

**REPORT OF  
GEOTECHNICAL EXPLORATION**

**Fort Smith National Cemetery  
Fort Smith, Sebastian County, Arkansas**

Prepared for:

**U. S. Department of Veterans Affairs  
Office of Construction Management (41F1)  
811 Vermont Avenue, NW  
Washington, DC 20420**

**MACTEC Project 6151-08-0263-01**

**December 2008**



engineering and constructing a better tomorrow

December 10, 2008

Mr. Lu Richards, PM  
U. S. Department of Veterans Affairs  
Office of Construction Management (41F1)  
811 Vermont Avenue, NW  
Washington, DC 20420

**Subject: Report of Geotechnical Exploration**  
Fort Smith National Cemetery  
Fort Smith, Sebastian County, Arkansas  
MACTEC Project 6151-08-0263-01

Dear Mr. Richards:

MACTEC Engineering and Consulting, Inc. (MACTEC) is pleased to submit this Report of Geotechnical Exploration for the Fort Smith National Cemetery project located on the blocks bordered by South B Street, South D Street, South 5<sup>th</sup> Street and South 7<sup>th</sup> Street in Fort Smith, Arkansas. Our work was performed in accordance with MACTEC proposal PROP08ATLN – Task 149, dated July 14, 2008. The purpose of this exploration was to evaluate general subsurface conditions and to provide geotechnical recommendations for site preparation, foundation and pavement design, and construction.

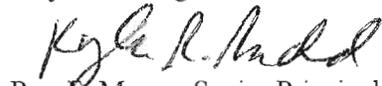
The primary geotechnical aspects for this project are the presence of silty soils and the existing fill material at or near the surface of the site. The site should be suitable for support of the proposed building on conventional shallow footings, roads, and 4' by 8' double-depth gravesites with the site preparation, foundation design, and construction considerations provided in this report.

The report briefly discusses our understanding of the project information, describes our exploratory procedures and findings, and presents our recommendations and conclusions. We appreciate your selection of MACTEC for this project and look forward to assisting you further on this and other projects. If you have any questions, please do not hesitate to contact us.

Sincerely,

**MACTEC Engineering and Consulting, Inc.**

  
Brandy R. Unger  
Project Geologist

  
Roy E. Moore, Senior Principal

For R. Moore With Permission



**Fort Smith National Cemetery  
Fort Smith, Arkansas  
MACTEC Project 6151-08-0263-01**

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## 1.0 PURPOSE OF EXPLORATION

The purpose of this exploration was to perform a site reconnaissance and to provide geotechnical recommendations for site preparation, foundation and pavement design and construction. Our scope of work included:

- A discussion of the overall exploration and laboratory testing program.
- A discussion of site subsurface conditions, including soil profiles and properties, geologic settings and characteristics, and subsurface water conditions, as revealed by the exploratory program.
- Comments and recommendations for design of foundations for engineered structures.
- Comments and recommendations for pavement sections for maintenance roads, building support area, parking, and access roads.
- Comments and recommendations relative to earthwork operations, site preparation, and suitability of on-site materials for use as engineered fill.

The scope of this exploration did not include geologic or seismic studies for the site. Accordingly, our conclusions and recommendations are for static loading conditions only; however, this does not imply that there are no geologic or seismic hazards affecting the site. The assessment of general site environmental conditions or the presence of pollutants in the soil, rock, and ground water of the site was beyond the scope of this exploration.

Our conclusions and recommendations are based on the results of our field explorations, laboratory tests, and appropriate engineering analyses. The results of the field exploration and laboratory tests, which form the basis of our recommendations, are presented in the attached appendices.

## 2.0 PROJECT INFORMATION

Project information was provided to MACTEC's Mr. Russ Zora via e-mail by Mr. Charlie Phillips of MACTEC on April 22, 2008. The project site is located on the blocks bordered by South B Street, South D Street, South 5<sup>th</sup> Street and South 7<sup>th</sup> Street in Fort Smith, Arkansas. A **Site Vicinity Map** is provided as **Figure 1 in Appendix A.**

The proposed project at this site includes construction of 4 foot by 8 foot double-depth gravesites, roads, and possible buildings. Loading conditions for the structure or structures at this site were not available at the time of this report, but are anticipated to be light. The maximum floor load for the possible building is expected to be in the order of 125 pounds per square foot (psf). Building location(s) on the site is also unknown at this time.

## 3.0 FIELD EXPLORATION AND LABORATORY TESTING

### 3.1 Drilling and Sampling

Subsurface conditions at the site were explored by advancing 16 soil test borings at the approximate locations shown on the attached **Figures 2, Boring Location Plan, in Appendix A.** All borings were advanced to an approximate depth of 10 feet below the existing ground surface. The boring locations and depths proposed by MACTEC were based on the project information provided to us. The boring locations were staked in the field using preliminary drawings and a measuring wheel. These locations should be considered accurate within customary limits for the methods employed.

The borings were advanced utilizing a truck-mounted drill rig with solid flight augers. Drilling operations were performed by a subcontract driller. Disturbed soil samples were obtained using a “split barrel” standard penetration test (SPT) sampler in cohesive and granular materials in accordance to ASTM D 1586. The “split barrel” sampling procedure utilized a standard two-inch O.D. split barrel sampler that was driven into the bottom of the boring with a 140-pound automatic hammer system, falling a distance of 30-inches. The number of blows required to advance the sampler 18-inches was recorded in 6-inch increments. The number of blows for the last 12-inches of the 18-inch penetration was recorded as the Standard Penetration Resistance (SPT-N) value. The SPT-N values provide an indication of the relative density of the granular materials and consistency of cohesive materials encountered in the borings.

Drilling and sampling was performed in general compliance with applicable ASTM standards. The soil samples obtained in the borings were sealed and returned to our laboratory with the field logs for further examination, classification, and laboratory testing. Detailed subsurface conditions encountered at the boring locations are shown on the **Soil Test Boring Records** presented in **Appendix B**. The Soil Test Boring Records represent our interpretation of the field conditions based on the field logs together with engineering observation and classification of the soil samples in our laboratory. The lines designating the interfaces between various strata represent approximate boundaries only, as transitions between materials may be gradual.

### **3.2 Laboratory Testing**

Laboratory tests were performed on selected samples obtained from the borings to aid in the classification of the soils and to evaluate the engineering properties of the foundation soils. Testing was performed in general accordance with applicable ASTM specifications. Soil classifications are in accordance with the Unified Soil Classification System (USCS) using ASTM method D 2488. Moisture content (ASTM D 2216), Atterberg limits (ASTM D 4318), and sieve analysis (ASTM D 422) were performed on these samples.

Laboratory test results are provided on the Soil Test Boring Records and in **Appendix C** of this report. Detailed descriptions of testing procedures are presented with the laboratory test data in **Appendix C**.

## 4.0 SITE AND SUBSURFACE CONDITIONS

### 4.1 Site Conditions

The project site is located adjacent to the existing Fort Smith National Cemetery and is currently used a baseball complex with five baseball diamonds. Based on the NRCS website, the soils at the site are comprised of the Leadvale Series. This series is characterized by a very deep, moderately well drained, and slow to moderately slowly permeable soil. The unit formed in silty materials in uplands or local silty alluvium from nearby uplands underlain largely by shale and siltstone or in places by sandstone, phyllite, and slate. Topographically, the site is relatively level with some surface fill material present in the southwest portion of the property.

### 4.2 Subsurface Conditions

The general stratigraphy in the borings consists of layers of silty sand, silt with sand, lean clay with sand, and lean clay extending from the surface to approximate depths of 2 to 3.5 feet below the existing ground surface. Borings B-6 and B-7 consisted of fill material containing some gravel and extending from the surface to an approximate depth of 5 feet. Borings B-6 and B-12 terminated in lean clay with sand at a depth of 9.5 feet. All other borings terminated in lean clay to approximate depths of 10 feet below existing ground surface. Standard penetration test N-values in soils within the top 5 feet of each boring ranged from 3 to 23 blows per foot of penetration, corresponding to relative densities ranging from loose to medium dense. Standard penetration test N-values in soils within the bottom 5 feet of each boring ranged from 7 to 25 blows per foot of penetration, corresponding to relative consistencies ranging from stiff to very stiff.

Laboratory tests performed on selected samples of the subsurface soils indicated a natural moisture content ranging from 16 to 29 percent. Atterberg limits tests resulted in liquid limit values ranging from nonplastic (NP) to 49. Plastic limit values ranged from NP to 19 and corresponding plasticity indexes (PI) ranged from NP to 35. Grain size analyses performed on the selected samples indicated 31 to 98 percent fines passing the No. 200 sieve.

## **Groundwater Conditions**

Subsurface observations were made in the borings during the drilling operations to observe the short-term ground water levels. Water was not encountered in any of the borings during or after drilling. Fluctuations in rainfall, evaporation, construction activity, surface runoff, and other site specific factors could cause ground water elevations at the time of construction to vary from that observed during this exploration event.

## **5.0 CONCLUSIONS AND RECOMMENDATIONS**

The following conclusions and recommendations are based on the previously discussed project information and assumptions, our observations at the site, interpretation of the field data obtained during the exploration, and our experience with similar subsurface conditions. Subsurface conditions in uninvestigated locations may vary from those encountered at specific boring locations. Additional consultation and/or investigation may be required as the project develops.

### **5.1 Grading Recommendations**

We understand that existing site grades are approximately level with the planned grades and anticipated finished floor elevations. Therefore, site grading is anticipated to be minimal; however, we are providing site preparation recommendations for your convenience.

Prior to proceeding with construction, vegetation, root systems, topsoil, refuse and other deleterious non-soil materials should be stripped from proposed construction areas. Clean topsoil may be stockpiled and re-used later in landscaped areas.

After clearing and stripping, areas intended to support floor slabs, new fill and foundations should be carefully observed by a geotechnical engineer. At that time, the engineer may require proofrolling of the subgrade with a 20 to 30-ton loaded truck or other pneumatic-tired vehicle of similar size and weight. The purpose of the proofrolling is to locate soft, weak or excessively wet soils present at the time of construction. Unsuitable soils containing deleterious materials, or that are soft or wet, noted during the observation and proofrolling operations should be undercut and replaced with compacted fill or stabilized in-place.

Fill material to replace undercut areas or to achieve finished grades should be low to moderate plasticity soils (PI less than 30), be free of deleterious materials and contain no gravel or rock fragments larger than 3 inches in diameter. Structural fill should be placed in maximum 8-inch thick loose lifts and compacted to at least 95 percent of the soil's maximum dry density as determined by the standard Proctor compaction test (ASTM D 698). The upper eight inches of soil beneath pavements and building slabs should be compacted to at least 98 percent. Soil moisture during placement and compaction should be maintained within 3 percent of the optimum moisture content. Fill should be placed in horizontal lifts and adequately keyed into stripped and scarified subgrade soils.

## **5.2 Foundations**

The natural soils encountered and acceptable fill material, when prepared as described above, will allow support of light building loads using conventional, shallow foundations. Foundations bearing on undisturbed soils or compacted structural fill may be designed for a maximum allowable bearing pressure of 3,000 pounds per square foot (psf).

Several soil layers of a soft to loose consistency were encountered in the upper 5 feet. These zones, if not excavated and compacted, may contribute to settlement of foundations. We expect most of the settlement due to the dead loads would be on the order of 1 inch and would occur relatively soon after completion of construction. Remaining settlement due to live loads would also likely occur relatively quickly as the load is applied and the magnitude will be related to the amount of the load that is generally long term load rather than short term live loads such as wind or seismic.

We anticipate that differential settlements of less than 1 inch may be associated with the settlement described above and are typically permissible for the type of structures anticipated at this time. We recommend foundation widths of not less than 24 inches for footings for ease of construction and to reduce the possibility of localized shear failures. In addition, exterior footing bottoms should be at least 18 inches below the lowest, adjacent, exterior grades for stability. Interior foundations should be at least 12 inches below the bottom of the adjacent floor slab. A qualified geotechnical engineer should observe all footing excavations and assess if the foundations are placed on a competent bearing stratum similar to the soils encountered in our borings.

### **5.3 Slabs**

Soil supported slabs should be jointed around columns and along footing supported walls to minimize cracking as a result of differential movement. A modulus of subgrade reaction of  $k_s$ , of 100 pounds per cubic inch (pci) may be used for preliminary slab design. An appropriate vapor barrier should be placed beneath the slab based on the type of floor covering, and the manufacture's recommendations, that will be installed. All slabs-on-grade should be detailed by a structural engineer, and should be at least 4 inches thick with appropriate reinforcement.

### **5.4 Pavements**

In order for service roads and vehicle parking areas to perform satisfactorily, the subgrade soils must have sufficient strength and be stable enough to avoid deterioration from construction traffic and service vehicles. Existing site grades appear stable, but were not observed in wet conditions. The final design California Bearing Ratio (CBR) value will depend on the subgrade soil present after the site is graded. We anticipate that compacted site soils, as observed in the borings, would have a CBR of about 4, if saturated. If granular (sandy) fill is brought to the site for subgrade or to raise site grades, higher CBR's may be available.

A uniform, well-drained subgrade is critical to long term pavement life. The pavement section should include a base drainage layer of graded aggregate and provision should be made to allow water to drain out of the base. Subgrade should be sloped to drain and suitable outlets for water from the base should be provided at curb or drop inlets to prevent accumulation of water over the clayey subgrade.

Pavements may be designed for anticipated traffic based on a (CBR) value of 4. Pavement subgrade should be sloped to drain and all flexible and rigid pavements should have a minimum of 6 inches of appropriate graded aggregate (GAB) base for strength and drainage. GAB should be provided with filtered outlets into storm drains or at the pavement edges to prevent trapping water over the subgrade and consequent saturation of the subgrade. A minimum flexible pavement of 4 inches of surface course asphalt over 6 inches of GAB is recommended for areas subject to automotive traffic and the occasional light truck. Thicker pavement sections may be required depending upon anticipated traffic loads. Where rigid pavement is deemed warranted, a minimum rigid (concrete) pavement of 7 inches of 4,000 psi concrete is recommended. Dumpster pads should be rigid pavement and should be large enough to accommodate the front wheels of the garbage truck. Areas where heavy trucks will maneuver should also consider rigid pavements. The geotechnical engineer or his representative should observe proofrolling (see Grading Recommendations section above) of pavement subgrade to confirm that these recommendations are acceptable.

## **5.5 Excavations**

The site soils, as described above, should not be expected to support stable vertical excavations over 4 feet deep. Standard OSHA guidelines for support of all temporary excavations should be strictly observed. Should design criteria for shoring be required, appropriate guidelines and values can be provided upon request and authorization.

## 6.0 QUALIFICATIONS OF RECOMMENDATIONS

Our evaluation of foundation design and construction conditions has been based on our understanding of the site and project information, interpretation of the data obtained during our field exploration, and our experience with similar subsurface conditions. The general subsurface conditions used were based on interpolation of the subsurface data between the borings. The design recommendations in this report have been developed on the basis of the previously described project characteristics and our interpretation of subsurface conditions. If project criteria or locations are not as described, these recommendations should be reviewed and revised.

Subsurface conditions in unexplored locations may vary from those encountered at specific boring locations. The nature and extent of variations between the borings may not become evident until the course of construction. Regardless of the thoroughness of a subsurface investigation, there is the possibility that conditions between borings will differ from those at the boring locations, that conditions are not as anticipated by the designers, or that the construction process has altered the soil conditions.

Our professional services have been performed, our findings derived, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties either expressed or implied. This company is not responsible for the conclusions, opinions or recommendations of others based on these data.

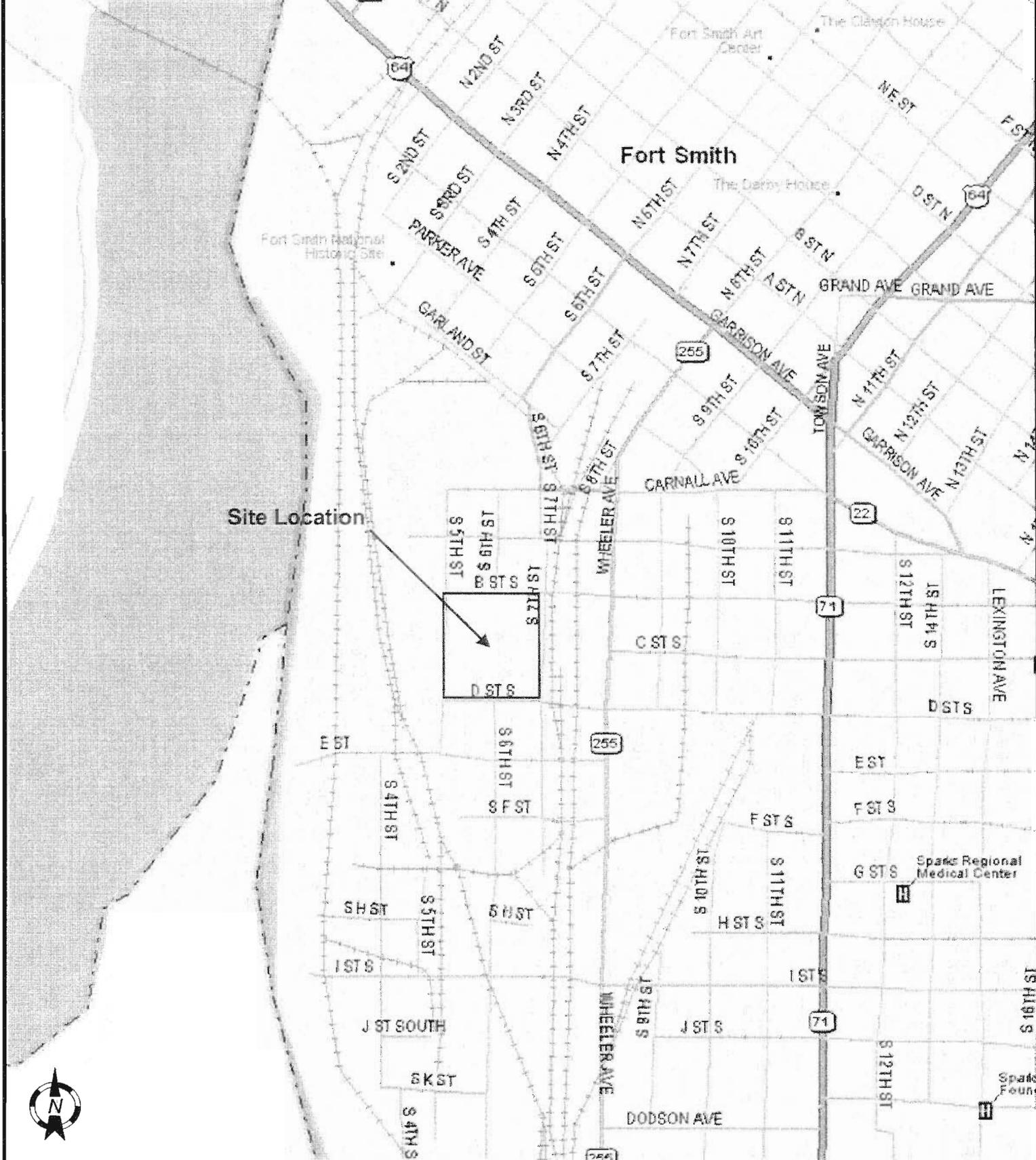


# **APPENDIX A**

## **DRAWINGS AND FIGURES**

Our drawings and figures are assembled from drawings and information supplied to us by others, together with our field measurements, tests, and observations. The plans and profiles are intended to provide clarification of the report discussions, and to aid in the understanding of the field conditions.





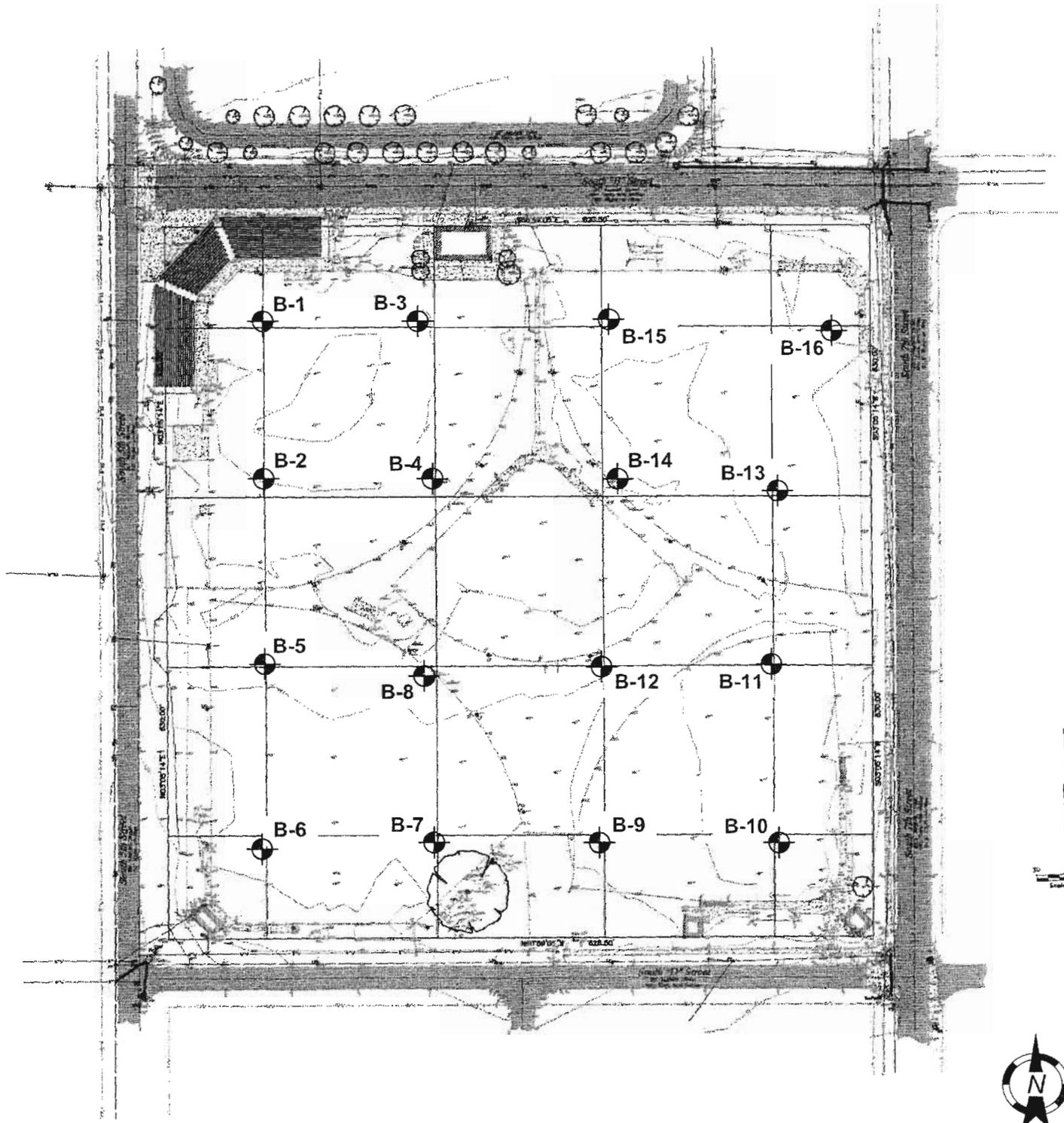
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|                                     |               |
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| Source: DeLorme                     |               |
| Scale: Not to Scale                 |               |
| Drawn By: K. Rudd                   | Date: 12/4/08 |
| Checked By: <i>K. Rudd 12-10-08</i> |               |

**FIGURE 1**  
**SITE VICINITY MAP**

Fort Smith National Cemetery  
 Fort Smith, Sebastian County, Arkansas

MACTEC PROJECT 6151-08-0263/01



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| Drawn By: K. Rudd               | Date<br>12/4/08 |
| Checked By: <i>Tom 12-10-08</i> |                 |

**FIGURE 2**  
**BORING LOCATION PLAN**

Fort Smith National Cemetery  
 Fort Smith, Sebastian County, Arkansas

MACTEC PROJECT 6151-08-0263/01

# **APPENDIX B**

## **FIELD OPERATIONS**

The general field procedures employed by MACTEC Engineering and Consulting, Inc. are summarized in ASTM Specification D-420, entitled "Investigating and Sampling Soils and Rocks for Engineering Purposes." This recommended practice lists recognized methods for determining soil and rock distribution and groundwater conditions. These methods include geophysical and in situ methods as well as borings.

The detailed collection methods used during this study are discussed on the following pages in this Appendix.



# STANDARD DRILLING TECHNIQUES

To obtain subsurface samples, borings are drilled using one of several alternate techniques, depending upon the subsurface conditions. These techniques are:

- In Soils:
- a) Continuous hollow stem augers
  - b) Continuous solid stem augers
  - c) Rotary borings with roller cones or drag bits, using water or drilling mud to flush the hole
  - d) Hand auger
- In Rock:
- a) Core drilling with diamond-faced double-tube core barrels

## **Hollow Stem Auger**

A hollow stem auger consists of a hollow steel tube with a continuous exterior spiral flange termed a flight. The auger is screwed into the ground, returning the cuttings along the flights. The hollow center permits a variety of sampling and testing tools to be used without removing the auger.

## **Solid Stem Auger**

A solid stem auger consists of a smaller diameter auger, similar to the hollow stem, but not large enough to permit sampling through the center of the auger. The solid stem must be removed from the boring to allow for sampling.

## **Rotary Borings**

Rotary drilling involves the use of roller cone or drag type drill bits attached to the end of standard drill rods. A flushing medium, normally water or bentonite slurry, is pumped through the rods to clear the cuttings from the bit face and flush them to the surface. Temporary casing is sometimes installed behind the advancing bit to prevent the hole from collapsing and to restrict the penetration of the drilling fluid into the surrounding soils. Cuttings returned to the surface by the drilling fluid are typically collected by screens and in a settling tank, thus allowing the fluid to recirculate.

## **Hand Auger Boring**

Hand auger borings are advanced by manually twisting a 4" diameter steel bucket auger into the ground and withdrawing it when filled to examine the sample collected. Occasionally these hand auger borings are used for driving 3" diameter steel tubes to obtain soil samples. These samples are used for soil classification purposes only.

## **Core Drilling**

Soil drilling methods are not normally capable of penetrating through hard cemented soil, weathered rock, coarse gravel or boulders, thin rock seams, or the upper surface of sound or jointed rock. Material, which cannot be penetrated by auger or rotary soil-drilling methods at a reasonable rate, is designated as "refusal material". Core drilling procedures are required to penetrate and sample refusal materials.

Prior to coring, casing may be set in the drilled hole through the overburden soils, to keep the hole from caving and to prevent excessive water loss. The refusal materials are then cored according to ASTM D-2133 using a diamond-studded bit fastened to the end of a hollow double tube core barrel. This device is rotated at high speeds, and the cuttings are brought to the surface by circulating water. Core samples of the material penetrated are protected and retained in the swivel-mounted inner tube. Upon completion of each drill run, the core barrel is brought to the surface, the core recovery is measured, and the core is placed, in sequence, in boxes for storage and transported to the laboratory.



## SAMPLING AND TESTING IN BOREHOLES

Several techniques are used to obtain samples and data in soils, however the standard methods are:

- a) Standard Penetration Testing
- b) Undisturbed Sampling
- c) Dynamic Cone Penetrometer
- d) Water Level Readings

These procedures are discussed below. Any additional testing techniques employed during this study are discussed in other sections of this Appendix.

### **Standard Penetration Testing**

At regular intervals, the drilling tools are removed and soil samples obtained with a standard 2" diameter split tube sampler connected to an AW-rod. The sampler is first seated 6" to penetrate any loose cuttings, then driven an additional 12" with blows of 140 lb. safety hammer falling 30". Generally, the number of hammer blows required to drive the sampler the final 12" is designated the "penetration resistance" or "N" value, in blows per foot (bpf). The split barrel sampler is designed to retain the soil penetrated, so that it may be returned to the surface for examination. Representative portions of the soil samples obtained from each split barrel sample are placed in jars or bags, sealed and transported to our laboratory.

The standard penetration test, when properly evaluated, provides an indication of the soil strength and compressibility. The tests are conducted according to ASTM Specification D-1586. The depths and N-values of Standard Penetration tests are shown on the Test Boring Record. Split barrel samples are suitable for visual examination and classification tests but are not sufficiently intact for quantitative laboratory testing.

### **Undisturbed Sampling**

Relatively undisturbed samples are obtained by pushing a 3" diameter steel tubing (Shelby Tube) into the soil at the desired sampling levels (ASTM Designation D-1587). Each tube, together with the encased soil, is removed from the ground, extruded at the surface or in the laboratory, capped or sealed with wax, and transported to the laboratory. Locations and depths of undisturbed samples are shown on the Test Boring Record.

### **Dynamic Cone Penetrometer**

The Dynamic Cone is a hand-operated penetrometer used in hand auger borings and test pits. This test is intended to provide data that can be correlated to the Standard Penetration Test. A 1.5" diameter cone is seated to penetrate any loose cuttings, then driven two, 1-3/4" increments with blows from a 15-pound weight falling 20". The average number of blows required to drive the two increments is an index to soil strength and density, and is designated as "n".

### **Water Level Readings**

Water table readings are normally taken in the borings and are recorded on the Test Boring Records. In sandy soils, these readings indicate the approximate location of the hydrostatic water table at the time of our field investigation. In clayey soils, the rate of water seepage into the boring is low and it is generally not possible to establish the location of the hydrostatic water table through short-term water level readings. Also, fluctuation in the water table should be expected with variations in precipitation, surface run-off, evaporation and other factors. For long-term monitoring of water levels, it is necessary to install standpipes or piezometers.

The water level reported on the Test Boring Records is determined by field crews immediately after the drilling tools are removed, and several hours after the borings are completed, if possible. The time lag is intended to permit stabilization of the groundwater table, which may have been disrupted by the drilling operation. Occasionally the borings will cave-in, preventing water level readings from being obtained or trapping drilling water above the caved-in zone. The cave-in depth is measured and recorded on the Test Boring Records, under these circumstances.

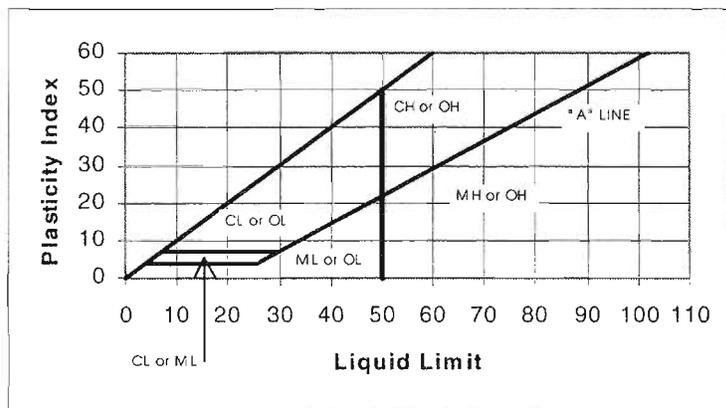
# UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified by the Unified Soil Classification system on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, please refer to ASTM Designation D-2487 or US Army Technical Memorandum No. 3-357.

| MAJOR DIVISIONS   |  | GROUP SYMBOL   | TYPICAL NAMES                               |  |
|---|--|--|---|--|
| <b>COARSE GRAINED SOILS</b><br>(Less than 50% passes No. 200 sieve) | <b>GRAVELS</b><br>(Less than 50% of coarse fraction passes No. 4 sieve)        | <b>CLEAN GRAVELS</b><br>(Less than 5% passes No. 200 Sieve)    |   |  |
|   |  | GW   | Well-graded gravels, gravel-sand mixtures.  |  |
|   |  | GP   | Poorly graded gravel, gravel-sand mixtures. |  |
|   |  | GM   | Silty gravels, gravel-sand-silt mixtures.   |  |
|   | <b>SANDS</b><br>(50% or more of coarse fraction passes No. 4 sieve)            | <b>CLEAN SANDS</b><br>(Less than 5% passes No. 200 Sieve)      |   |  |
|   |  | SW   | Well-graded sand, gravelly sands.           |  |
|   |  | SP   | Poorly graded sand, gravelly sands.         |  |
|   |  | SM   | Silty sand, sand-silt mixtures.             |  |
| <b>FINE GRAINED SOILS</b><br>(50% or more passes No. 200 sieve)     | <b>SILTS</b><br>Limits Plot below "A" line & hatched zone on Plasticity Chart  | <b>SILTS OF LOW PLASTICITY</b><br>(Liquid Limit Less than 50)  | ML  | Inorganic silts, clayey silts with slight plasticity.  |
|   |  | <b>SILTS OF HIGH PLASTICITY</b><br>(Liquid Limit More Than 50) | MH  | Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.                     |
|   | <b>CLAYS</b><br>Limits Plot above "A" line & hatched zone on Plasticity chart. | <b>CLAYS OF LOW PLASTICITY</b><br>(Liquid Limit Less than 50)  | CL  | Inorganic clays at low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. |
|   |  | <b>CLAYS OF HIGH PLASTICITY</b><br>(Liquid Limit More than 50) | CH  | Inorganic clays with high plasticity, fat clays.   |

NOTE: Coarse soils with between 5% and 12% passing the No. 200 sieve and fine grained soils with limits plotting in the hatched zone of the plasticity chart are to have dual symbols.

PLASTICITY CHART



DEGREE OF PLASTICITY OF COHESIVE SOILS\*

| Degree of Plasticity | Plasticity Index |
|----------------------|------------------|
| None to Slight       | 0 - 4            |
| Slight               | 5 - 7            |
| Medium               | 8 - 22           |
| High to Very High    | over 22          |

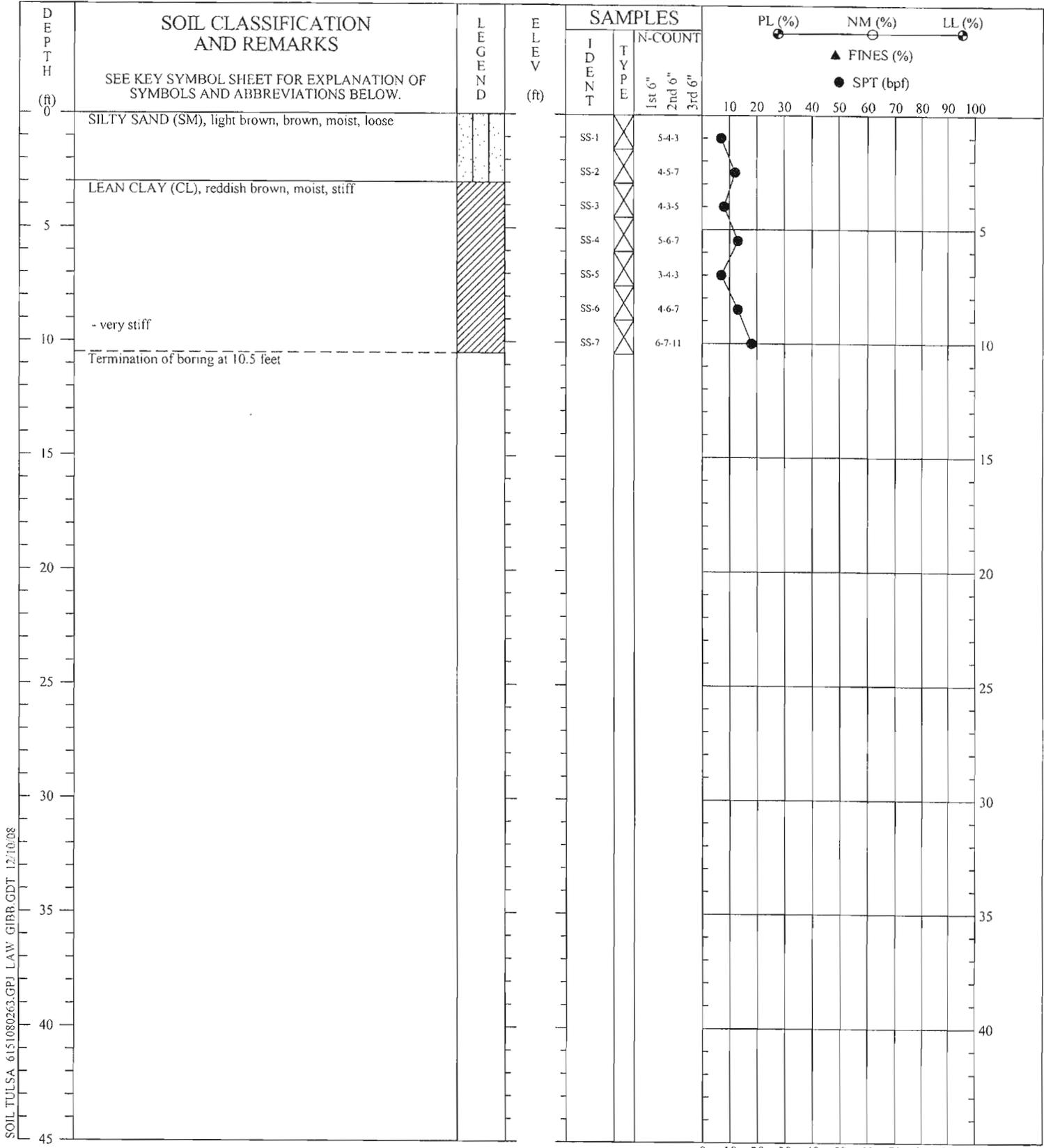


| MAJOR DIVISIONS   |   | GROUP SYMBOLS               | TYPICAL NAMES   | Undisturbed Sample (UD) | Auger Cuttings  |                          |  |
|---|---|-----------------------------|---|-------------------------|---|--------------------------|--|
| COARSE GRAINED SOILS<br>(More than 50% of material is LARGER than No. 200 sieve size) | GRAVELS<br>(More than 50% of coarse fraction is LARGER than the No. 4 sieve size) |                             | CLEAN GRAVELS<br>(Little or no fines)   | GW                      | Well graded gravels, gravel - sand mixtures, little or no fines.  |                          |  |
|   | SANDS<br>(More than 50% of coarse fraction is SMALLER than the No. 4 Sieve Size)  |                             | GRAVELS WITH FINES<br>(Appreciable amount of fines)   | GP                      | Poorly graded gravels or gravel - sand mixtures, little or no fines.  |                          |  |
| FINE GRAINED SOILS<br>(More than 50% of material is SMALLER than No. 200 sieve size)  | SANDS WITH FINES<br>(Appreciable amount of fines)                                 |                             | Silty gravels, gravel - sand - silt mixtures.   | GM                      | Silty gravels, gravel - sand - silt mixtures.   |                          |  |
|   |   |                             | Clayey gravels, gravel - sand - clay mixtures.  | GC                      | Clayey gravels, gravel - sand - clay mixtures.  |                          |  |
|   | SILTS AND CLAYS<br>(Liquid limit LESS than 50)                                    |                             | CLEAN SANDS<br>(Little or no fines)   | SW                      | Well graded sands, gravelly sands, little or no fines.  |                          |  |
|   |   |                             | Poorly graded sands or gravelly sands, little or no fines.  | SP                      | Poorly graded sands or gravelly sands, little or no fines.  |                          |  |
| SILTS AND CLAYS<br>(Liquid limit GREATER than 50)                                     | HIGHLY ORGANIC SOILS  |                             | Silty sands, sand - silt mixtures   | SM                      | Silty sands, sand - silt mixtures   |                          |  |
|   |   |                             | Clayey sands, sand - clay mixtures.   | SC                      | Clayey sands, sand - clay mixtures.   |                          |  |
| CORRELATION OF PENETRATION RESISTANCE (N) WITH RELATIVE DENSITY AND CONSISTENCY       | SAND & GRAVEL   |                             | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts and with slight plasticity. | ML                      | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts and with slight plasticity. |                          |  |
|   |   |                             | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.                      | CL                      | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.                      |                          |  |
|   |   |                             | Organic silts and organic silty clays of low plasticity.  | OL                      | Organic silts and organic silty clays of low plasticity.  |                          |  |
|   |   |                             | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.                                    | MH                      | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.                                    |                          |  |
|   |   |                             | Inorganic clays of high plasticity, fat clays   | CH                      | Inorganic clays of high plasticity, fat clays   |                          |  |
|   |   |                             | Organic clays of medium to high plasticity, organic silts.  | OH                      | Organic clays of medium to high plasticity, organic silts.  |                          |  |
|   |   |                             | Peat and other highly organic soils.  | PT                      | Peat and other highly organic soils.  |                          |  |
|   |   | No. 200 No. 40 No. 10 No. 4 |   | 3/4" 3" 12"             |   | U.S. STANDARD SIEVE SIZE |  |
|   |   | SILT OR CLAY                |   | SAND                    |   | GRAVEL                   |  |
|   |   |                             |   | Fine Medium Coarse      |   | Cobbles Boulders         |  |

BOUNDARY CLASSIFICATIONS: Soils possessing characteristics of two groups are designated by combinations of group symbols.

# KEY TO SYMBOLS AND DESCRIPTIONS





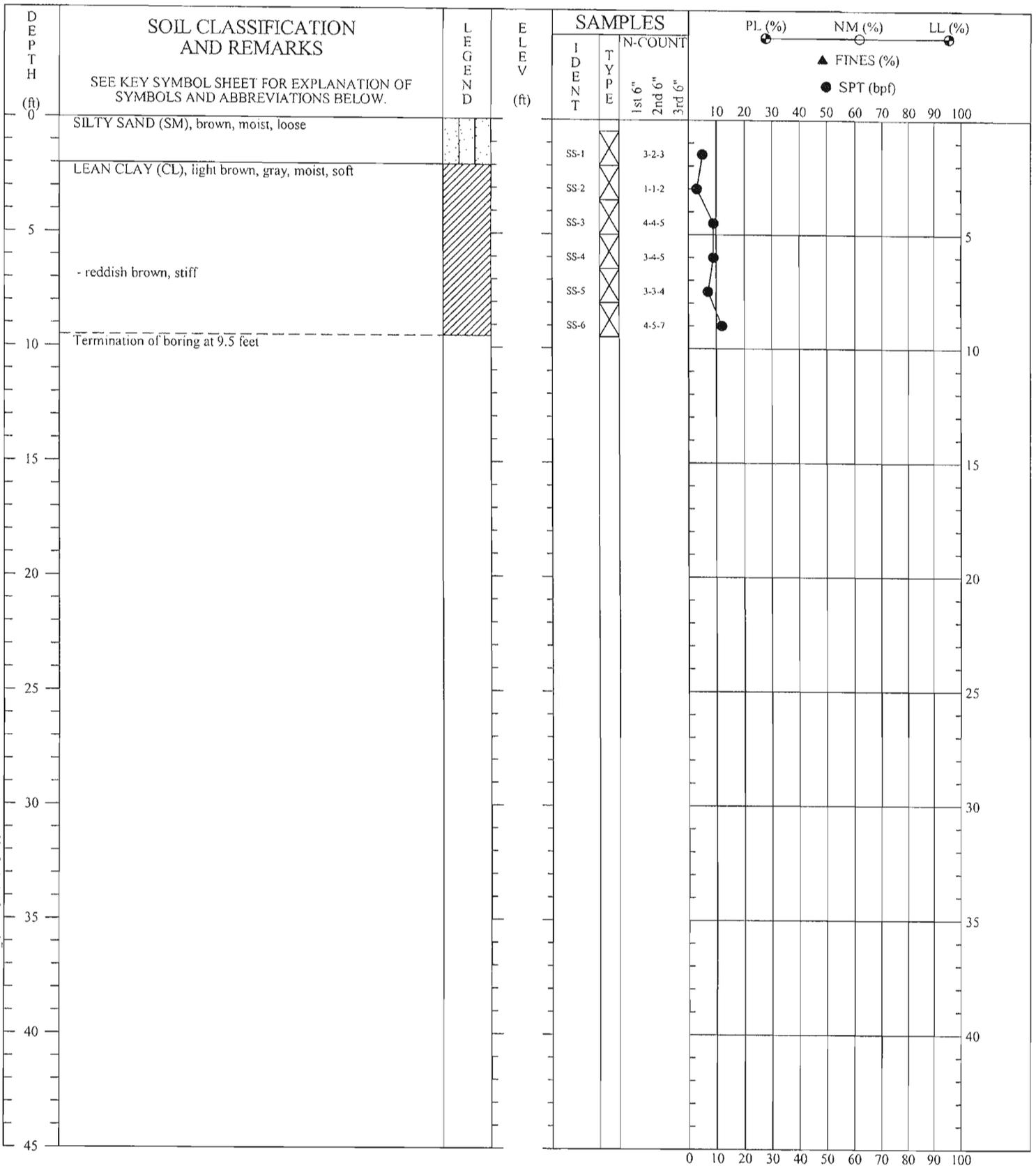
SOIL\_TULSA\_6151080263.GPJ LAW\_GIBB.GDT 12/10/08

CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

| SOIL TEST BORING RECORD                      |                               |  |  |
|--|-------------------------------|--|--|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-1        |  |  |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU       |  |  |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>KMM</i> |  |  |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b> 12.10.08         |  |  |
| <b>Proj. No.:</b> 6151-08-0263               |                               |  |  |
|  |                               |  |  |

SOIL\_TULSA\_6151080263.GPJ LAW\_GIBB.GDT 11/26/08

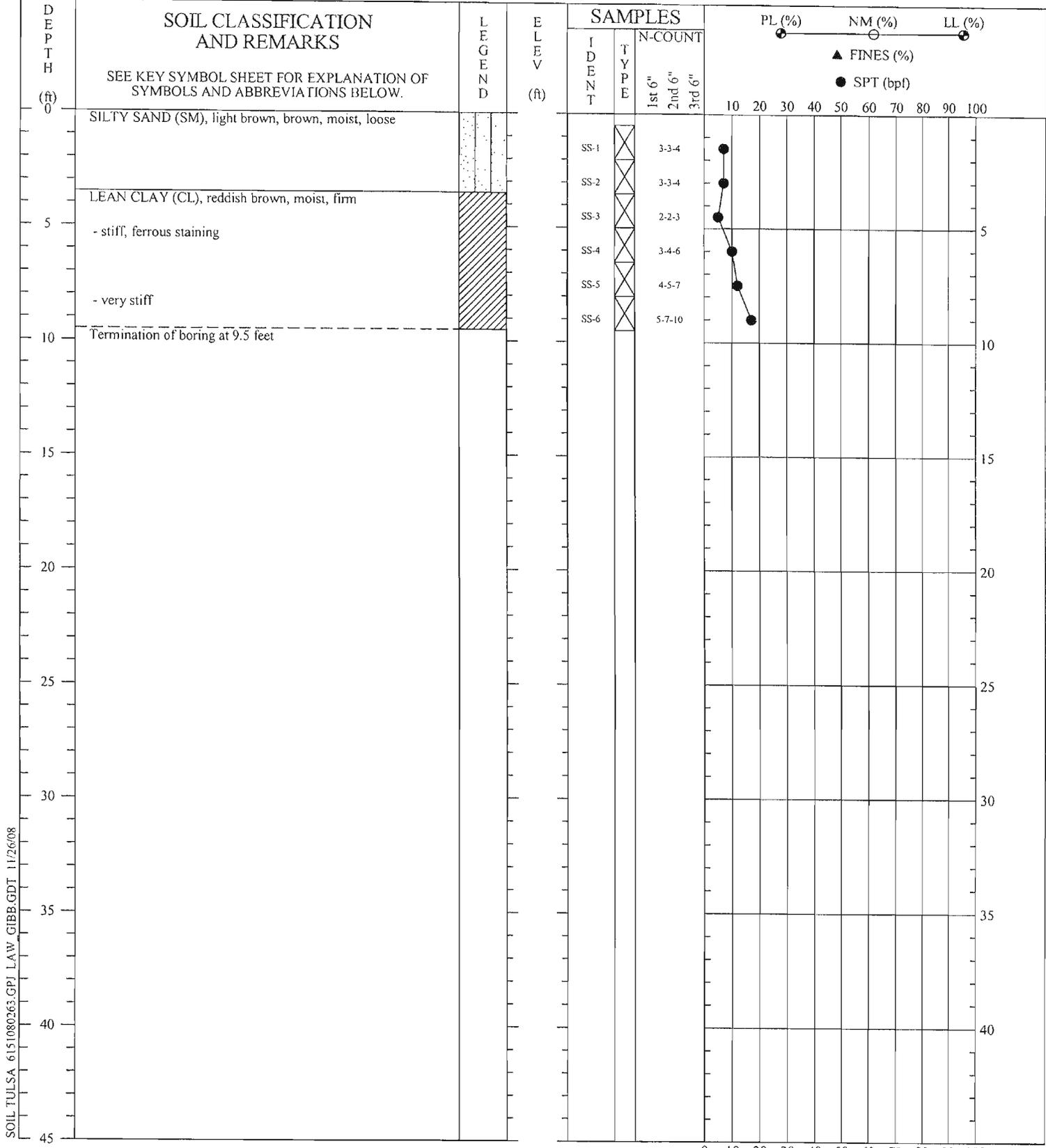


CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

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| SOIL TEST BORING RECORD                      |                              |
|--|------------------------------|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-2       |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU      |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>RM</i> |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b> 12-10-08        |
| <b>Proj. No.:</b> 6151-08-0263               |                              |

**MACTEC**



SOIL\_TULSA\_6151080263.GPJ LAW\_GIBB.GDT 11/26/08

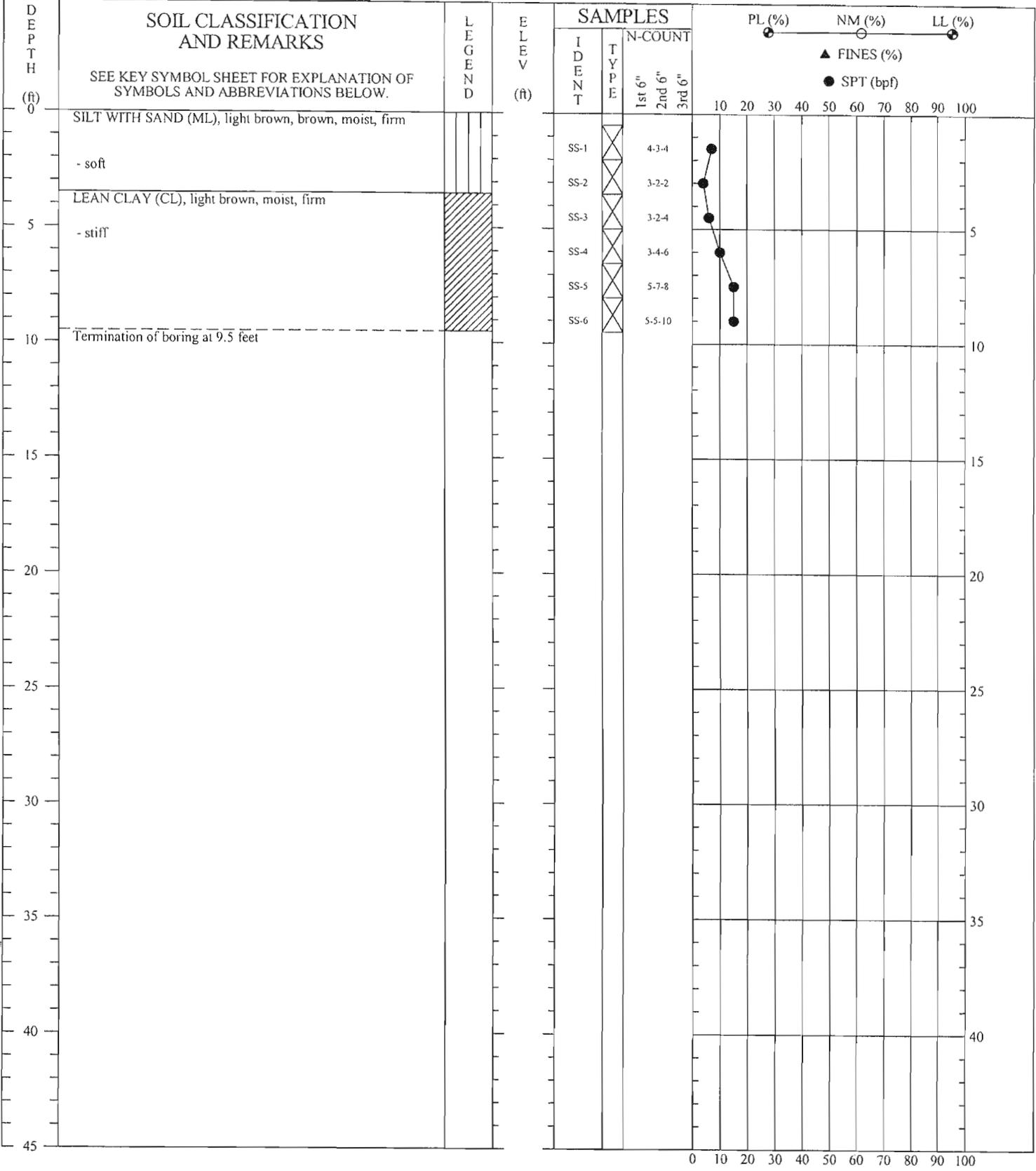
CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

| SOIL TEST BORING RECORD                      |                               |
|--|-------------------------------|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-3        |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU       |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>KBR</i> |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b>                  |
| <b>Proj. No.:</b> 6151-08-0263               | 12-10-08                      |

**MACTEC**

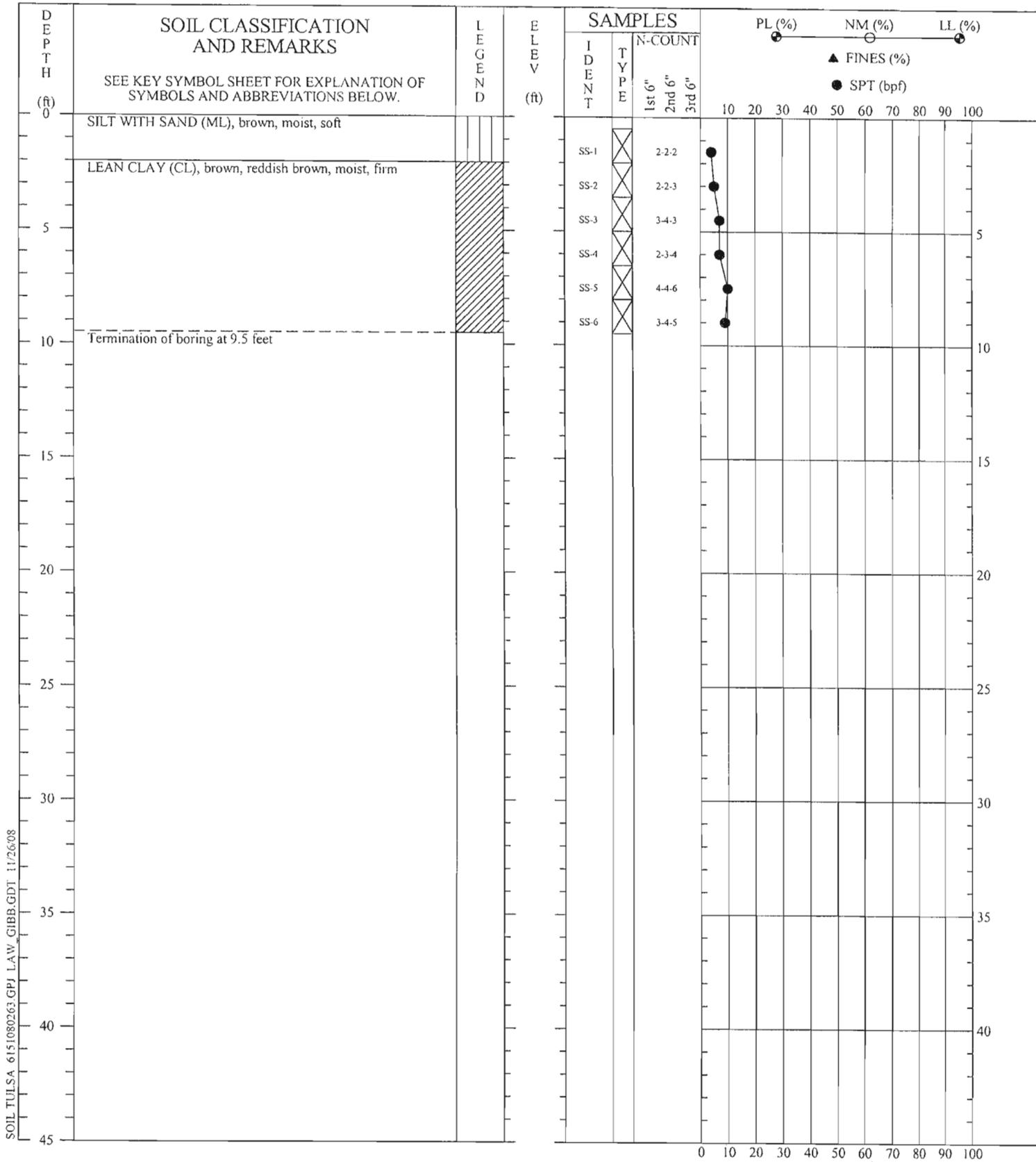
SOIL TULSA 6151080263.GPJ LAW\_GIBB.GDT 11/26/08



CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

| SOIL TEST BORING RECORD  |                        |
|--|------------------------|
| Project: Fort Smith National Cemetery  | Boring No.: B-4        |
| Coord N:   | Prepared By: BRU       |
| Coord E:   | Checked By: <i>kan</i> |
| Drilled: October 22, 2008  | Date: <i>(21)10-08</i> |
| Proj. No.: 6151-08-0263  |                        |
|  |                        |



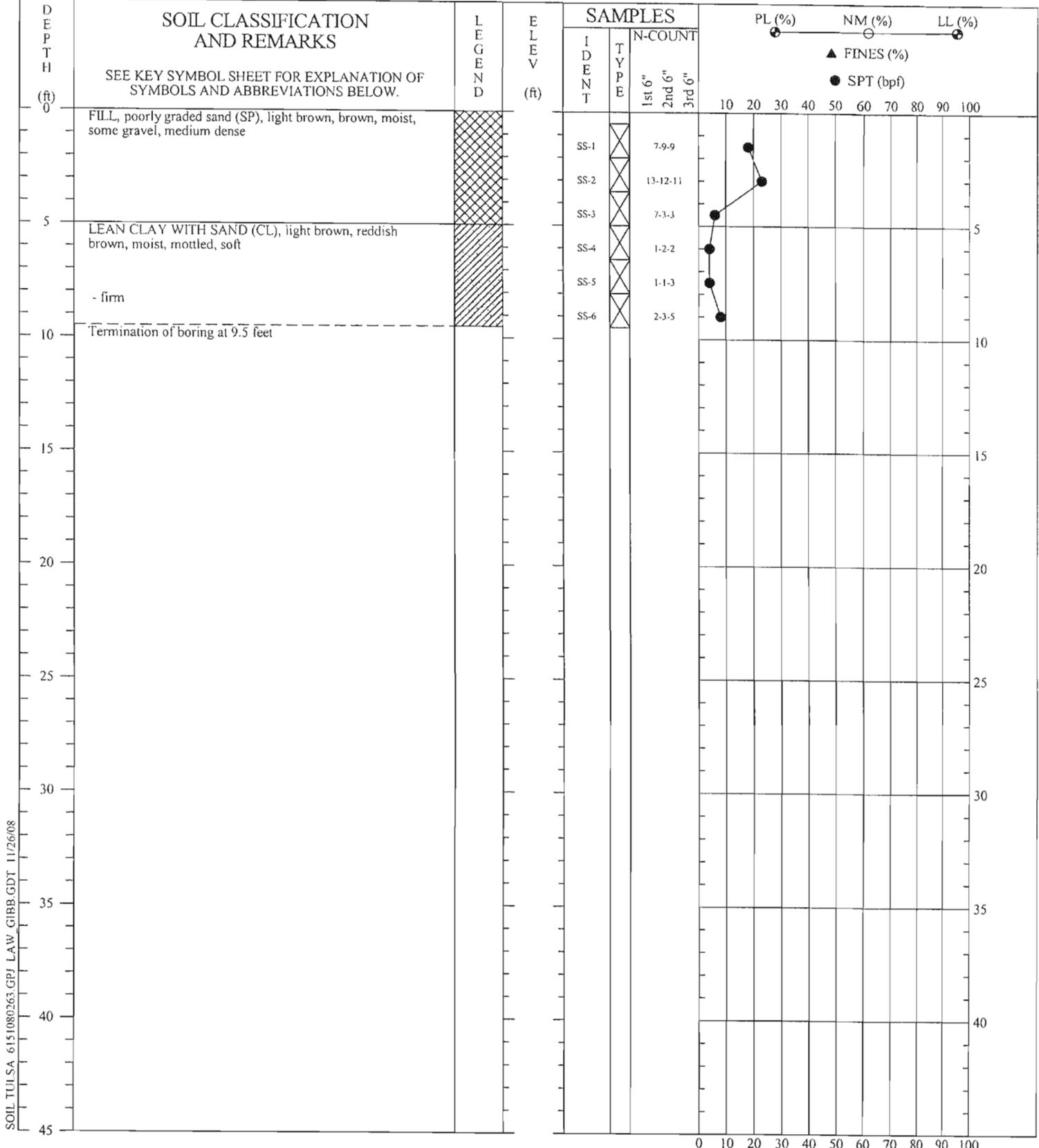
SOIL TULSA 6151080263.GPJ LAW\_GIBB.GDT 11/26/08

CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

| SOIL TEST BORING RECORD               |                        |
|---------------------------------------|------------------------|
| Project: Fort Smith National Cemetery | Boring No.: B-5        |
| Coord N:                              | Prepared By: BRU       |
| Coord E:                              | Checked By: <i>knw</i> |
| Drilled: October 22, 2008             | Date: <i>12.10.08</i>  |
| Proj. No.: 6151-08-0263               |                        |

**MACTEC**



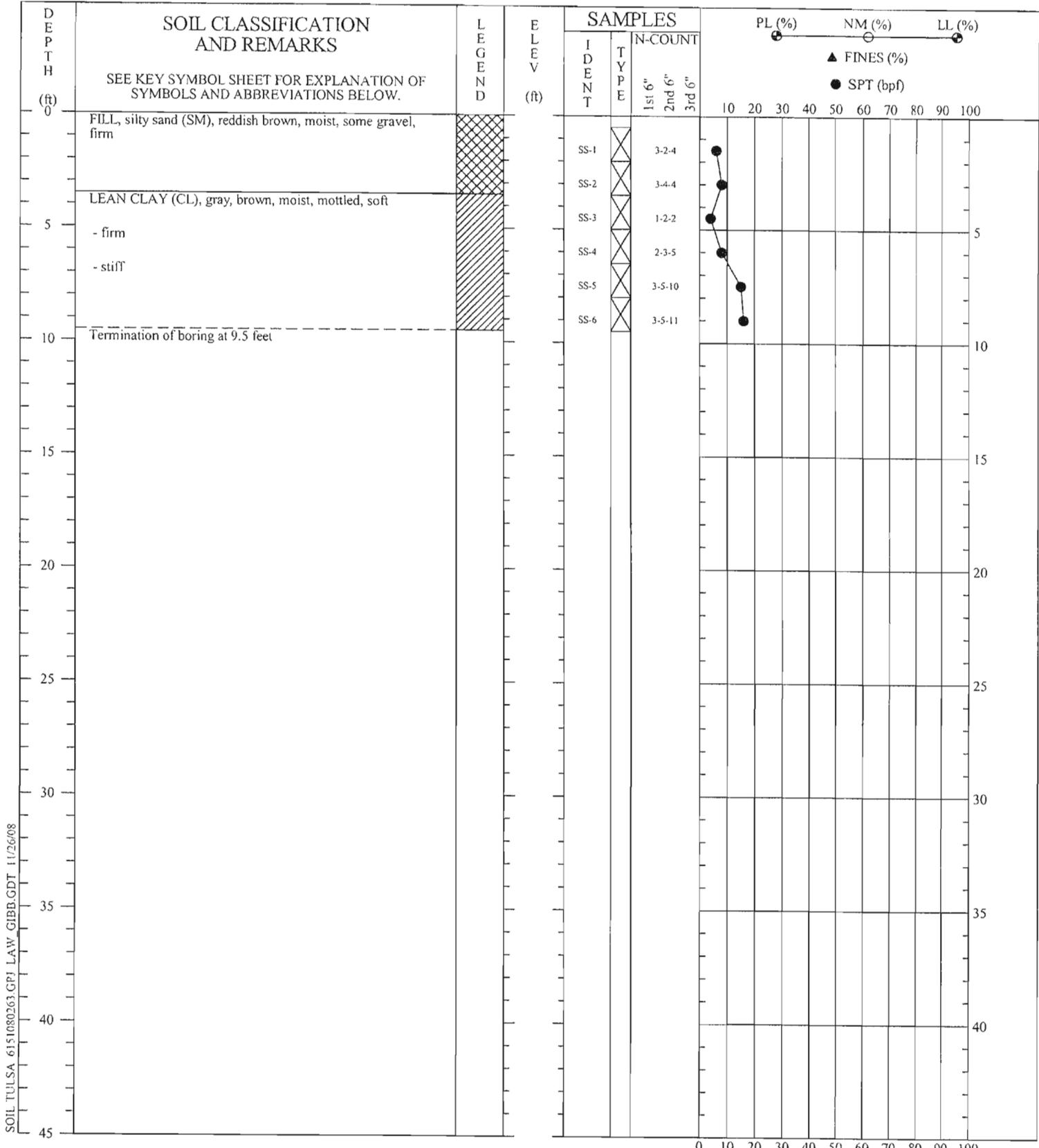
SOIL TULSA 6151080263.GPJ LAW\_GIBB.GDT 11/26/08

CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

| SOIL TEST BORING RECORD                      |                              |
|--|------------------------------|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-6       |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU      |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>KW</i> |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b>                 |
| <b>Proj. No.:</b> 6151-08-0263               | <i>(2.10.08)</i>             |

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.





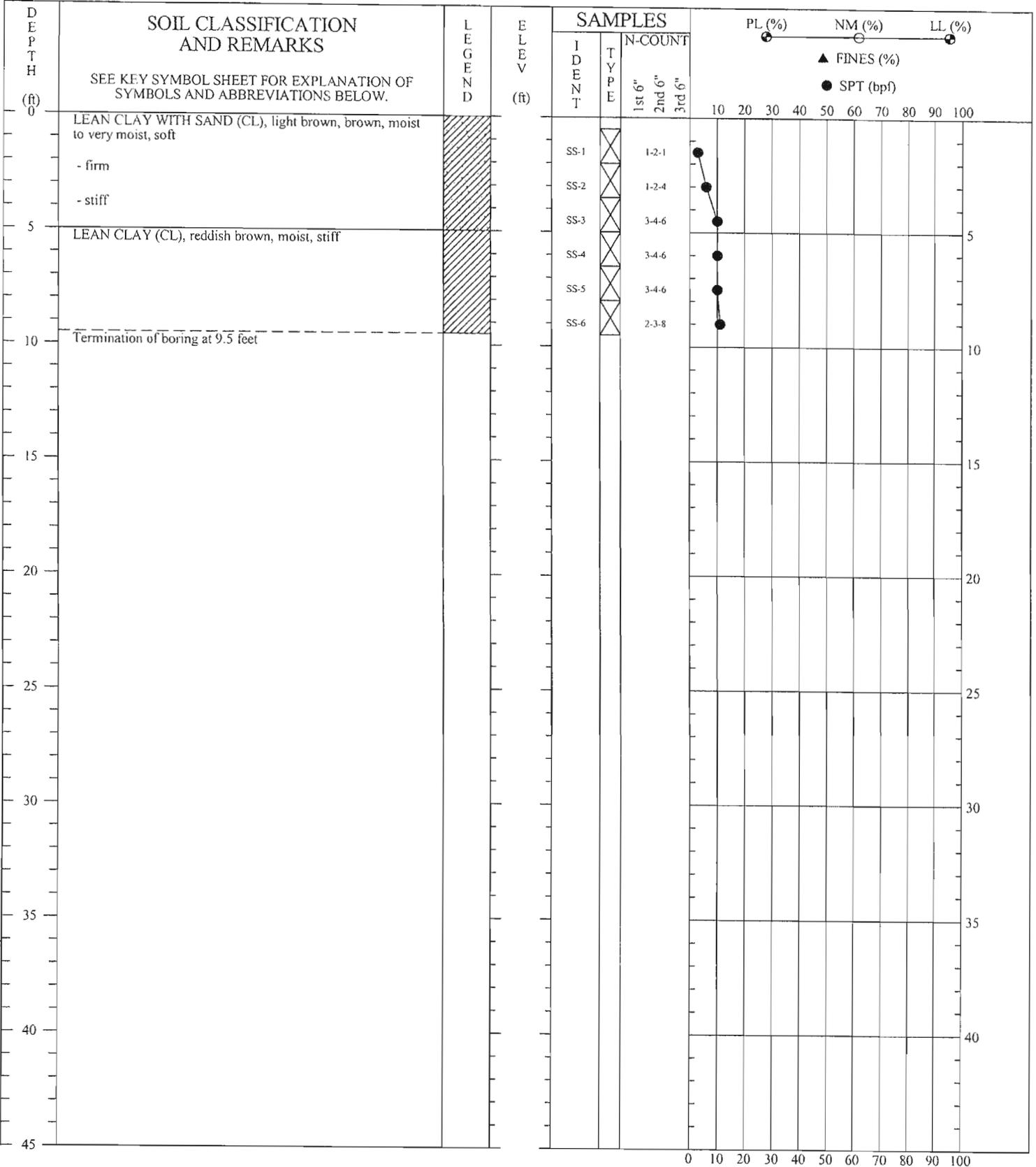
SOIL TULSA 6151080263.GPJ LAW GIBB.GDT 11/26/08

CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

| SOIL TEST BORING RECORD                      |                               |  |  |
|--|-------------------------------|--|--|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-7        |  |  |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU       |  |  |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>KEM</i> |  |  |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b>                  |  |  |
| <b>Proj. No.:</b> 6151-08-0263               | <i>12-10-08</i>               |  |  |
|  |                               |  |  |

SOIL TULSA 6151080263.GPJ LAW GIBB.GDT 11/26/08

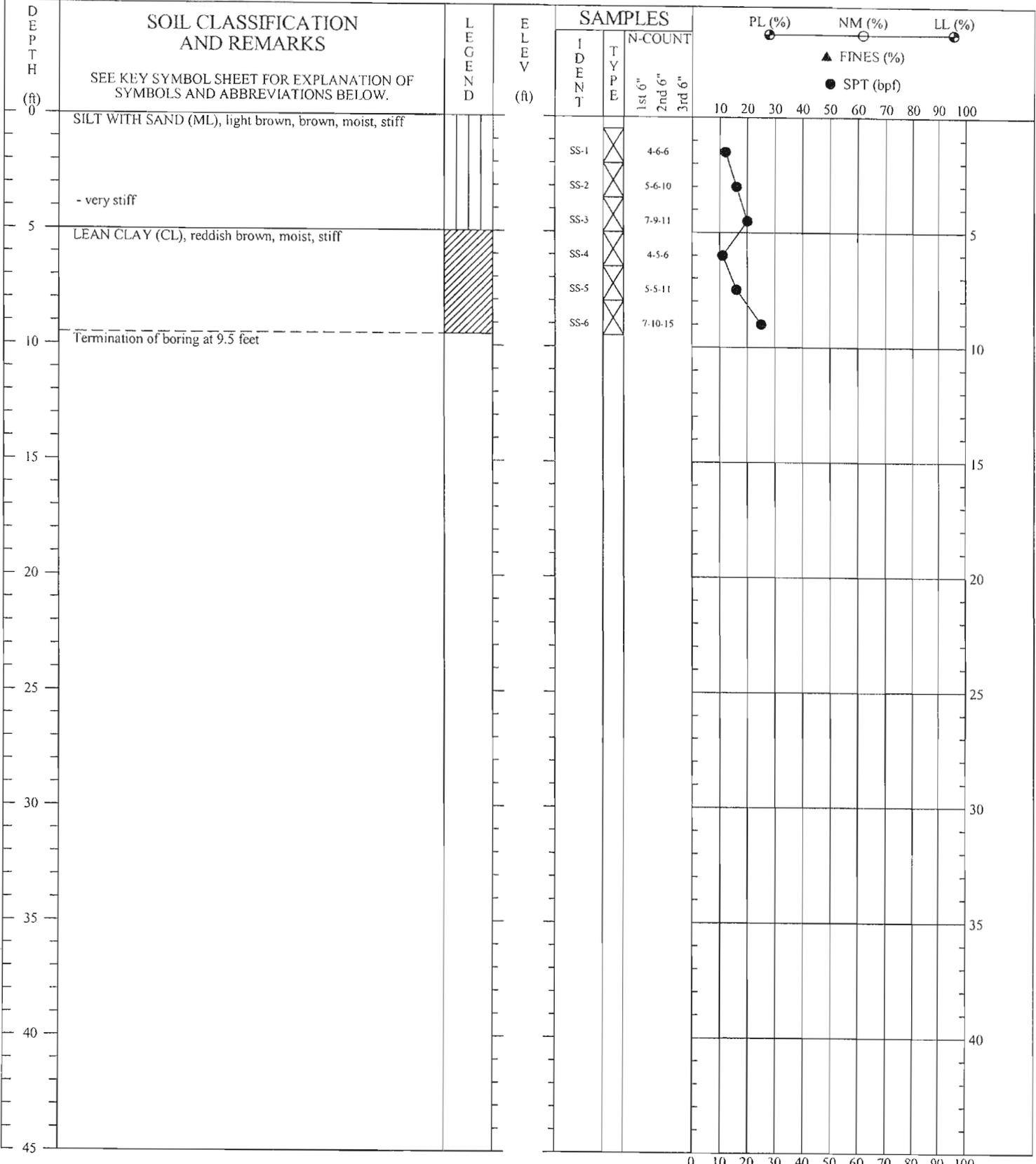


CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

| SOIL TEST BORING RECORD                      |                                       |  |  |
|--|---------------------------------------|--|--|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-8                |  |  |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU               |  |  |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>[Signature]</i> |  |  |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b>                          |  |  |
| <b>Proj. No.:</b> 6151-08-0263               | <i>12-10-08</i>                       |  |  |

SOIL TULSA 6151080263.GPJ LAW GIBB.GDT 11/26/08

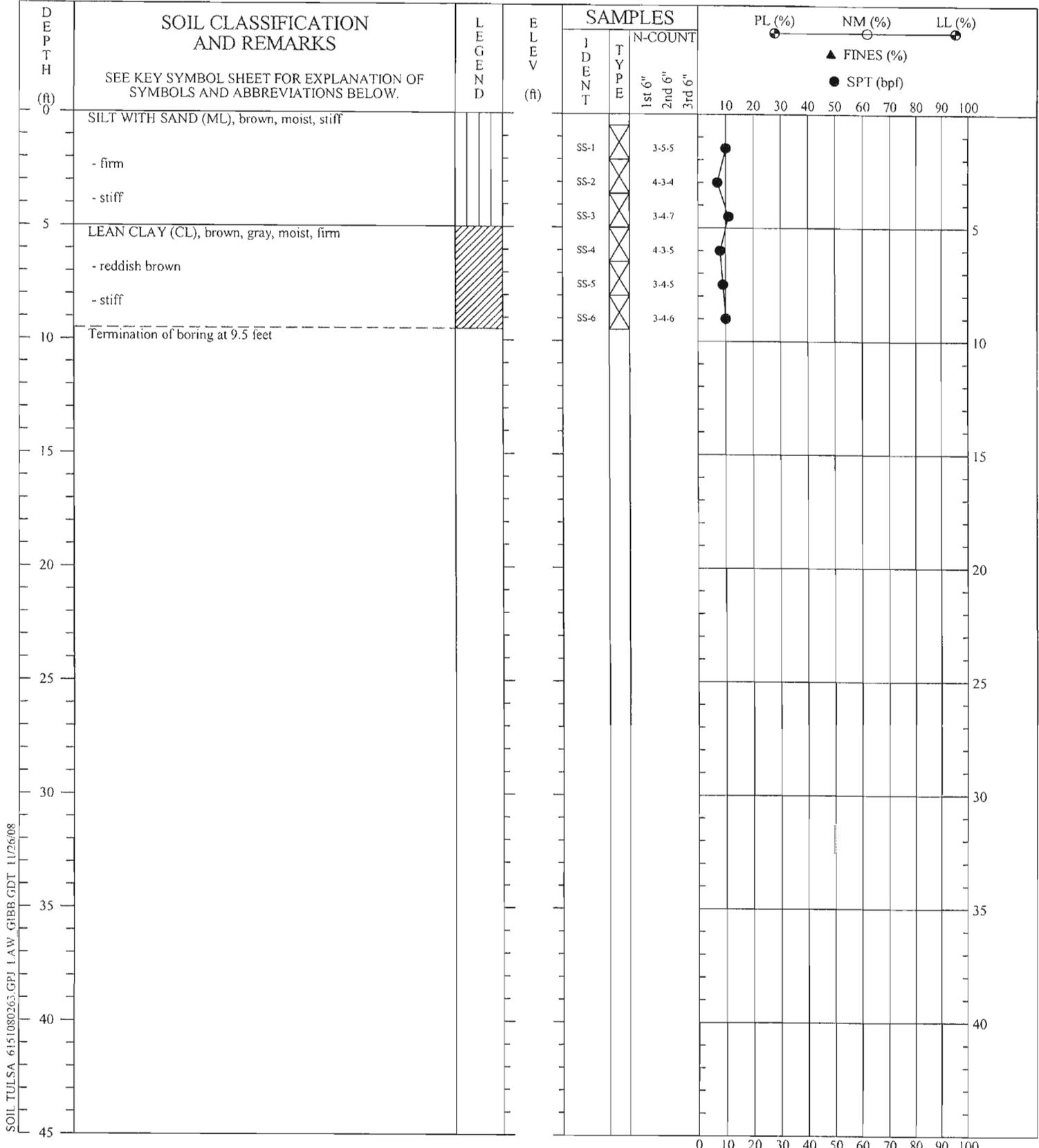


CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

| SOIL TEST BORING RECORD                      |                               |
|--|-------------------------------|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-9        |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU       |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>kap</i> |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b>                  |
| <b>Proj. No.:</b> 6151-08-0263               | <i>12.10.08</i>               |

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.





SOIL\_TULSA\_6151080263.GPJ L.A.W. GIBB.GDT 11/26/08

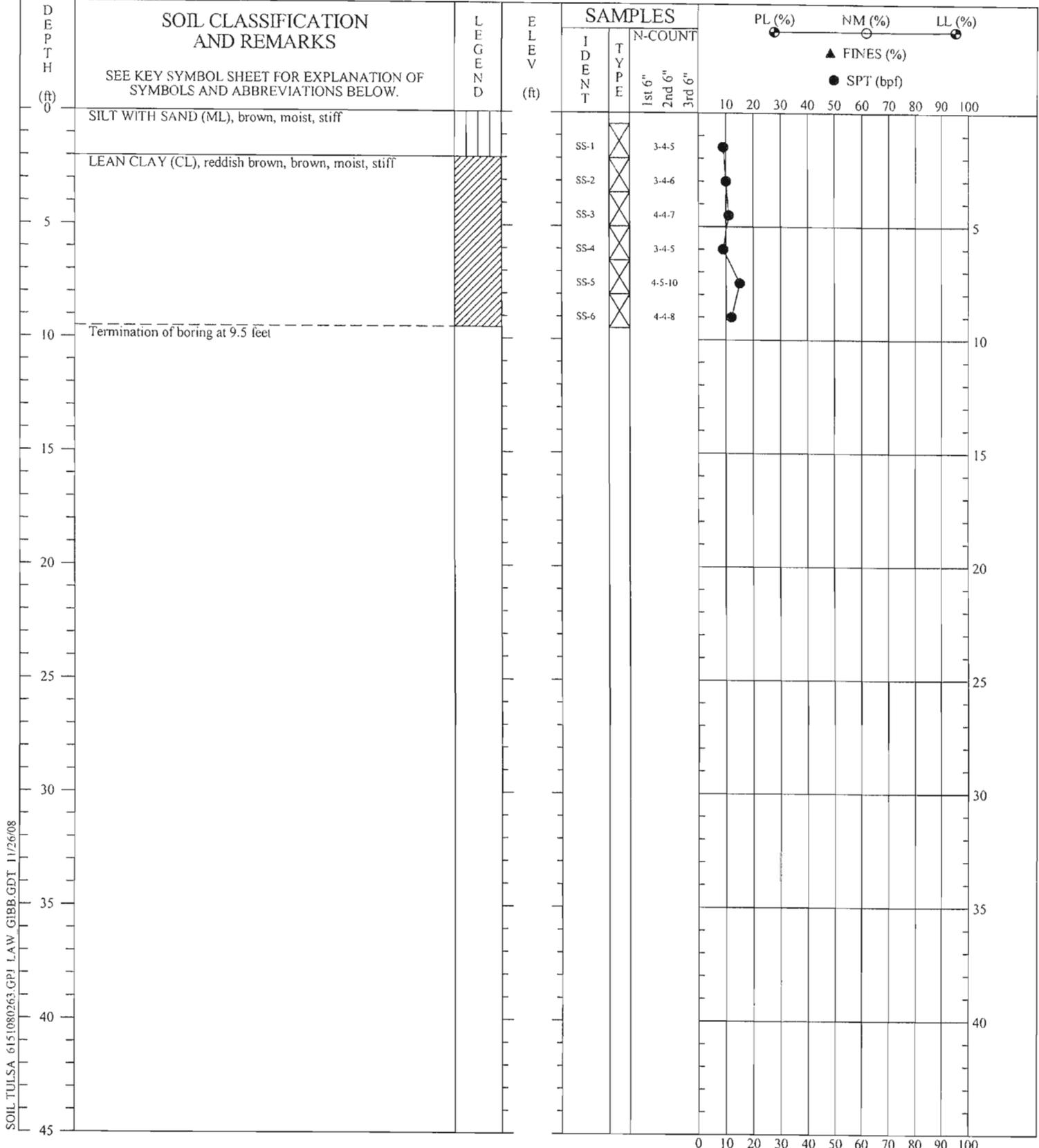
CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

**SOIL TEST BORING RECORD**

**Project:** Fort Smith National Cemetery      **Boring No.:** B-10  
**Coord N:**      **Prepared By:** BRU  
**Coord E:**      **Checked By:** *kan*  
**Drilled:** October 22, 2008      **Date:**  
**Proj. No.:** 6151-08-0263      12/10/08

**MACTEC**



SOIL TULSA 6151080263.CPJ LAW GIBB.GDT 11/26/08

CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

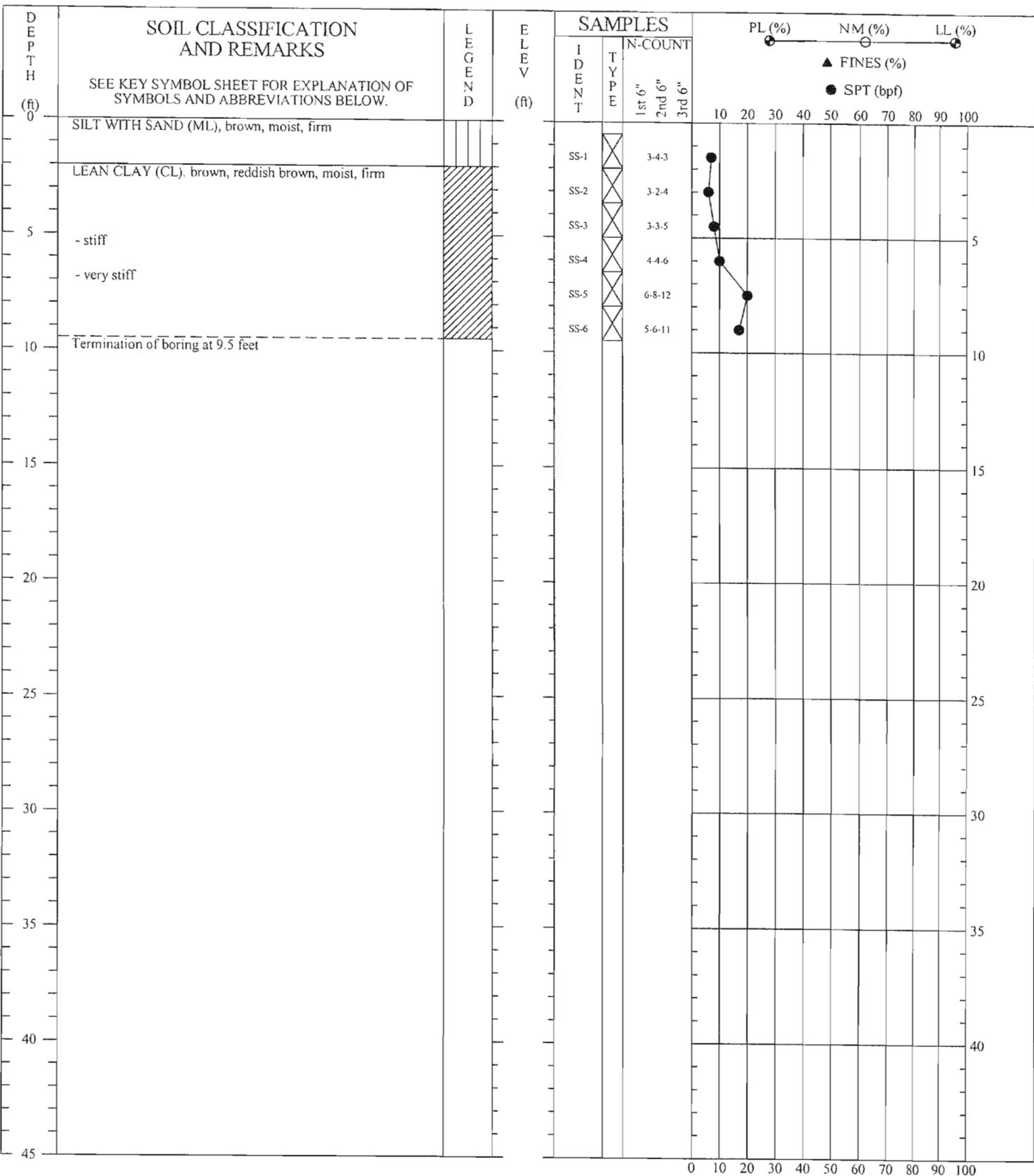
THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

| SOIL TEST BORING RECORD                      |                              |
|--|------------------------------|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-11      |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU      |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>KW</i> |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b>                 |
| <b>Proj. No.:</b> 6151-08-0263               | <i>12-10-08</i>              |

**MACTEC**



SOIL\_TULSA\_6151080263.GPJ LAW\_GIBB.GDT 11/26/08

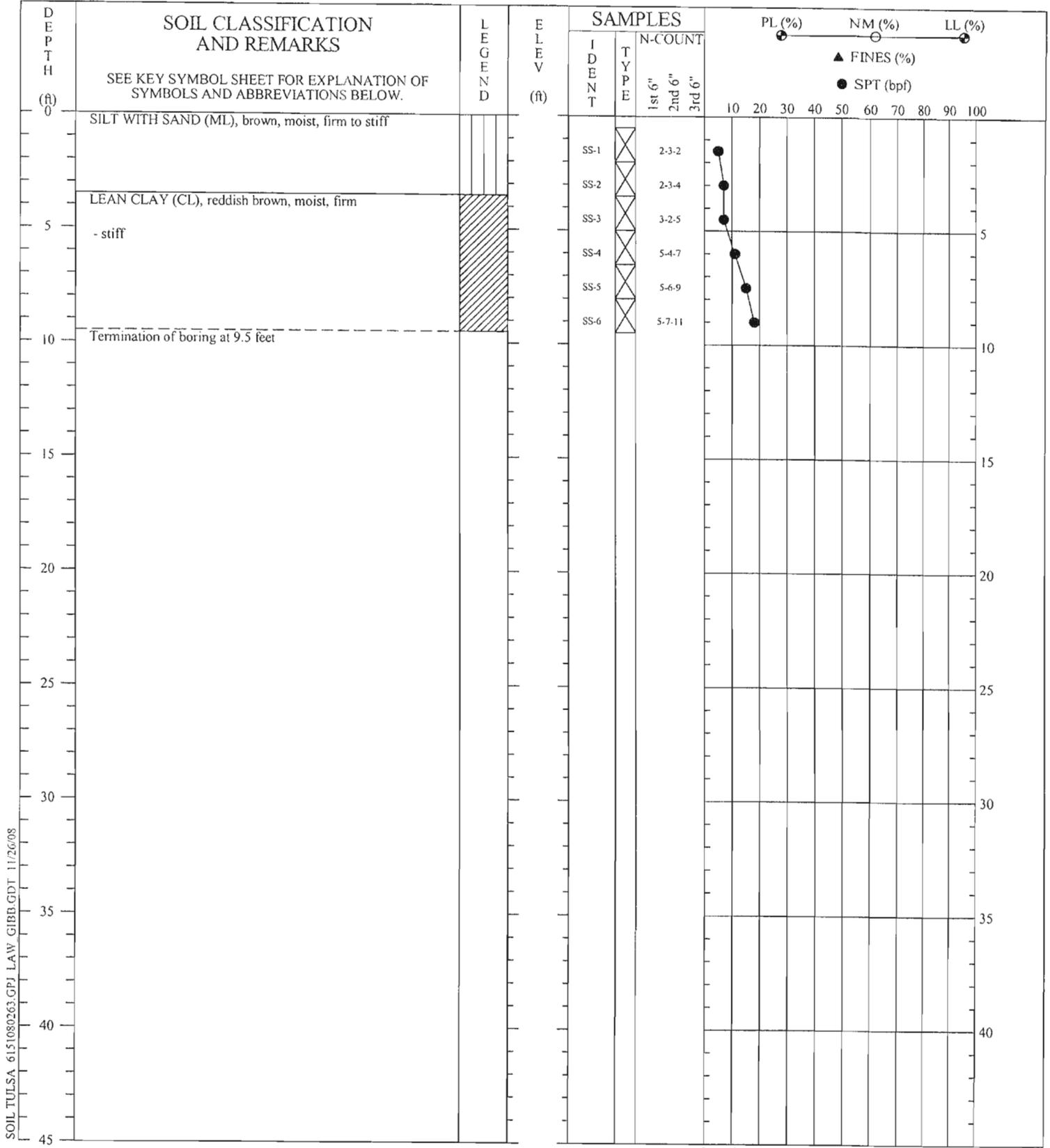


CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

| SOIL TEST BORING RECORD                      |                              |
|--|------------------------------|
| <b>Project:</b> Fort Smith National Cemetery | <b>Boring No.:</b> B-13      |
| <b>Coord N:</b>                              | <b>Prepared By:</b> BRU      |
| <b>Coord E:</b>                              | <b>Checked By:</b> <i>KW</i> |
| <b>Drilled:</b> October 22, 2008             | <b>Date:</b>                 |
| <b>Proj. No.:</b> 6151-08-0263               | <i>12-10-08</i>              |

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.





SOIL TULSA 6151080263.GPJ LAW GIBB.GDT 11/26/08

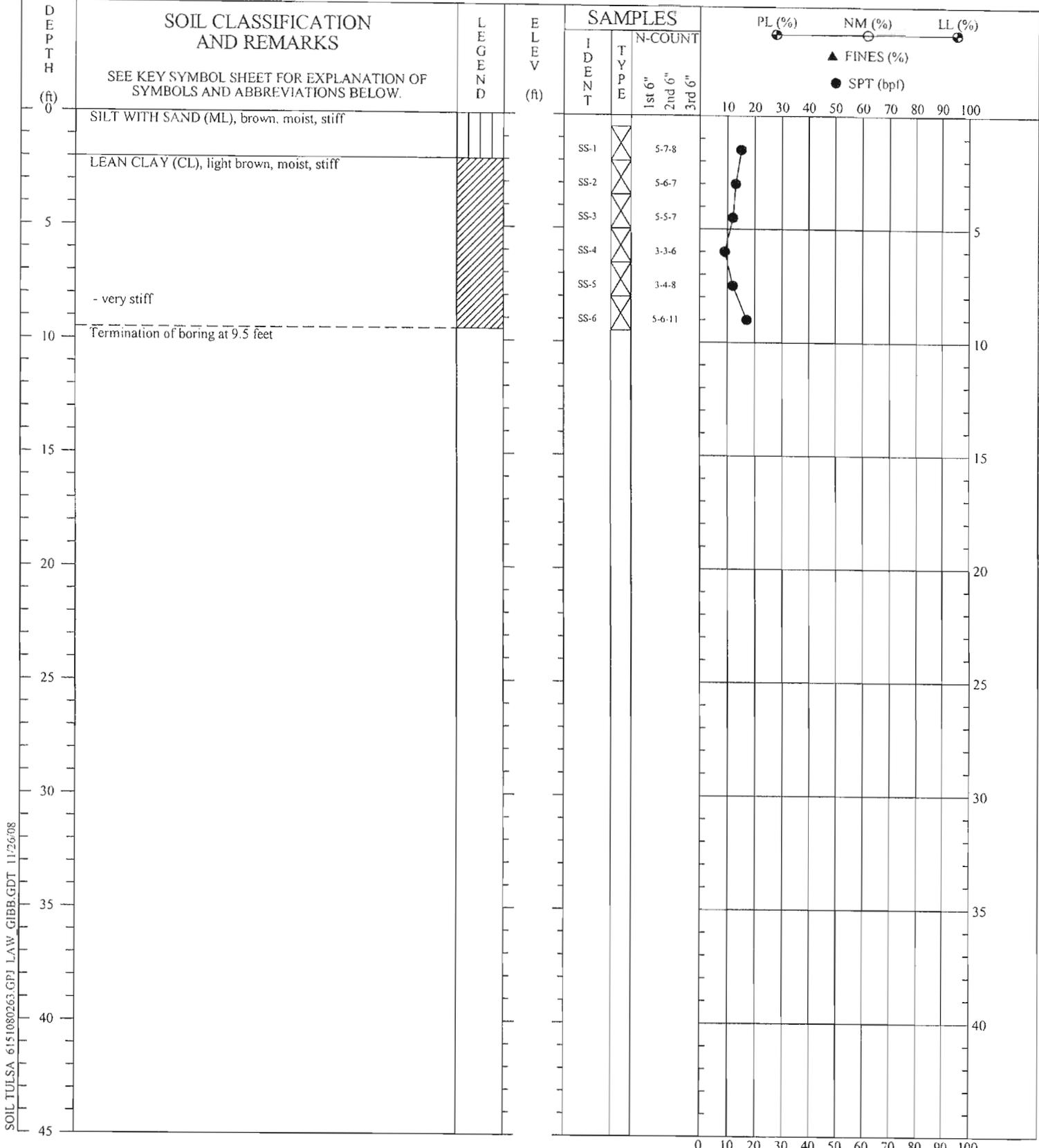
CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

**SOIL TEST BORING RECORD**

**Project:** Fort Smith National Cemetery      **Boring No.:** B-14  
**Coord N:**      **Prepared By:** BRU  
**Coord E:**      **Checked By:** *KAM*  
**Drilled:** October 22, 2008      **Date:**  
**Proj. No.:** 6151-08-0263      12/10/08

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.





SOIL\_TULSA\_6151080263.GPJ LAW\_GIBB.GDT 11/26/08

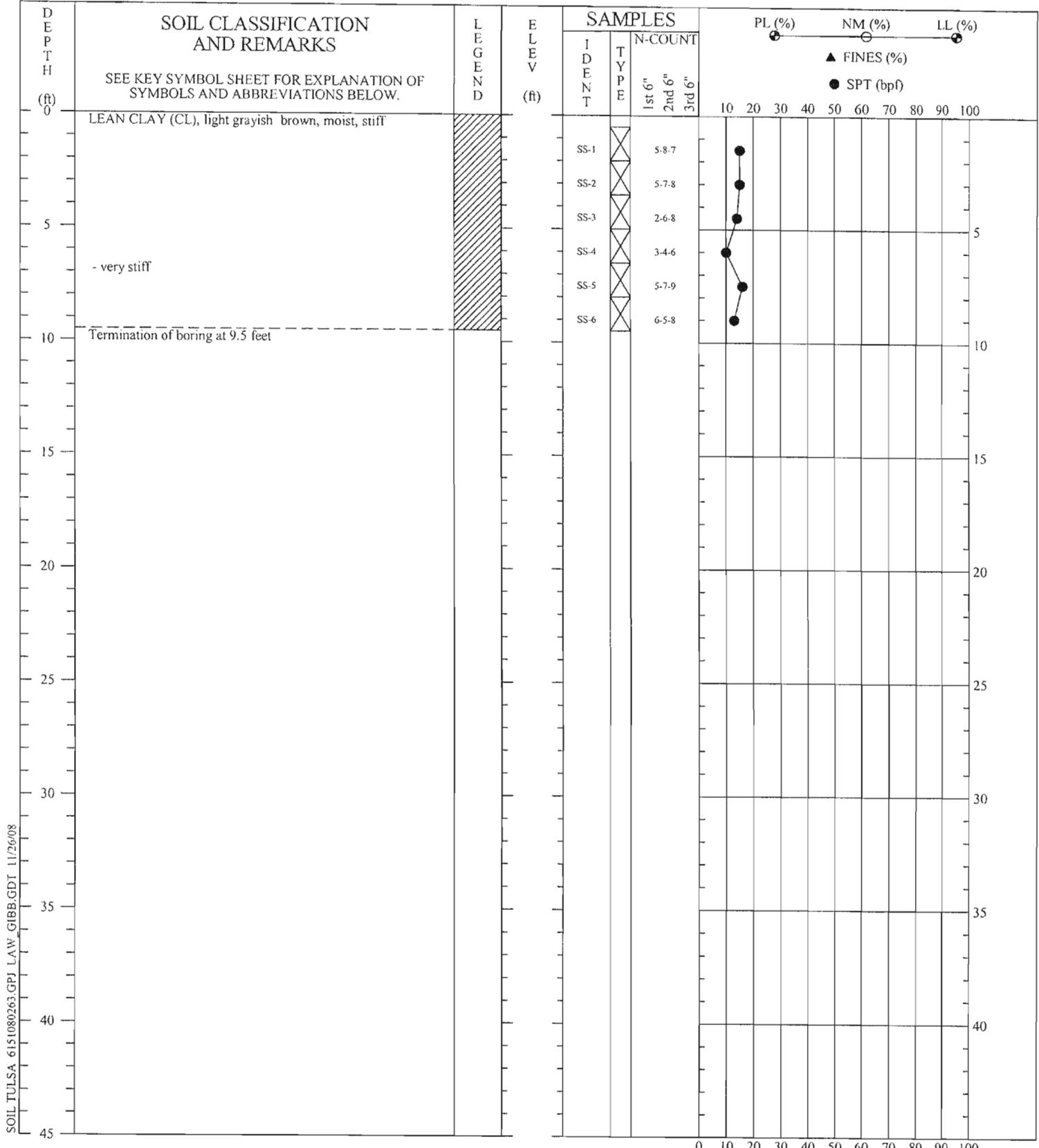
CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

**SOIL TEST BORING RECORD**

**Project:** Fort Smith National Cemetery      **Boring No.:** B-15  
**Coord N:**      **Prepared By:** BRU  
**Coord E:**      **Checked By:** *[Signature]*  
**Drilled:** October 22, 2008      **Date:**  
**Proj. No.:** 6151-08-0263      *12.10.08*

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.





SOIL TULSA 6151080263.GPJ LAW GIBB.GDT 11/26/08

CONTRACTOR: Mohawk Drilling, Inc.  
 DRILLER: P. Emmons  
 EQUIPMENT: Truck mounted drill rig  
 METHOD: Flight Auger  
 HOLE DIA.: 6"  
 REMARKS:

**SOIL TEST BORING RECORD**

**Project:** Fort Smith National Cemetery      **Boring No.:** B-16  
**Coord N:**      **Prepared By:** BRU  
**Coord E:**      **Checked By:** *KM*  
**Drilled:** October 22, 2008      **Date:**  
**Proj. No.:** 6151-08-0263      12.10.08

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BETWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

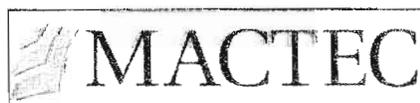


# APPENDIX C

## LABORATORY TESTING

The laboratory testing procedures employed by MACTEC Engineering and Consulting, Inc. are in general accordance with American Society for Testing Materials (ASTM) standard methods and other applicable specifications.

An outline of the test methods used in this study, together with the test results, is presented in this Appendix. The Laboratory Data Summary indicates the specific tests employed, and the results of all individual tests performed.



# SOIL CLASSIFICATION - GENERAL PROCEDURES

## Moisture Content and Unit Weight

An undisturbed sample is trimmed in the laboratory into a right circular cylinder approximately 3 to 6" long. The dimensions and weight of the specimen are determined and the total unit weight calculated. Moisture contents are determined from representative portions of the specimen removed from the top and bottom of each section. The soil is dried to a constant weight in an oven at 100°C for 24 hours and the loss of moisture during the drying process is measured. From this data, the moisture content and dry unit weight are computed.

Separate moisture content and unit weight determinations are made on samples selected for unconfined compression, shear and compressibility testing. These tests are made on the actual cut specimens by accurately measuring the dimensions and weighting the sample and portions of the cuttings before and after testing. Additional moisture content tests are made on selected jar or bag samples. These tests are made by weighing before and after drying, as described above.

## Atterberg Limits

Liquid Limit (LL), Plastic Limit (PL) and Shrinkage Limit (SL) tests are performed to aid in the classification of soils and to determine the plasticity and volume change characteristics of the materials. The Liquid Limit is the minimum moisture content at which a soil will flow as a heavy viscous fluid. The Plastic Limit is the minimum moisture content at which the soil begins to lose its plasticity. The Plasticity Index (PI) is the numeric difference of Liquid Limit and the Plastic Limit and indicates the range of moisture content over which a soil remains plastic. The Shrinkage Limit is the moisture content below which no further volume change will take place with continued drying. These tests are performed in accordance with ASTM D 4318.

## Particle Size Distribution

The distribution of soils coarser than the No. 200 (75- $\mu\text{m}$ ) sieve is determined by passing a representative specimen through a standard set of nested sieves. The weight of material retained on each sieve is determined and the percentage retained (or passing) is calculated.

The distribution of materials finer than the No. 200 sieve is determined by use of the Hydrometer. The particle sizes and distribution are computed from the time rate of settlement of the different size particles while suspended in water.

A specimen may be washed through only the No. 200 sieve. If the full range of particle sizes is not required, the percentage of material passing the No. 200 sieve is reported. The percentage of soil by weight passing the sieve is the percentage of fines or portion of the sample in the silt and clay range. These tests are performed in accordance with ASTM D 421, D 422 and D 1140, respectively.



# STRENGTH TESTS

## **Pocket Penetrometer Test**

A pocket penetrometer test is performed by pressing the tip of a small, spring loaded penetrometer with even pressure to a prescribed depth into a soil sample. This test yields a value for unconfined compressive strength, which may be correlated with unconfined compressive strengths obtained by other laboratory methods.

## **Strength test by Torvane**

The torvane test was developed in connection with an investigation of several massive landslides, which occurred as a result of the Alaska Earthquake in 1964. It is a rapid means of estimating the strength of clays for geotechnical exploration purposes. Correlation can be made between torvane test results and those results obtained from unconfined and triaxial compression tests. The test is performed by preparing a flat surface of the sample, pressing the blades of the torvane carefully into the surface, and slowly turning the knob by hand at a uniform rate while maintaining a constant vertical pressure. After sample failure occurs, the shear strength is indicated on the dial head.

## **Laboratory Van Shear Test**

This test consists of placing a four-bladed vane in an undisturbed very soft to soft, saturated, cohesive soil and rotating the vane to determine the torsional force required to cause a cylindrical surface to be sheared by the vane. This force is then converted to a unit shearing resistance of the cylindrical surface. A sample is selected, trimmed into a right circular cylinder about 6" long, and clamped vertically below a spring-loaded vane shaft. The vane is inserted into the sample to a depth, which is sufficient to insure that shearing would take place without movement of the soil sample surface. The vane is then attached to a torsional spring to determine the torsional resistance of the soil. The vane is rotated mechanically at a constant rate until the sample shears. The maximum deflection of the spring is recorded and the shear strength is calculated.

## **Unconfined Compression Test (UNC)**

Portions of undisturbed samples are cut into sections approximately 6" long, the ends are trimmed and the specimen weighted and measured. The sample is then placed in the testing device and subjected to vertical axial loads. The vertical loads are continuously increased at a constant rate of strain until the sample fails. The maximum load and corresponding deformation produced by the loading process are recorded. This test is performed in accordance with ASTM D-2166.

## **Direct Shear Test**

An undisturbed sample is selected and trimmed into a disc 2.5" in diameter and about 2" thick, and confined in a shear box, consisting of a split stainless steel ring and stainless steel end platens. A normal stress is applied to the specimen to consolidate the sample. The split ring is slightly separated to define the sample's failure plane. The top ring is subjected to a constant rate of horizontal deflection and the resulting horizontal force and deflection measured at periodic time intervals. The horizontal deflection was at a rate slow enough to allow excess pore water pressure within the sample to dissipate, resulting in effective stress parameters. Results are presented in the form of load vs. displacement curves and normal stress vs. shear stress curves.

## **Consolidated-Undrained (CU) Triaxial Test with Pore Pressure Measurements**

The shear strength properties of selected representative samples are evaluated by performing this test on three undisturbed samples. For each test, three cylindrical test samples, extruded from the undisturbed sample and trimmed to an appropriate size, are encased in a thin rubber membrane and saturated. After saturating and mounting the sample in the triaxial chamber, it is allowed to fully consolidate with the drainage ports open while subjected to a confining fluid pressure. Each of the three samples is subjected to a different confining pressure. A pressure transducer is connected to the sample for measurement of pore pressures. The drainage ports are closed after consolidation is complete and the sample is sheared at a constant rate of strain under an axial load. Measurements of axial load, deformation, and pore pressure are taken at selected intervals. The results are presented in the form of deviator stress vs. strain for each specimen tested. Mohr's Circles and p-q diagrams are also presented for both total stress and effective stress cases.

## **Consolidated-Drained (CD) Triaxial Shear Test**

This test differs from the CU test in that drainage is allowed during the shear phase of the test. The results presented are for total (drained) stress only.



# Summary of Laboratory Results

| Borehole | Depth (ft) | Water Content (%) | Liquid Limit | Plasticity Limit | Plasticity Index | < 1/2" | < 3/8" | < #4 | < #10 | < #40 | < #200 | Dry Unit Weight (pcf) | Strength (psf) |
|----------|------------|-------------------|--------------|------------------|------------------|--------|--------|------|-------|-------|--------|-----------------------|----------------|
| B-1      | 2.3        | 20.1              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-1      | 8.3        | 22.3              | 49           | 15               | 34               |        |        |      |       |       | 97     |                       |                |
| B-10     | 2.8        | 18.7              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-10     | 7.3        | 20.7              | 49           | 14               | 35               |        |        |      |       |       | 90     |                       |                |
| B-11     | 2.8        | 20.5              | 35           | 15               | 20               |        |        |      |       |       | 92     |                       |                |
| B-11     | 5.8        | 26.3              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-12     | 2.8        | 19.2              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-12     | 5.8        | 21.2              | 41           | 14               | 27               |        |        |      |       |       | 81     |                       |                |
| B-13     | 5.8        | 22.0              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-13     | 7.3        | 19.0              | 47           | 16               | 31               |        |        |      |       |       | 98     |                       |                |
| B-14     | 4.3        | 22.8              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-14     | 8.8        | 19.2              | 47           | 16               | 31               |        |        |      |       |       | 87     |                       |                |
| B-15     | 1.3        | 16.2              | 22           | 19               | 3                |        |        |      |       |       | 83     |                       |                |
| B-15     | 5.8        | 24.1              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-16     | 4.3        | 21.8              | 33           | 13               | 20               |        |        |      |       |       | 86     |                       |                |
| B-16     | 7.3        | 17.7              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-2      | 4.3        | 20.0              | 33           | 13               | 20               |        |        |      |       |       | 91     |                       |                |
| B-2      | 8.8        | 23.7              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-3      | 4.3        | 26.4              |              |                  |                  |        |        |      |       |       |        |                       |                |
| B-3      | 7.3        | 20.4              | 48           | 15               | 33               |        |        |      |       |       | 94     |                       |                |
| B-4      | 4.3        | 22.8              | 39           | 13               | 26               |        |        |      |       |       | 93     |                       |                |
| B-4      | 7.3        | 20.7              |              |                  |                  |        |        |      |       |       |        |                       |                |

Prepared by: BRU      Reviewed by: *km*  
 Client: Veterans Administration  
 Project: Fort Smith National Cemetery  
 Project Number: 6151-08-0263-01

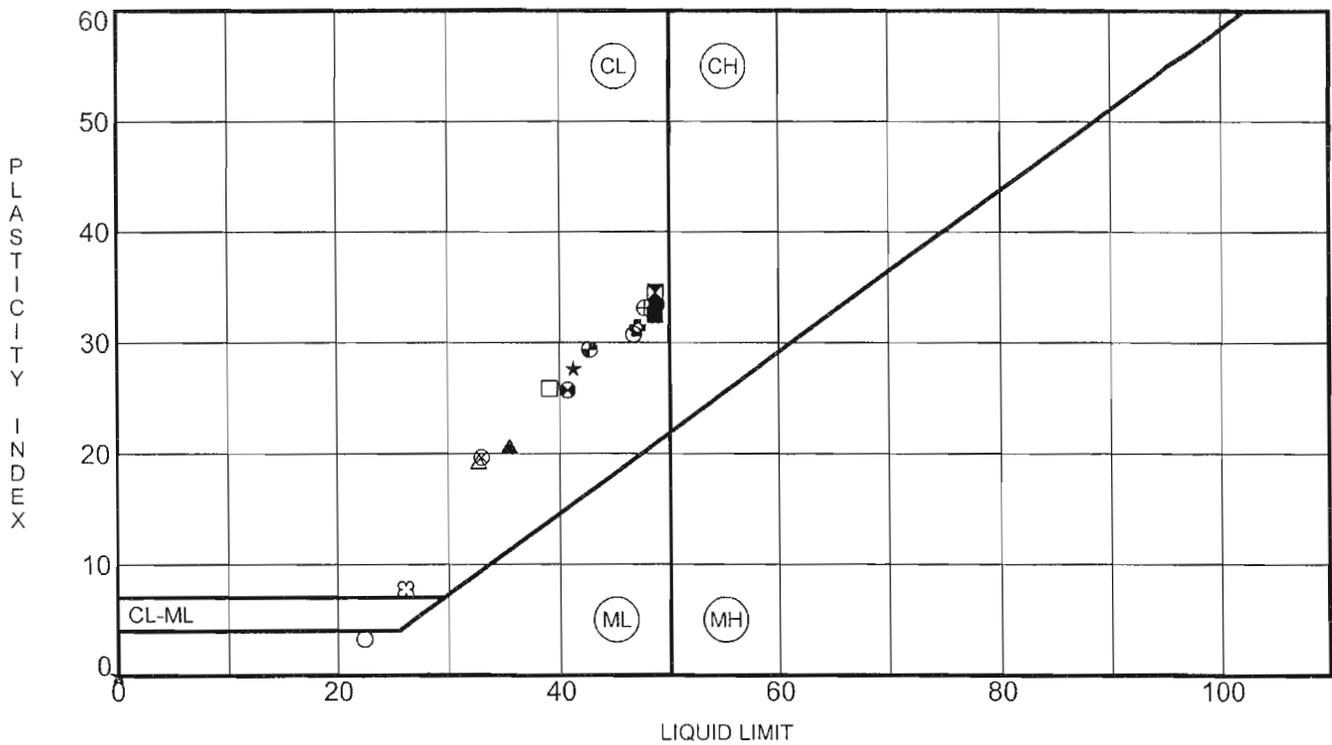


# Summary of Laboratory Results

| Borehole | Depth (ft) | Water Content (%) | Liquid Limit | Plastic Limit | Plasticity Index | < 1/2" | < 3/8" | < #4 | < #10 | < #40 | < #200 | Dry Unit Weight (pcf) | Strength (psf) |
|----------|------------|-------------------|--------------|---------------|------------------|--------|--------|------|-------|-------|--------|-----------------------|----------------|
| B-5      | 2.8        | 23.6              | 41           | 15            | 26               |        |        |      |       |       | 92     |                       |                |
| B-5      | 8.8        | 24.3              |              |               |                  |        |        |      |       |       |        |                       |                |
| B-6      | 5.8        | 23.5              |              |               |                  |        |        |      |       |       |        |                       |                |
| B-6      | 7.3        | 21.5              | 43           | 13            | 30               |        |        |      |       |       | 79     |                       |                |
| B-7      | 2.8        | 15.8              | NP           | NP            | NP               |        |        |      |       |       | 31     |                       |                |
| B-7      | 5.8        | 24.1              |              |               |                  |        |        |      |       |       |        |                       |                |
| B-8      | 2.8        | 17.5              | 26           | 18            | 8                |        |        |      |       |       | 75     |                       |                |
| B-8      | 5.8        | 28.8              |              |               |                  |        |        |      |       |       |        |                       |                |
| B-9      | 2.8        | 17.1              |              |               |                  |        |        |      |       |       |        |                       |                |
| B-9      | 5.8        | 20.2              | 49           | 16            | 33               |        |        |      |       |       | 85     |                       |                |

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 Client: Veterans Administration  
 Project: Fort Smith National Cemetery  
 Project Number: 6151-08-0263-01





| Specimen Identification | LL | PL | PI | % Fines | Moisture Content (%) | Classification                      |
|-------------------------|----|----|----|---------|----------------------|-------------------------------------|
| ● B-1 @ 8.3 ft          | 49 | 15 | 34 | 97      | 22.3                 | LEAN CLAY, CL, A-7-6 (35)           |
| ⊠ B-10 @ 7.3 ft         | 49 | 14 | 35 | 90      | 20.7                 | LEAN CLAY, CL, A-7-6 (32)           |
| ▲ B-11 @ 2.8 ft         | 35 | 15 | 20 | 92      | 20.5                 | LEAN CLAY, CL, A-6 (18)             |
| ★ B-12 @ 5.8 ft         | 41 | 14 | 27 | 81      | 21.2                 | LEAN CLAY with SAND, CL, A-7-6 (21) |
| ⊙ B-13 @ 7.3 ft         | 47 | 16 | 31 | 98      | 19.0                 | LEAN CLAY, CL, A-7-6 (32)           |
| ⊕ B-14 @ 8.8 ft         | 47 | 16 | 31 | 87      | 19.2                 | LEAN CLAY, CL, A-7-6 (27)           |
| ○ B-15 @ 1.3 ft         | 22 | 19 | 3  | 83      | 16.2                 | SILT with SAND, ML, A-4 (1)         |
| △ B-16 @ 4.3 ft         | 33 | 13 | 20 | 86      | 21.8                 | LEAN CLAY, CL, A-6 (16)             |
| ⊗ B-2 @ 4.3 ft          | 33 | 13 | 20 | 91      | 20.0                 | LEAN CLAY, CL, A-6 (17)             |
| ⊕ B-3 @ 7.3 ft          | 48 | 15 | 33 | 94      | 20.4                 | LEAN CLAY, CL, A-7-6 (32)           |
| □ B-4 @ 4.3 ft          | 39 | 13 | 26 | 93      | 22.8                 | LEAN CLAY, CL, A-6 (24)             |
| ⊕ B-5 @ 2.8 ft          | 41 | 15 | 26 | 92      | 23.6                 | LEAN CLAY, CL, A-7-6 (24)           |
| ⊕ B-6 @ 7.3 ft          | 43 | 13 | 30 | 79      | 21.5                 | LEAN CLAY with SAND, CL, A-7-6 (22) |
| ★ B-7 @ 2.8 ft          | NP | NP | NP | 31      | 15.8                 | SILTY SAND, SM, A-2-4 (0)           |
| ⊗ B-8 @ 2.8 ft          | 26 | 18 | 8  | 75      | 17.5                 | LEAN CLAY with SAND, CL, A-4 (4)    |
| ■ B-9 @ 5.8 ft          | 49 | 16 | 33 | 85      | 20.2                 | LEAN CLAY, CL, A-7-6 (28)           |
|                         |    |    |    |         |                      |                                     |
|                         |    |    |    |         |                      |                                     |
|                         |    |    |    |         |                      |                                     |
|                         |    |    |    |         |                      |                                     |

**ATTERBERG LIMITS RESULTS**

Prepared by: BRU      Reviewed by: *km*



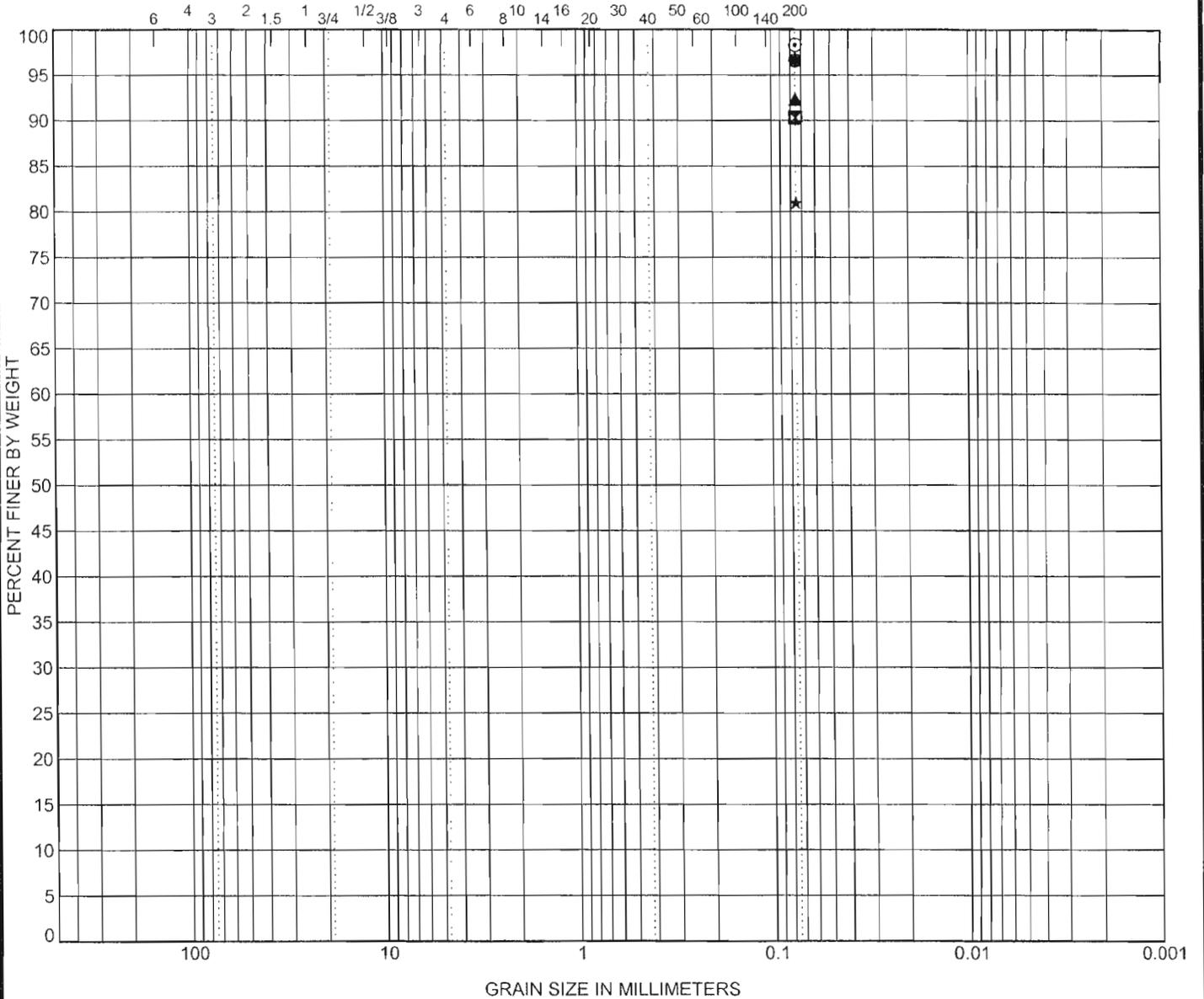
Client: Veterans Administration  
 Project: Fort Smith National Cemetery  
 Project Number: 6151-08-0263-01

U.S. ATTERBERG LIMITS ASTM 6151(08)0263-01.GPJ LAW: GIBB.GDT 11/17/08

U.S. SIEVE OPENING IN INCHES

U.S. SIEVE NUMBERS

HYDROMETER



| COBBLES | GRAVEL |      | SAND   |        |      | SILT OR CLAY |
|---------|--------|------|--------|--------|------|--------------|
|         | coarse | fine | coarse | medium | fine |              |

| Specimen Identification | Classification                 | LL | PL | PI | Cc | Cu |
|-------------------------|--------------------------------|----|----|----|----|----|
| ● B-1 @ 8.3 feet        | LEAN CLAY, A-7-6, CL           | 49 | 15 | 34 |    |    |
| ☒ B-10 @ 7.3 feet       | LEAN CLAY, A-7-6, CL           | 49 | 14 | 35 |    |    |
| ▲ B-11 @ 2.8 feet       | LEAN CLAY, A-6, CL             | 35 | 15 | 20 |    |    |
| ★ B-12 @ 5.8 feet       | LEAN CLAY with SAND, A-7-6, CL | 41 | 14 | 27 |    |    |
| ◎ B-13 @ 7.3 feet       | LEAN CLAY, A-7-6, CL           | 47 | 16 | 31 |    |    |

| Specimen Identification | D100  | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|-------------------------|-------|-----|-----|-----|---------|-------|-------|-------|
| ● B-1                   | 0.075 |     |     |     | 0.0     | 0.0   |       | 96.6  |
| ☒ B-10                  | 0.075 |     |     |     | 0.0     | 0.0   |       | 90.3  |
| ▲ B-11                  | 0.075 |     |     |     | 0.0     | 0.0   |       | 92.3  |
| ★ B-12                  | 0.075 |     |     |     | 0.0     | 0.0   |       | 81.0  |
| ◎ B-13                  | 0.075 |     |     |     | 0.0     | 0.0   |       | 98.3  |

**GRAIN SIZE DISTRIBUTION**

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Reviewed by: *KM*

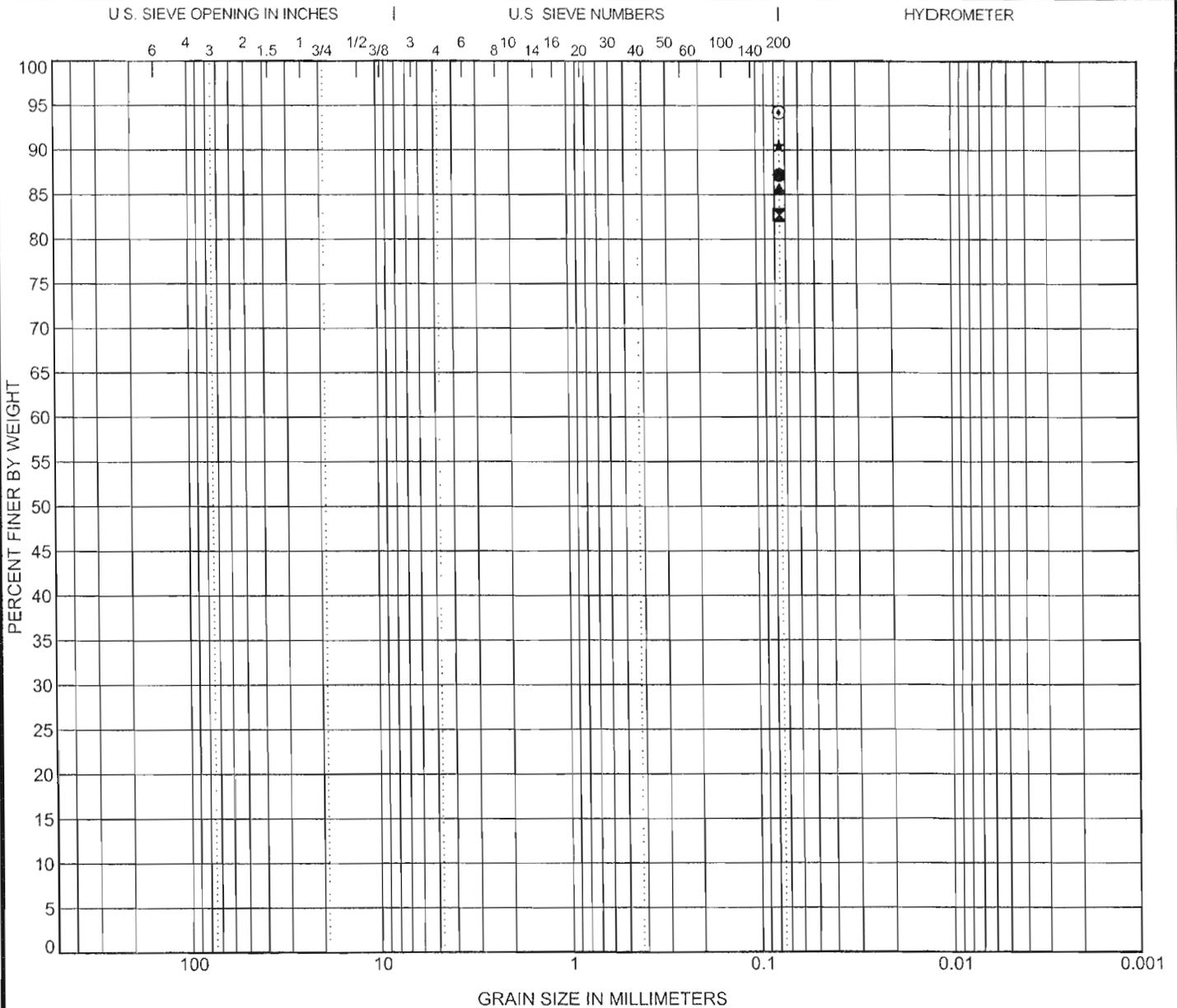


Client: Veterans Administration

Project: Fort Smith National Cemetery

Project Number: 6151-08-0263-01

US GRAIN SIZE ASTM 6151080263-01 G.P.J. LAW GIBB.GDT. 11/17/08



| COBBLES | GRAVEL |      | SAND   |        |      | SILT OR CLAY |
|---------|--------|------|--------|--------|------|--------------|
|         | coarse | fine | coarse | medium | fine |              |

| Specimen Identification | Classification          |     |     |     |         | LL    | PL    | PI    | Cc | Cu |
|-------------------------|-------------------------|-----|-----|-----|---------|-------|-------|-------|----|----|
| ● B-14 @ 8.8 feet       | LEAN CLAY, A-7-6, CL    |     |     |     |         | 47    | 16    | 31    |    |    |
| ☒ B-15 @ 1.3 feet       | SILT with SAND, A-4, ML |     |     |     |         | 22    | 19    | 3     |    |    |
| ▲ B-16 @ 4.3 feet       | LEAN CLAY, A-6, CL      |     |     |     |         | 33    | 13    | 20    |    |    |
| ★ B-2 @ 4.3 feet        | LEAN CLAY, A-6, CL      |     |     |     |         | 33    | 13    | 20    |    |    |
| ⊙ B-3 @ 7.3 feet        | LEAN CLAY, A-7-6, CL    |     |     |     |         | 48    | 15    | 33    |    |    |
| Specimen Identification | D100                    | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |    |    |
| ● B-14                  | 0.075                   |     |     |     | 0.0     | 0.0   | 87.2  |       |    |    |
| ☒ B-15                  | 0.075                   |     |     |     | 0.0     | 0.0   | 82.7  |       |    |    |
| ▲ B-16                  | 0.075                   |     |     |     | 0.0     | 0.0   | 85.6  |       |    |    |
| ★ B-2                   | 0.075                   |     |     |     | 0.0     | 0.0   | 90.5  |       |    |    |
| ⊙ B-3                   | 0.075                   |     |     |     | 0.0     | 0.0   | 94.2  |       |    |    |

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Reviewed by: *KMA*



Client: Veterans Administration

Project: Fort Smith National Cemetery

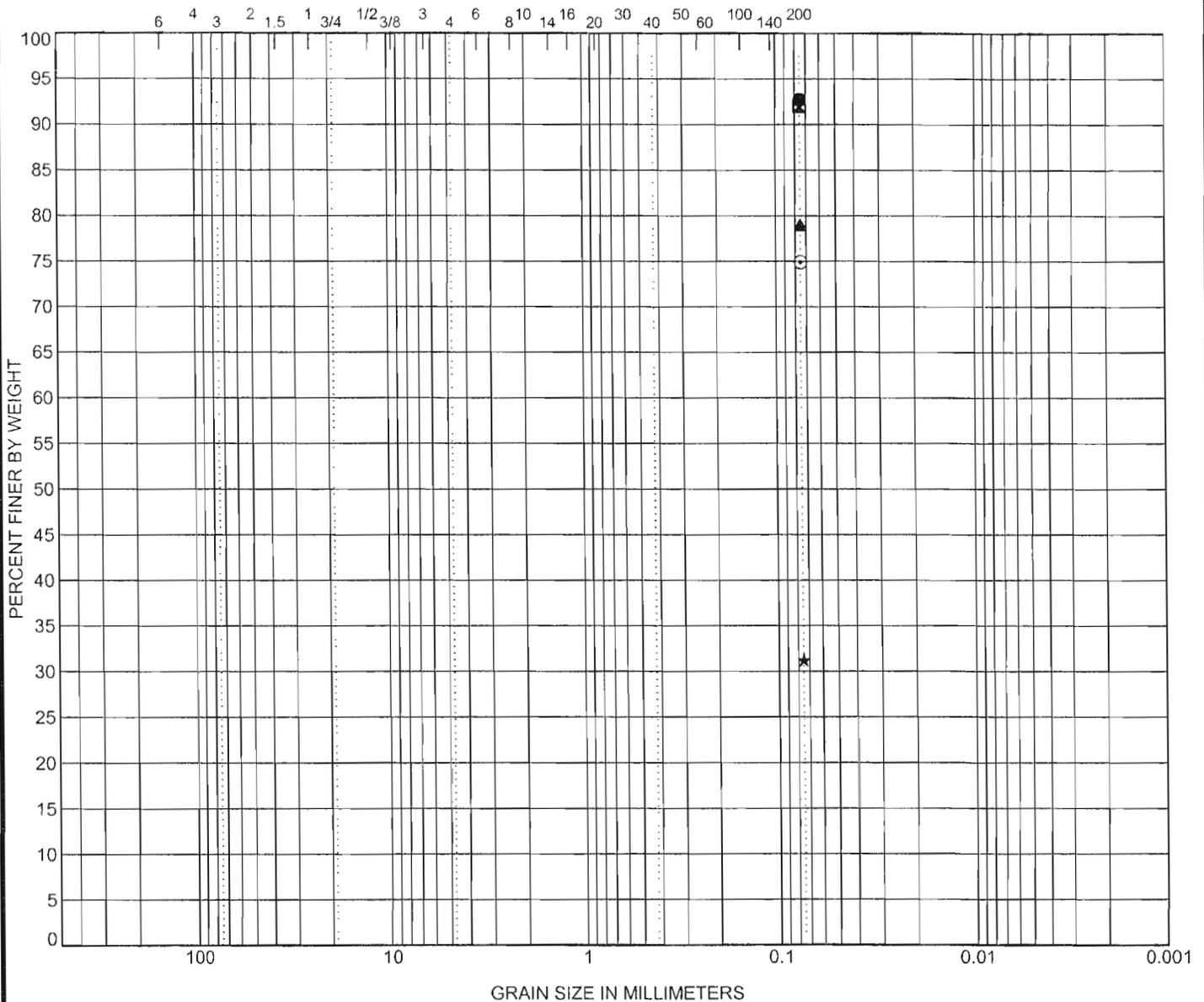
Project Number: 6151-08-0263-01

US GRAIN SIZE ASTM 6151080263-01.GPJ LAW GIBB.GDT 11/17/08

U.S. SIEVE OPENING IN INCHES

U.S. SIEVE NUMBERS

HYDROMETER



| COBBLES | GRAVEL |      | SAND   |        |      | SILT OR CLAY |
|---------|--------|------|--------|--------|------|--------------|
|         | coarse | fine | coarse | medium | fine |              |

| Specimen Identification | Classification                 | LL | PL | PI | Cc | Cu |
|-------------------------|--------------------------------|----|----|----|----|----|
| ● B-4 @ 4.3 feet        | LEAN CLAY, A-6, CL             | 39 | 13 | 26 |    |    |
| ☒ B-5 @ 2.8 feet        | LEAN CLAY, A-7-6, CL           | 41 | 15 | 26 |    |    |
| ▲ B-6 @ 7.3 feet        | LEAN CLAY with SAND, A-7-6, CL | 43 | 13 | 30 |    |    |
| ★ B-7 @ 2.8 feet        | SILTY SAND, A-2-4, SM          | NP | NP | NP |    |    |
| ⊙ B-8 @ 2.8 feet        | LEAN CLAY with SAND, A-4, CL   | 26 | 18 | 8  |    |    |

| Specimen Identification | D100  | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|-------------------------|-------|-----|-----|-----|---------|-------|-------|-------|
| ● B-4                   | 0.075 |     |     |     | 0.0     | 0.0   |       | 92.7  |
| ☒ B-5                   | 0.075 |     |     |     | 0.0     | 0.0   |       | 92.0  |
| ▲ B-6                   | 0.075 |     |     |     | 0.0     | 0.0   |       | 79.0  |
| ★ B-7                   | 0.075 |     |     |     | 0.0     | 0.0   |       | 31.2  |
| ⊙ B-8                   | 0.075 |     |     |     | 0.0     | 0.0   |       | 74.9  |

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Reviewed by: *km*



Client: Veterans Administration

Project: Fort Smith National Cemetery

Project Number: 6151-08-0263-01

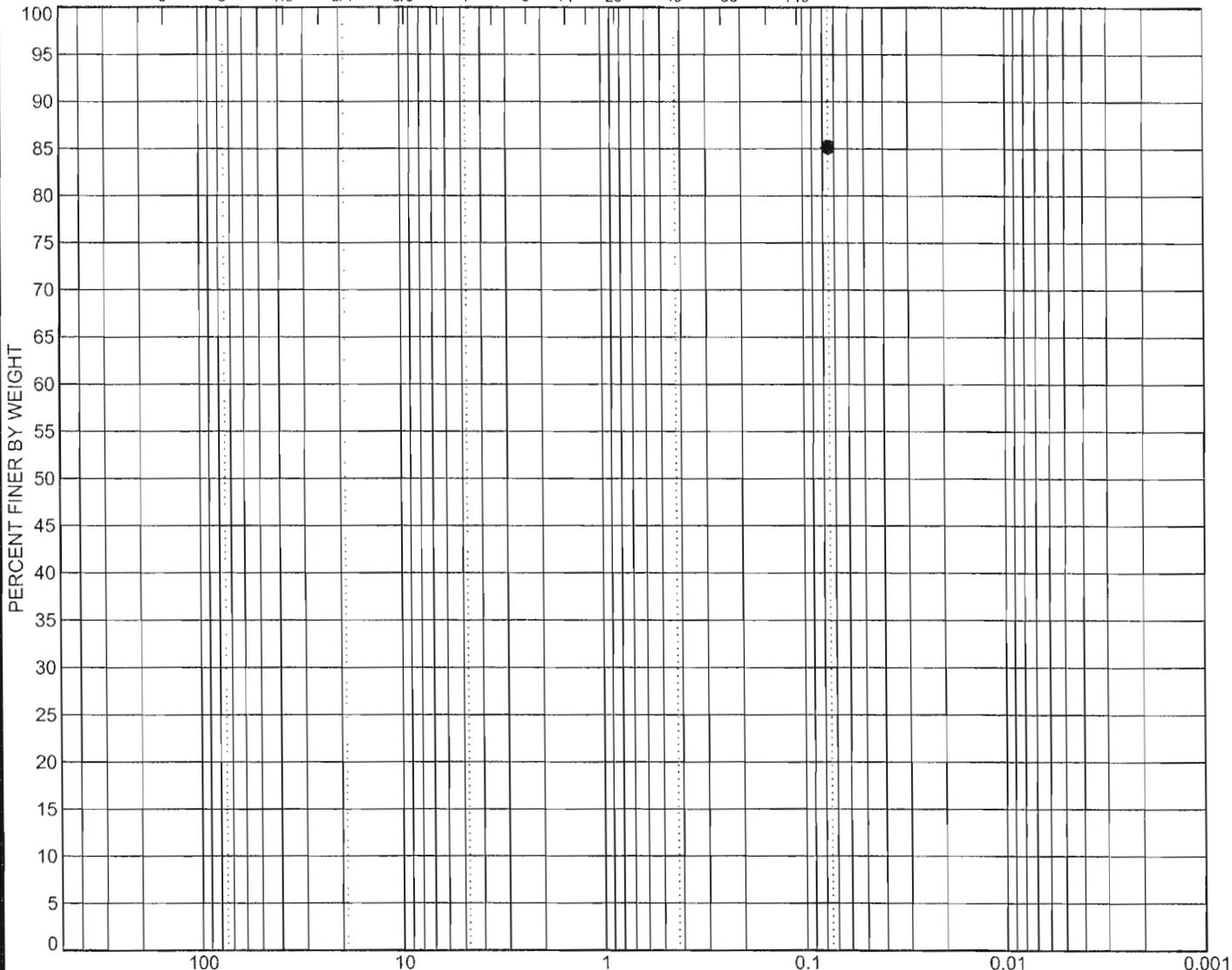
U.S. GRAIN SIZE ASTM 6151080263-01.GPJ L.A.W. GIBB.GDT. 11/17/08

U.S. SIEVE OPENING IN INCHES

U.S. SIEVE NUMBERS

HYDROMETER

6 4 3 2 1.5 1 3/4 1/2 3/8 3 4 6 8 10 14 16 20 30 40 50 60 100 140 200



GRAIN SIZE IN MILLIMETERS

|         |        |      |        |        |      |              |
|---------|--------|------|--------|--------|------|--------------|
| COBBLES | GRAVEL |      | SAND   |        |      | SILT OR CLAY |
|         | coarse | fine | coarse | medium | fine |              |

| Specimen Identification | Classification       | LL | PL | PI | Cc | Cu |
|-------------------------|----------------------|----|----|----|----|----|
| ● B-9 @ 5.8 feet        | LEAN CLAY, A-7-6, CL | 49 | 16 | 33 |    |    |

| Specimen Identification | D100  | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|-------------------------|-------|-----|-----|-----|---------|-------|-------|-------|
| ● B-9                   | 0.075 |     |     |     | 0.0     | 0.0   | 85.2  |       |

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 Project: Fort Smith National Cemetery  
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