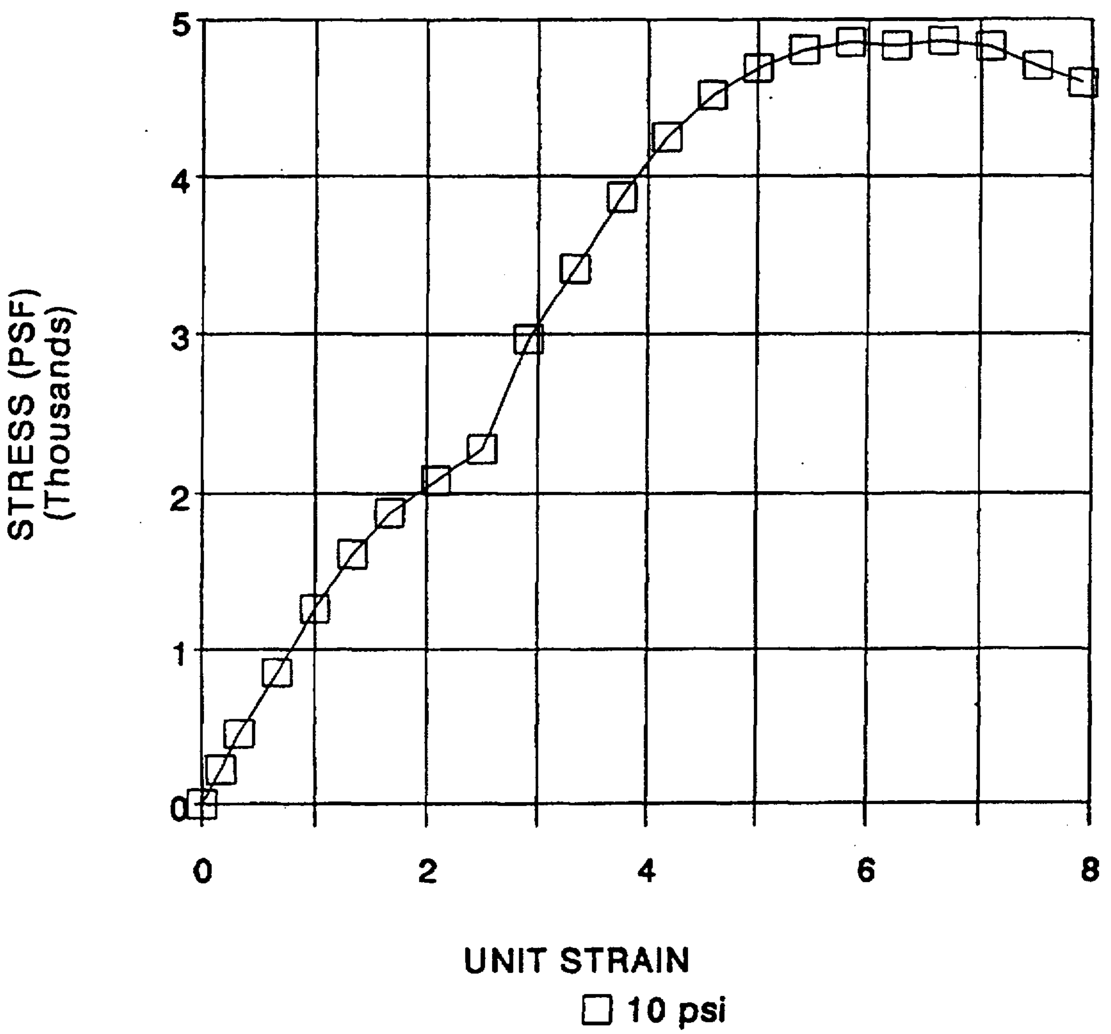
READING NUMBER	LOAD DIAL READING	DEFORM. DIAL READING	LOAD	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
0	0	0.000	0.00	0.000	6.20	0.00
1	26	0.010	9.46	0.167	6.21	219.39
2	53	0.020	19.29	0.333	6.22	446.46
3	101	0.040	36.76	0.667	6.24	847.96
4	151	0.060	54.96	1.000	6.26	1263.49
5	194	0.080	70.62	1.333	6.29	1617.83
6	226	0.100	82.26	1.667	6.31	1878.32
7	251	0.125	91.36	2.083	6.33	2077.26
8	276	0.150	100.46	2.500	6.36	2274.44
9	302	0.175	131.60	2.917	6.39	2966.60
10	328	0.200	152.40	3.333	6.42	3420.74
11	354	0.225	173.20	3.750	6.44	3870.86
12	376	0.250	190.80	4.167	6.47	4245.75
13	392	0.275	203.60	4.583	6.50	4510.88
14	403	0.300	212.40	5.000	6.53	4685.30
15	411	0.325	218.80	5.417	6.56	4805.30
16	415	0.350	222.00	5.833	6.59	4854.10
17	415	0.375	222.00	6.250	6.62	4832.63
18	418	0.400	224.40	6.667	6.64	4863.16
19	417	0.425	223.60	7.083	6.67	4824.19
20	411	0.450	218.80	7.500	6.70	4699.46
21	406	0.475	214.80	7.917	6.73	4592.77

MAX AXIAL STRESS: 4863.16

NI02B054

STRESS vs UNIT STRAIN

F-9A, UD-1, 4.0'-6.0'



NI02B055

UNCONFINED COMPRESSION TEST

Objective: To estimate the load per unit area (compressive strength) that an unconfined, cohesive soil will fail in a simple compression test. The compressive strength is taken as the maximum load (e.g. load at failure) per unit area or the load per unit area at 20% axial strain, whichever occurs first.

Procedure: A cylinder of soil having a height of 1.5 to 2 times the average diameter is loaded to failure, in simple compression, quickly enough that the water content of the soil does not change. The test load is applied using a strain-controlled method. Simultaneous observations are made of the applied load and of the axial strain. The failure load or the load required to produce 20 percent axial strain is expressed as the load per unit of cross-sectional area, in KIPS per square foot.

References: ASTM Specification D-2166, "Standard Methods of Test for Unconfined Compressive Strength of Cohesive Soil".

Laboratory Soils Testing, EM 1110-2-1906 by The Department of the Army, Appendix XI.

UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 6B3
Sample: UD-1
Sample Depth (ft): 2.0-3.5
Soil Description: Reddish Brown Clayey Silt

Sample Data:

Height (in):	6.0	Wet Density (pcf):	111.4
Diameter (in):	2.84	Dry Density (pcf):	84.8
Weight (g):	1110.7	Moisture %:	31.4

READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.33	0.00
2	0.010	46.0	16.73	0.002	6.34	379.76
3	0.020	83.0	30.18	0.003	6.35	684.08
4	0.030	92.0	33.45	0.005	6.36	756.99
5	0.040	112.0	40.72	0.007	6.37	920.01
6	0.050	135.0	49.09	0.008	6.38	1107.08
7	0.060	154.0	55.99	0.010	6.40	1260.77
8	0.070	174.0	63.27	0.012	6.41	1422.11
9	0.080	195.0	70.90	0.013	6.42	1591.05
10	0.090	210.0	76.36	0.015	6.43	1710.55
11	0.100	230.0	83.63	0.017	6.44	1870.29
12	0.110	248.0	90.17	0.018	6.45	2013.24
13	0.120	251.0	91.26	0.020	6.46	2034.14
14	0.130	252.0	91.63	0.022	6.47	2038.77
15	0.140	252.0	91.63	0.023	6.48	2035.29
16	0.150	249.0	90.54	0.025	6.49	2007.63

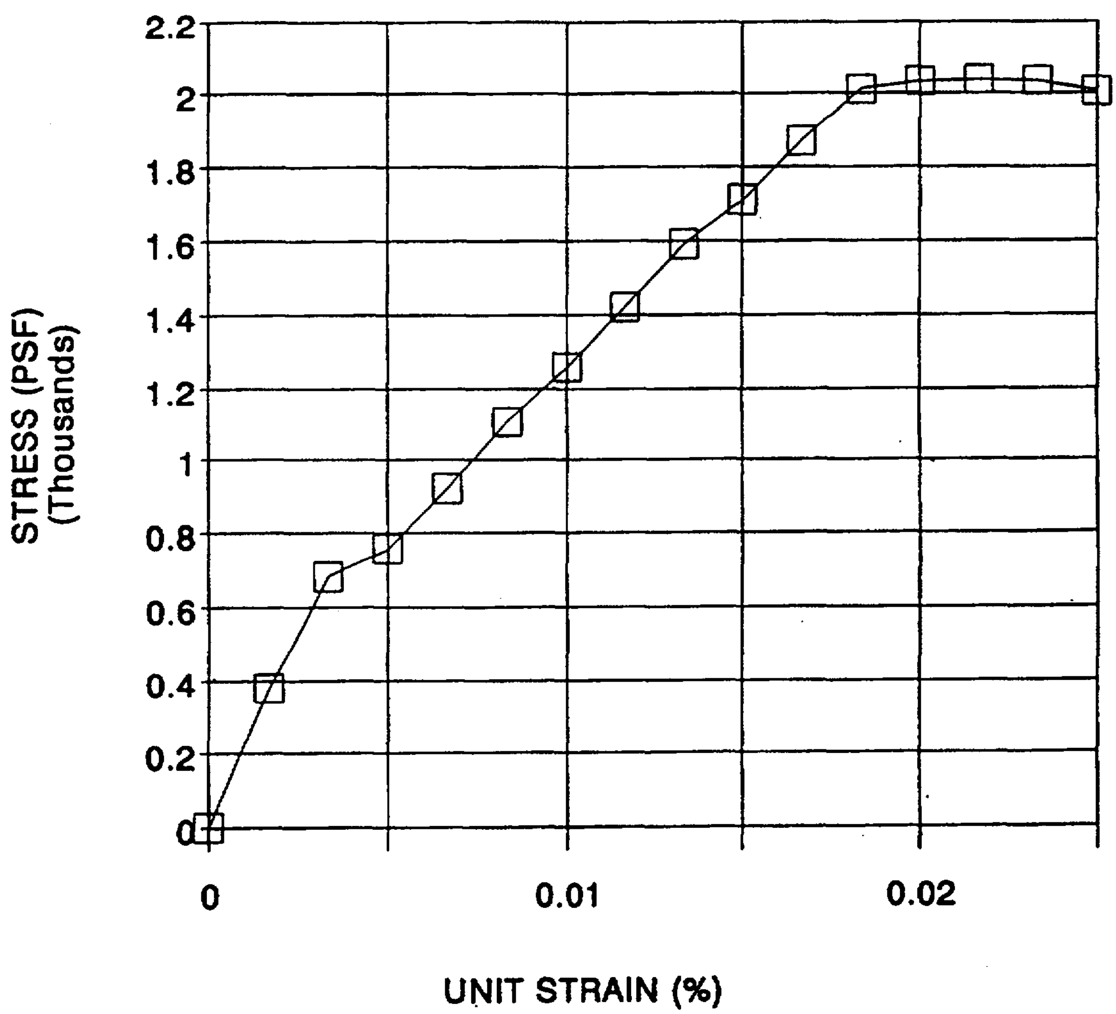
MAX. AXIAL STRESS (psf) 2038.77

* Shelby tube secured with backhoe

NI02B057

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 6B3
Sample No.: UD - 1
Sample Depth (ft): 2.0-3.5

UNCONFINED COMPRESSION TEST



NI02B058

UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 7B1
Sample: UD-1
Sample Depth (ft): 1.5-3.0
Soil Description: Reddish Brown Clayey Silt

Sample Data:

Height (in):	6.0	Wet Density (pcf):	114.7
Diameter (in):	2.84	Dry Density (pcf):	82.6
Weight (g):	1143.6	Moisture %:	38.9

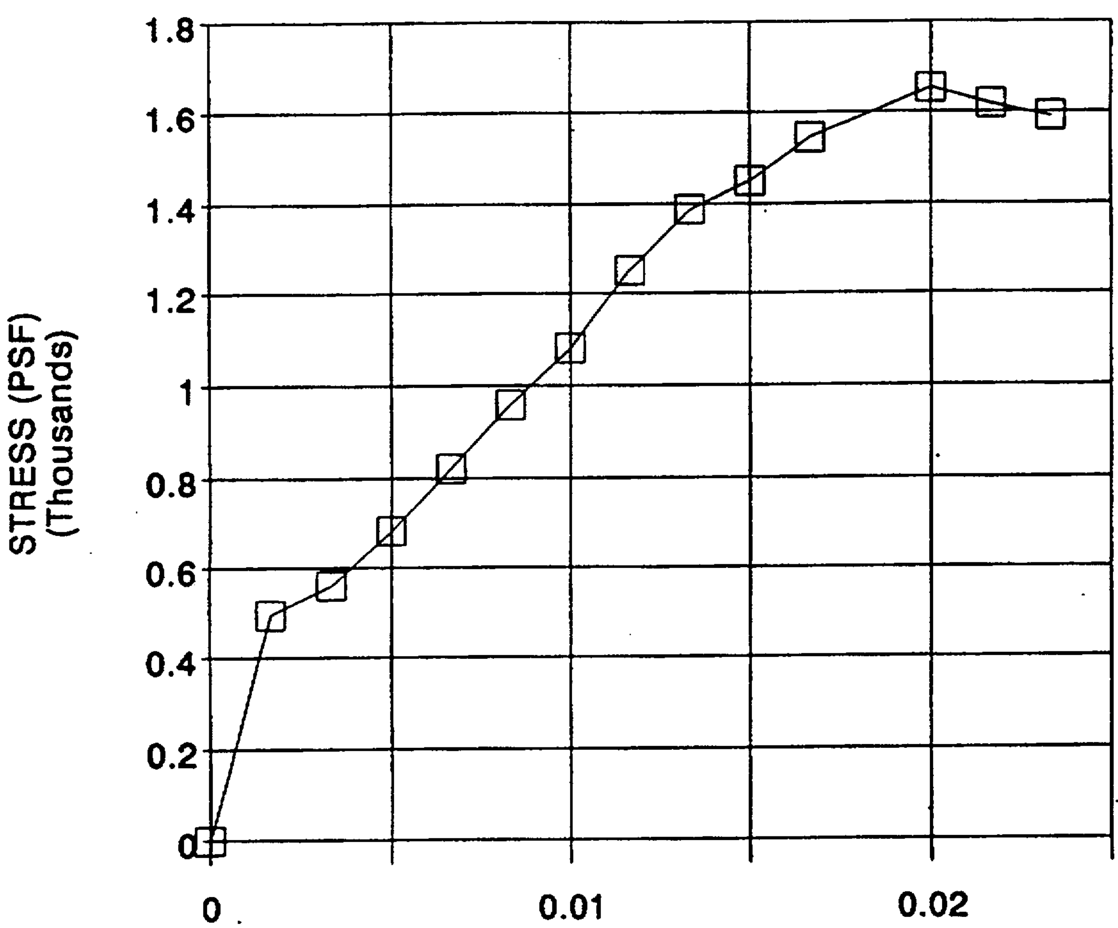
READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.33	0.00
2	0.010	60.0	21.82	0.002	6.34	495.34
3	0.020	68.0	24.72	0.003	6.35	560.45
4	0.030	83.0	30.18	0.005	6.36	682.94
5	0.040	100.0	36.36	0.007	6.37	821.44
6	0.050	117.0	42.54	0.008	6.38	959.47
7	0.060	132.0	48.00	0.010	6.40	1080.66
8	0.070	153.0	55.63	0.012	6.41	1250.47
9	0.080	170.0	61.81	0.013	6.42	1387.07
10	0.090	178.0	64.72	0.015	6.43	1449.89
11	0.100	190.0	69.08	0.017	6.44	1545.02
12	0.120	204.0	74.17	0.020	6.46	1653.24
13	0.130	200.0	72.72	0.022	6.47	1618.07
14	0.140	197.0	71.63	0.023	6.48	1591.08

MAX. AXIAL STRESS (psf) 1653.24

* Organics were observed along the sheer plane after termination of the test
** Shelby tube secured with backhoe

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: 7B1
Sample No.: UD - 1
Sample Depth (ft): 1.5-3.0

UNCONFINED COMPRESSION TEST



NI02B060

SINCE F&R 1961

UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample: UD-1
Sample Depth (ft): 4.0-6.0
Soil Description: Reddish Brown Clayey Silt

Sample Data:

Height (in):	6.0	Wet Density (pcf):	109.3
Diameter (in):	2.81	Dry Density (pcf):	80.9
Weight (g):	1067.5	Moisture %:	35.2

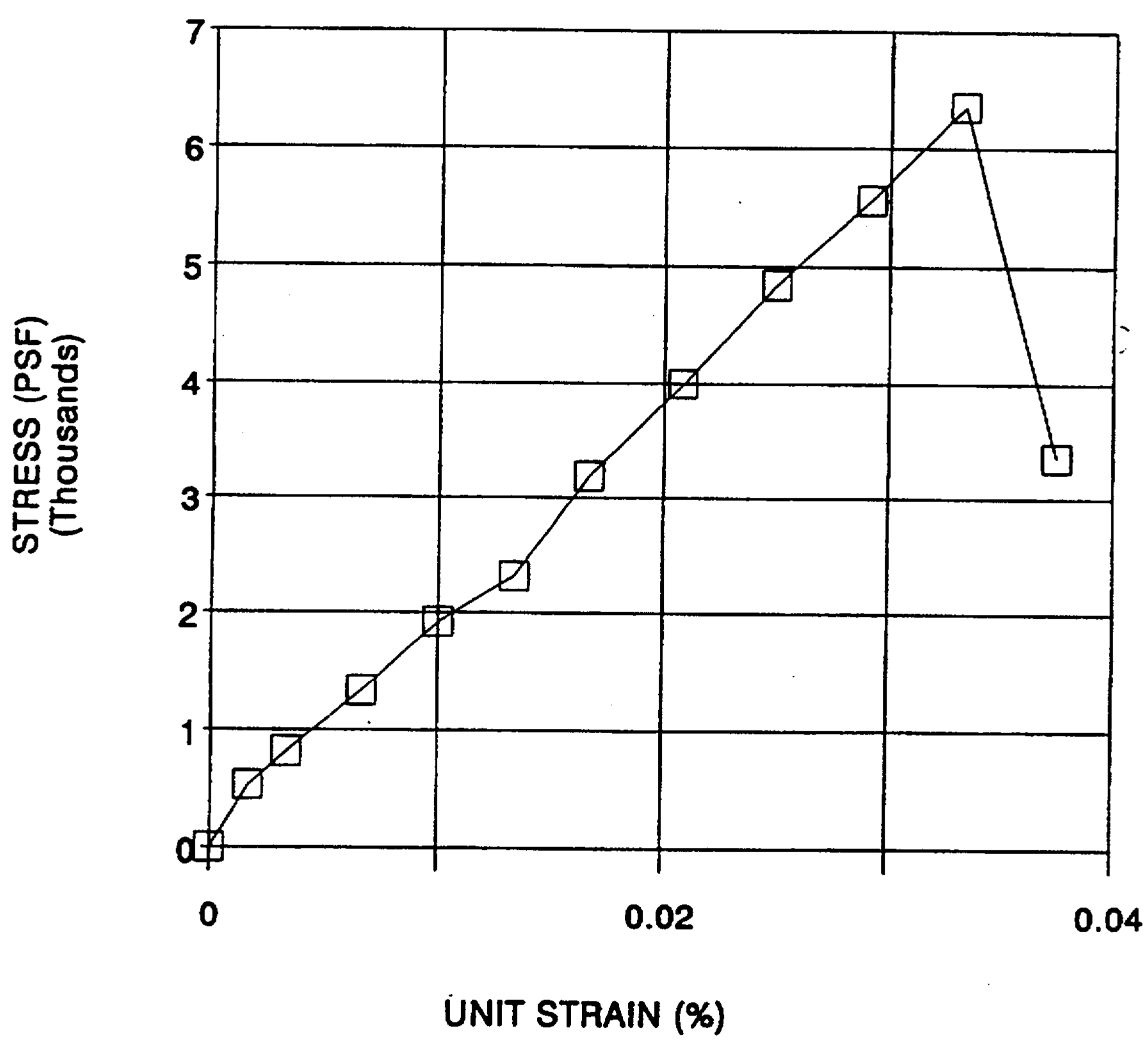
READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.20	0.00
2	0.010	64.0	23.27	0.002	6.21	539.71
3	0.020	98.0	35.63	0.003	6.22	825.05
4	0.040	159.0	57.81	0.007	6.24	1334.12
5	0.060	230.0	83.63	0.010	6.26	1923.39
6	0.080	278.0	101.08	0.013	6.28	2316.96
7	0.100	312.0	139.60	0.017	6.30	3189.09
8	0.125	357.0	175.60	0.021	6.33	3994.49
9	0.150	405.0	214.00	0.025	6.36	4847.29
10	0.175	446.0	246.80	0.029	6.38	5566.34
11	0.200	491.0	282.80	0.033	6.41	6350.92
12	0.225	325.0	150.00	0.038	6.44	3354.07

MAX. AXIAL STRESS (psf) 6350.92

NI02B061

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample No.: UD - 1
Sample Depth (ft): 4.0-6.0

UNCONFINED COMPRESSION TEST



NI02B062

UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample: UD-2
Sample Depth (ft): 16.0-18.0
Soil Description: Red and Brown Silty Sand

Sample Data:

Height (in):	6.0	Wet Density (pcf):	98.0
Diameter (in):	2.81	Dry Density (pcf):	72.1
Weight (g):	957.2	Moisture %:	36.1

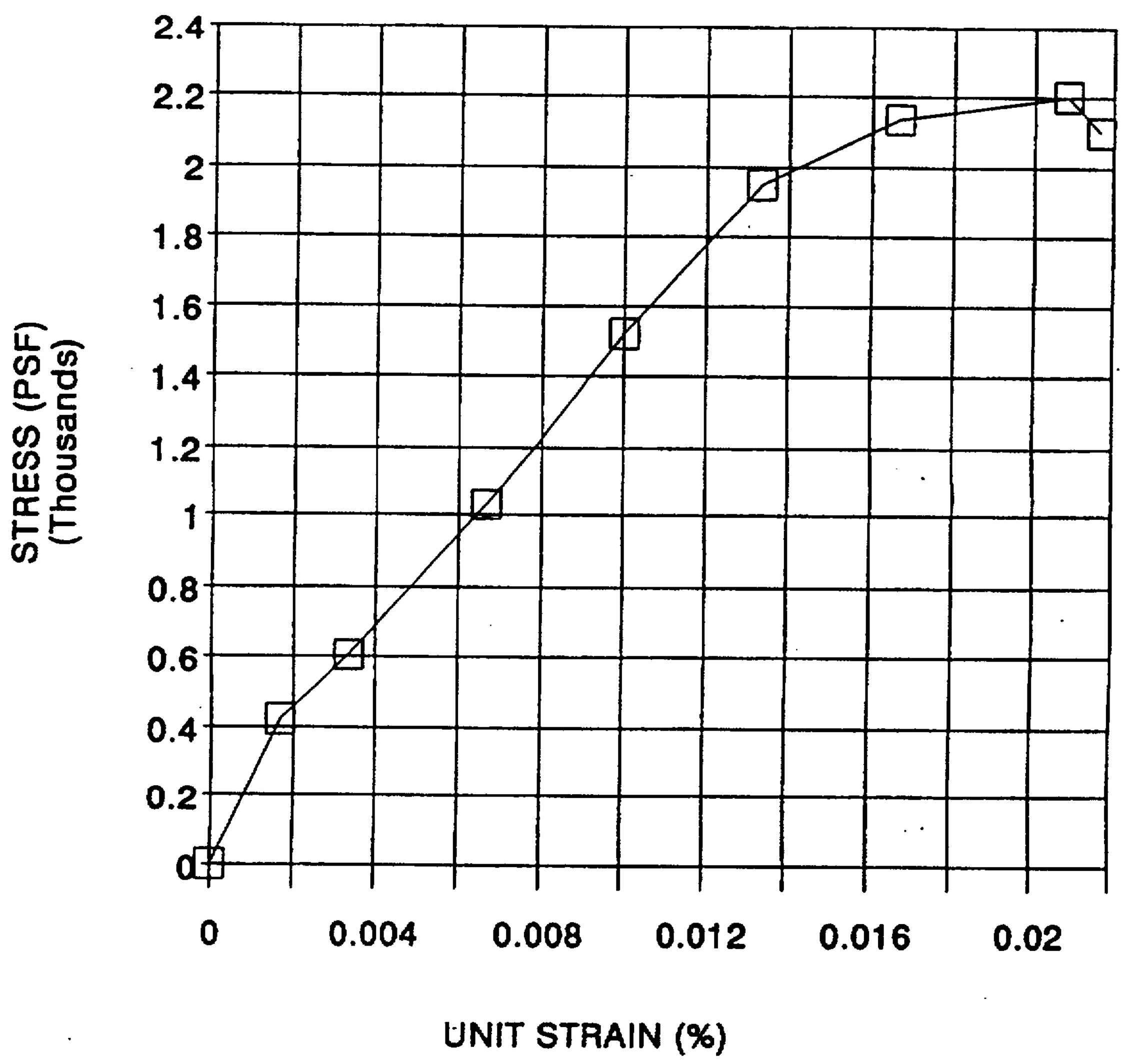
READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.20	0.00
2	0.010	50.0	18.18	0.002	6.21	421.65
3	0.020	72.0	26.18	0.003	6.22	606.16
4	0.040	123.0	44.72	0.007	6.24	1032.06
5	0.060	182.0	66.18	0.010	6.26	1521.99
6	0.080	234.0	85.08	0.013	6.28	1950.25
7	0.100	257.0	93.45	0.017	6.30	2134.71
8	0.125	266.0	96.72	0.021	6.33	2200.10
8	0.130	254.0	92.35	0.022	6.34	2099.06

MAX. AXIAL STRESS (psf) 2200.10

NI02B063

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-7A
Sample No.: UD-2
Sample Depth (ft): 16.0-18.0

UNCONFINED COMPRESSION TEST



NI02B064

UNCONFINED COMPRESSION TEST

Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-9A
Sample No.: UD - 1
Sample Depth (ft): 4.0-6.0
Soil Description: Reddish Brown Silty Sand

Sample Data:

Height (in):	6.0	Wet Density (pcf):	110.5
Diameter (in):	2.81	Dry Density (pcf):	85.0
Weight (g):	1079.1	Moisture %:	30.1

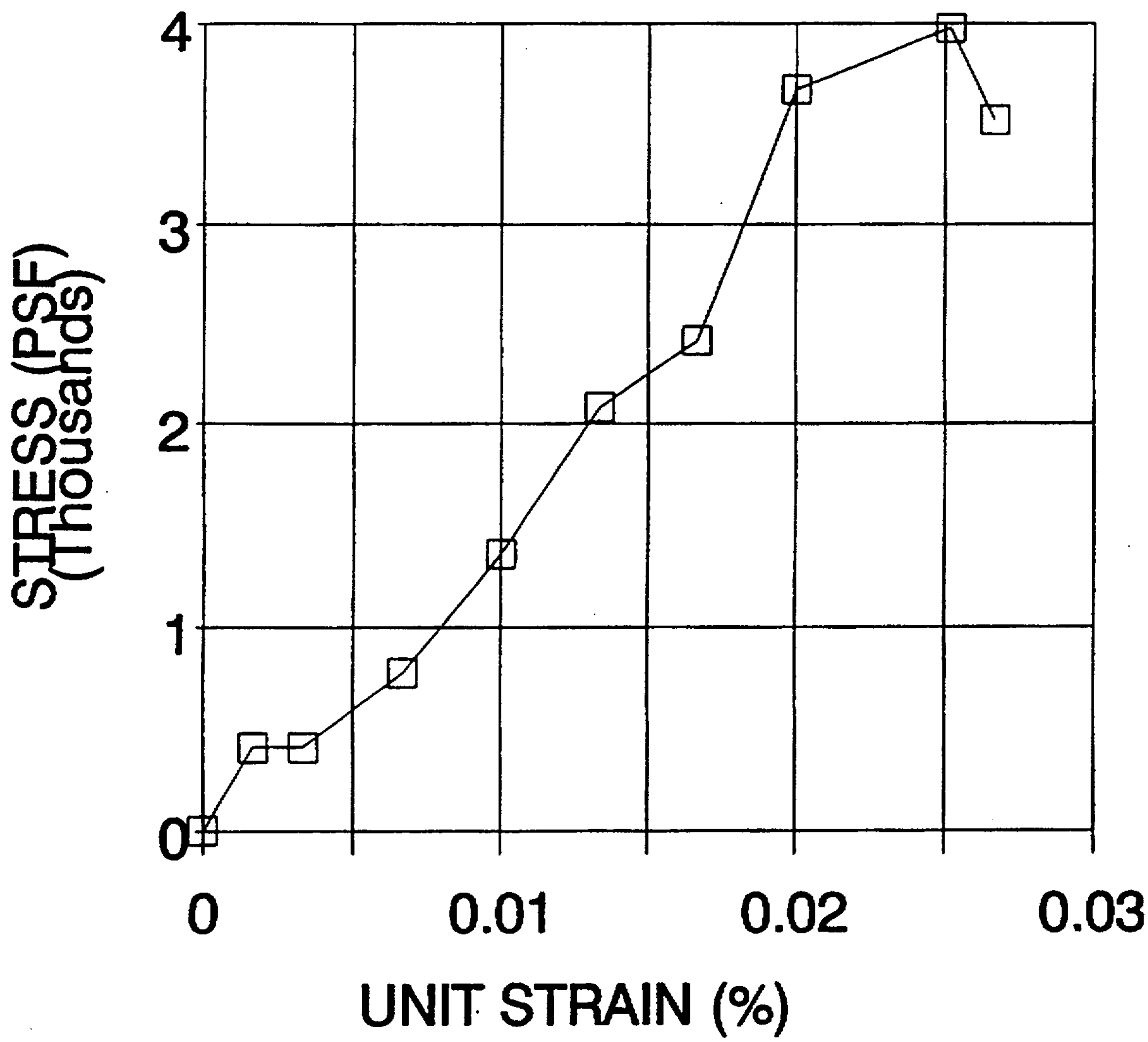
READING NUMBER	DEFORM DIAL READING	LOAD DIAL READING	LOAD (lbs)	UNIT STRAIN	CORRECT AREA (sq.in.)	AXIAL STRESS (psf)
1	0.000	0.0	0.00	0.000	6.20	0.00
2	0.010	48.0	17.45	0.002	6.21	404.78
3	0.020	48.0	17.45	0.003	6.22	404.11
4	0.040	92.0	33.45	0.007	6.24	771.95
5	0.060	163.0	59.27	0.010	6.26	1363.10
6	0.080	250.0	90.90	0.013	6.28	2083.60
7	0.100	291.0	105.81	0.017	6.30	2417.12
8	0.120	339.0	161.20	0.020	6.32	3670.04
9	0.151	357.0	175.60	0.025	6.36	3976.81
10	0.160	332.0	155.60	0.027	6.37	3518.45

MAX. AXIAL STRESS (psf) 3976.81

NI02B065

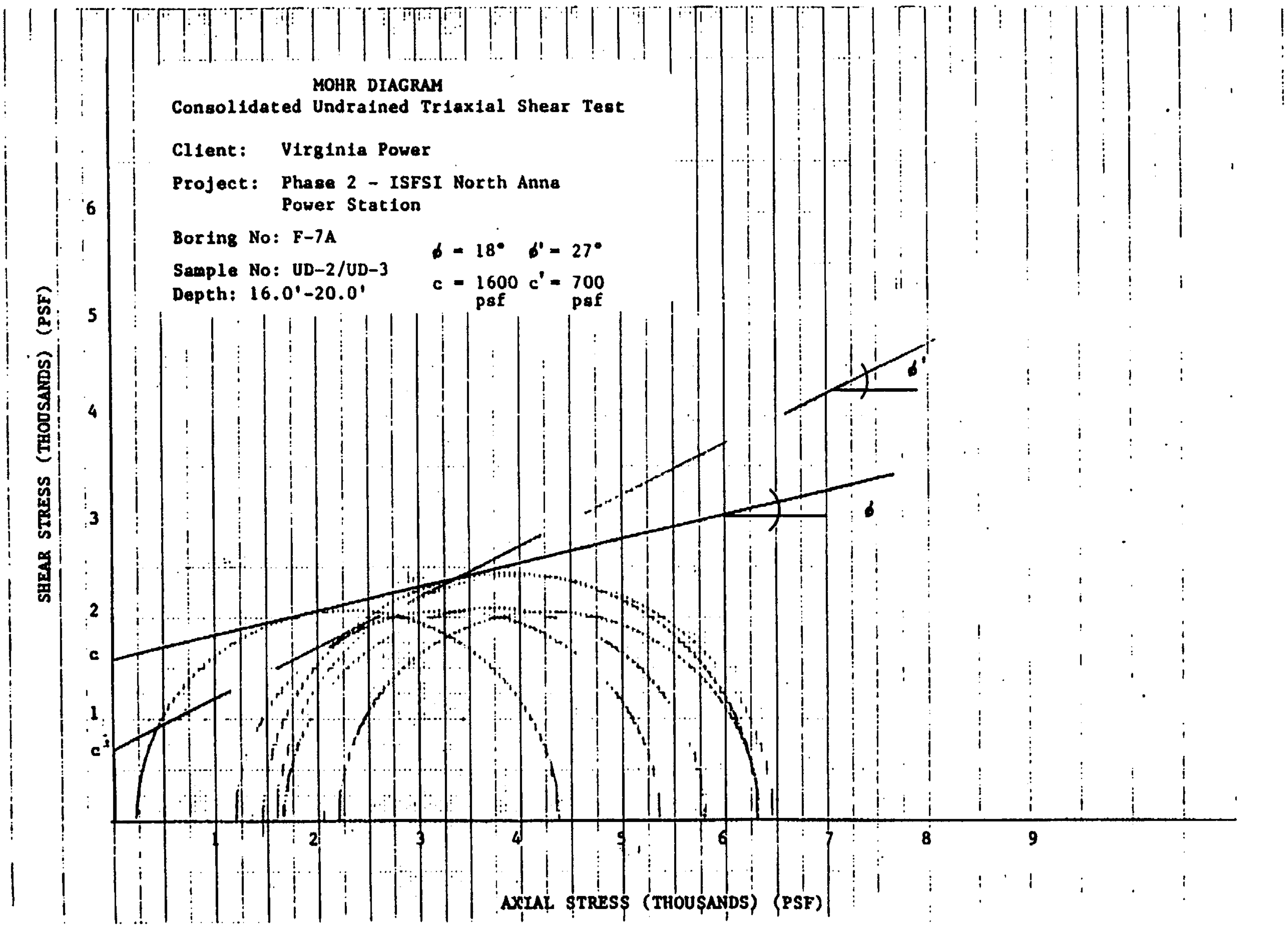
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
F&R #: V60-073
Boring: F-9A
Sample No.: UD - 1
Sample Depth (ft): 4.0-6.0

UNCONFINED COMPRESSION TEST



NI02B066

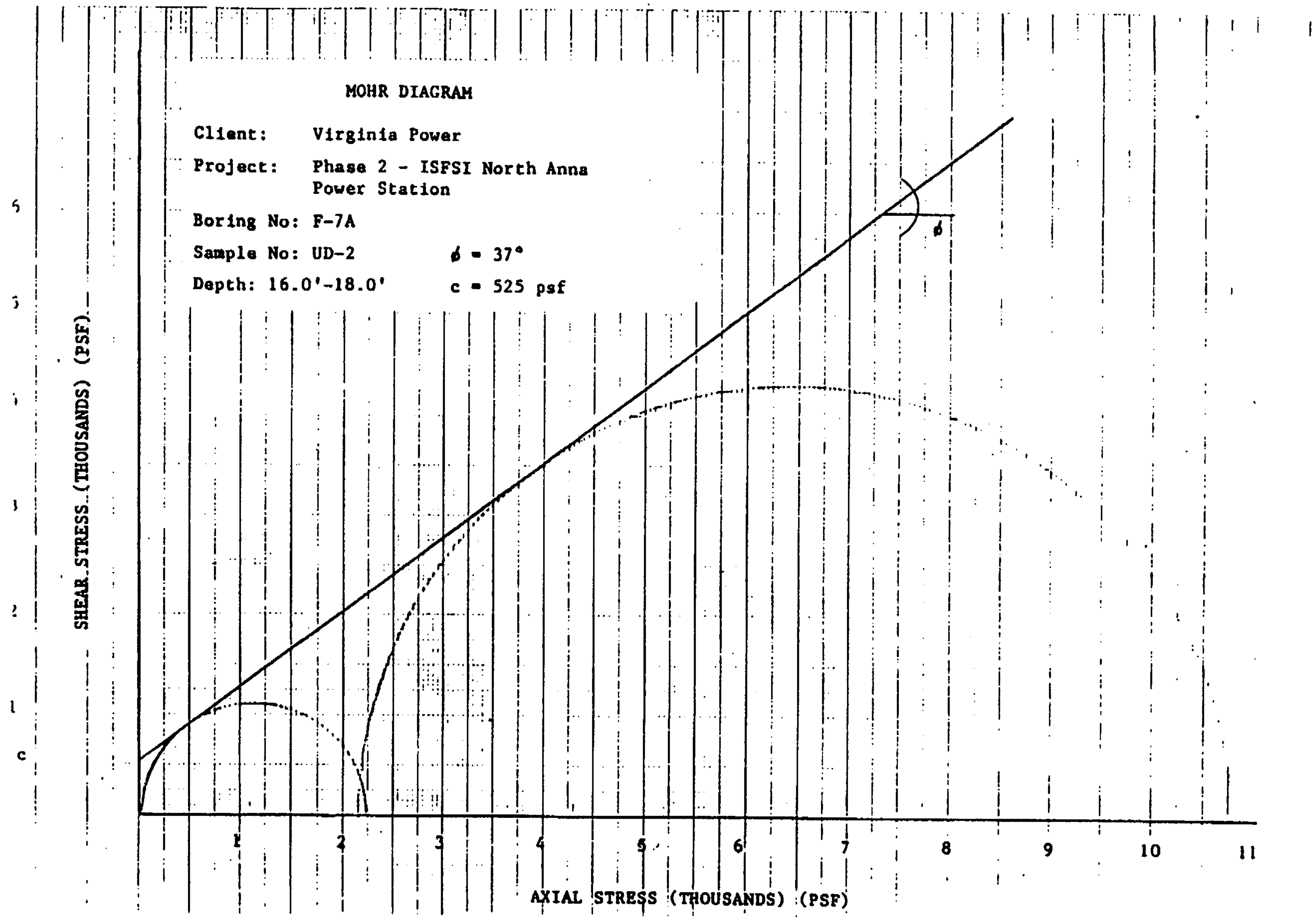
K+E 10 X 10 TO THE CENTIMETER 46 1510



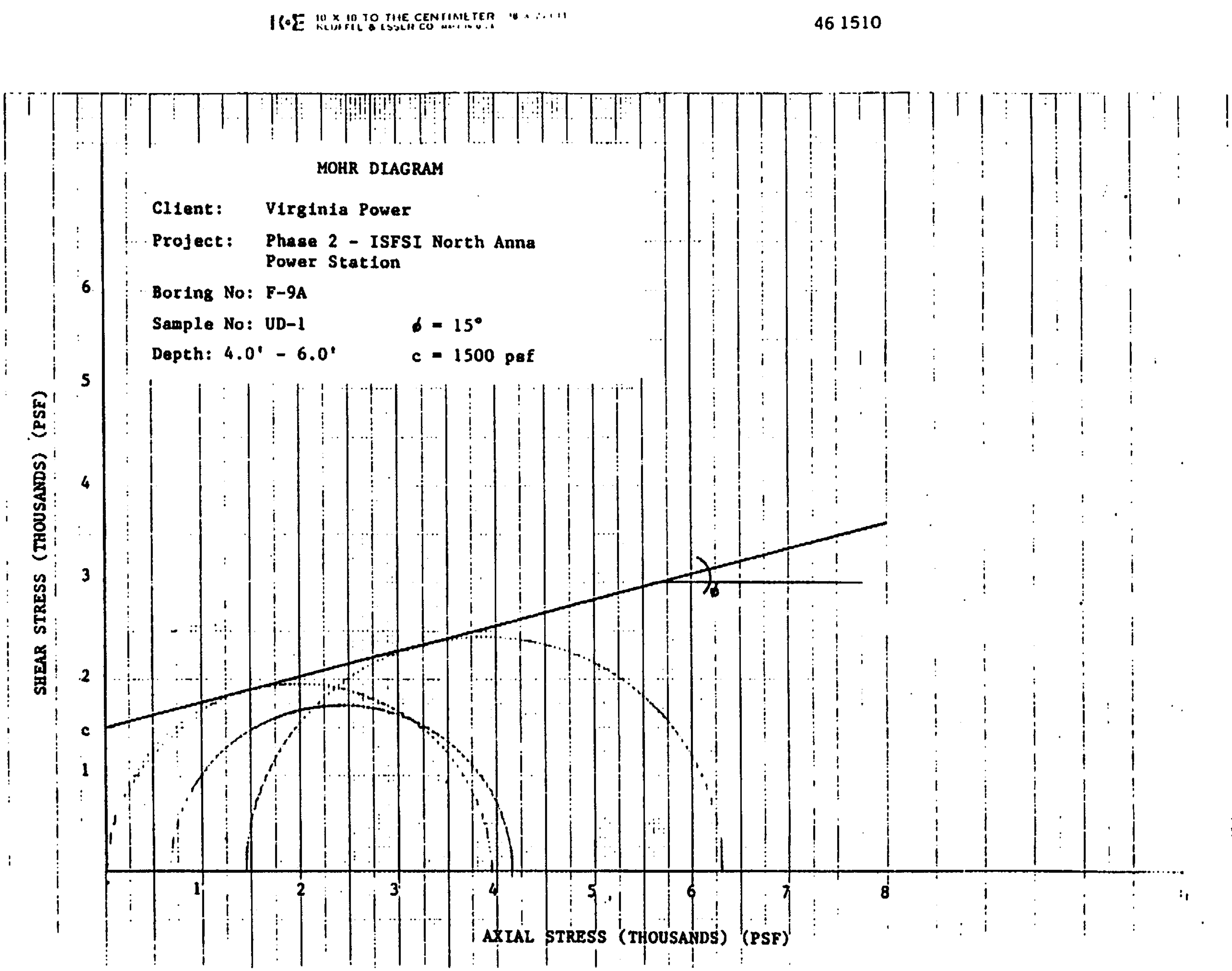
NI02B067

K&E 10 X 10 TO THE CENTIMETER
KEUFFEL & ESSER CO.

46 1510

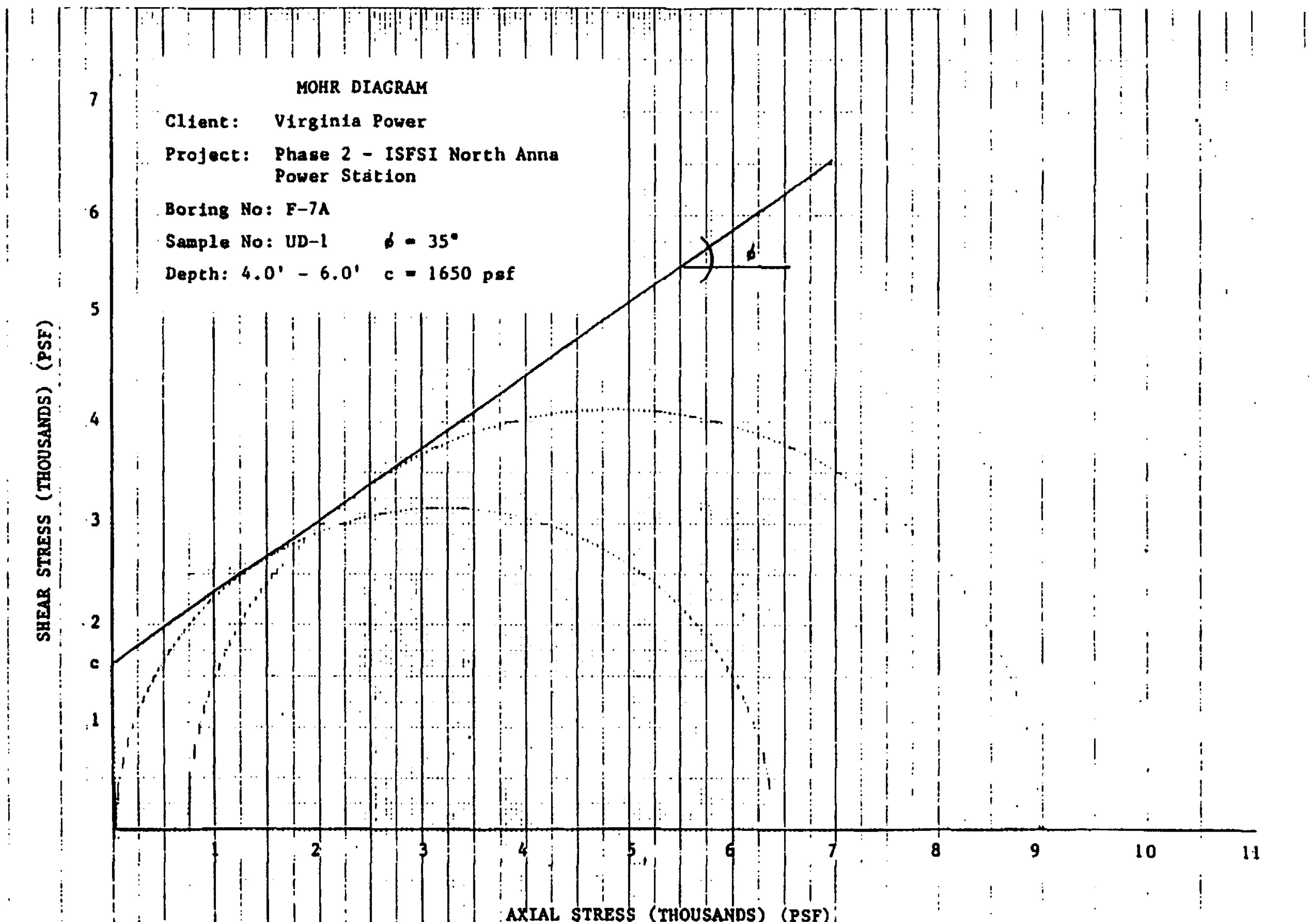


NI02B068


K&E 10 X 10 TO THE CENTIMETER
46 1510
MOHR DIAGRAM
Client: Virginia Power
Project: Phase 2 - ISFSI North Anna Power Station
Boring No: F-9A
Sample No: UD-1
Depth: 4.0' - 6.0'
ø = 15°
c = 1500 psf
SHEAR STRESS (THOUSANDS) (PSF)
AXIAL STRESS (THOUSANDS) (PSF)
c
1
2
3
4
5
6
7
8
ø

NI02B069

K+E 10 X 10 TO THE CENTIMETER 46 1510



NI02B070

Froehling & Robertson, Inc

PERMEABILITY TEST

ASTM 5084

CLIENT: Virginial Power
PROJECT: Phase 2 - ISFSI North Anna Power Station
F&R NO: V60-073

Date: August 24, 1994

Boring: F-7A   Sample: UD-2   Depth: 16.0-18.0
Sample Description: Red and Brown Silty Sand

SAMPLE DATA	
LENGTH (in.)	6.00
DIAMETER (in.)	2.81
AREA (cm^2)	40.01
VOLUME (cm^3)	609.75
WEIGHT (g)	1039.90
% MOISTURE	38.80
Dry Density (pcf)	78.70

PRESURE DATA (psi)	
CHAMBER PRESSURE	35
BACK PRESSUE, bottom	30
BACK PRESSUE, top	25
HEAD ACROSS SAMPLE	5

DATE	TIME	t (sec)	h_1 (in)	v_1 (cm^3)	h_2 (in)	v_2 (cm^3)	delta v_1	delta v_2	i	Q (cm^3/sec)	k (cm/sec)
August 16, 1994	08:15	0	21.8	7.3	13.0	44.5	0.0	0.0	24.53		
	12:25	15000	20.4	13.4	14.4	38.7	6.1	5.8	24.07	3.97E-04	4.12E-07
	14:02	5820	19.8	15.6	14.9	36.5	2.2	2.2	23.89	3.78E-04	3.95E-07
	15:02	3600	19.5	16.9	15.2	35.3	1.3	1.2	23.80	3.47E-04	3.65E-07
	16:26	5040	19.1	18.8	15.6	33.5	1.9	1.8	23.65	3.67E-04	3.88E-07
	16:43	1020	19.0	19.1	15.7	33.2	0.3	0.3	23.63	2.94E-04	3.11E-07

Avgerage k, 3.74E-07

NI02B071

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