SSCL-SR-1196
SGR-10

Engineers, Geologists, Chemists, Water Planners, Hygienists and Environmental Scientists

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Project No. ASA91-020-00
July 8, 1991

Mr. Charles Daugherty
The PB/MK Team
Redbird Business Center, Building 5
5610 Redbird Center Drive, Suite 400
Dallas, Texas 75237

Re.: Geotechnical Study
Tank Farm Facility - E1 Site
Superconducting Super Collider
Waxahachie, Texas

Dear Mr. Daugherty:

Submitted here is a report of subsurface conditions at the designated Tank Farm facility for the West Campus (E1 Site) of the Superconducting Super Collider Project in Ellis County, Texas. Facilities proposed include a series of above-ground, cylindrical storage tanks. Preliminary plans call for the tanks to be supported on two footings, each carrying maximum loads of 32 kips. Both shallow and deep footings are being considered for the tank foundations.

This engineering report has been prepared for the use of The PB/MK Team and their design associates for design purposes in accordance with accepted Geotechnical Engineering practices. This report may not contain sufficient information for purposes of other parties or other

uses. This work was conducted under PB/MK Subcontract No. SC-A43-1013, dated February 4, 1991.

FIELD EXPLORATION AND LABORATORY TESTS

Borings Subsurface conditions at the site were evaluated by one boring drilled at the location shown on the Plan of Boring, Plate 1. The number of borings included in this study, their field locations, and their termination depths were selected by The PB/MK Team. The boring was drilled to a depth of 12.3 ft below existing grade using rotary drilling and coring techniques in accordance with ASTM D 420 procedures. A staff geologist was present at the site to coordinate the drilling operations and stratigraphically log the boring. The field log contains information concerning the boring method, drill crew, time of drilling, samples attempted and recovered, indications of the presence of various materials such as silt, clay, gravel, sand or rock, and observations of ground water.

The final log represents our interpretation of the contents of the field log for the purpose delineated by our client. The final log is included in the Illustrations section of this report, Plate 2. A key to classification terms and symbols used on the log appears on Plate 3.

Sampling The following samples were collected as a part of our subsurface exploration procedures:

Type of Sample	ASTM Procedure	Number Collected
Undisturbed Shelby Tube	D 1587	1
NX Core, feet	D 2113	12

Representative portions of all soil samples, as well as all rock core recovered, were sealed to reduce moisture loss, placed in protective containers, and transported to our laboratory for testing.

Laboratory Testing In the laboratory, each sample was inspected and classified by a geotechnical engineer. The geotechnical engineering properties of the soils/rock were evaluated by the following tests:

Type of Test	Procedure	Number Conducted
Moisture Content	ASTM D 2216	3
Atterberg Limits	ASTM D 2217 ASTM D 4318	1
Dry Unit Weight	ASTM D 2938	3
Unconfined Compression	ASTM D 2938	3

The results of all laboratory tests are presented in graphical or numerical form on the boring log.

GENERAL SITE AND SUBSURFACE CONDITIONS

Existing Conditions The project site generally consist of an open, native grass-covered tract of land most recently used for agricultural purposes and livestock grazing. The topography in this region is generally described as gently rolling, with the ground surface at the E1 Site sloping gently downward in an east-southeasterly direction. Existing site drainage is considered to be fair to poor.

Stratigraphy The soils/rock underlying the proposed Tank Farm site can be divided into three generalized strata that possess similar physical and engineering characteristics, as described below.

Stratum I consists of dark brown clays and extends to a depth of 0.3 ft below existing grade in the test boring. These clays are indicated to be plastic to highly plastic, with a measured liquid limit of 58

percent and a corresponding plasticity index of 37. Designated as CH soils under the Unified Soil Classification System (USCS), clays of this plasticity are generally recognized to possess moderate to high shrink/swell potential. Based on the results of a hand penetrometer test performed on the undisturbed specimen, these clays exhibit hard consistencies.

Stratum II consists of tan, slightly weathered, soft to moderately hard limestone of the Austin Chalk Formation and extends to a depth of 6.0 ft below existing grade in the test boring. Argillaceous seams and close horizontal partings/joints are common within this formation. Recovery ratios and rock quality designations (RQD) measured for core runs performed in this stratum substantiate the weathered, intermittently jointed nature of the limestone. An RQD of 46 percent was measured for the one core run performed in this stratum. Unconfined compressive strengths measured for specimens of the weathered limestone vary from 80.4 to 191 tsf.

Stratum III consists of gray to dark gray, unweathered, soft to moderately hard limestone of the Austin Chalk Formation and extends to at least the 12.3 ft termination depth of the test boring. Argillaceous seams/layers and close horizontal partings are also common within this stratum within the depth explored. Recovery ratios were excellent for core runs performed in this stratum, while RQD values varied from good to excellent (in excess of 80 percent). The strength of one specimen of the unweathered limestone tested in unconfined compression was 143 tsf.

<u>Ground Water</u> Ground water was not encountered in the test borings prior to the introduction of drilling fluids for rock coring activities. However, ground water seepage may exist on a transient basis within the weathered upper reaches of the Stratum II limestone, particularly following periods of heavy precipitation.

FOUNDATION ANALYSIS AND RECOMMENDATIONS

Vertical Movements As mentioned previously, the Stratum I clays at this site are generally recognized to possess moderate to high shrink/swell potential when subjected to fluctuating moisture conditions. Although surficial in nature in the Tank Farm boring (0.3 ft in depth), previous drilling at the E1 Site has shown that slightly deeper deposits are possible. While not expected to affect the performance of the tank foundations (since the footings will bear in the underlying limestone), these soils may influence the future performance of ancillary buried piping and conduits servicing the tanks. Potential vertical movements of up to 1 in. have been previously estimated for at-grade construction using the Texas State Department of Highways and Public Transportation procedures (TSDHPT, Tex-124-E) for predicting Potential Vertical Rise (PVR).

Based on the above discussion, we recommend that the Stratum I clays be removed from beneath all below grade conduits/piping servicing the tank farm. Utility trenches resulting from overexcavation of the Stratum I clays should be backfilled in accordance with the manufacturer's recommendations concerning backfill materials and compaction requirements.

Foundation Options Based on the anticipated tank loads and the shallow nature of the limestone formation underlying this site, the proposed tanks may be founded on either shallow conventional square spread or circular drilled footings bearing in the Stratum II weathered limestone, or on straight drilled shafts bearing at deeper depths in the unweathered limestone underlying this site. Recommendations and design criteria for both foundation schemes are presented below. Cost analyses have not been conducted for any foundation system, and are beyond the scope of this study.

Shallow Footing Foundations Conventional square spread footings should be a minimum of 36 in. wide and founded at a minimum depth of 12

in. into the native, intact Stratum II weathered limestone. Circular drilled footings should be a minimum of 36 in. in diameter, and also founded at a minimum depth of 12 in. into native, intact limestone.

Additional footing embedment into the limestone may be required due to the presence of highly fractured, clayey, and/or extremely weathered zones at the proposed bearing depth. If such conditions are indicated beneath the footings at the time of excavation, additional embedment will be required to bear the foundations at or below the bottom of the discontinuities.

Bearing Capacity Shallow, conventional spread and drilled footings bearing at the minimum specified depth in native, intact limestone may be designed using a maximum allowable end bearing pressure of 16,000 psf. This allowable end bearing capacity should provide a factor of safety in excess of 5 with respect to the intact shear strength of the limestone. This relatively high factor of safety is considered necessary to account for the weathered nature of the limestone and the intermittent clay seams present within the bearing formation, which increase the compressibility of the rock mass from what would be expected for intact rock without such discontinuities.

Settlements Foundation settlements of less than 1/2 in. are anticipated for footings designed using the allowable end bearing pressure recommended above.

Foundation Bearing Levels In the limestone formation encountered at this site, stratigraphic delineations and selection of proper base levels for foundations which are to bear on rock are complicated by the weathered nature of the rock. Typically, clayey soils overlying such rock contain significant proportions of limestone fragments, and discontinuities within the rock are often filled with clay. Such features containing both rock and clay may lead to misinterpretations of stratigraphy based on data from small diameter sample borings. Isolated, clay-filled discontinuities or depressions in the rock may be

missed even by a grid of relatively closely spaced, small diameter borings.

Based on the above discussion, we believe that the single boring drilled for this site should be supplemented by the excavation of observation pits at the final foundation locations as soon as these locations are selected. Definitive interpretations of proper bearing levels may then be facilitated. These interpretations should be made by the Geotechnical Engineer or his representative after observations of the open pits and before excessive rock excavation has been performed or steel reinforcing placed for foundations.

Straight Drilled Shafts As an alternative to a shallow footing foundation, consideration may be given to supporting the tanks on straight drilled shafts penetrating deeper into the unweathered portion of the limestone formation underlying this site.

Bearing Capacity Drilled footings penetrating a minimum of 2 ft into the native, intact Stratum III unweathered limestone may be designed using a maximum allowable end bearing capacity of up to 53,000 psf. If necessary, a side shear stress capacity of 15,000 psf of footing circumference is also available for that portion of the drilled shaft penetrating unweathered limestone.

As with shallow footings, additional shaft embedment into the unweathered limestone may be required due to the presence of appreciable clayey or extremely weathered zones within the proposed bearing depth. If such conditions are observed within the drilled shaft excavations during construction, additional embedment will be required to account for reductions in end bearing and side shear resistance resulting from such discontinuities. However, the drilled shafts should not extend below El. 746 ft without supplemental field exploration to verify the engineering characteristics of the unweathered limestone at depths exceeding the depth of the test boring.

The above allowable end and side shear capacities should provide factors of safety in excess of 5. As for shallow footing design, a relatively high factor of safety is considered necessary to account for the weathered nature of the limestone and the intermittent clay seams present within the bearing formation, which increase the compressibility of the rock mass from what would be expected for intact rock without such discontinuities.

Settlements Foundation settlements of less than 1/2 in. are anticipated for drilled shafts designed using the parameters recommended above.

CONSTRUCTION PROCEDURES

Site Drainage Drainage is an important key to the successful performance of any foundation scheme. Good surface drainage should be established prior to and maintained after construction to prevent water from ponding within or adjacent to the tank foundations.

Foundation Excavation High-powered, high-torque excavation equipment will likely be required for foundation excavation in the weathered/unweathered limestone underlying this site.

Foundation Observations Each foundation excavation (either shallow footing or drilled shaft) must be examined by a qualified individual who is familiar with the geotechnical aspects of the stratigraphy, tank configuration, foundation design details and assumptions prior to placing concrete. This is to observe that:

- The footing has been excavated to the specified dimensions at the correct depth established by the previously mentioned criteria;
- All drilled shafts have been drilled plumb within specified tolerances along its total length; and
- Excessive cuttings, buildup and soft, compressible materials have been removed from the bottom of the excavations.

Placement of concrete should be accomplished as soon as possible for each footing excavation to reduce changes in the state of stress of the foundation bearing materials. No footings should be concreted without the approval of the Engineer.

Casing Ground water seepage was not observed at the time of our field exploration. However, shallow ground water seepage has been noted at the E1 Site, generally within the weathered upper reaches of the Austin Chalk following periods of heavy precipitation. We recommend that the bid documents require the foundation contractor to specify unit costs for different lengths of casing, should drilled shafts be designed to support the tanks.

LIMITATIONS

The analyses and recommendations submitted in this report are based on the data obtained from one boring drilled at this site and previous geotechnical studies conducted at the West Campus of the Superconducting Super Collider.

This report may not reflect the exact variations of subsurface conditions across the Tank Farm site. The nature and extent of variations across the site may not become evident until construction commences. If variations then appear evident, it may be necessary to reevaluate our recommendations after performing on-site observations and tests to establish the engineering significance of the variations.

* * * * *

The following illustrations are attached and complete this report:

Plate 1	Plan of Boring
Plate 2	Log of Boring
Plate 3	Key to Terms and Symbols

We appreciate the opportunity to be of service to you on this project. Please call should you have questions concerning this study or other aspects of the project.

Very truly yours,

RABA-KISTNER CONSULTANTS, INC.

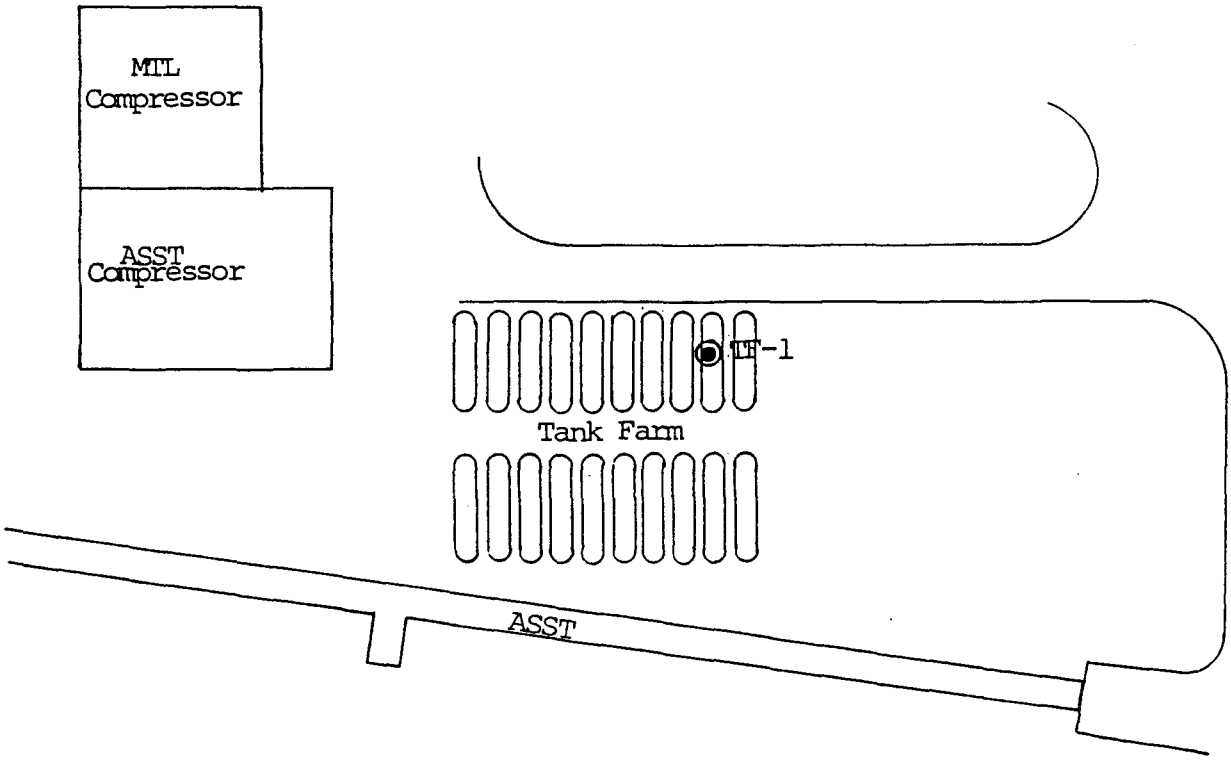
A. Scot Harrell

STATE OF TEXAS
A. SCOT HARRELL
69103
REGISTERED
PROFESSIONAL ENGINEER

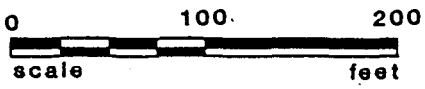
A. Scot Harrell, P.E.
Project Manager
Geotechnical Engineering

ASH/cad
Copies submitted: Above (4)

ILLUSTRATIONS



PLAN OF BORINGS



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Proj.No.ASA91-020-00
Plate 1

LOG OF BORING NO. TF-1
TANK FARM - E1 SITE - SSC PROJECT
WAXAHACHIE, TEXAS

Raba-Kistner Consultants, Inc.

DRILLING METHOD: Hollow Stem Auger / NX Core Barrel

LOCATION: N6818860.00 / E2448765.00

DEPTH, FT	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL	BLOWS PER FT	UNIT DRY WEIGHT, pcf	UNCONF. COMPRESSION, tsf (10 20 30 40 50 60 70) / PLASTIC LIMIT — WATER CONTENT — LIQUID LIMIT (10 20 30 40 50 60 70)	%-200
			SURFACE ELEVATION: 756.40'				
			CLAY, Hard, Plastic, Dark Brown with limestone fragments 0.3'		102	4.5+	80.4
			LIMESTONE, Slightly Weathered, Soft to Moderately Hard, Light Tan - close horizontal partings to 2' - 25 degree joint at 1.0' and 1.3' - argillaceous seam at 3.8' - brown with horizontal partings from 5.3' to 5.9' 6.0'		120		191
			LIMESTONE, Unweathered, Moderately Hard, Gray to Dark Gray - slightly argillaceous from 10.9' to 11.7' - horizontal parting at 11.9'		127		143

START: 2:00 PM
END: 4:05 PM

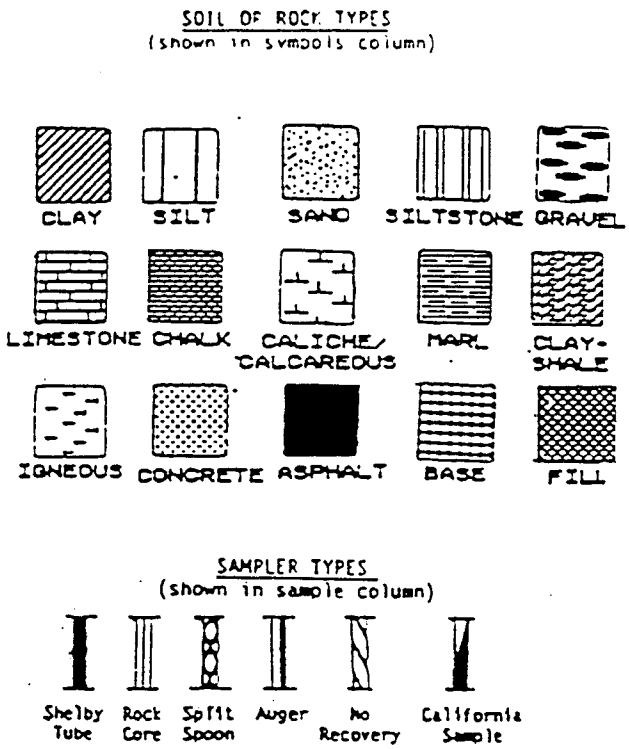
GEOLOGIST:
MICHAEL A. GILES

DRILL CREW:
LARRY TAYLOR
JAMES STUBBS
JOHN SALMON

Core Run #	Core Depth (ft)	% Rec.	% RQD
1	0.3'-5.3'	84	46
2	5.3'-10.3'	98	86
3	10.3'-12.3'	95	80

DEPTH DRILLED: 12.3'	DEPTH TO WATER:	PROJ. No. ASA91-020-00
DATE DRILLED: 6-13-91	DATE MEASURED:	PLATE 2

SYMBOLS AND TERMS USED ON BORING LOGS



STRENGTH TEST RESULTS

- Pocket Penetrometer
- Torvane
- Unconfined Compression

TRIAXIAL COMPRESSION

- Unconsolidated-undrained
- Consolidated-undrained
- C Cohesion (Total)
- Angle of Internal Friction (Total)
- C′ Cohesion (Effective)
- Angle of Internal Friction (Effective)

NOTE: Values symbolized on boring logs represent shear strengths unless otherwise noted.

TERMS DESCRIBING CONSISTENCY, CONDITION OR TEXTURE

Terms used in this report to describe soils with regard to their consistency or conditions are in general accordance with the discussion presented in Article 45 of SOIL MECHANICS IN ENGINEERING PRACTICE, Terzaghi and Peck, John Wiley & Sons, Inc. 1967, using the most reliable information available from the field and laboratory investigations. Terms used for describing soils according to their texture or grain size distribution are in accordance with the UNIFIED SOIL CLASSIFICATION SYSTEM, as described in Technical Memorandum No. 3-357, Waterways Experiment Station, March 1953.

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	having inclined planes of weakness that are slick and glossy in appearance
Fissured	containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical
Laminated	composed of thin layers of varying colors and texture
Interbedded	composed of alternate layers of different soil types
Calcareous	containing appreciable quantities of calcium carbonate
Well graded	having wide range in grain sizes and substantial amounts of all intermediate particle sizes
Poorly graded	predominantly of one grain size, or having a range of sizes with some intermediate size missing

TERMS DESCRIBING CONSISTENCY OR CONDITION

RELATIVE DENSITY		COHESIVE STRENGTH			PLASTICITY	
Penetration Resistance, blows per ft	Relative Density	Penetration Resistance, blows per ft	Consistency	Cohesion TSF	Plasticity Index	Degree of Plasticity
0-4	Very loose	0-2	Very Soft	0-0.125	0-5	None
4-10	Loose	2-4	Soft	0.125-0.25	5-10	Low
10-30	Medium Dense	4-8	Firm	0.25-0.5	10-20	Moderate
30-50	Dense	8-15	Stiff	0.5-1.0	20-40	Plastic
>50	Very Dense	15-30	Very Stiff	1.0-2.0	>40	Highly Plastic
		>30	Hard	>2.0		

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above because of planes of weakness or cracks in the soil. The consistency ratings of such soils are based on penetrometer readings.