8.0 GEOTECHNICAL INVESTIGATIONS

Throughout this section, reference to the "Contractor" simply means the entity responsible for the subject work. The same procedures and requirements generally apply to anyone providing geotechnical investigation services, whether the work is done in-house or by other USACE districts.

8.1 Contractor Requirements

Each work unit shall consist of personnel duly qualified and experienced to perform the type of required services. The Contractor shall use professional judgment in determining what equipment and/or supplies are needed to complete each delivery order assignment. The Government reserves the right to inspect and to monitor the activities of the A-E's work in determining that the A-E is performing the required services in accordance with Government standards procedures. The Contractor shall submit a time and cost estimate for each proposed assignment. The Contractor shall also submit detailed plans for performance of the work. The Contractor shall perform soil borings, testing, logging, reporting and plotting in the Corps of Engineers, New Orleans Districts (Government) format. The Corps of Engineers (or the Designer of Record) will pick the type of soil borings, boring sample size and length, boring locations, type and location of required soil lab tests.

8.1.1 Field Assignments

The Contractor will be responsible for locating, clearing, determining ground surface elevations and water tables, retrieving soil borings (including 1-7/8" I.D. Splitspoon, 3" general type and undisturbed type and 5" Undisturbed soil borings), sealing boreholes, and acquiring other equipment as necessary to complete the field assignments. Borings may include work in marsh areas, and/or work over water.

8.1.2 Office and Laboratory Assignments

The Contractor will be responsible for classifying and testing soil samples and computing, compiling and furnishing plotted boring logs of the resulting field and laboratory data.

8.1.3 Quality Assurance

The Contractor shall discuss each proposed assignment to develop a mutual understanding of:

(1) Type of work to be done
(2) Received Soil Boring Locations
(3) End result expected by the COR

(4) Methods to be used by the Contractor
(5) Format of computations and/or drawings
(6) Completion data required by a date to be determined by the Government.

A Government representative shall be present during boring retrieval and sample testing at various times to be determined by the Government in order to perform quality assurance and to verify boring sample quality and soils testing accuracy.

8.1.4 Government Furnished Materials

The Contractors automated computations shall follow the same format as that used by the Government. The necessary, locally derived, MS-DOS/Windows programs can be made available if required by the Contractor. Due to copyright laws commercially available off-the-shelf programs, such as CADD-type programs, will not be available from the Corps.

Point of Contact is Denis J. Beer, P.E. at Denis.J.Beer@usace.army.mil.

8.2 Subsurface Investigations

8.2.1 Locating and Setting-Up for Borings

Normally the Government will obtain right of entry to take soil borings and inform the local sponsor that clearing of small trees and underbrush may be required. The Contractor shall locate borings; cut brush and/or timber to provide access to the site; obtain latitude, longitude, ground surface elevations and water table elevations; and set-up soil boring drill rigs in the field. The Government (or Designer of Record) will furnish soil boring locations. The Government (or Designer of Record) will supply a map showing the soil boring locations. The locations will be either tied to a baseline with a station, distance and azimuth to each boring location, if one exists, or lat/longs or X-Y coordinates are provided for each location. Vertical control for use in determining the ground surface elevations of the borings will be furnished by the Contractor. The Contractor should contact the Government for benchmark information.

8.2.2 Sampling of Borings

The Contractor shall use a fixed-piston type sampling method (Hvorslev fixed-piston or equivalent) for (CH), (CL) and (ML) type soils and be capable of providing undisturbed sampling to depths of 300 ft. Bentonite based drilling mud shall be used throughout the sampling process to improve sample recovery and minimize sample disturbance. The sampler for (SM) and (SP) type soils shall be standard Splitspoon sampler (1-7/8 inch I.D., 2 inch O.D.). The driving resistance in blows per foot shall be determined for (SM) and (SP) type soil with a 140 pound driving hammer having a 30" drop. The Driller shall state the type of hammer used for the SPT, such as automatic or two rope-wraps around cathead.

The driller will measure the hammer energy delivered to the drill rods from the sampler for each drill rig. The hammer and how the hammer energy was obtained will be placed on the boring log. The Government or the Designer of Record should determine if a correction factor is applied to the SPT results. The Contractor should be aware that a number of borings will be taken from marshy environments that may require special equipment, such as marsh buggies.

8.2.2.1 Shelby Tube Sampling

The general type piston sampler shall utilize a minimum of 3 inch Shelby Tubes (3" O.D., approx. 2-7/8" I.D.) that are a minimum of 46 inches in length with sealing caps. An undisturbed type piston sampler shall utilize a minimum of 5 inch thin-wall Shelby Tubes (5" O.D., approx. 4-3/4" I.D.) that are a minimum of 54 inches in length with sealing caps. During sampling with the fixed-piston type sampler, the piston should be locked at the bottom of the sampling tube until it is seated on the bottom of the borehole. The piston shall be released, piston rod held in place, and the tube shall be pushed in one or two pushes to obtain sample. The sample tube is then removed hydraulically through a vacuum then with hoists and cables. The Contractor shall use the Government field boring log form as a record of soil stratification and soil sampling (see Figure 8.3). A copy of the original field boring logs shall be supplied to the Government. The soil samples will be preserved in airtight containers to prevent loss of moisture.

8.2.2.2 Sample Storage, Extrusion and Shipment

Once samples have been removed from the boreholes for undisturbed soil borings, they must be sealed within the sampling tube with end caps and ends taped prior to shipment to the laboratory for extrusion, classification and testing. Hydraulically activated sample jacks shall be used to extrude the samples from the tubes. Mechanical and pneumatically activated sample jacks shall not be used to extrude the samples. All tubes shall be identified and labeled immediately to ensure correct orientation and to accurately identify the samples. ENG Form 1742 and/or ENG Form 1743, as shown in Figure 8.2 (or equivalent), should be completed and securely fastened to each sample. Sample tubes shall be shipped to the testing laboratory such that they are not allowed to roll around in the shipping vehicle, nor should they be dropped or otherwise roughly handled. Samples shall be protected from extreme temperatures and exposure to moisture. Samples shall be extruded from the tube within 5 days after retrieval and shall be kept in air-tight container. Any samples that will be tested more than seven (7) days after extrusion shall be waxed. Waxed samples shall be stored in a humid room. All storage, extrusion and shipment procedures shall be done in accordance with EM 1110-1-1804, Chapter F, paragraphs 6-5 through 6-7. Samples remaining after testing will remain at the Contractor's office until the Government requests their disposal or collected by the Government.

8.2.2.3 Backfilling of Borehole

Upon completion of the borings, the borehole shall be grouted full depth in accordance with State of Louisiana regulations. Grout mix should consist of 2 part cement and 1 part bentonite and shall be tremie grouted from the bottom of the hole within three feet of the ground surface. The top three feet will be backfilled with native soil.

8.3 Laboratory Soil Testing

8.3.1 Laboratory Facilities

A laboratory preferably should be on a ground floor or basement with a solid floor and should be free of traffic and machinery vibrations. Separate areas should be designated for dust producing activities such as sieve analyses and sample processing. Temperature control of the entire laboratory is to be preferred. If the temperature-controlled space is limited, this space should be used for triaxial compression, consolidation, and permeability testing. A humid room large enough to permit the storage of samples and the preparation of test specimens should be available. The Contractor shall, at its own expense, obtain validation as an approved testing laboratory by the Materials Testing Center (MTC) of the Engineering Research and Development Center (ERDC). This shall be done in accordance with ER 1110-1-8100 and ER 1110-1-261. Depending upon the workload by the Government inspecting agency, acceptance or rejection of the Contractor proposed testing laboratory is usually done approximately 60 to 120 days after notification is received from the Contractor. The certification is typically valid for three years.

8.3.2 Soil Classification

The Contractor shall classify, record and plot soil data within 7 days of obtaining the samples from the field. A water content determination shall be made and recorded on all samples classified as (CH), (CL), and (ML). The Unified Soil Classification System and the “Guide for Moisture Contents adapted to CEMVN-ED-F Soils” shall be used in classifying the soils (see Figures 8.4 and 8.5). All data recorded during the classification process (including but not limited to strata elevations, soil type, moisture content, consistency, color and modifiers) shall be recorded and furnished on LMN form 721, Nov 69 (see Figure 8.1), as well as in a computer file format specified by the Government.

The soil borings logs shall also be plotted and supplied to the Government using computer software available from the government. Request should be made for the General Boring Log Program (FG002) and Undisturbed Boring Log Program (FS008). Note: This software will only execute under Micro Station SE or J. The location, number and type of soils testing shall be furnished to the Contractor within 3 days of the receipt of the soil classification and boring log data.

8.3.3 General Soils Testing

All general soils testing shall begin within 14 days of the receipt of the number and location of the soils tests from the Government (or the Designer of Record). Atterberg Limits determinations will be made on representative clay (CH) and clayey (CL & ML) fractions of the boring at a rate and/or at a location defined by the Government (or the Designer of Record). Grain size distribution determinations may be required; these may include both sieve and hydrometer testing. General soils testing shall be in accordance with EM 1110-2-1906.

8.3.4 Compressive Strength Tests

All compressive strength testing shall begin within 14 days of the receipt of the number and location of the soils tests from the Government (or the Designer of Record). An explanation of any atypical data, such as calibration factors, correction factors, shall be furnished in addition to the following. Upon request, the Contractor shall furnish to the Government duplicate samples of test specimens for possible testing by the Government.

8.3.4.1 Unconfined Compression Tests

Unconfined Compression Tests (UCT) described in EM 1110-2-1906 will be performed on representative samples on 3-inch general type and 5-inch undisturbed samples at an interval and/or at locations defined by the Government (or Designer of Record). UCT specimens shall have a diameter of 1.4 inches and a minimum length of 3.0 inches. UCT results shall include, but not be limited to, boring name, sample elevation, sample location, strain rate, specific gravity, water content, wet density, dry density, saturation, void ratio, diameter and height. In addition, the Contractor shall supply plotted compressive stress vs. axial strain plots, to include unconfined compressive strength, failure strain, and undrained shear strength.

8.3.4.2 Triaxial Shear Tests

Triaxial shear tests described in EM 1110-2-1906 will be required on selected 5 inch undisturbed samples. The 5 inch diameter sample shall be cut into 4 equal specimens such that each specimen can be trimmed for testing. The specimen size for triaxial testing shall be 1.4 inches in diameter and 3 to 3.5 inches in length. The triaxial shear test is defined by a suite of three tests performed at three different confining stresses (the maximum confining pressure shall be at least equal to the maximum normal pressure expected in the field with the project in place) performed on three trimmed specimens from the same 5-inch sample. The fourth specimen shall be tested if verification of one of the first three tests in necessary. The Triaxial shear testing will be Unconsolidated Undrained (Q) tests, Consolidated Undrained (R) tests with pore pressure data measured and recorded, and Consolidated Drained Direct (S) tests. The axial load induced to the

specimens shall be done so at a rate of 1.0 percent per minute until an axial strain of 20 percent has been reached. A strain rate of 0.3 percent per minute shall be used for materials that achieve maximum deviator stress at about 3 to 6 percent strain. Results from triaxial tests shall include, but not be limited to, the boring name, sample elevation, sample location, Atterberg Limits, unit weight, specific gravity, water content, dry density, saturation, void ratio, diameter and height, back pressure, cell pressure, failure stress, ultimate stress, and deviator stress at failure. In addition, plotted stress strain curves and Mohr Circle plots shall be furnished for each specimen tested. Generated Mohr-Coulomb failure envelope plots (to include computer generated/selected compressive stress values (cohesion) and values for internal friction angles) shall be furnished.

8.3.5 Consolidation Testing

Consolidation tests described in EM 1110-2-1906 will be required on selected 5 inch undisturbed samples. The 5 inch diameter sample shall be trimmed to tightly fit a consolidation ring with diameter not less than 4.0 inches in diameter. The specimen should be loaded according to the following normal increments: 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 tons per square foot. Lower starting load may be necessary for a sample with minor overburden. Readings of deformation (as determined from dial indicator readings) versus time shall be measured and recorded at the following times: 0.1, 0.2, 0.5, 1.0, 2.0, 4.0, 8.0, 15.0, and 30.0 minutes and 1, 2, 4, 8, and 24 hours. If primary consolidation has not occurred in the first 24 hours, hold the load for an additional 24 hours each day until primary consolidation has occurred. Continuous saturation of the sample shall be maintained until each test is complete. Results from consolidation tests shall include, but not be limited to, the boring name, sample elevation, sample location, Atterberg Limits, specific gravity, water content, dry density, saturation, initial void ratio, and diameter and height of the sample. In addition, plotted curves of (1) applied pressure versus void ratio, (2) applied pressure vs. Cv, and (3) dial gage reading versus time for each load increment shall be furnished and (3) Casagrande construction to indicate the maximum past preconsolidation pressure.

8.3.6 Logging and Reporting

The results of the field borings and laboratory tests shall be shown and furnished on LMN form 721, Nov 69, as well as in a computer file format specified by the Government. The completed logs and test results shall be furnished to the Government no later than 15 days after testing has been completed. The soil borings shall also be reported and furnished as plotted stratified soil logs and shall contain all field/laboratory testing information. In addition the logs will be furnished and named as specified by the Government. They shall be furnished in a Windows 2000 compatible file format and/or Microstation 4.0 (or later) Intergraph CADD file format. The government will furnish the computer software necessary to plot the soil borings as stated in 8.3.2.

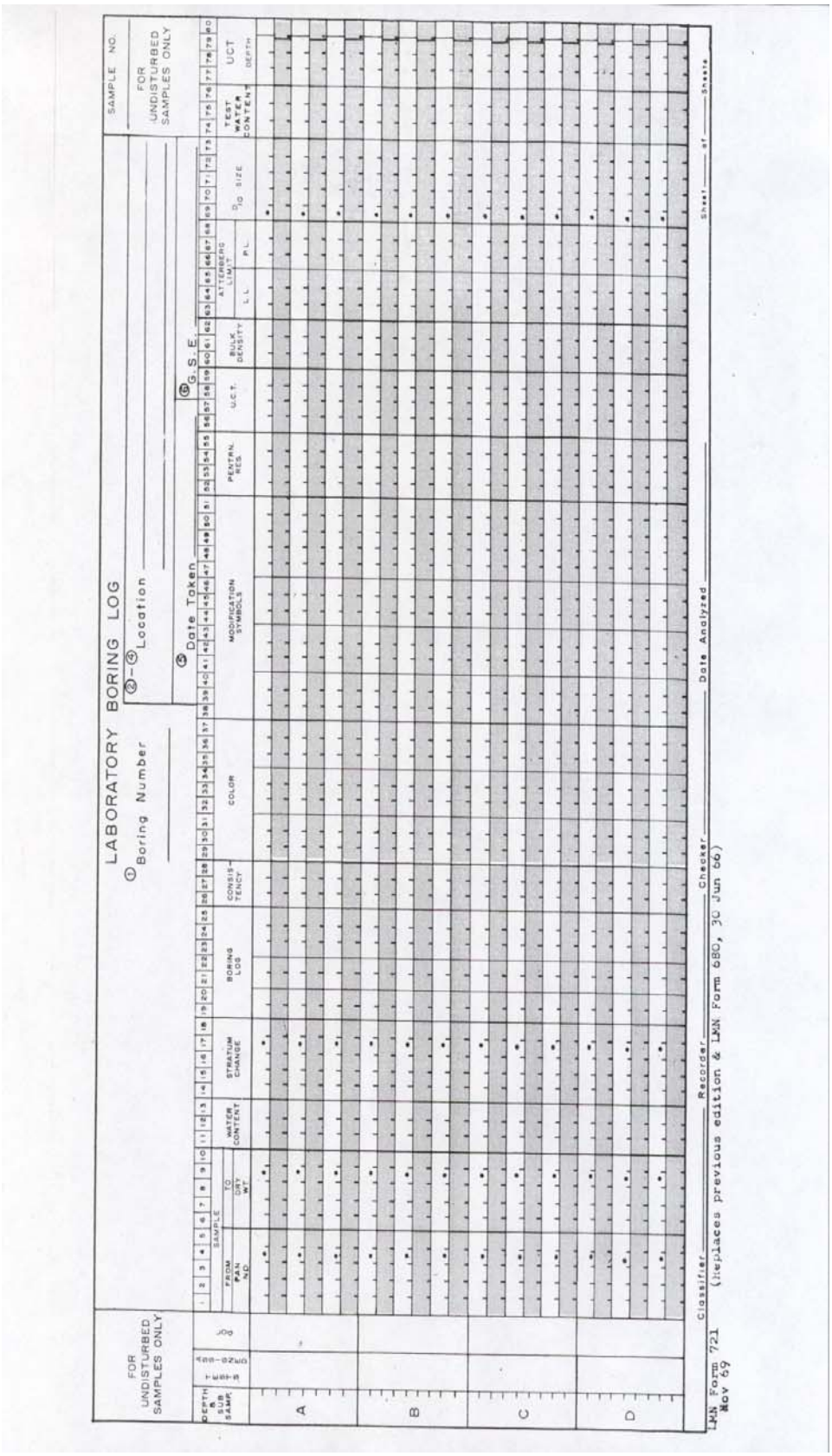


Figure 8.1. LMN Form 721

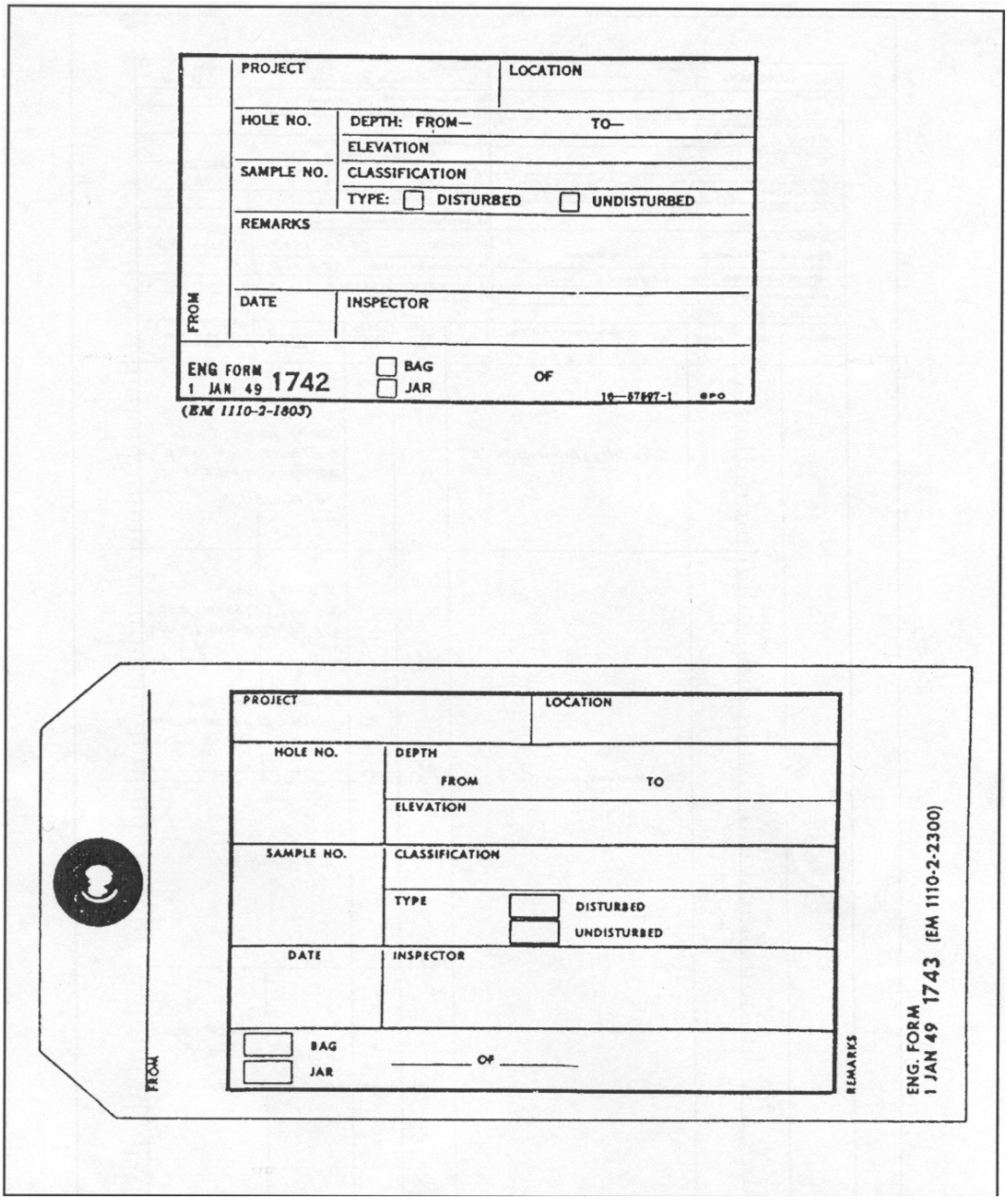


Figure 8.2 ENG Forms 1742 & 1743

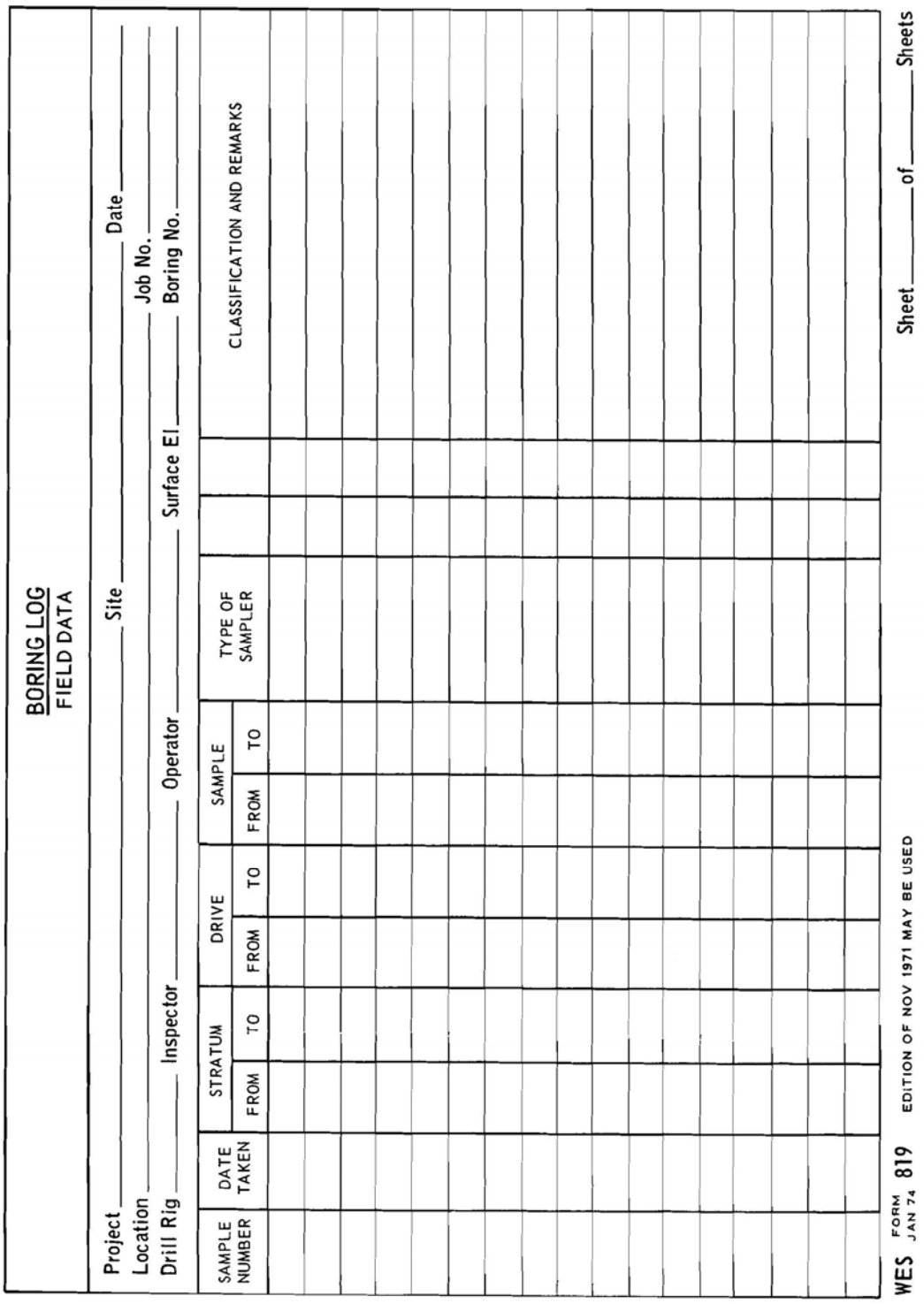


Figure 8.3 WES Form 819

UPDATED 04 OCT 07

UNIFIED SOIL CLASSIFICATION

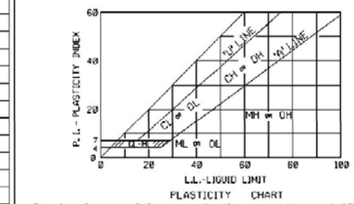
MAJOR DIVISION		TYPE	LETTER SYMBOL	SYMBOL	TYPICAL NAMES
COARSE - GRAINED SOILS	GRAVELS (More than half of coarse fraction is larger than No. 4 sieve size.)		GW		GRAVEL,Well Graded,gravel-sand mixtures,little or no fines
			GP		GRAVEL,Poorly Graded,gravel-sand mixtures,little or no fines
		GRAVEL WITH FINES (Appreciable amount of fines)	GM		SILTY GRAVEL,gravel-sand-silt mixtures
			GC		CLAYEY GRAVEL,gravel-sand-clay mixtures
	SANDS (More than half of coarse fraction is smaller than No. 4 sieve size.)	CLEAN SANDS (Little or No Fines)	SW		SAND,Well-Graded,gravelly sands
			SP		SAND,Poorly-Graded,gravelly sands
		SANDS WITH FINES (Appreciable amount of fines)	SM		SILTY SAND,sand-silt mixtures
			SC		CLAYEY SAND,sand-clay mixtures
FINE - GRAINED SOILS (More than half the material is smaller than No. 200 sieve size.)		SILTS AND CLAYS (Liquid Limit less than 50)	ML		SILT & very fine sand,silty or clayey fine sand or clayey silt with slight plasticity
			CL		LEAN CLAY,Sandy Clay,Silty Clay,of low to medium plasticity
			OL		ORGANIC SILTS,and organic silty clays of low plasticity
		SILTS AND CLAYS (Liquid Limit greater than 50)	MH		SILT,fine sandy or silty soil with high plasticity
			CH		FAT CLAY,inorganic clay of high plasticity
			OH		ORGANIC CLAYS of medium to high plasticity,organic silts
HIGHLY ORGANIC SOILS			Pt		PEAT,and other highly organic soil
WOOD			Wd		WOOD
SHELLS			SJ		SHELLS
NO SAMPLE			NS		No Sample Retrieved

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

DESCRIPTIVE SYMBOLS

COLOR	SYMBOL
TAN	T
YELLOW	Y
RED	R
BLACK	BK
GRAY	Gr
LIGHT GRAY	lGr
DARK GRAY	dGr
BROWN	Br
LIGHT BROWN	lBr
DARK BROWN	dBr
BROWNISH-GRAY	brGr
GRAYISH-BROWN	gyBr
GREENISH-GRAY	gnGr
GRAYISH-GREEN	gyGn
GREEN	Gn
BLUE	Bl
BLUE-GREEN	BlGn
WHITE	Wh
MOTTLED	Mot

CONSISTENCY FOR COHESIVE SOILS		
CONSISTENCY	COHESION IN LBS./SQ.FT. FROM UNCONFINED COMPRESSION TEST	SYMBOL
VERY SOFT	< 250	vSo
SOFT	250-500	So
MEDIUM	500-1000	M
STIFF	1000-2000	St
VERY STIFF	2000-4000	vSt
HARD	> 4000	H



PLASTICITY CHART

For classification of fine-grained soils in accordance with ASTM D 2487

MODIFICATIONS	
MODIFICATION	SYMBOL
Traces	Tr
Fine	F
Medium	M
Coarse	C
Concretions	cc
Rootlets	rt
Lignite fragments	lg
Shale fragments	sh
Sandstone fragments	sds
Shell fragments	slf
Organic matter	O
Clay strata or lenses	CS
Silt strata or lenses	SIS
Sand strata or lenses	SS
Sandy	S
Gravelly	G
Boulders	B
Slickensides	SL
Wood	Wd
Oxidized	Ox

NOTES:

FIGURES TO LEFT OF BORING UNDER COLUMN "W OR D_{10}"

Are natural water contents in percent dry weight

When underlined denotes D_{10} size in mm *

FIGURES TO LEFT OF BORING UNDER COLUMNS "LL" AND "PL"

Are liquid and plastic limits, respectively

SYMBOLS TO LEFT OF BORING

▽	Ground-water surface and date observed
Ⓒ	Denotes location of consolidation test**
Ⓢ	Denotes location of consolidated-drained direct shear test **
Ⓟ	Denotes location of consolidated-undrained triaxial compression test **
Ⓤ	Denotes location of unconsolidated-undrained triaxial compression test **
Ⓣ	Denotes location of sample subjected to consolidation test and each of the above three types of shear test **
FW	Denotes free water encountered in boring or sample

FIGURES TO RIGHT OF BORING

Are values of cohesion in lbs./sq.ft. from unconfined compression tests

In parenthesis are driving resistances in blows per foot determined with a standard split spoon sampler (1 3/8" I.D., 2" O.D.) and a 140 lb. driving hammer with a 30" drop

Where underlined with a solid line denotes laboratory permeability in centimeters per second of undisturbed sample

Where underlined with a dashed line denotes laboratory permeability in centimeters per second of sample remoulded to the estimated natural void ratio

*The D_{10} size of a soil is the grain diameter in millimeters of which 10% of the soil is finer, and 90% coarser than D_{10}

**Results of these tests are available for inspection in the U.S. Army Engineer District Office, if these symbols appear beside the boring logs on the drawings.

TYPICAL NOTES:

1. While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of the region are anticipated and, if encountered, such variations will not be considered as differing materially within the purview of the contract clause entitled "Differing Site Conditions".
2. Ground-water elevations shown on the boring logs represent ground-water surfaces encountered in such borings on the dates shown. Absence of water surface data on certain borings indicates that no ground-water data are available from the boring but does not necessarily mean that ground-water will not be encountered at the locations or within the vertical reaches of such borings.
3. Consistency of cohesive soils shown on the boring logs is based on driller's log and visual examination and is approximate, except within those vertical reaches of the borings where shear strengths from unconfined compression tests are shown.
4. Unless otherwise noted:
   a. Undisturbed borings, indicated by the letter "U", are taken with a 5" I.D. Piston Type Sampler.
   b. General type borings are taken with a 1 7/8" I.D. Tube Sampler and/or a 1 3/8" I.D. Split Spoon Sampler.

REVISED 25 JUNE 92

SOIL BORING LEGEND

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
NEW ORLEANS, LOUISIANA

DESIGNED BY: VOJKOVICH	DATE: APRIL 1992	CADD FILE: SOILLEGEND
DRAWN BY: WOODS	PLOT DATE: 30 MAR 93	FILE NO: H-2-30962
CHECKED BY: RICHARDSON	SCALE: 200	

PLATE A

Figure 8.4 Unified Soil Classification System

Guide for
*** MOISTURE CONTENTS**
ADAPTED TO CEMVN-ED-F SOILS

CLASS	STIFF	MEDIUM	SOFT	V. SOFT	LIQUID LIMIT	PLASTICITY INDEX
CH-4	41-53	43-65	55-80	67-130	70-110	45-75
CH-3	32-43	34-55	44-67	55-114	55-80	30-55
CH-2	27-34	30-44	38-55	48-90	50-60	25-40
CL-6	23-30	25-39	33-48	40-79	40-50	20-35
CL-4	20-25	21-33	27-41	35-67	28-43	10-25
CH-OA	.....				110-160	75-97
CH-OB	.....				160-185	97-115
CH-OC	.....				185-	115-

* For brown or oxidized soils, subtract 10% from the above Moisture Contents.

NOTE: We are using this with the Unified Soil Classification System as a guide and supplementation breakdown for CH's and CL's. We use the CHOA, CHOB and CHOC for organic fat clays in lieu of "OH" and CLOA, CLOB and CLOC for organic lean clays in lieu of OL when used for lean clays. Also, double classes are not used, such as SC-SM or CL-ML. The major class governs and the secondary is recorded as a modification or stratum as appropriate.

Figure 8.5 Unified Soil Classification System Modified for New Orleans Soils