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Subsurface Conditions Data Report
Additional Field Explorations
and Advanced Testing
Third Runway Embankment
Sea-Tac International Airport

HARTCROWSER
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Prepared for
HNTB

September 5, 2000
J-4978-23, -26, -27, and -31

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SUBSURFACE CONDITIONS DATA REPORT
ADDITIONAL FIELD EXPLORATIONS AND ADVANCED TESTING
THIRD RUNWAY EMBANKMENT
SEA-TAC INTERNATIONAL AIRPORT

INTRODUCTION

This data report presents information on subsurface conditions, based on geotechnical and laboratory testing to support the final design within wetlands and elsewhere along the toe of the permanent embankment slope, detention ponds outside the embankment area, and MSE walls for the Third Runway Embankment Project at the Sea-Tac International Airport.

The site is located at the Sea-Tac International Airport, in SeaTac, Washington (refer to Figure 1, Vicinity Map). The shaded areas on Figure 1 are presented on Figures 2 through 6, Site and Exploration Plan, showing exploration locations both for this report and those performed previously by Hart Crowser and others.

This report discusses the subsurface soil conditions in the toe of the permanent embankment slope, Detention Ponds A, E, F, 52, and the Miller Creek Detention Facility Area, explorations performed for advanced testing in the north, west, and south wall areas, and explorations performed in the permanent embankment area between the north and the west wall areas. Appendices A and B follow the main text and present results of our subsurface explorations and laboratory testing, respectively. Appendices C, D, and E present the results of cone penetrometer (piezocone), shear wave velocity and pressure meter testing performed at the site by subconsultants to Hart Crowser.

Appendix F presents the results of our subsurface explorations in the Miller Creek Detention Facility Area.

PURPOSE AND SCOPE

The purpose of this report is to provide information on subsurface soil and groundwater conditions affecting construction in these areas:

- Toe of the 2H:1V embankment between MSE wall locations;
- 2H:1V embankment between the north and west wall locations;
- MSE wall foundation soils;
- Viewpoint Park Stockpile;
- Detention Ponds A, E, F, and 52; and

- Miller Creek Detention Facility Area.

Other reports with additional information are listed in the references at the end of this report. The information presented herein provides the basis for our geotechnical engineering analyses and recommendations. Table 1 provides a summary list of the explorations performed for this phase and their general locations.

Information presented herein was obtained in general accordance with Tasks 1.3.1 through 1.3.3, 1.5, and 6.2 presented in our proposal dated April 5, 2000, and subsequent modification.

GENERALIZED GEOLOGIC DESCRIPTION AND SUBSURFACE SOIL CONDITIONS

This section provides a description of the geologic and subsurface soil conditions within the areas of interest, shown on Figures 2 through 6, based on Hart Crowser's explorations at the site and explorations by others.

Generalized Geologic Conditions

Generalized geologic conditions in the project area have been described in the Preliminary Engineering Report, Volume 2 (Applied Geotechnology Inc., 1994). The following is a summary of the geologic units identified at the Third Runway project site:

- Fill (loose to medium dense, locally dense, variably graded, silt, sand, and gravel);
- Alluvium (primarily soft to stiff peat, clay, and silt; and very loose to medium dense, fine to medium sand);
- Recessional Outwash (primarily loose to dense, silty sand and gravel, and/or medium stiff to hard, sandy silt and/or sandy clay);
- Glacial Till (dense to very dense, silty sand and gravel, and hard sandy silt);
- Advance Outwash (dense to very dense, non-silty to silty sand and gravel); and
- Lawton Clay (very stiff to hard silt and clay).

Subsurface Conditions

Subsurface soil conditions interpreted from materials encountered in explorations at the site and soil properties inferred from laboratory tests formed the basis for the information contained in this report. Variations between explorations occur due to the variability in gradation, moisture content, and density/consistency of soils at the site. The nature and extent of these variations may not become evident until construction. If variations become evident, it will be necessary to re-evaluate our interpretation of the soil conditions at the site, as well as any recommendations based on those interpretations.

North MSE Wall

Three additional borings, designated HC00-B222, HC00-B225, and HC00-B301, were drilled in this area. The soils encountered in HC00-B222 and HC00-B225 were similar to those described in the Subsurface Conditions Data Report, North Safety Area, Third Runway Embankment, Sea-Tac International Airport (Hart Crowser Inc., March 20, 2000). HC00-B222 extended to a depth of 100 feet, much deeper than existing explorations. These borings confirmed prior assumptions of the "underlying" soil unit at the North Wall location. This unit was observed to be:

Very dense, non-silty to silty, non-gravelly to gravelly SAND. This unit was encountered at a depth of 19 feet in HC00-B222 and at 20 feet in HC00-B225 and extended beyond the bottom of each exploration.

HC00-B301 was drilled within the area where the sewer line realignment might potentially cross Miller Creek. The soils encountered in the area were:

(Medium dense) silty SAND with organic material; over

(Soft) PEAT; over

Loose-medium dense, non-gravelly-slightly gravelly SAND with some organic material; overlying

Very dense, slightly gravelly, silty SAND.

Embankment Between South 156th and South 160th

The following soil materials were observed in this area:

Medium dense, non-silty to silty SAND with organic material. This unit was encountered in the test pits, HC00-B300, and HC00-B302 through HC00-B306 to depths ranging from about 1 to 7 feet below the existing ground surface. HC00-TP303 and HC00-TP304 graded from slightly gravelly to gravelly, HC00-TP302 encountered interbedded lenses of silt and gravel, and HC00-B305 included a discrete area of dense, gravelly sand.

Medium stiff to hard, non-sandy to slightly sandy, slightly silty to silty CLAY. This unit was encountered in HC00-TP301, HC00-B137, HC00-B300, and HC00-B302 through HC00-B306 at depths of about 2.5 to 7 feet below the existing ground surface. The layer thicknesses were about 2 to 9.5 feet.

Stiff to hard, non-gravelly to slightly gravelly, sandy to very sandy SILT. These materials were encountered in the majority of the explorations in the area. Depths to the top of this unit ranged from about 3 to 5.5 feet below the existing ground surface, with thicknesses ranging from 6 to 12 feet. A discrete 2-foot-thick layer of very sandy, very clayey silt was encountered in HC00-TP300 at a depth of about 4.5 feet below grade.

Dense to very dense, slightly gravelly to gravelly, slightly silty to silty SAND. This soil was encountered underlying HC00-TP301, HC00-TP304, HC00-TP305, HC00-B137, HC00-B300, and HC00-B302 through HC00-B306 at depths of about 1 to 17 feet below the existing ground surface. The thickness of this sand unit is not readily inferred as the explorations terminated within this soil layer.

Embankment Between South 160th and South 163rd

The following soil materials were observed in the area northwest of the proposed West MSE Wall:

Medium dense FILL. Fill was encountered in HC00-TP308 and HC00-TP309 consisting of SAND with varying amounts of gravel, silt, and organic material. The fill was encountered at depths of 4 to 5 feet below the existing ground surface.

Loose to (dense), silty to very silty SAND with organic material. This soil was encountered in HC00-B138 and HC00-B307 at depths of about 4.5 and 2 feet below the existing ground surface, respectively.

Medium stiff to stiff, slightly sandy to sandy SILT. HC00-TP308 and HC00-B138 encountered this soil unit at depths of about 4.5 to 5 feet below the existing ground surface. The thicknesses ranged from 1.5 to 8.5 feet.

Medium dense to very dense, slightly gravelly to gravelly, silty to very silty SAND. This unit was the underlying layer, and was encountered at depths of about 0 to 13 feet below the existing ground surface. The thickness of the layer was not readily inferred as the test pits and borings terminated within this soil layer.

West MSE Wall

Two additional borings designated HC00-B224 and HC00-B221 were drilled and five cone penetrometer probes designated HC00-P22 through HC00-P26 were pushed in this area. The soils encountered were similar to those described in the Subsurface Conditions Data Report, West MSE Wall, Third Runway Embankment, Sea-Tac International Airport (Hart Crowser Inc., June, 2000). HC00-B221 extended to a depth of 101 feet, much deeper than existing explorations. These borings confirmed prior assumptions of the "underlying" soil unit at the West MSE Wall location. Two units were observed at depth in this area including:

Very stiff to hard, clayey SILT, silty CLAY, and sandy SILT. Many of the existing explorations in this area terminated in this unit. In HC00-B221, this unit was observed from depths of about 20 to 58 feet.

Dense to very dense, slightly gravelly to gravelly, slightly silty to silty SAND. This unit was encountered at below a depth of 58 feet the existing ground surface. The thickness of the layer was not readily inferred as the borings terminated within this soil layer. However, this layer extends at least to a depth of 101 feet as evidenced in HC00-B221.

Embankment Between South 168th and South 171st

The following soil materials were observed to the south of the proposed West MSE Wall:

Medium dense FILL. Fill was encountered in HC00-TP311, HC00-TP313, HC00-TP315, and HC00-TP317 consisting of Sand and Gravel with varying amounts of sand, gravel, silt, organic material, and debris. The fill was encountered at depths of 0.5 to 2.5 feet below the existing ground surface.

Loose to dense, non-silty to silty, non-gravelly to very gravelly SAND with organic material. These soils were encountered in the test pits excavated in this area except HC00-TP311, HC00-TP313, and HC00-TP315. The depth of the unit ranged from 0 to 3.5 feet below the existing ground surface, at thicknesses from 2.5 to 5 feet. HC00-TP311 encountered a large boulder in this unit.

Medium dense, silty SAND with silt and sand lenses. HC00-TP315 encountered this soil unit at a depth of 2 feet below the existing ground surface, with a thickness of 1.5 feet.

Medium stiff, SILT with organic material. This unit was encountered in HC00-TP311 at a depth of 0.5 foot below the existing ground surface, with a thickness of 3 feet.

Dense to very dense, slightly silty to silty, non-gravelly to gravelly SAND. This unit was encountered at depths of 2.5 to 6.5 feet below the existing ground surface. The thickness of the layer encountered in HC00-TP310 was 6 feet. The layer thicknesses in the other explorations were not readily inferred as the test pits terminated within this soil layer.

Hard SILT. This unit was encountered only in HC00-TP310 at a depth of 11 feet. The layer thickness was not readily inferred as the test pit terminated within this soil layer.

Viewpoint Park Stock Pile and Pond 52 Area Between South 171st and South 176th (east of 12th Avenue South)

The following soil materials were observed in the area of the Viewpoint Park Stockpile footprint:

Medium dense to dense FILL. HC00-TP221 encountered silty, gravelly Sand with cobbles, organic material, and roots at a depth of 3.5 feet.

Loose to medium dense, slightly gravelly to gravelly, silty SAND with varying organic material content. This unit was encountered in the test pits excavated in this area except HC00-TP224. The depth of the soil layer varied from 0 to 3.5 feet below the existing ground surface, with layer thicknesses ranging from 2 to 4 feet.

Medium dense to dense, slightly silty to silty, slightly gravelly to very gravelly SAND. This soil unit was encountered in HC00-TP222, HC00-TP224, and HC00-TP226 at depths ranging from 0 to 2.5 feet below the existing ground surface. The thickness of the unit was from 1 to 11 feet.

Dense, sandy GRAVEL. This soil was encountered only in HC00-TP224 at a depth of 11 feet below the existing ground surface, and was 1.5 feet thick.

Dense to very dense, silty, gravelly SAND. This soil unit was encountered at depths of 2 to 12.5 feet below the existing ground surface. The layer thicknesses were not readily inferred as the test pits terminated within this soil layer.

South MSE Wall

Two additional borings, designated HC00-B223 and HC00-B220, were drilled in this area. The soils encountered were similar to those described in the Subsurface Conditions Data Report, South MSE Wall and Adjacent Embankment, Third Runway Project, Sea-Tac International Airport (Hart Crowser Inc., April 7, 2000). HC00-B220 extended to a depth of 101 feet, much deeper than existing explorations. These borings confirmed the assumptions of the underlying soil unit at the South MSE Wall location. This unit was observed to be:

Dense to very dense, slightly silty to silty, non-gravelly to gravelly SAND. This unit was encountered in both of the new borings in this area. The layer extends from a depth of about 20 feet to the bottom of each exploration, which is a depth of 101 feet for HC00-B220.

Detention Ponds A, E, and F

Pond A. Hand augers HC00-A300 and HC00-A301 were performed in this area. The explorations encountered (loose to medium dense), slightly silty to silty SAND at depths ranging from 3.5 to 4 below the existing ground surface. A (medium stiff to stiff), sandy SILT with organic material was encountered below this layer. The silt layer thickness was not inferred as the auger terminated within this soil layer.

Pond E. HC00-TP306 and HC00-TP307 were performed in the proposed footprint of Pond E. Fill soils were encountered in the test pits at a depth of 2 feet below the existing ground surface. The Fill in HC00-TP307 consisted mainly of Sand with varying amounts of silt, gravel, and asphalt debris. In HC00-TP306, a (stiff), gravelly, very sandy SILT with asphalt debris was encountered.

A (dense) sandy GRAVEL, encountered at a depth of 2 feet below existing ground surface with a thickness of 4 feet was encountered below the fill in HC00-TP306. This unit was overlying a 2.5-foot-thick layer of (medium dense) SAND with organic material. Underneath this layer was a (stiff to very stiff) slightly sandy to sandy, non-clayey to clayey SILT with some cobbles. The thickness of this silt layer was not inferred as the test pit terminated within this soil layer.

A (medium dense to dense) slightly clayey, slightly silty SAND, encountered at a depth of 2 feet below the existing ground surface, with a thickness of 2.5 feet was encountered below the fill in HC00-TP307. This unit was overlying a 2.5-foot-thick layer of (soft) sandy PEAT. Underlying the Peat was a 2-foot-thick layer of (medium dense) very silty SAND with organic material. Underlying this unit was a (medium stiff to stiff) non-sandy to sandy, non-clayey to clayey SILT layer. The thickness of this silt layer was not inferred as the test pit terminated within this soil layer.

Pond F. HC00-TP318 and HC00-TP319 were performed in footprint of the proposed pond. HC00-TP318 encountered a (medium dense) FILL consisting of slightly silty to silty, gravelly SAND with organic material at a depth of 3.5 feet below the existing ground surface. HC00-TP319 encountered (loose to medium dense), silty, gravelly SAND with organic material at a depth of 1 foot below the existing ground surface.

These soils were overlying a (medium dense to dense) slightly gravelly to gravelly, slightly silty to very silty SAND at depths ranging from 1 to 3.5 feet below the existing ground surface with thicknesses of 2.5 to 7 feet.

Underlying this layer in HC00-TP318, a (stiff) very sandy SILT was encountered at a depth of 6 feet below the existing ground surface with a thickness of 6.5 feet. In both test pits (dense to very dense) gravelly, silty SAND was encountered at depths of 8 to 12.5 feet. The layer thickness was not inferred as the test pits terminated within this soil layer.

Miller Creek Detention Facility. This area contains Pond J and another pond located abut 500 feet northwest of Pond J.

Pond J. HC00-B308 and HC00-B309 were performed within the footprint of Pond J. Fill soils were encountered in both borings at thicknesses ranging from 10 to 17 feet. The fill in HC00-B309 consisted of medium dense to very dense Sand with varying amounts of organic material and asphalt debris. The fill in HC00-B308 consisted of medium stiff Peat with some amounts of gravel and brick debris.

Underlying the fill was a soft to very stiff Peat. This soil was encountered at depths from 10 to 17.5 feet below present grade, with a thickness ranging from 4.5 to 15 feet. The Peat contained varying amounts of gravel, sand, and silt. This soil was overlying a medium dense to dense Sand encountered at depths of 22 to 25 feet from the existing ground surface. HC00-B309 had a 15-foot thick layer containing gravel, which was not encountered in HC00-B308. The thickness of this soil unit was not inferred as the borings terminated in this layer.

Proposed Pond. HC00-B310 through HC00-B312 were performed within the footprint of the pond adjacent to Des Moines Memorial Drive.

A very loose to dense Fill soil was encountered in HC00-B310 and HC00-B312 at thicknesses from 6 to 11 feet. The Fill consisted of Sand with varying amounts of silt, gravel, clay, and asphalt debris. This soil unit was overlying a loose to medium dense Sand with varying amounts of silt and gravel. The soil was encountered at depths ranging from 2 to 11 feet below present grade, with layer thicknesses of at least 9 feet. In HC00-B310 and HC00-B312, the layer thickness was not inferred as the borings terminated in this layer. In HC00-B311 the soil underlying the sand was a stiff, sandy Silt. This layer was encountered about 11 feet from the existing ground surface, and its thickness was not inferred due to termination of the exploration.

USE OF THIS REPORT

This report has been prepared for the exclusive use of HNTB and the Port of Seattle, for the site and project described herein. We completed this work according to generally accepted geotechnical engineering practices in the same or similar localities, related to the nature of the work accomplished, at the time the services were accomplished. We make no other warranty, express or implied.

Hart Crowser appreciates the opportunity to provide this information. Please call if you have any questions.

Sincerely,
HART CROWSER, INC.

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Senior Staff Geotechnical Engineer

MICHAEL J. BAILEY, P.E.
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Hart Crowser, 2000b. Draft Subsurface Conditions Data Report, South MSE Wall and Adjacent Embankment, Third Runway Project, Sea-Tac International Airport, SeaTac, Washington, April 7, 2000.

Hart Crowser, 2000c. Draft Subsurface Conditions Data Report, West MSE Wall, Third Runway Embankment, Sea-Tac International Airport, SeaTac, Washington, June 2000.

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Table 1 - List of Explorations

Exploration Number	Exploration Depth in Feet	Comments
North MSE Wall		
HC00-B225	34.5	Pressuremeter Tests
HC00-B222	100.2	Pressuremeter/Shear Wave Tests
HC00-B301	24	Miller Creek Sewer Crossing
Between South 156th and South 160th		
HC00-TP300	15	Toe of Embankment
HC00-TP301	15	Toe of Embankment
HC00-TP302	15	Toe of Embankment
HC00-TP303	15	Toe of Embankment
HC00-TP304	15	Toe of Embankment
HC00-TP305	11	Toe of Embankment
HC00-B137	15.6	Toe of Embankment, in Wetland A8, Observation Well
HC00-B300	15.3	Toe of Embankment, near Wetland A7
HC00-B302	18.9	2:1 Embankment
HC00-B303	23.5	2:1 Embankment
HC00-B304	16.5	2:1 Embankment
HC00-B305	18.5	2:1 Embankment
HC00-B306	18.3	2:1 Embankment
Between South 160th and South 163rd		
HC00-B138	20.4	Toe of Embankment, in Wetland 35d
HC00-B143	10.9	Toe of Embankment, in Wetland 18, Observation Well
HC00-B307	18.8	2:1 Embankment
HC00-TP308	15	Toe of Permanent Embankment
HC00-TP309	15	Toe of Permanent Embankment
HC00-TP310	14	Toe of Permanent Embankment
West MSE Wall		
HC00-B224	35.3	Pressuremeter Tests
HC00-B221	100.5	Pressuremeter/Shear Wave Tests
HC00-P22	24	Piezocone Penetrometer/Shear Wave Tests
HC00-P23	11	Piezocone Penetrometer/Shear Wave Tests
HC00-P24	20	Piezocone Penetrometer/Shear Wave Tests
HC00-P25	22	Piezocone Penetrometer/Shear Wave Tests
HC00-P26	21	Piezocone Penetrometer/Shear Wave Tests

Exploration Number	Exploration Depth in Feet	Comments
Between South 168th and South 171st		
HC00-TP311	11	Toe of Embankment
HC00-TP312	9	Toe of Embankment
HC00-TP313	9	Toe of Embankment
HC00-TP314	9	Toe of Embankment
HC00-TP315	10	Toe of Embankment
HC00-TP316	7	Toe of Embankment
HC00-TP317	8	Toe of Embankment
VPP Stockpile and Pond 52 Area Between South 171st and South 176th (East of 12th Avenue South)		
HC00-TP220	9	Proposed Stockpile
HC00-TP221	10	Proposed Stockpile
HC00-TP222	13	Proposed Stockpile
HC00-TP223	13	Proposed Stockpile
HC00-TP224	15	Proposed Stockpile
HC00-TP226	9	Proposed Stockpile
South MSE Wall		
HC00-B223	35.0	Pressuremeter Tests
HC00-B220	100.9	Pressuremeter/Shear Wave Tests
Detention Ponds A, E, and F		
HC00-A300	4	Proposed Pond A
HC00-A301	5.5	Proposed Pond A
HC00-TP306	15	Proposed Pond E
HC00-TP307	15	Proposed Pond E
HC00-TP318	14	Proposed Pond F
HC00-TP319	9	Proposed Pond F
Miller Creek Detention Facility		
HC00-B308	30.5	Proposed Pond J
HC00-B309	40.5	Proposed Pond J
HC00-B310	19	Proposed Pond
HC00-B311	19	Proposed Pond
HC00-B312	29	Proposed Pond

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Vicinity Map

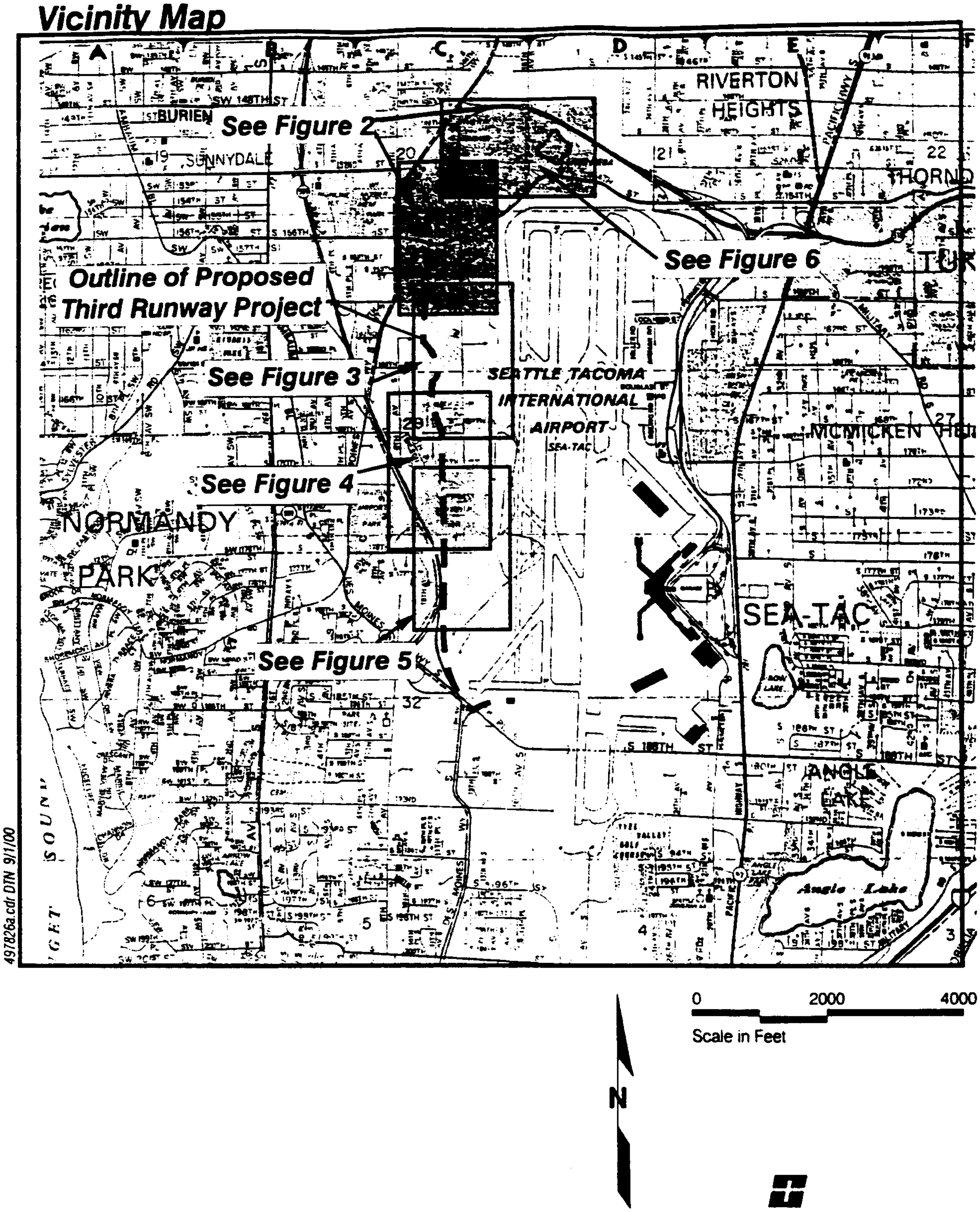

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Figure 1

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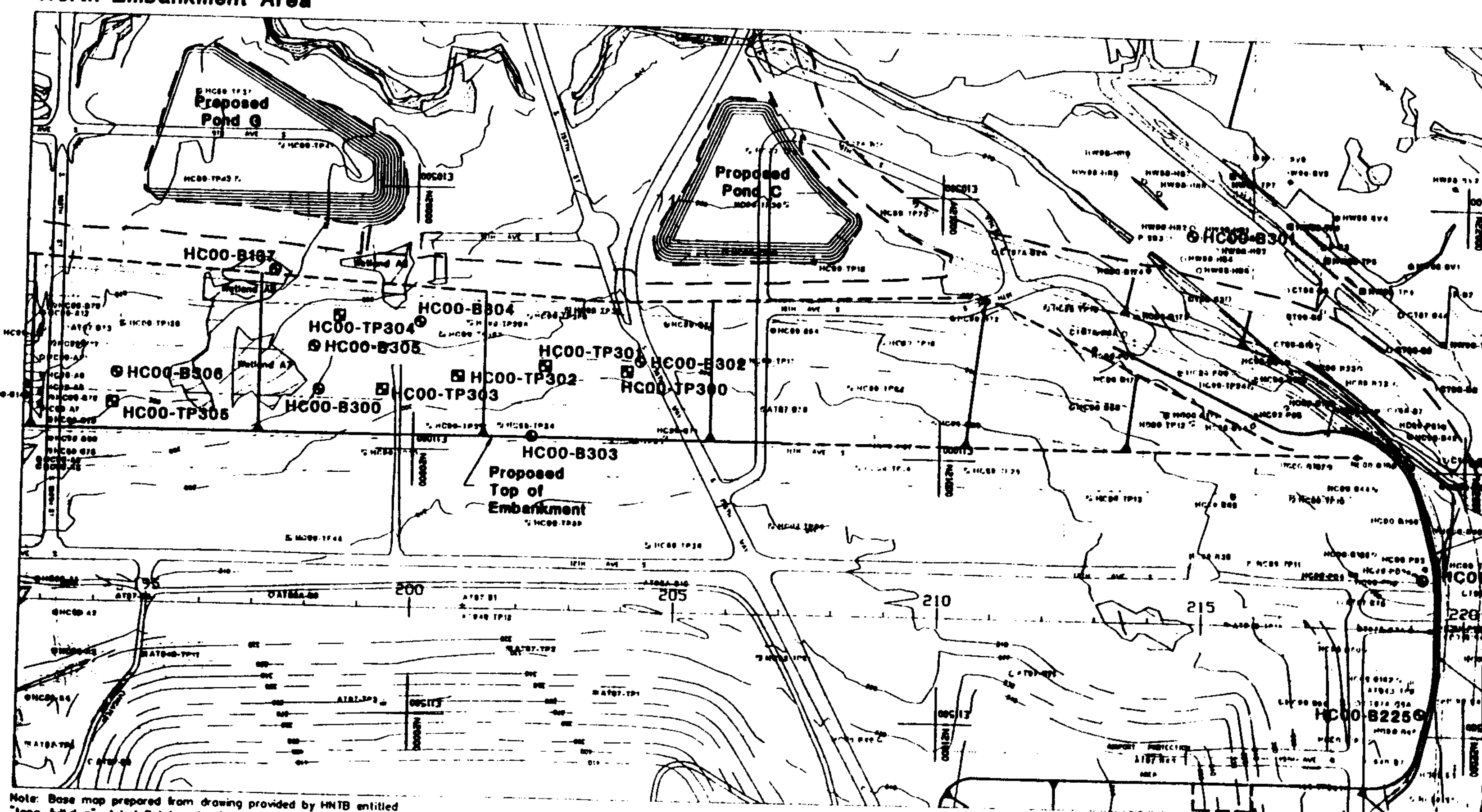
Site and Exploration Plan
North Embankment Area



Note: Base map prepared from drawing provided by HNTB entitled "topo_full.dwg", dated October 4, 1999. Wetland locations based on drawing provided by Parametrix entitled "w_062700.dwg", dated June 27, 2000

HC00-B137 Boring, Hart Crowser (Current Study)

HC00-TP300 Test Pit, Hart Crowser (Current Study)

Boring, Hart Crowser (Previous Study)

Boring, by others (Previous Study)

Test Pit, Hart Crowser (Previous Study)

Test Pit, by others (Previous Study)

175 Runway Stationing

Proposed Elevation Contour in Feet

Existing Elevation Contour in Feet

Wetland Location

0 200 400

Scale in Feet

N

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Figure 2

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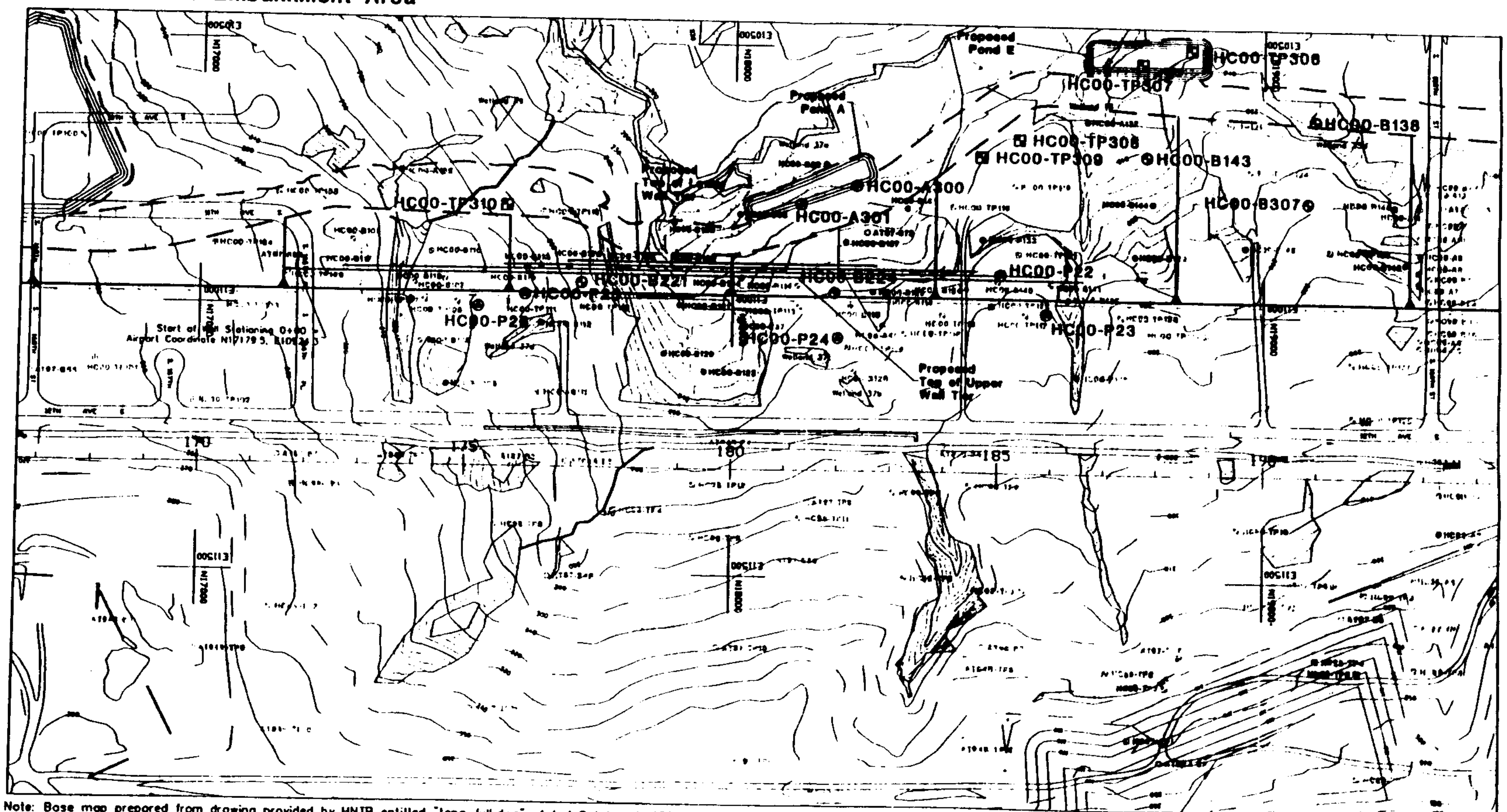
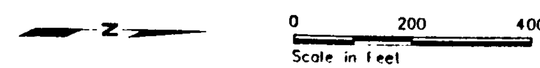
Site and Exploration Plan
West Wall and Embankment Area



Note: Base map prepared from drawing provided by HNTB entitled "topo_full.dwg", dated October 4, 1999
Wetland locations based on drawing provided by Parametrix entitled "w_062700.dwg", dated June 27, 2000



HC00-P23	Piezocone, Hart Crowser (Current Study)	Boring, Hart Crowser (Previous Study)	Runway Stationing
HC00-B143	Boring, Hart Crowser (Current Study)	Boring, by others (Previous Study)	
HC00-TP306	Test Pit, Hart Crowser (Current Study)	Test Pit, Hart Crowser (Previous Study)	Wetland Location and Designation
HC00-A300	Hand-Auger Boring, Hart Crowser (Current Study)	Test Pit, by others (Previous Study)	

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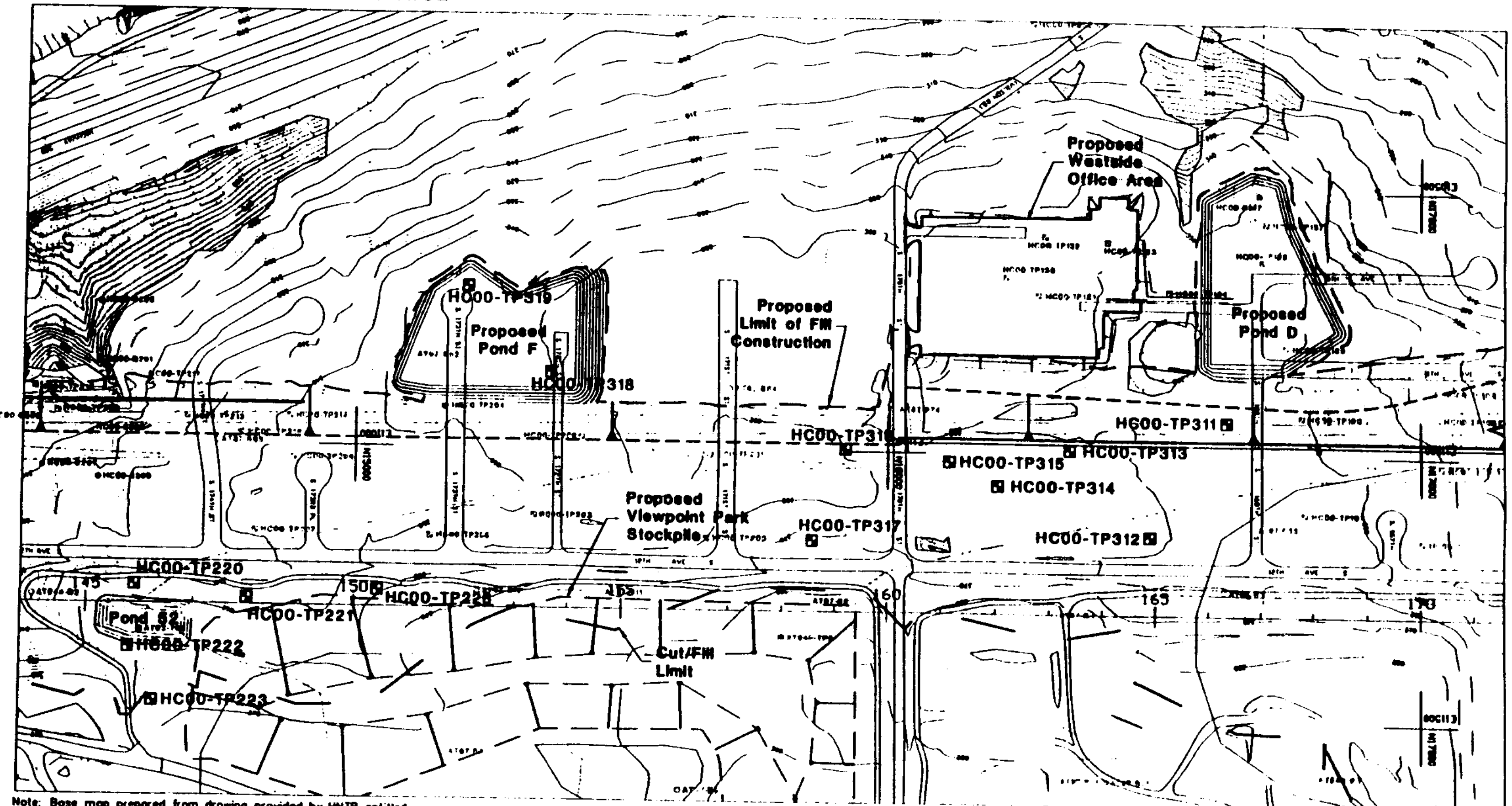
Figure 3

AR 045823

Site and Exploration Plan
Pond F and West Side Office Area



Note: Base map prepared from drawing provided by HNTB entitled "topo_full.dwg", dated October 4, 1999. Wetland locations based on drawing provided by Parametrix entitled "w_062700.dwg", dated June 27, 2000

- HC00-TP220 Test Pit, Hart Crowser (Current Study)
- Boring, Hart Crowser (Previous Study)
- Boring, by others (Previous Study)
- Test Pit, Hart Crowser (Previous Study)
- Test Pit, by others (Previous Study)
- 175 Runway Stationing
- Proposed Elevation Contour in Feet
- Existing Elevation Contour in Feet
- Wetland Location

0 200 400
Scale in Feet

N

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Figure 4

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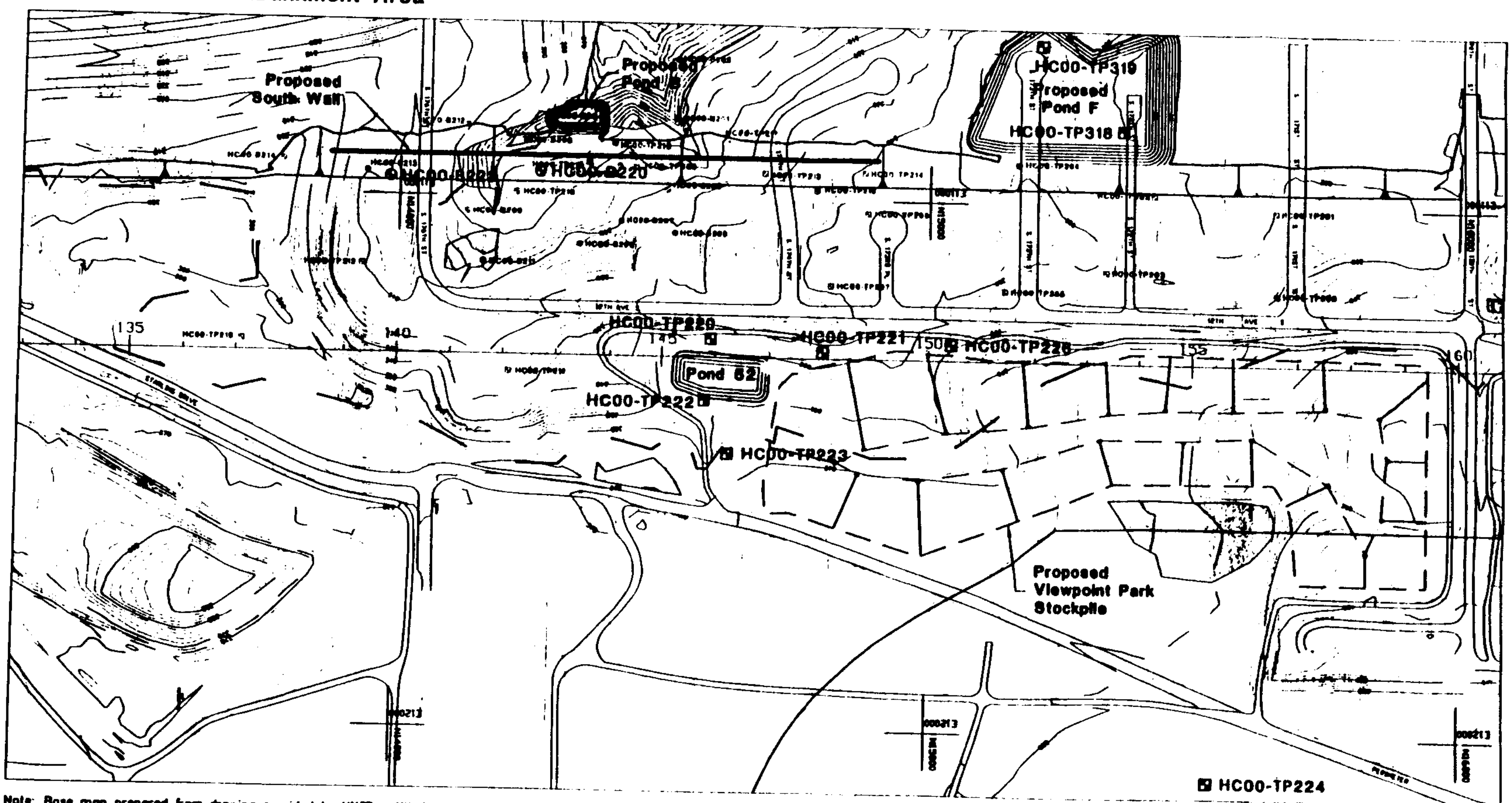
Site and Exploration Plan
South Wall and Embankment Area



Note: Base map prepared from drawing provided by HNTB entitled "topo_full.dwg", dated October 4, 1999. Wetland locations based on drawing provided by Parametrix entitled "w_062700.dwg", dated June 27, 2000.

HC00-B143	Boring, Hart Crowser (Current Study)		Boring, Hart Crowser (Previous Study)
HC00-TP220	Test Pit, Hart Crowser (Current Study)		Test Pit, Hart Crowser (Previous Study)
	Wetland Location and Designation	175	Runway Stationing

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Figure 5

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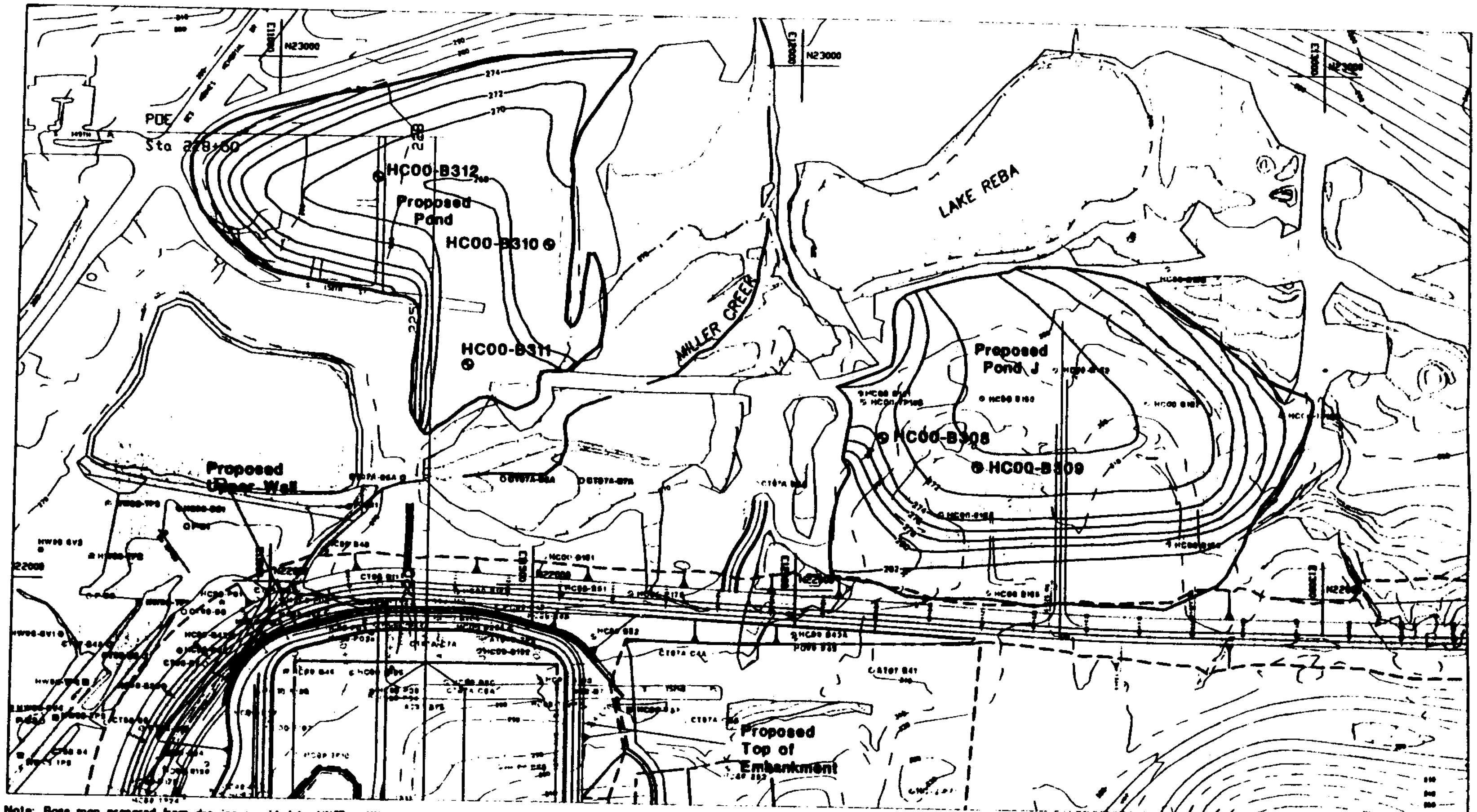
Site and Exploration Plan
Miller Creek Detention Facility



Note: Base map prepared from drawing provided by HNTB entitled "topo_full.dwg", dated October 4, 1999. Wetland locations based on drawing provided by Parametrix entitled "w_062700.dwg", dated June 6, 2000

HC00-B137 Boring, Hart Crowser (Current Study)

HC00-TP300 Test Pit, Hart Crowser (Current Study)

Boring, Hart Crowser (Previous Study)

Boring, by others (Previous Study)

Test Pit, Hart Crowser (Previous Study)

Test Pit, by others (Previous Study)

175 Runway Stationing

272 Proposed Elevation Contour in Feet

Existing Elevation Contour in Feet

Wetland Location

HARTCROWSER
J-4978-26 9/00
Figure 6

AR 045826

APPENDIX A
FIELD EXPLORATIONS METHODS AND ANALYSIS

APPENDIX A
FIELD EXPLORATIONS METHODS AND ANALYSIS

This appendix documents the processes Hart Crowser used in determining the nature of the soils underlying the project site addressed by this report. The discussion includes information on the following subjects:

- Explorations and Their Location;
- The Use of Auger Borings;
- Standard Penetration Test (SPT) Procedures;
- Use of Shelby Tubes;
- Pocket Penetrometer (PP);
- Excavation of Test Pits;
- Piezocone Penetrometer Probes;
- Cone Penetration Test Procedures;
- Monitoring Well Installation;
- Monitoring Well Development, and
- Water Level Measurement

Explorations and Their Location

Subsurface explorations for this project include the following:

- **Borings**
  HC00-B137 through HC00-B138, HC00-B143, HC00-B220 through HC00-B225, and HC00-B300 through HC00-B312.

- **Hand-Augers Borings**
  HC00-A300 and HC00-A301.

- **Test Pits**
  HC00-TP220 though HC00-TP224, HC00-TP226, HC00-TP300 through HC00-TP319.

- **Piezocones**
  HC00-P22 through HC00-P26

The exploration logs within this appendix show our interpretation of the material encountered based on drilling (or excavation), sampling, and testing data. They indicate the depth where the soils change. Note that the change may be gradual. In the field, we classified the samples taken from the explorations according to the methods presented on Figure A-1 (Sheet 1/2) - Key to

Exploration Logs. This figure also provides a legend explaining the svmbols and abbreviations used in the logs.

Boring logs for HC00-B308 through HC00-B312 are located in Appendix F.

Location of Explorations. Figures 2 through 6 show the location of explorations. HC00-B301A is shown as HC00-B301 on Figure 2. These explorations were located using a global positioning system (GPS) survey by Hart Crowser. Port of Seattle surveyors performed an x, y, z survey for the borings that were completed with wells. Where available, the Port's survey supersedes the GPS locations. Where Port survey data are not available ground surface elevations were interpreted from the aerial survey topography shown on Figures 2 through 6. The method used determines the accuracy of the location and elevation of the explorations.

The Use of Auger Borings

With depths ranging from 11 to 101 feet below the ground surface, twenty-two hollow-stem auger borings, designated HC00-B137, HC00-B138, HC00-B143, HC00-B220 through HC00-B225, and HC00-B300 through HC00-B312 were drilled between May 17, 2000, and August 16, 2000. Samples were obtained by use of the Standard Penetration Test (SPT) samples or a hydraulically pushed thin wall sampler referred to as a "Shelby tube." The borings typically used a 3-3/8-inch inside diameter hollow-stem auger and were advanced with a truck-mounted or track-mounted drill rig subcontracted by Hart Crowser. For borings where pressuremeter testing was performed (HC00-B220 through HC00-B225), mud rotary drilling was performed to 40 feet using a closed system to keep the drilling mud off the ground.

In two locations, hand-auger borings, designated HC00-A300 and HC00-A301, were drilled using portable gear rather than hollow-stem auger borings because of access restraints. These hand-auger borings were drilled on May 12, 2000.

An engineering geologist from Hart Crowser continuously observed the drilling. Detailed field logs were prepared of each boring. Using the Standard Penetration Test (SPT), we obtained samples at 2-1/2- to 5-foot-depth intervals for all borings.

Groundwater levels in the borings were noted at the time of drilling (ATD) and following installation and development of observation wells where noted on the boring logs. Borings HC00-B137, HC00-B143, HC00-B301, HC00-B302, HC00-B305 to HC00-B306, and HC00-B308 through HC00-B312 were completed as observation wells. Groundwater level cannot be evaluated for borings using mud rotary drilling.

The borings logs are presented on Figures A-2 through A-18 at the end of this appendix. Figure A-19 presents the hand-auger boring logs.

Standard Penetration Test (SPT) Procedures

This test is an approximate measure of soil density and consistency. To be useful, the results must be used with engineering judgment in conjunction with other tests. The SPT (as described in ASTM D 1587) was used to obtain disturbed samples. This test employs a standard 2-inch outside diameter split-spoon sampler. Using a 140-pound hammer, free falling 30 inches; the sampler is driven into the soil for 18 inches. The number of blows (N value) required to drive the sampler the last 12 inches only is the Standard Penetration Resistance. This resistance, or blow count, measures the relative density of granular soils and the consistency of cohesive soils. The blow counts are plotted on the boring logs at their respective sample depths.

Soil samples are recovered from the split-barrel sampler, field classified, and placed into watertight jars. They are then taken to Hart Crowser's laboratory for further testing.

Some instances of "heave" are noted on boring logs. Heave is a phenomenon that occurs typically within a sand soil where there is excess seepage pressure at the bottom of the auger (i.e., water within the augers is at a lower elevation than the groundwater level surrounding the boring). A sufficient difference in water levels will cause the sandy soils to be displace upward into the auger, thereby disturbing the soil formation. Therefore, the corresponding SPT N values may not accurately indicate density. Heave is typically controlled by sustaining the water level within the auger at or near the surrounding groundwater level; no drilling mud was used in the explorations described in this report.

In the Event of Hard Driving

Occasionally very dense materials or the presence of gravel and/or cobbles prevented driving the total 18-inch sample. When this happens, the penetration resistance is entered on logs as follows:

Penetration less than six inches. The log indicates the total number of blows over the number of inches of penetration.

Penetration greater than six inches. The blow count noted on the log is the sum of the total number of blows completed after the first 6 inches of penetration. This sum is expressed over the number of inches driven that exceed the first 6 inches. The number of blows needed to drive the first 6 inches is not reported. For example, a blow count series of 12 blows for 6 inches, 30 blows for 6 inches, and 50 (the maximum number of blows counted within a 6-inch increment for SPT) for 3 inches would be recorded as 80/9.

Use of Shelby Tubes

In some locations, a 3-inch-diameter thin-walled steel (Shelby) tube sampler was pushed hydraulically below the auger to obtain a relatively undisturbed sample for classification and testing of fine-grain soils. This was accomplished in borings HC00-B221, HC00-B222, HC00-B300 to HC00-B301, and HC00-B308, to obtain relatively undisturbed samples. The tubes were sealed in the field and taken to our laboratory for extrusion and classification. The undisturbed samples were typically obtained for consolidation and shear strength testing.

Pocket Penetrometer (PP)

The pocket penetrometer provides a quick approximate test of the consistency (undrained shear strength) of a cohesive soil sample.

The pocket penetrometer device consists of a calibrated spring mechanism that measures penetration resistance of a 1/4-inch-diameter steel tip over a given distance. The penetration resistance is correlated to the unconfined compressive strength of the soil, which is typically twice the undrained shear strength of a saturated, cohesive soil. The exploration logs show the results of the pocket penetrometer tests.

Pocket penetrometer results are generally considered valid only for predominantly fine-grained (non-sandy soils). Results may be artificially low for tests on disturbed samples (i.e., SPT) compared to relatively undisturbed samples from test pits or Shelby tubes.

Excavation of Test Pits

Twenty-six test pits, designated HC00-TP220 though HC00-TP224, HC00-TP226, and HC00-TP300 through HC00-TP319, were excavated across the site with a tractor-mounted backhoe provided by Port Construction Services (PCS). The test pits were excavated on March 16, 2000, and May 2 through 5, 2000. The sides of these excavated pits offer direct observation of the subgrade soils. The test pits were located by and excavated under the direction of an engineering geologist from Hart Crowser. The geologist observed the soil exposed in the test pits and reported the findings on a field log. Our geologist took representative samples of soil types for testing at Hart Crowser's laboratory. Groundwater levels or seepage during excavation was noted by the geologist on the log. The density/consistency of the soils (as presented parenthetically on the test pit logs to indicate their having been estimated) is based on visual observation only, as disturbed soils cannot be measured for in-place density.

The test pit logs are presented on Figures A-20 through A-32.

Piezocone Penetrometer Probes

We used a piezocone penetrometer as a means to supplement our visual classification of soils provided in SPT samples. Piezocone locations are shown on Figure 3. The logs of the piezocone probes performed by Northwest Cone Exploration are presented on Figures A-33 through A-38. The cone probes, designated HC00-P22A, HC00-P22B, and HC00-P23 through HC00-P26, were advanced to depths ranging from 5 to 24 feet below the ground surface by Northwest Cone Exploration on May 18 and 19, 1999. The piezocones were advanced using a cone truck at all locations. The cone penetrometer HC00-P22A met with refusal and the truck was moved 10 feet west for HC00-P22B. HC00-P22A and HC00-P22B are shown as HC00-P22 on Figure 3. The cone probe configuration used in the investigation is similar to that shown on Figure A-1 (Sheet 2/2). This figure also shows the classification method used to develop the *soil behavior index* represented on the individual logs for classification purposes. The piezocone is arranged to measure the following parameters, which are used for the soil classification:

- Tip resistance, Q_c in tsf (resistance to soil penetration developed at the cone tip);

- Friction resistance, F_s in tsf (resistance to soil penetration developed along the friction sleeve); and

- Pore water pressure behind the cone tip, U_{bt} in psi.

Cone Penetration Test Procedures

The electric piezocone penetrometer test procedure involves hydraulically pushing a series of cylindrical rods into the soil at a constant rate of 2 centimeters per second and subsequently monitoring soil and pore fluid response near the conical tip. The cylindrical rod at the bottom of the drill string houses the pressure transducer and load cells which, during probing, measure the parameters indicated above. To be useful, the results must be used with engineering judgment in conjunction with other tests, preferably the SPT procedure, which allows soil sample collection for direct comparison purposes. Tests were performed in general accordance with procedures outlined in ASTM D 3441, Standard Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil.

The cone system is mounted on a truck or bulldozer to provide the necessary reaction for the applied loads. The cone tip has a surface area of about 10 square centimeters (cm^2) and an angle of 30 degrees from the axis. The friction sleeve has a surface area of about 150 cm^2. Prior to testing, a plastic filter element, which has been saturated under vacuum in glycerin, is placed behind the cone tip. This filter element transmits pore pressures to the transducer. Load cells measure end resistance on the tip and frictional resistance on the friction sleeve. As the cone penetrates the soil, measurements are continuously recorded on a portable computer at depth increments of about 5 centimeters.

The classification method used to develop an interpreted soil profile is based on normalized parameters provided by the piezocone, as there are no soil samples collected with a penetrometer system of this type.

The relationship between the cone tip resistance and friction ratio, which has been normalized for soil overburden stresses, can be established to predict soil behavior (Jeffries and Davies, 1991 and 1993). This relationship has been applied to the soil classification chart developed by Robertson as reported in Lunne et al., 1997 (refer to Figure A-1 [Sheet 2/2]) according to the following equation:

$$I_C = \sqrt{\{3 - \log[Q \cdot (1 - B_q)]\}^2 + [1.5 + 1.3 \cdot \log(F)]^2}$$

Where:

Ic = Soil behavior index

Q = Normalized cone tip resistance

$$Q = \frac{q_T - \sigma_{vo}}{\sigma'_{vo}}$$

q_T = Corrected cone tip resistance

σ_{VO} = Total overburden stress

σ'_{VO} = Effective overburdens stress

B_q = Normalized pore pressure

$$B_q = \frac{\Delta u}{q_T - \sigma_{vo}}$$

F = Normalized friction ratio

$$R_f = \frac{f_s}{q_T - \sigma_{vo}} \cdot 100\%$$

f_s = Sleeve friction

Using the above equation and the classification chart presented on Figure A-1 (Sheet 2/2), we were able to develop the interpreted soil profiles provided on Figures A-33 through A-38. The classification chart used for this study has been established based on observed soil behavior from numerous studies for various soil types.

Monitoring Well Installation

Monitoring wells were completed in HC00-B137, HC00-B143, HC00-B302, HC00-B305 to HC00-B306, and HC00-B308 to HC00-B312, to allow long-term groundwater elevation monitoring. The wells were drilled using standard hollow-stem auger equipment. Two-inch-diameter Schedule 40 PVC riser pipe and 2-inch-diameter 0.020-inch machine-slotted screen were used for the well casings and screens. The well screen and casing riser were lowered down through the hollow-stem auger. As the auger was withdrawn, No. 10/20 silica sand was placed in the annular space from the base of the boring to approximately 2 to 3 feet above the top of the well screen.

Well seals were constructed by placing bentonite chips in the annular space on top of the filter sand to within 3 feet of ground surface. The remaining annular space was backfilled with concrete to complete the surface seal. For security, the monitoring wells were completed with locking stick-up steel monuments set in concrete. The monitoring well construction details are illustrated on the boring logs.

The monitoring well were installed in accordance with Washington State Department of Ecology regulations.

Monitoring Well Development

The monitoring wells were developed using a Whale electric submersible pump, surge block, and/or a stainless steel bailer. First, sediment was removed from the bottom of the wells using a stainless steel bailer. Then the wells were surged during development using either a surge block, a stainless steel bailer, or by moving the submersible pump up and down within the well screen depth interval.

A minimum of ten casing volumes was removed during development, in addition to the volume of water added during drilling, if any. Where possible, development continued until negligible turbidity was visible. Sediment thickness at the bottom of the well was measured and recorded before and after development. Observations were recorded on a Well Development data form. Visual changes in turbidity during development were recorded in the comments space on this form. The development water was discharged to the ground surface in accordance with the Third Runway project Storm Water Pollution Prevention Plan (Parametrix, 1999).

References for Appendix A

Jeffries, Michael G., and Michael P. Davies, 1991. Soil classification by the cone penetrometer test: Discussion, Can. Geotech. J. 28, 173-176.

Jeffries, Michael G., and Michael P. Davies, 1993. Use of CPTu to Estimate Equivalent SPT N_{60}. Geotechnical Testing Journal. GTJODJ, Vol. 16, No. 4, 458-468.

Lunne, T., P.K. Robertson, and J.J.M. Powell, 1997. Cone Penetration Testing in Geotechnical Practice, Blackie Academic and Professional, London.

Parametrix, 1999. Seattle-Tacoma International Airport Third Runway Project Geotechnical Explorations Stormwater Pollution Prevention Plan, Prepared for Port of Seattle, January 29, 1999.

F:\docs\jobs\497826\DataReport.doc

Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling Test Symbols

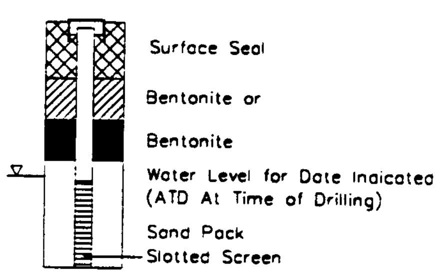
BORING SAMPLES

- Split Spoon
- Shelby Tube
- Cuttings
- Core Run
- * No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

- Grab (Jar)
- Shelby Tube
- Bag

Groundwater Observations



Test Symbols

GS	Grain Size Classification
CN	Consolidation
TUU	Triaxial Unconsolidated Undrained
TCU	Triaxial Consolidated Undrained
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits
	Water Content in Percent Liquid Limit Natural Plastic Limit
PID	Photoionization Reading
CA	Chemical Analysis
DT	In Situ Density Test

DIN 9/5/00 1=1 charlie pc2
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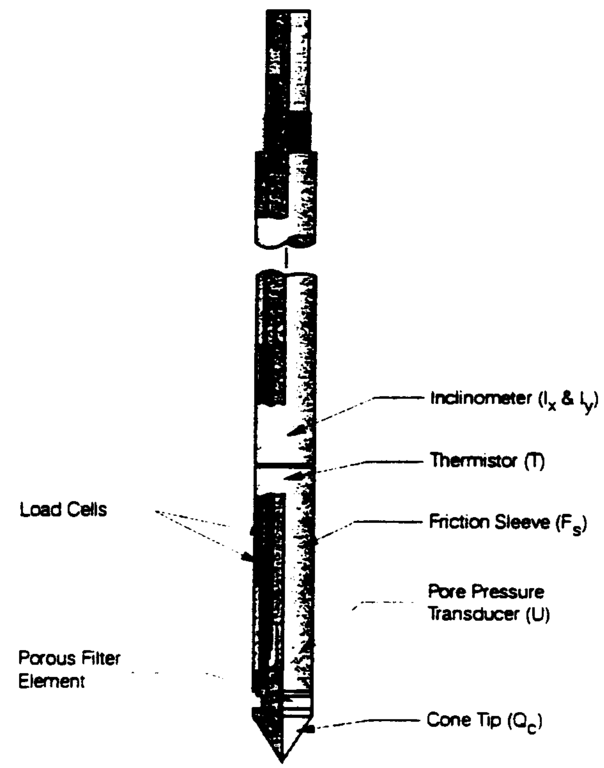
J-4978-26 9/00
Figure A-1

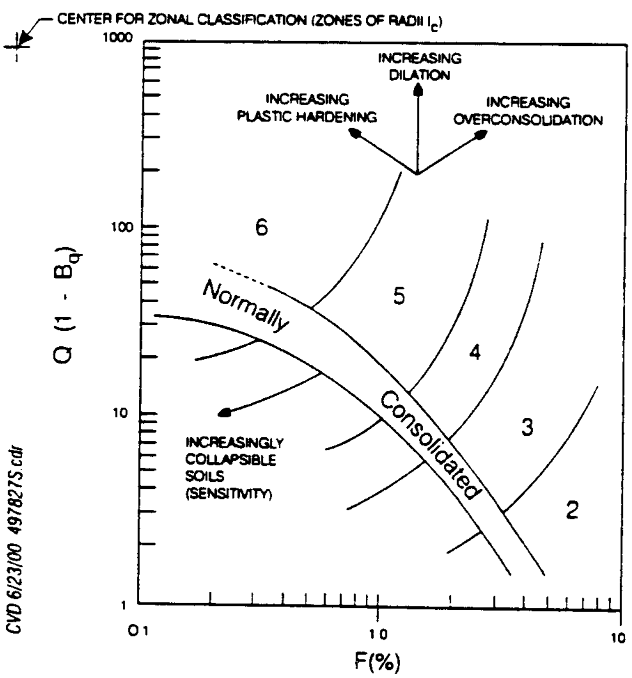
AR 045836

Electric (Piezocone) Cone Penetrometer

Schematic of Electric Piezocone (Typical)



Simplified Classification Chart (Jefferies and Davies, 1993 after Lunne et al., 1990)



Zone	Soil Behavior Type
1	sensitive fine grained
2	organic soils - peats
3	clays - clay to silty clay
4	silt mixtures - clayey silt to silty clay
5	sand mixtures - silty sand to sandy silt
6	sands - clean sand to silty sand

$$Q = \frac{q_T - F_{vo}}{F_{vo}'}$$

$$B_q = \frac{u - u_o}{q_T - F_{vo}}$$

$$F = \frac{f_s'}{q_T - F_{vo}} \times 100\%$$

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HARTCROWSER

J-4978-26 6/00

Figure A-1 2/2

AR 045837

Boring Log HC00-B137

N 19714
E 10657

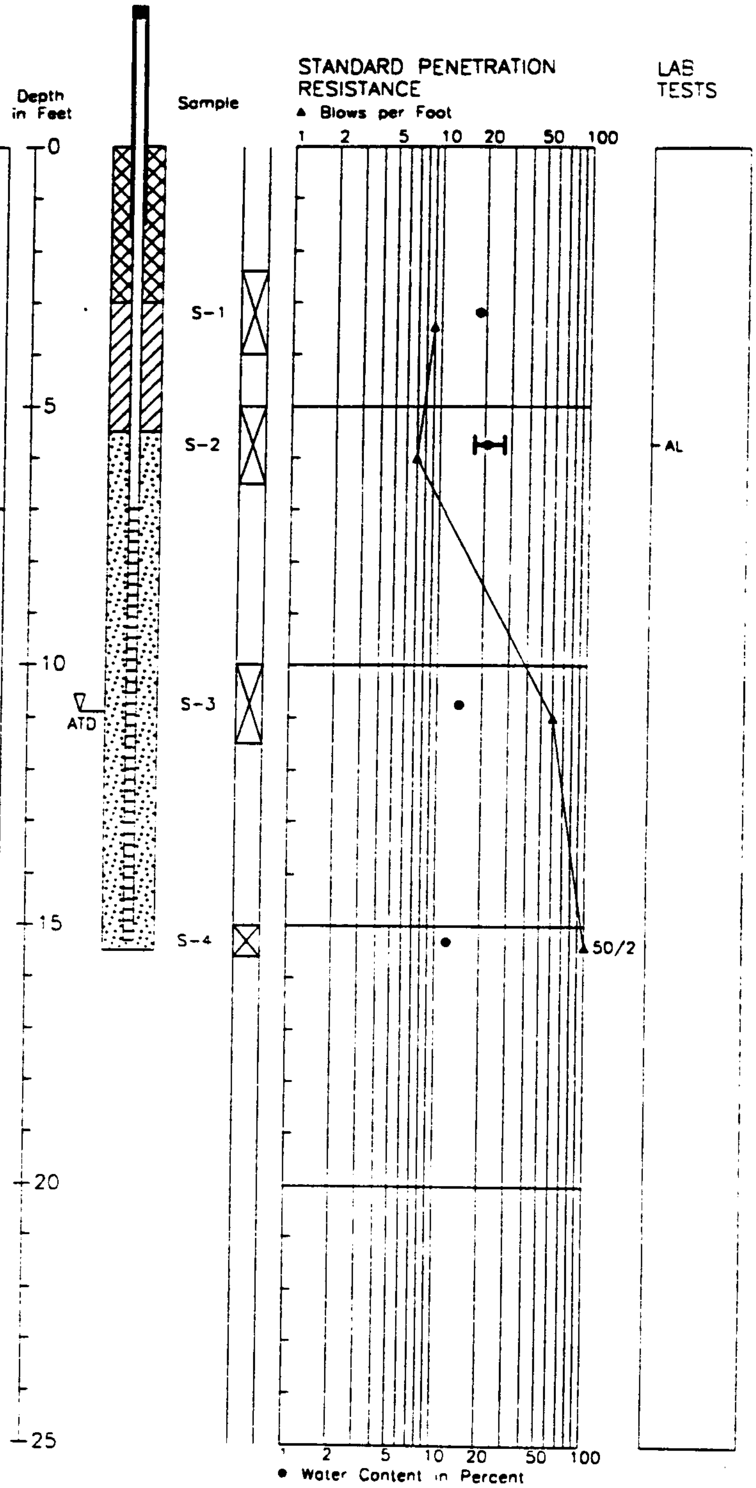
Soil Descriptions
Top of casing elevation in Feet: 267.21
Approx. Ground Surface Elevation in Feet: 264

Medium stiff, to stiff, moist, gray, slightly sandy, silty CLAY with roots and organic material.

Very dense, moist to wet, gray, slightly gravelly, slightly silty to silty SAND with trace organic material.

Gravelly zone

Bottom of Boring at 15.6 Feet.
Completed 5/23/00.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DTN 8/30/00 1=1 CHARLIE-B PC2
BORINGS

HARTCROWSER
J-4978-26 5/00
Figure A-2

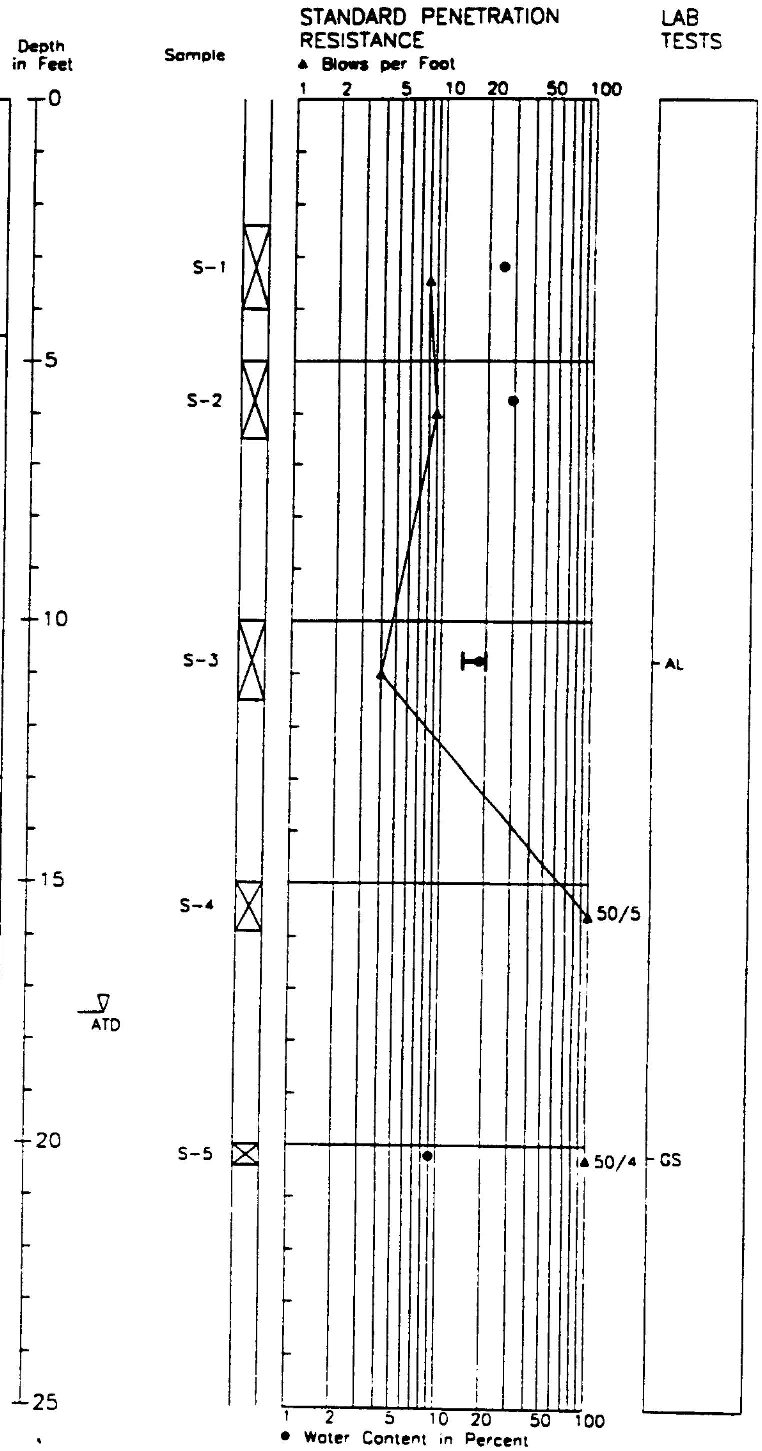
AR 045838

Boring Log HC00-B138
N 19096
E 10627

Soil Descriptions

Ground Surface Elevation in Feet: 247

Soil Descriptions	Depth in Feet
Loose, moist to wet, orange and brown, silty, fine SAND with trace organic material.	0
Medium stiff to stiff, moist to wet, gray with orange mottling, slightly sandy CLAY-SILT.	
Changes to gray.	10
Very dense, moist, gray, gravelly, silty SAND.	
Bottom of Boring at 20.4 Feet. Completed 5/30/00.	20



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

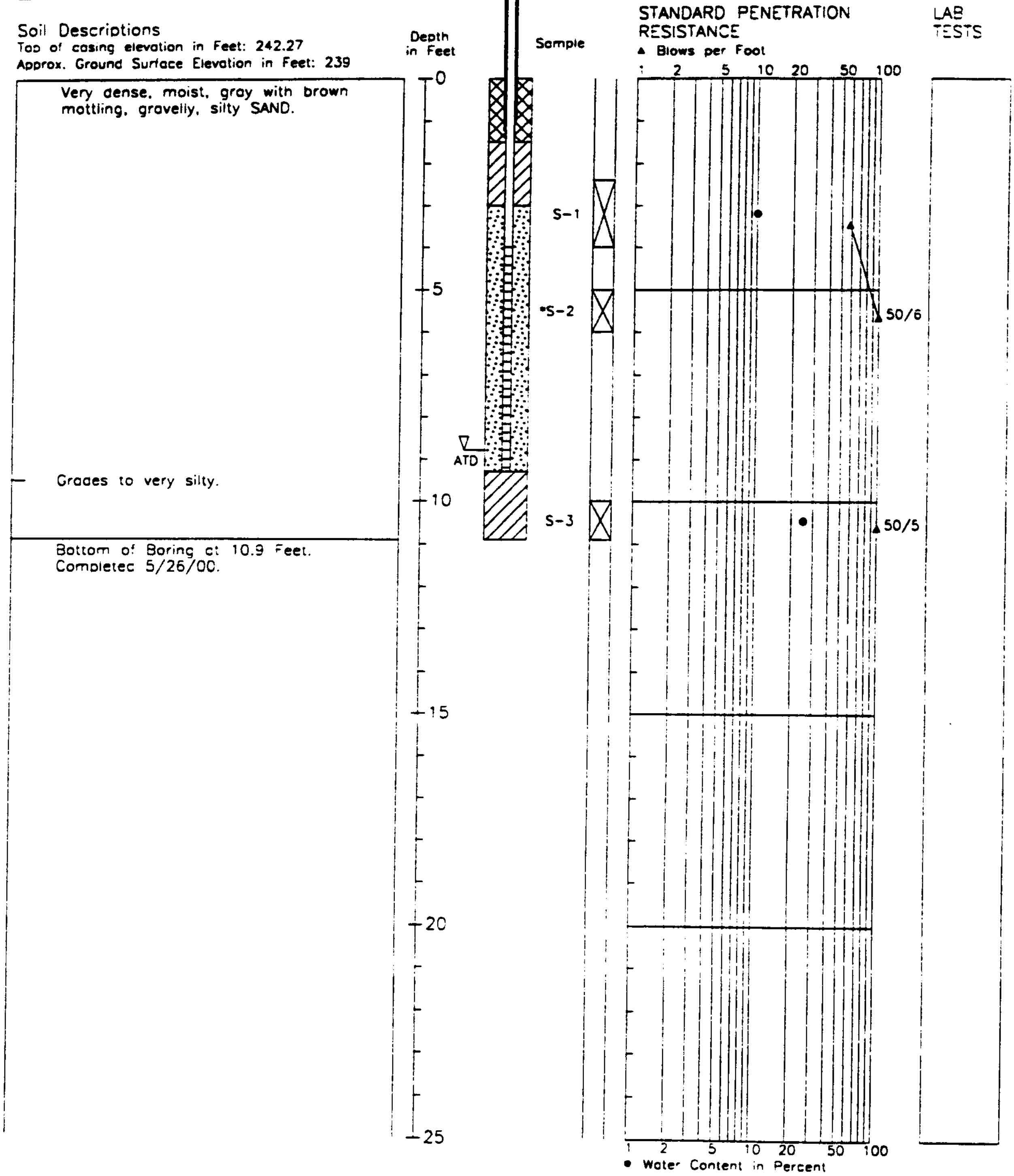
CVD 6/16/00 1=1 CHARLIE-B PC2 BORINGS

HARTCROWSER

J-4978-26 5/00

Figure A-3

Boring Log HC00-B143
N 18759
E 10701



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DTN 8/30/00 1=1 CHARLIE - 8 PC2
BORINGS

HARTCROWSER
J-4978-28 5/00
Figure A-4

Boring Log HC00-B220

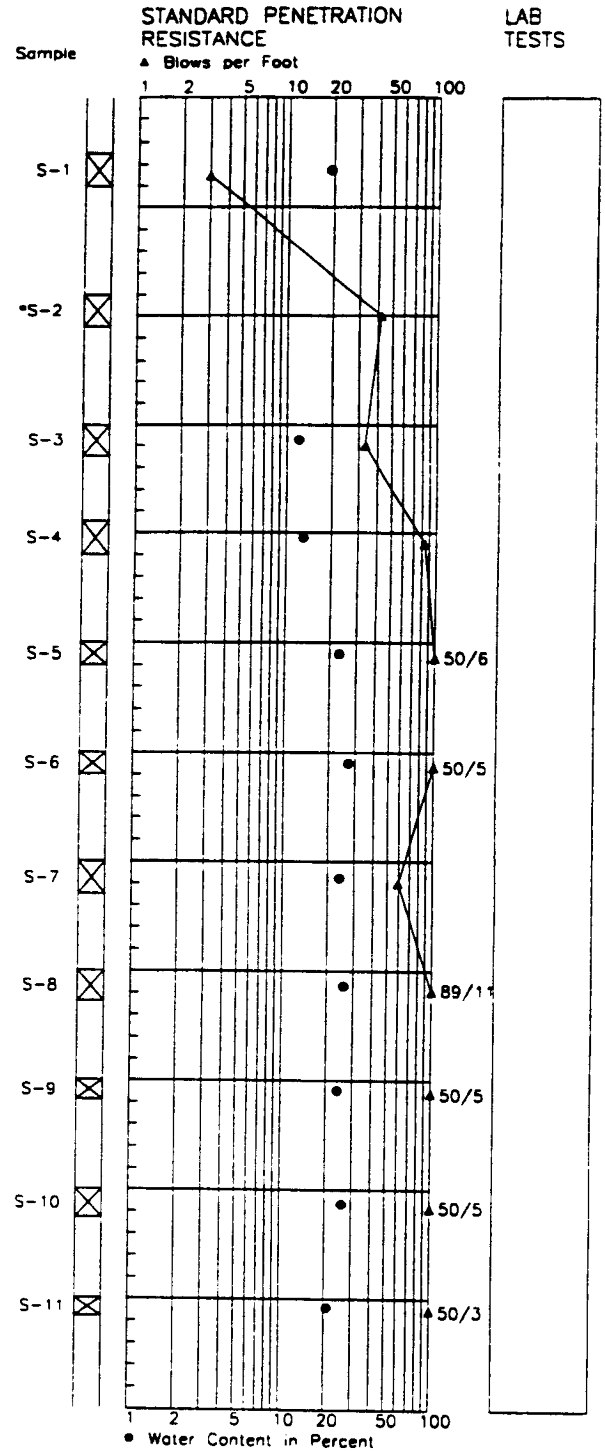
N 14264

E 10953

Soil Descriptions

Approx. Ground Surface Elevation in Feet: 294

Depth in Feet	Soil Descriptions
0	Very loose, moist, brownish red, silty SAND with high organic content.
5	Cuttings indicate sandy SILT with red and brown mottling.
10	Pressuremeter test.
10	Dense, wet, brown, silty, very sandy, GRAVEL.
19	Pressuremeter test.
20	Very dense, wet, light gray, slightly silty, sandy GRAVEL.
22	Very dense, wet, light gray, silty, fine to medium SAND.
29	Pressuremeter test.
39	Pressuremeter test.
44	Very dense, wet, gray SAND.
60	



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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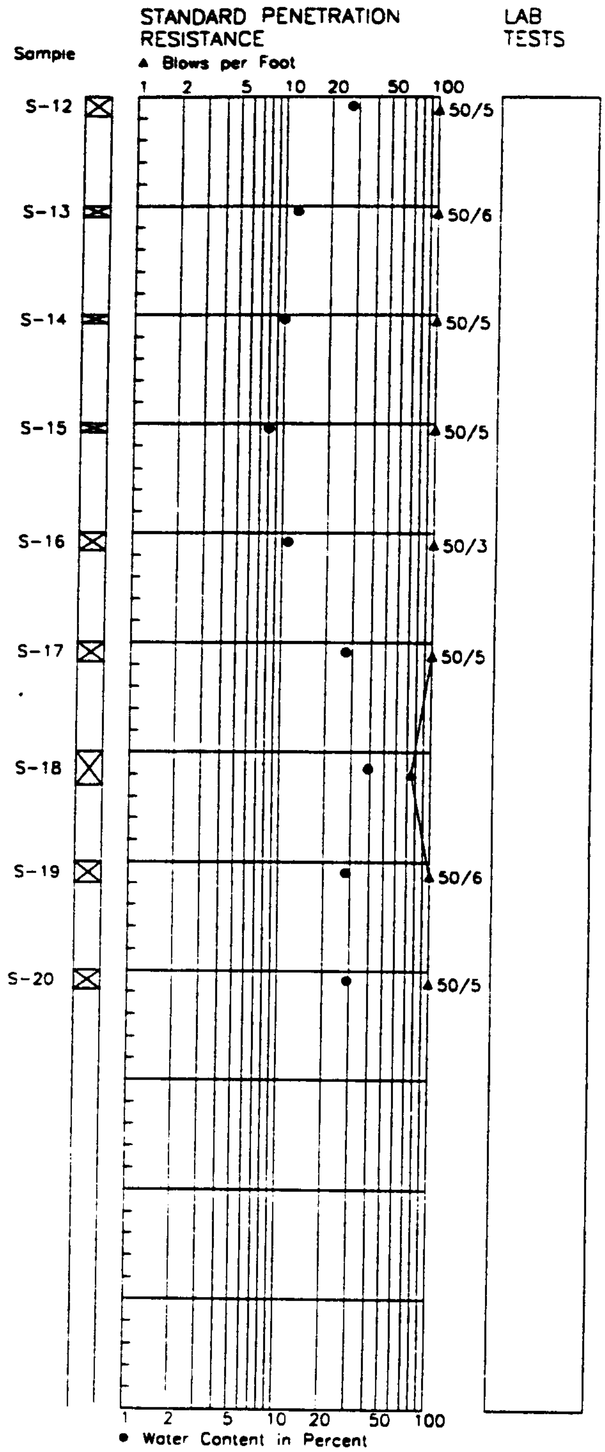
HARTCROWSER

J-4978-27 5/00

Figure A-5 1/2

Boring Log HC00-B220

Soil Descriptions	Depth in Feet
	60
Very dense, wet, gray, very gravelly SAND.	65
	70
Very dense, wet, gray, very sandy GRAVEL.	75
Very dense, wet, gray, very gravelly, medium SAND.	80
Very dense, wet, gray, very silty, fine SAND.	85
	90
	95
	100
Bottom of Boring at 100.9 Feet. Completed 5/24/00.	105
	110
	115
	120



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

CVD 7/12/00 1=1 charlie-B pc2
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HARTCROWSER
J-4978-27 5/00
Figure A-5 2/2

AR 045842

Boring Log HC00-B221

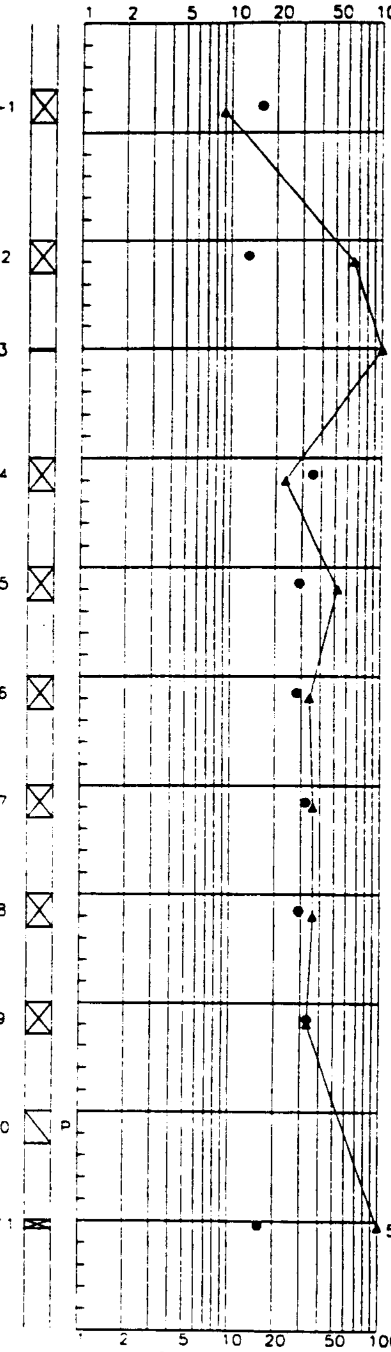
N 17715
E 10953

Soil Descriptions
Approximate Ground Surface Elevation in Feet: 256

Depth in Feet	Soil Descriptions
0	Loose, wet, gray and brown mottled, silty, gravelly, fine to medium SAND. (WEATHERED)
	Pressuremeter test.
	Pressuremeter test.
9	Very dense, wet, gray-brown, silty, gravelly, fine to medium SAND.
	Drilled through 8-inch cobble.
	Pressuremeter test.
	Pressuremeter test.
19	Very stiff to hard, moist, gray, clayey SILT and silty CLAY.
	Pressuremeter test.
	Pressuremeter test.
	Becomes laminated and layered.
	Pressuremeter test.
	Some slickensides.
50	Hard, moist, gray, sandy SILT.
58	Very dense, wet, gray, slightly silty SAND.

Sample: S-1, S-2, *S-3, S-4, S-5, S-6, S-7, S-8, S-9, S-10 (P), S-11

STANDARD PENETRATION RESISTANCE
▲ Blows per Foot



● Water Content in Percent

LAB TESTS

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DTN 8/30/00 1=1 charlie 8pc2
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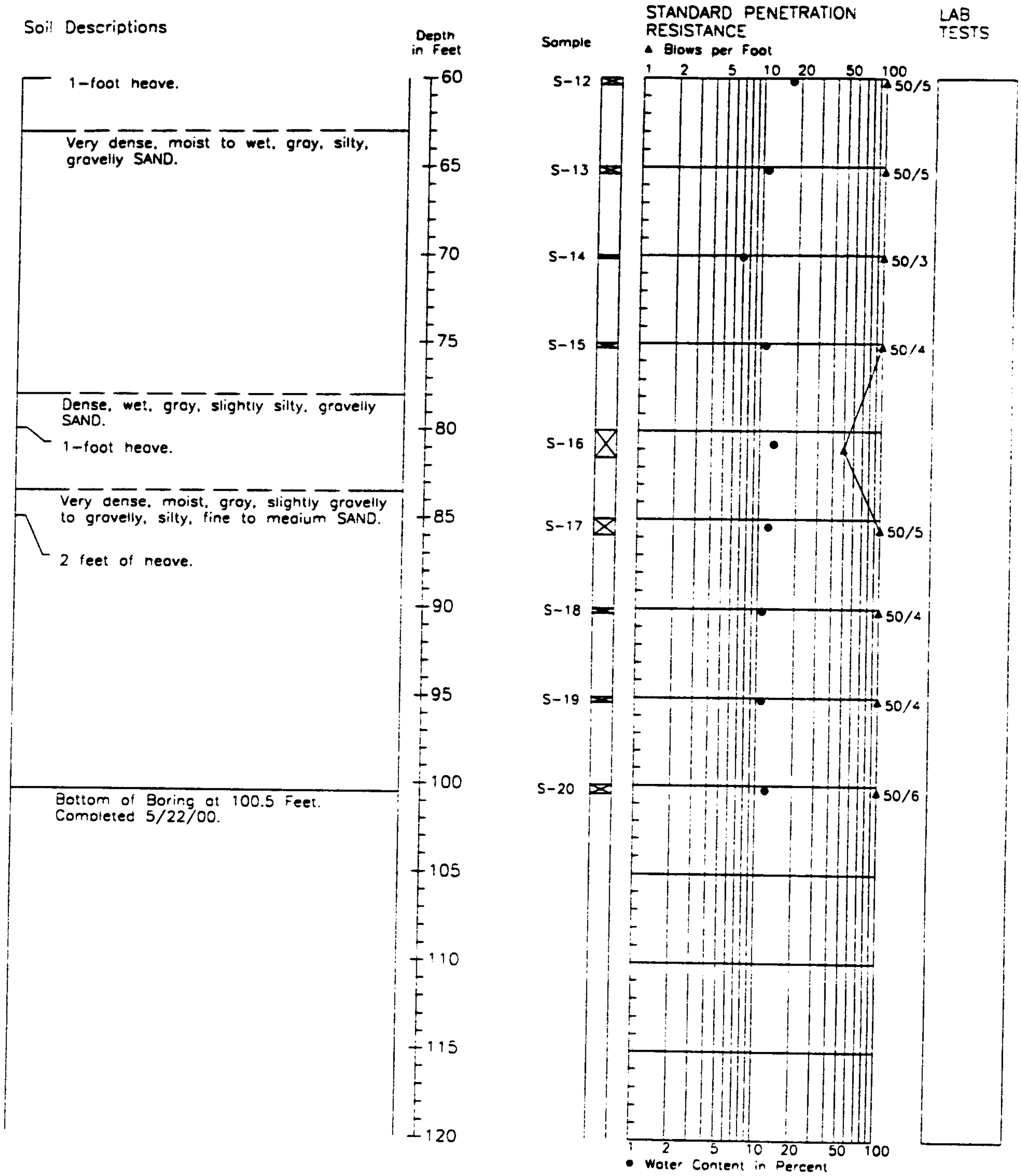
HARTCROWSER
J-4978-27 5/00
Figure A-6 1/2

Boring Log HC00-B221



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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HARTCROWSER
J-4978-27 5/00
Figure A-6 2/2

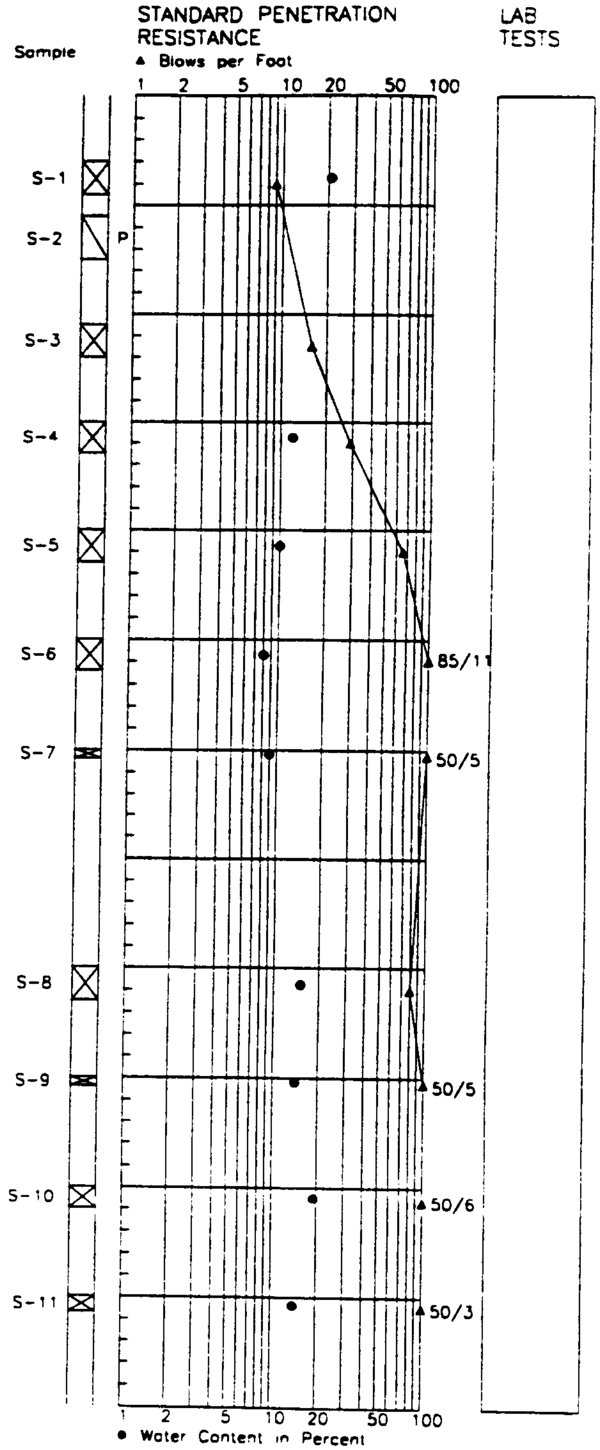
AR 045844

Boring Log HC00-B222

N 21920
E 11205

Soil Descriptions
Approximate Ground Surface Elevation in Feet: 276

Soil Descriptions	Depth in Feet
Loose to medium dense, moist to wet, brown to gray, slightly silty to silty, slightly gravelly to gravelly, fine to medium SAND.	0
Pressurementer test.	
Very dense, wet, gray, silty, gravelly, fine to medium SAND.	19
Pressuremeter test.	
Very dense, wet, gray, slightly silty, non-silty to very sandy GRAVEL.	24
Pressuremeter test.	
Very dense, wet, gray, silty, gravelly, fine to medium SAND.	38
Very dense, wet, gray, gravelly SAND.	44
Very dense, wet, gray, slightly silty SAND.	48.5
Some heave.	
5 feet of heave.	



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

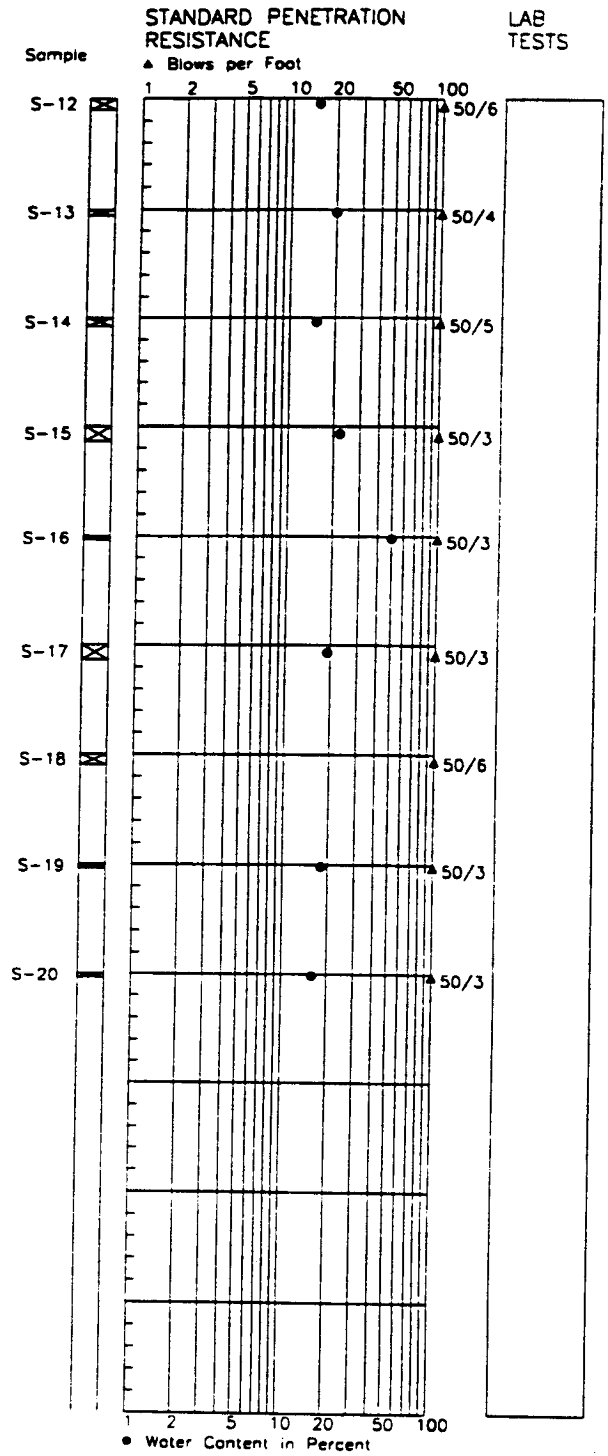
CVD 6/7/00 1=1 charlie-Bpc2
49782\1OCS.dwg

HARTCROWSER
J-4978-27 5/00
Figure A-7 1/2

Boring Log HC00-B222

Soil Descriptions (Depth in Feet)

Depth in Feet	Soil Descriptions
60	Very dense, wet, gray, gravelly SAND 1-foot of heave.
	Very dense, wet, gray SAND.
65	1 foot heave.
70	1 foot heave.
75	
	1-foot of heave @ 80'.
80	HARD, moist, brown, organic SILT 1-foot
	Very dense, wet, gray, gravelly SAND.
85	
	Grade to non-gravelly SAND.
90	1 foot heave.
	Very dense and hard, moist, light gray, silty SAND and SILT. (ASH)
	Very dense, wet, gray, gravelly SAND.
95	1 foot heave.
100	2 feet heave.
	Bottom of Boring at 100.2 Feet. Completed 5/18/00.
105	
110	
115	
120	



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

CVD 6/7/00 1:1 charlie-B.pc2
49787\LOGS.dwg

HARTCROWSER
J-4978-27 5/00
Figure A-7 2/2

Boring Log HC00-B223

N 13986

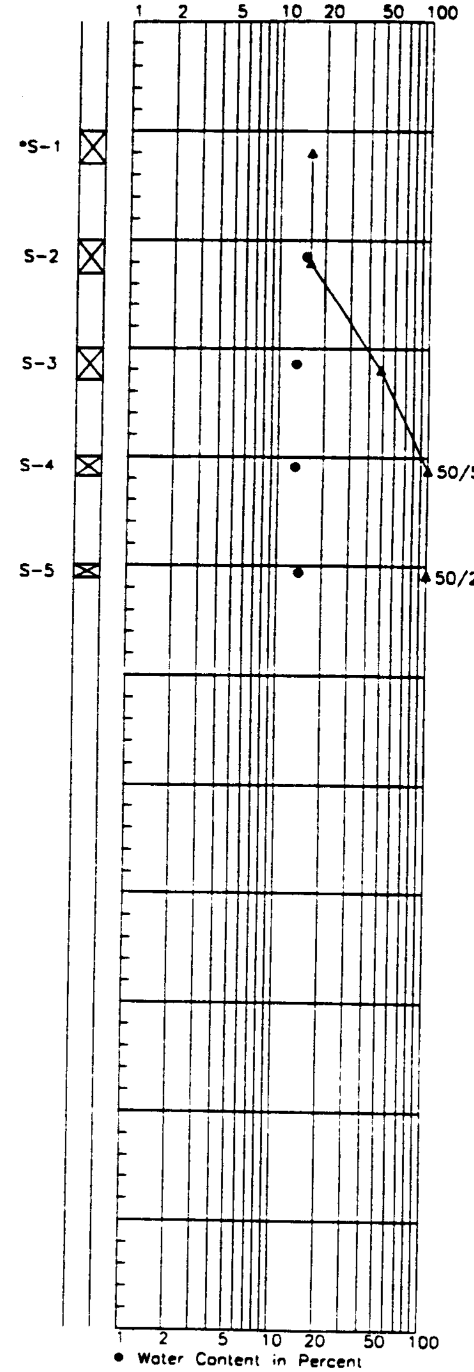
E 10965

Soil Descriptions

Approximate Ground Surface Elevation in Feet: 309

Depth in Feet

Depth (ft)	Soil Description
0	Drill action indicates gravel.
7.5	Medium dense, gray-brown, wet, slightly gravelly, silty SAND. Pressuremeter test.
13.5	Dense, wet, brown, slightly silty, gravelly SAND.
20	Very dense, moist, gray, gravelly, silty SAND. Pressuremeter test.
35	Bottom of Boring at 35.0 Feet. Completed 5/24/00.



LAB TESTS

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

CVO 6/7/00 1=1 charlie 8.pc2
497827\LOGS.dwg

HARTCROWSER

J-4978-27 5/00

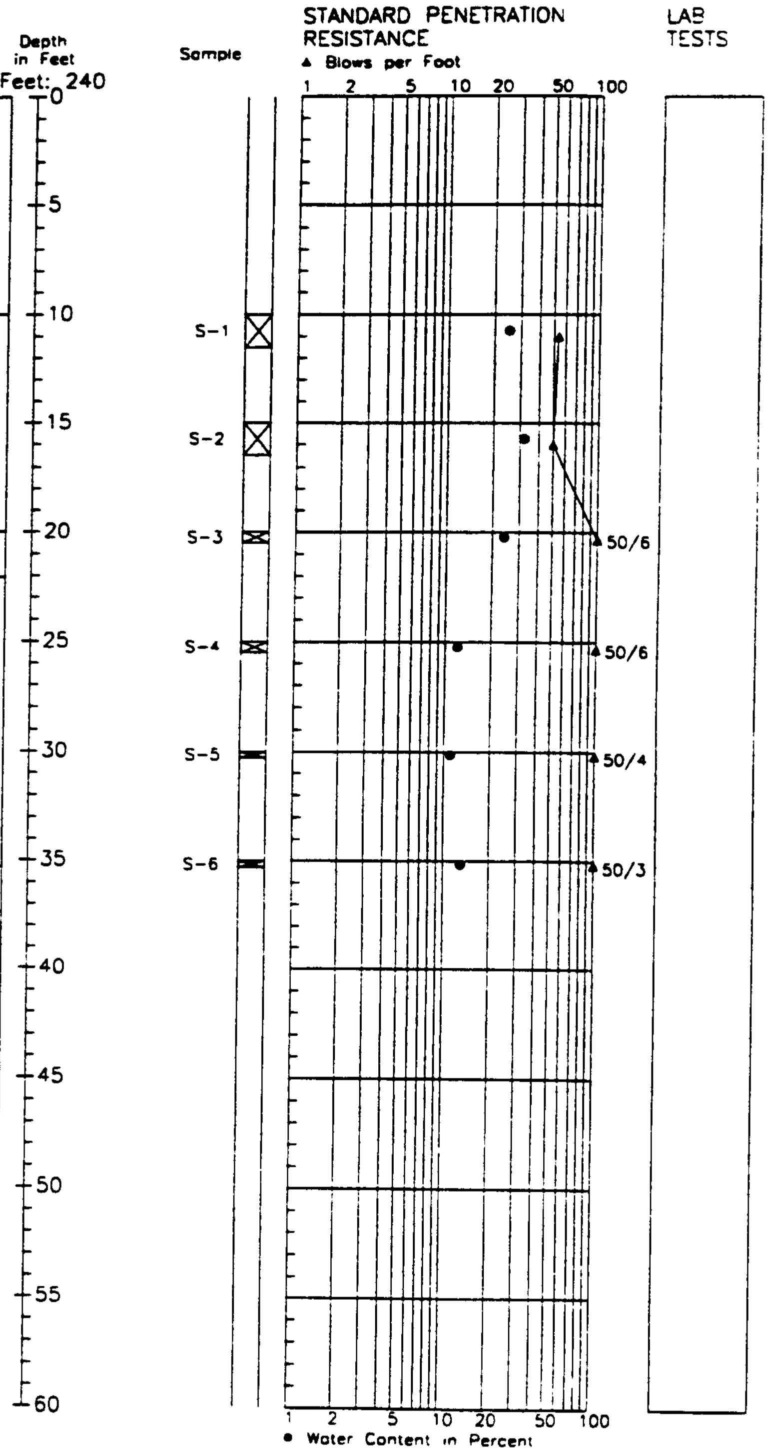
Figure A-8

Boring Log HC00-B224

N 18193
E 10965

Soil Descriptions
Approximate Ground Surface Elevation in Feet: 240

Depth in Feet	Soil Descriptions
0	Drill action indicates gravel.
10	Very dense, wet, gray, slightly silty, fine SAND.
20	Very dense, wet, gray, silty, gravelly SAND.
22	Pressuremeter test.
	Very dense, moist, gray, gravelly, silty SAND.
32	Pressuremeter test.
35	Bottom of Boring at 35.3 Feet. Completed 5/22/00.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

CVD 6/7/00 1=1 charlie-B.pc2
497827\LOGS.dwg

HARTCROWSER
J-4978-27 5/00
Figure A-9

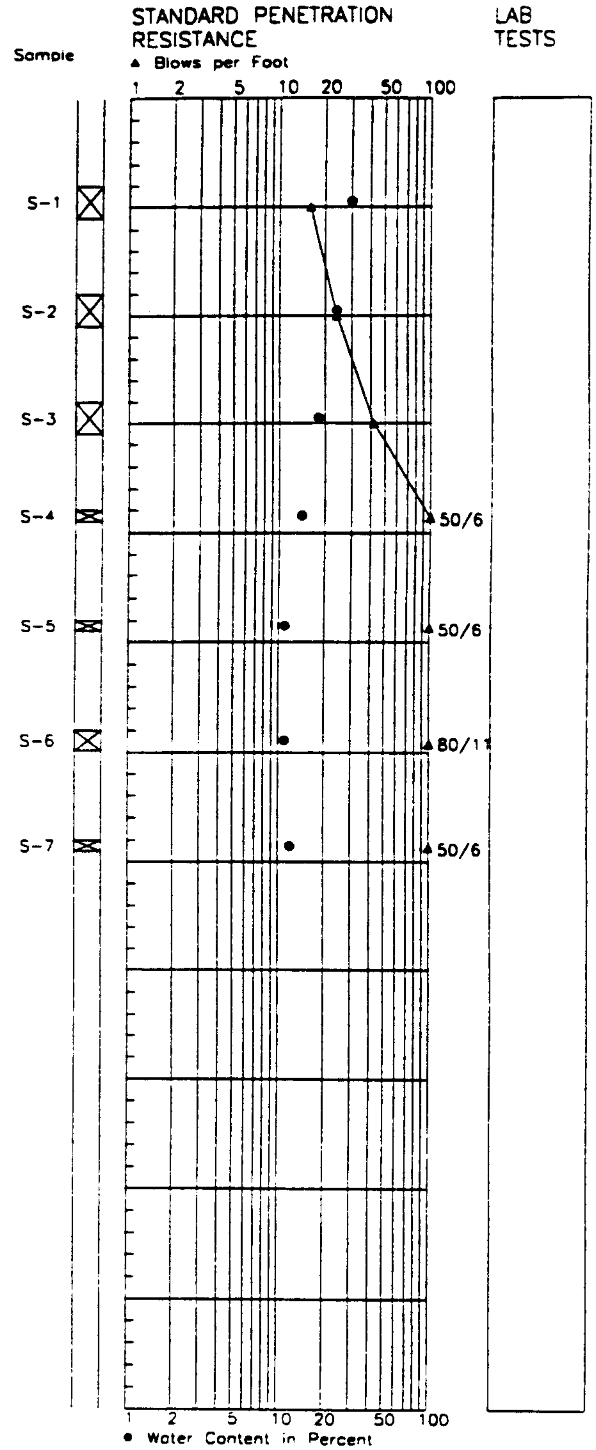
AR 045848

Boring Log HC00-B225

N 21916
E 11459

Soil Descriptions
Approximate Ground Surface Elevation in Feet: 283

Depth in Feet	Soil Descriptions
0	Very stiff, moist, light brown, slightly sandy, clayey SILT.
~8	Pressuremeter test.
~12	Hard, moist, gray, clayey, sandy SILT.
	Pressuremeter test.
~17	Hard, moist, gray, gravelly, very sandy SILT.
	Pressuremeter test.
~20	Very dense, moist, gray, silty, gravelly SAND.
	Pressuremeter test.
	Gravelly drill action.
	Pressuremeter test.
34.5	Bottom of Boring at 34.5 Feet. Completed 5/18/00.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

CVD 6/7/00 1=1 charlie-8 pc2
497827\LOGS.dwg

HARTCROWSER
J-4978-27 5/00
Figure A-10

AR 045849

Boring Log HC00-B300

N 19818

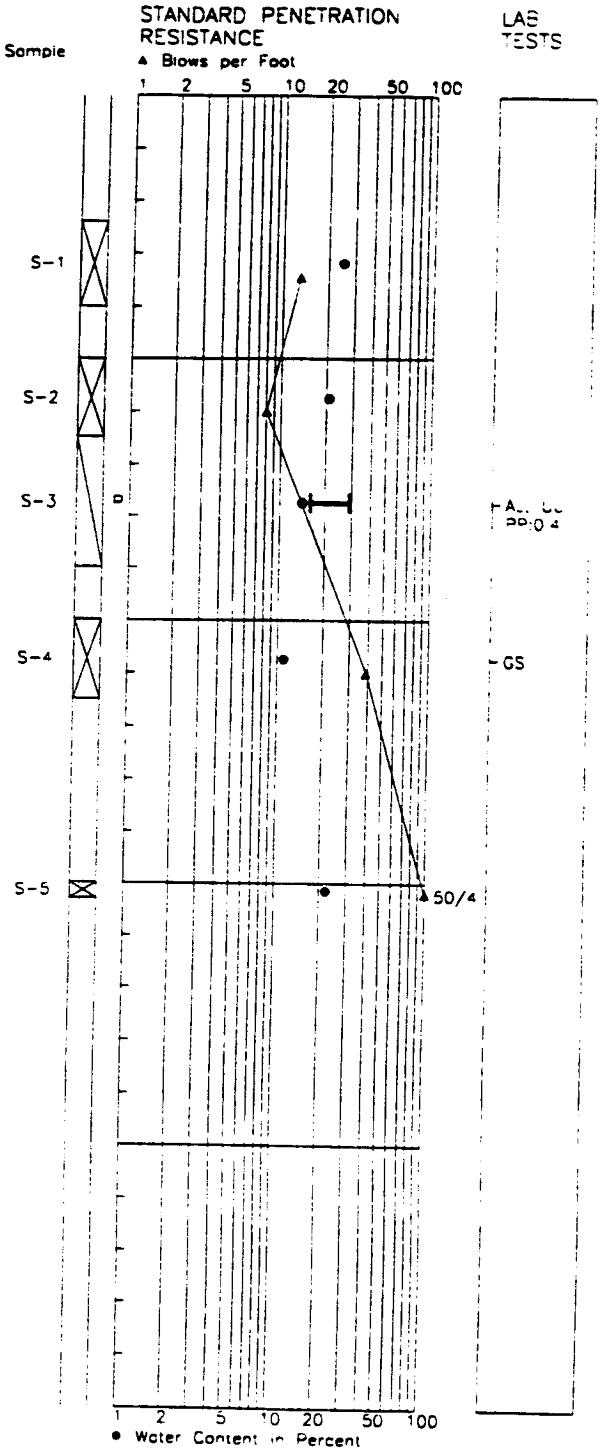
E 10889

Soil Descriptions

Ground Surface Elevation in Feet: 291

Soil Description	Depth in Feet
Medium dense, wet, brown, slightly silty SAND.	0
Medium stiff, moist, greenish gray with mottling, slightly sandy, slightly silty CLAY.	5
Dense to very dense, moist to wet, brown, slightly gravelly, very silty SAND.	10
Changes to gray, becomes silty.	15
Bottom of Boring at 15.3 Feet. Completed 5/25/00.	
	20
	25

ATD



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DIN 8/29/00 1=1 CHARLIE - 8 PC2
BORINGS

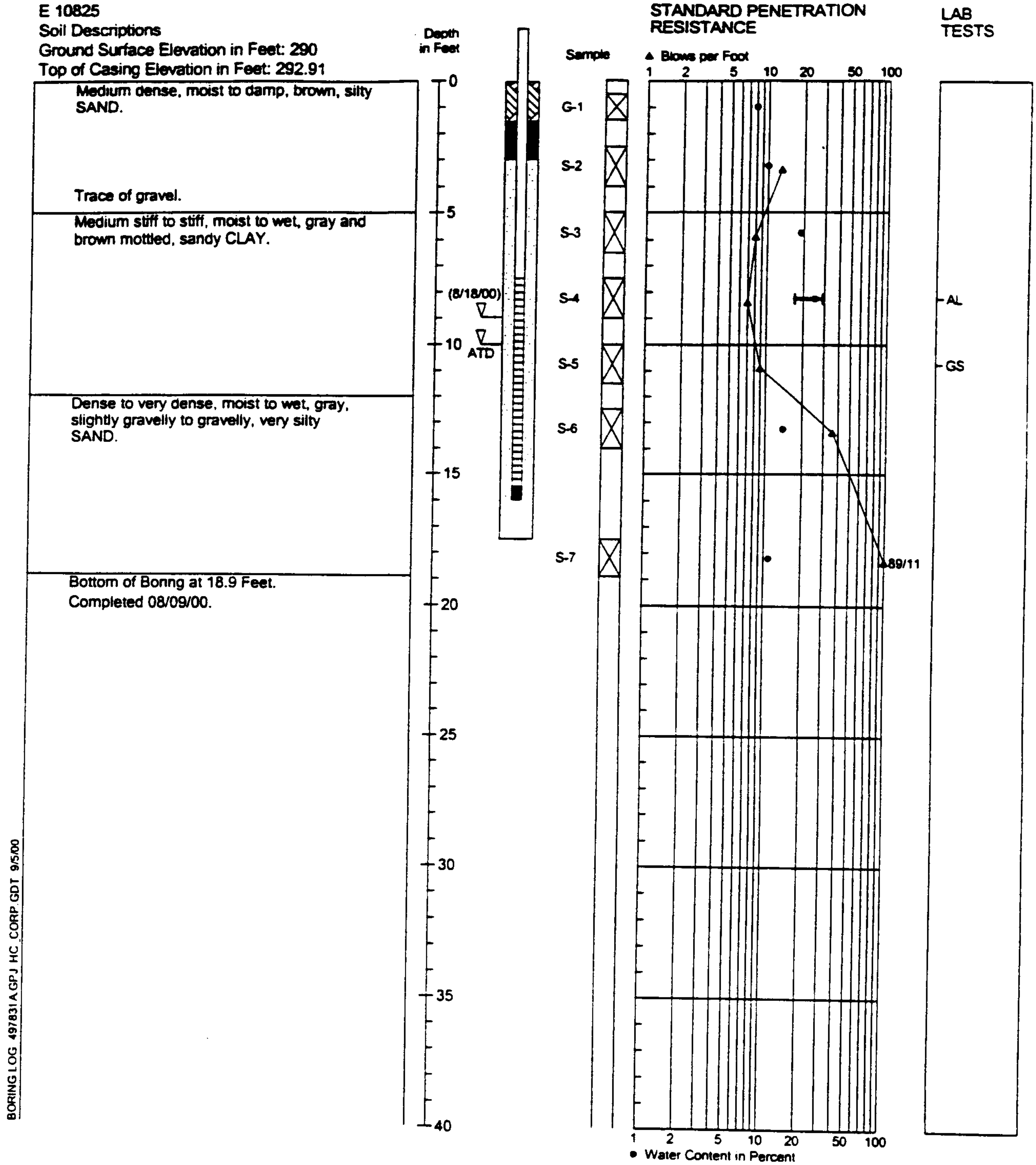
HARTCROWSER

J-4978-26 5/00

Figure A-11

Monitoring Well Log HC00-B302

N 20429
E 10825
Soil Descriptions
Ground Surface Elevation in Feet: 290
Top of Casing Elevation in Feet: 292.91



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

4978-31 *08/00*

Figure A-13

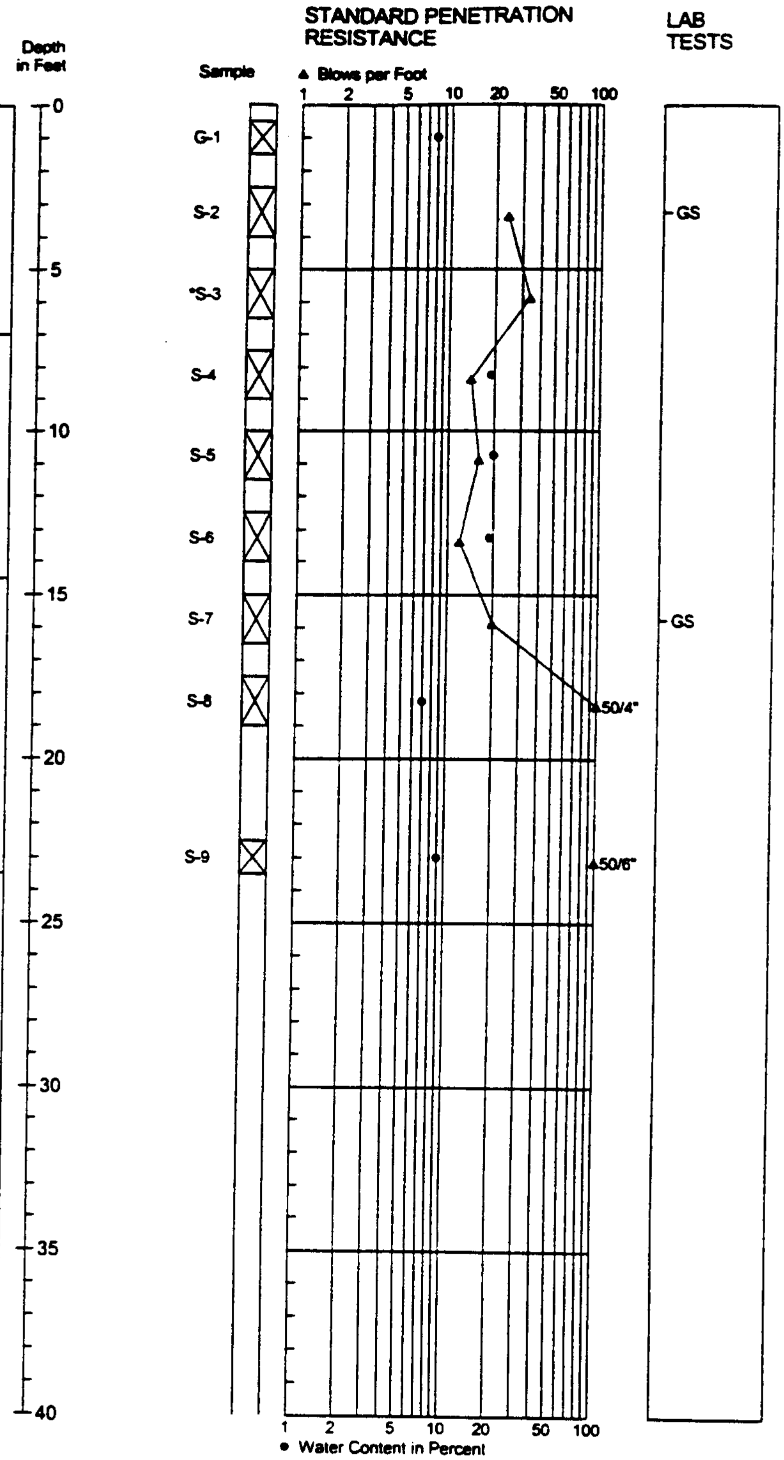
AR 045851

Monitoring Well Log HC00-B303

N 20224
E 10971
Soil Descriptions

Ground Surface Elevation in Feet: 304

Depth in Feet	Soil Descriptions
0	Medium dense to dense, moist to damp, brown, silty, fine to medium SAND.
	Stiff to very stiff, moist, brown with orange mottling, slightly sandy to sandy CLAY.
	Medium dense to very dense, moist, brown, slight gravelly, silty fine to medium SAND.
	Bottom of Boring at 23.5 Feet. Completed 08/10/00.



BORING LOG 497831A.GPJ HC_CORP.GDT 9/5/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

4978-31 *08/00*

Figure A-14

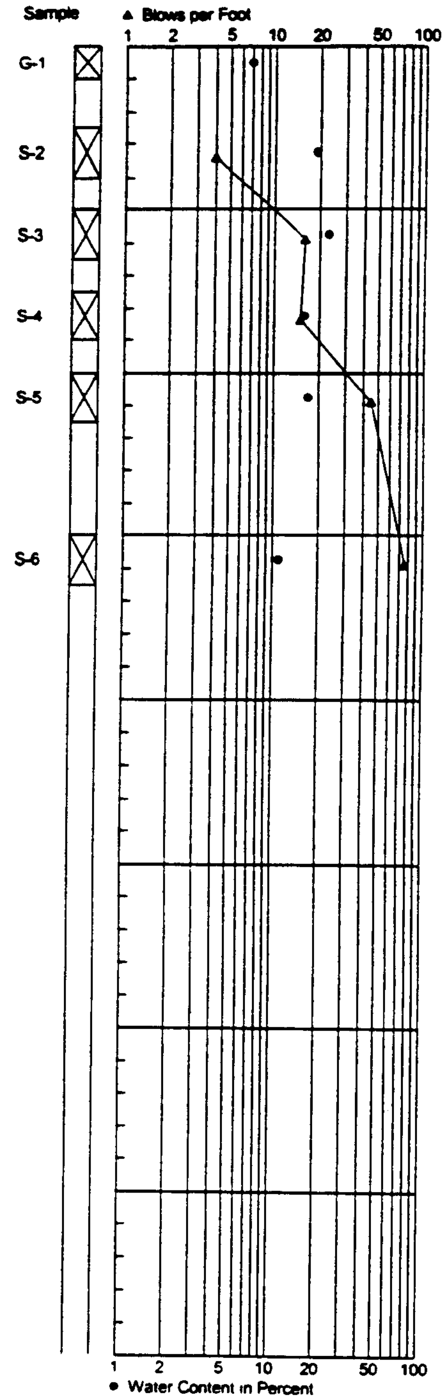
AR 045852

Boring Log HC00-B304

N 20009
E 10758
Soil Descriptions

Ground Surface Elevation in Feet: 286

Soil Descriptions	Depth in Feet
Very loose to (medium dense), damp to moist, brown and gray, slightly gravelly, silty SAND with organic material.	0
Very stiff to hard, moist, gray and orange mottled, sandy CLAY. Laminated layers and organic material noted.	5 – 10
Very dense, moist, gray, slightly gravelly, silty SAND.	15 ∇ ATD
Bottom of Boring at 16.5 Feet. Completed 08/09/00.	20 – 40



LAB TESTS

BORING LOG 497831A.GPJ HC_CORP.GDT 9/1/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

4978-31 08/00

Figure A-15

AR 045853

Monitoring Well Log HC00-B305

N 19808
E 10806
Soil Descriptions
Ground Surface Elevation in Feet: 284
Top of Casing Elevation in Feet: 286.89

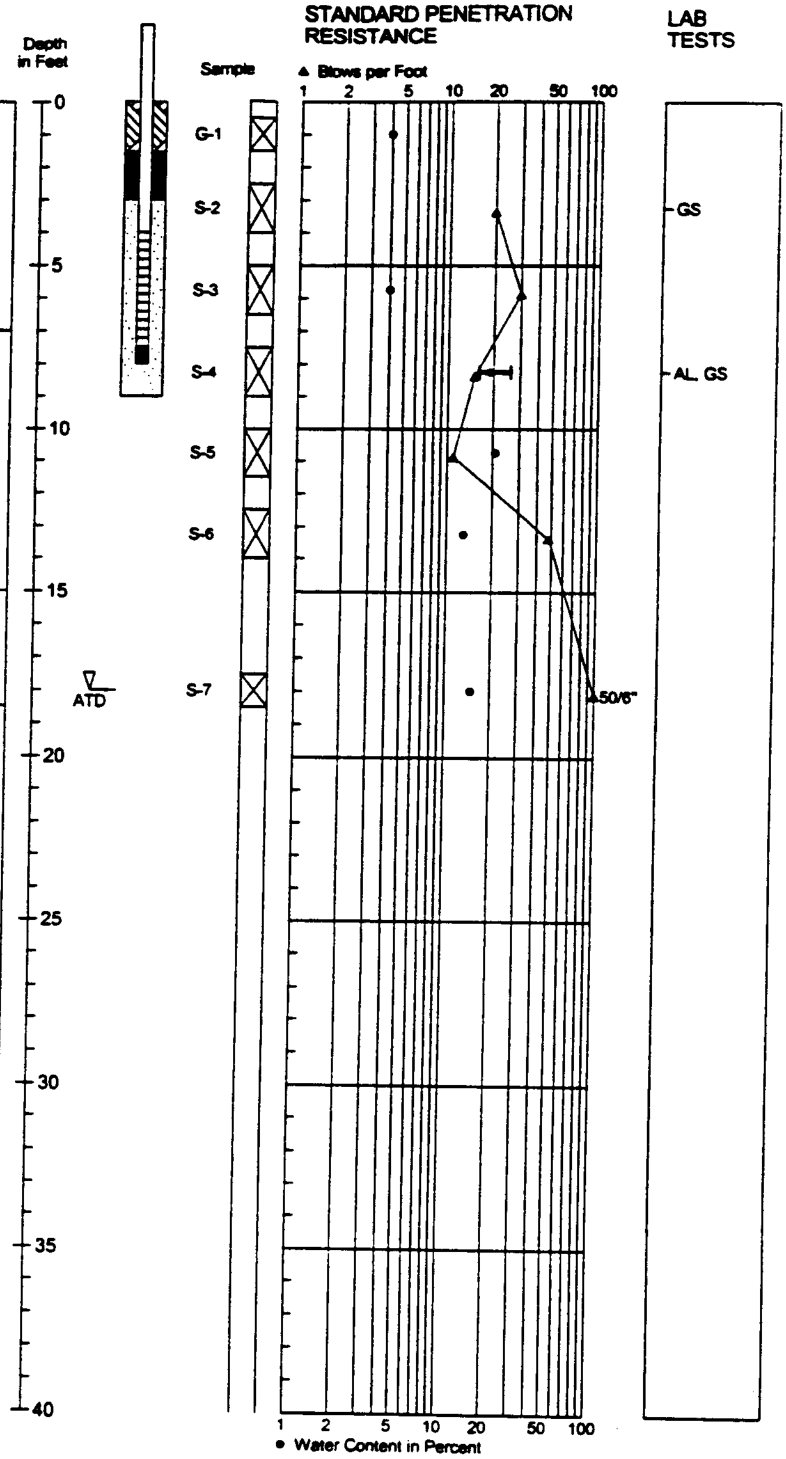
Medium dense to dense, damp to moist, slightly silty, very gravelly SAND.

Stiff to hard, moist, brownish-gray and orange mottled, sandy CLAY.

Sand and gravel noted at bottom 2" of sample.

Very dense, moist to wet, gray and brown, slightly gravelly, silty SAND.

Bottom of Boring at 18.5 Feet.
Completed 08/10/00.



BORING LOG 497831A.GPJ HC_CORP.GDT 9/5/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

4978-31 *08/00*

Figure A-16

Monitoring Well Log HC00-B306

N 19434
E 10866
Soil Descriptions
Ground Surface Elevation in Feet: 277
Top of Casing Elevation in Feet: 278.65

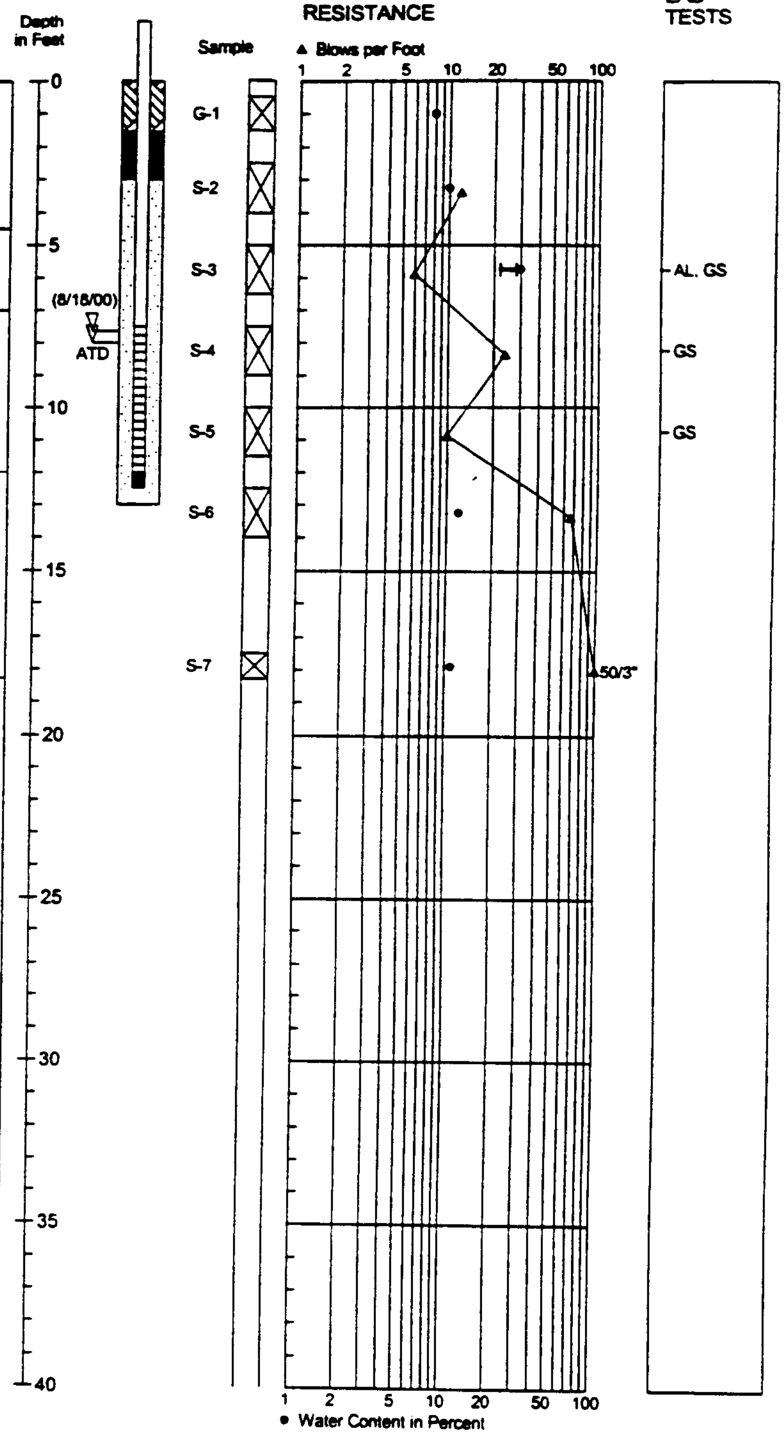
Medium dense, moist to damp, brown with orange mottling, slightly silty SAND.

Medium stiff, moist, gray and orange, mottled, sandy, very silty CLAY.

Loose to medium dense, moist to wet, gray with orange mottling, slightly gravelly, very silty, fine to medium SAND.

Very dense, damp to moist, brownish-gray, slightly gravelly, silty SAND.

Bottom of Boring at 18.3 Feet.
Completed 08/10/00.



BORING LOG 497831A.GPJ HC_CORP.GDT 9/1/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

4978-31 08/00

Figure A-17

AR 045855

Boring Log HC00-B307

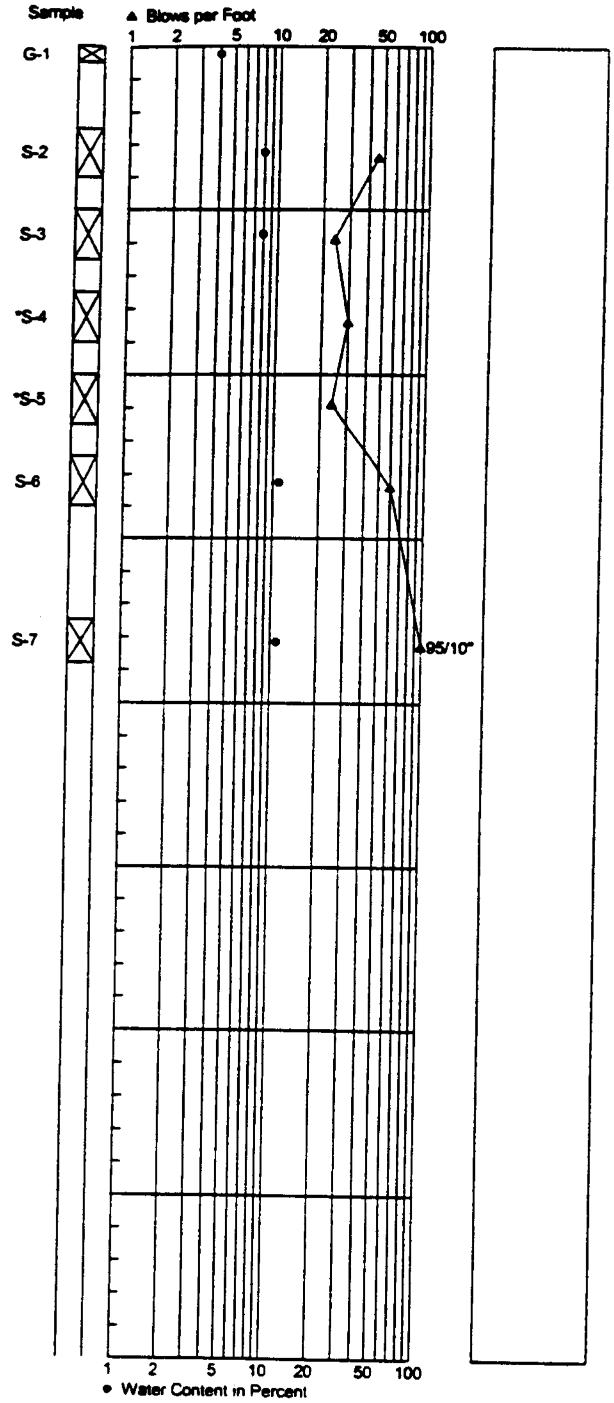
N 19082
E 10783
Soil Descriptions

Ground Surface Elevation in Feet: 267

Depth in Feet	Soil Descriptions
0	Medium dense to dense, moist to damp, brown and gray, gravelly, silty SAND.
	Noted gravels in run.
	Very dense, moist to wet, brownish-gray to gray, slightly gravelly, slightly silty to silty SAND.
	Bottom of Boring at 18.8 Feet. Completed 08/09/00.

STANDARD PENETRATION RESISTANCE

LAB TESTS



BORING LOG 497831A.GPJ HC_CORP.GDT 9/1/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

4978-31 08/00

Figure A-18

AR 045856

Hand-Auger Log HC00-A300

N 18235
E 10762

Sample	Water Content
S-1	33
S-2	27
S-3	33

Depth in Feet: 0–20

SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 228

Depth in Feet	SOIL DESCRIPTIONS
0–1	(Loose to medium dense), wet, dark brown, silty SAND with organic material.
1–3	(Medium dense), wet, gray, silty SAND with trace organic material.
3–4	(Medium stiff to stiff), wet, gray, clayey, sandy SILT with trace organic material.

Bottom of Hand-Auger at 4.0 Feet
Completed 5/12/00.

Seepage noted @ 1.0'

Hand-Auger Log HC00-A301

N 18127
E 10798

Sample	Water Content
S-1	47
S-2	2'
S-3	19
S-4	28
S-5	28

Depth in Feet: 0–20

SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 229

Depth in Feet	SOIL DESCRIPTIONS
0–1.5	(Loose to medium dense), moist to wet, dark brown, very gravelly, silty SAND with abundant organic material.
1.5–4	(Loose to medium dense), wet, brown to gray, silty SAND with trace organic material.
4–5.5	(Medium stiff to stiff), wet, gray, slightly clayey, sandy SILT with trace organic material

Bottom of Hand-Auger at 5.5 Feet
Completed 5/12/00.

Seepage noted @ 1.5'

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DTN 8/30/00 1=1 CHARLIE 8PC2
HANDAUGERS

HARTCROWSER
J-4978-26 5/00
Figure A-19

Test Pit Log HC00-TP220

N 14590
E 11265

Sample	Water Content	Depth in feet	SOIL DESCRIPTIONS Approximate Ground Surface Elevation in Feet: 346
S-1	23	0–2	(Loose to medium dense), moist to wet, brown, slightly gravelly, silty SAND.
S-2	8	2–9	(Very dense), moist, gray, silty, gravelly, fine to medium SAND.
		9	Bottom of Test Pit at 9.0 Feet. Completed 3/16/00.

Test Pit Log HC00-TP221

N 14801
E 11287

Sample	Water Content	Lab Tests	Depth in feet	SOIL DESCRIPTIONS Approximate Ground Surface Elevation in Feet: 344
S-1	16		0–3.5	(Medium dense to dense), moist, brown, silty, gravelly SAND with cobbles, and organic material and roots. (FILL)
S-2	22	GS	3.5–7	(Medium dense), moist, brown, gravelly, very silty SAND with organic material. Roots grades out.
S-3	8		7–10	(Very dense), moist, gray, silty, gravelly SAND.
			10	Bottom of Test Pit at 10.0 Feet. Completed 3/16/00.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

RC 497823 Pits 6/7/00

HARTCROWSER
J-4978-23 3/00
Figure A-20

Test Pit Log HC00-TP222

N 14579
E 11381

Sample	Water Content	Depth in feet	SOIL DESCRIPTIONS Approximate Ground Surface Elevation in Feet: 357
S-1	18	0–2.5	6 inches of Topsoil over (medium dense), wet, brown, silty, gravelly SAND with roots.
S-2	15	2.5–4	(Medium dense to dense), wet, gray, slightly silty, very gravelly SAND.
S-3	11	4–13	(Dense to very dense), moist, gray, silty, gravelly, fine to medium SAND.
		13	Bottom of Test Pit at 13.0 Feet. Completed 3/16/00.

Test Pit Log HC00-TP223

N 14625
E 11481

Sample	Water Content	Depth in feet	SOIL DESCRIPTIONS Approximate Ground Surface Elevation in Feet: 365
S-1	21	0–4	(Medium dense), wet, brown to dark brown, slightly gravelly, silty SAND with roots.
S-2	24	4–5.5	(Loose), wet, brown, silty, gravelly SAND.
S-3	11	5.5–13	(Dense to very dense), moist, gray, silty, gravelly SAND.
		13	Bottom of Test Pit at 13.0 Feet. Completed 3/16/00.

RC 49/823 Pits 6/7/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

HARTCROWSER
J-4978-23 3/00
Figure A-21

Test Pit Log HC00-TP224

N 15532
E 12085

Sample	Water Content	Lab Tests	Depth in feet	SOIL DESCRIPTIONS Approximate Ground Surface Elevation in Feet: 383
			0	(Medium dense), moist, gray, fine to medium SAND.
S-1	9	GS	3	
			4	Grades to dense.
S-2	11		11	(Dense), wet, gray, sandy GRAVEL.
S-3	10		12.5	(Very dense), moist, gray, silty, gravelly, fine to medium SAND.
			15	Bottom of Test Pit at 15.0 Feet. Completed 3/16/00.

Test Pit Log HC00-TP226

N 15042
E 11269

Sample	Water Content	Depth in feet	SOIL DESCRIPTIONS Approximate Ground Surface Elevation in Feet: 358
S-1	19	0	6 inches of Topsoil over (medium dense), moist, brown, slightly gravelly, silty SAND with organic material.
S-2	21	2	(Medium dense), wet, gray and orange mottled, slightly gravelly, silty SAND.
S-3	10	3.5	(Dense to very dense), moist, gray, silty, gravelly, fine to medium SAND.
		9	Bottom of Test Pit at 9.0 Feet. Completed 3/16/00.

RC 49/823 Pits 6/7/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

HARTCROWSER
J-4978-23 3/00
Figure A-22

AR 045860

Test Pit Log HC00-TP300

N 20404
E 10845

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 299
S-1	14	0–1	(Medium dense), moist, dark brown, slightly silty SAND with organic material. (TOPSOIL)
S-2	10	1.5–4.5	(Medium dense), moist, brown, slightly silty, fine SAND with trace organic material.
S-3	20	4.5–6.5	(Stiff), moist, orange to gray, very sandy, very clayey SILT.
S-4	20	6.5–9	(Stiff), moist, gray to orange, slightly gravelly, sandy SILT. (Weathered)
S-5	18	9–15	(Stiff), moist, gray, sandy SILT.

Bottom of Test Pit at 15 Feet.
Completed 5/2/00.

No groundwater seepage observed.

Test Pit Log HC00-TP301

N 20247
E 10838

Sample	Water Content		Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 295
S-1	23		0–1.5	(Medium dense), moist, brown, silty SAND with organic material. (TOPSOIL)
S-2	20		1.5–3.5	(Medium dense), moist, brown SAND with trace roots.
S-3	22	AL	3.5–5.5	(Stiff), moist, gray and orange CLAY.
S-4	21		5.5–13	(Stiff), moist, gray and orange, slightly gravelly, sandy SILT. (Weathered)
S-5	9		13–15	(Very dense), moist, gray, gravelly, silty SAND.

Bottom of Test Pit at 15 Feet.
Completed 5/2/00.

Groundwater seepage observed at a depth of 12½ feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DTN 6/30/00 1=1 CHART-BPC2
TESTPITS

HARTCROWSER
J-4978-26 5/00
Figure A-23

Test Pit Log HC00-TP302

N 20083
E 10860

Ground Surface Elevation in Feet: 295

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS
S-1	7	0–2	(Medium dense), moist, dark brown, slightly silty SAND with organic material.
S-2	13	2–4.5	(Medium dense), moist to wet, brown SAND with silt and grave lenses.
S-3	23	4.5–11.5	(Stiff to hard), moist, gray and orange, slightly gravelly, sandy SILT. (Weathered)
S-4	24	11.5–15	(Very stiff), moist, gray, slightly sandy to sandy SILT.
		15	Bottom of Test Pit at 15 Feet. Completed 5/2/00.

Groundwater seepage observed at a depth of 4 feet.

Test Pit Log HC00-TP303

N 19940
E 10887

Ground Surface Elevation in Feet: 297

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS
S-1	16	0–3	(Medium dense), moist, brown, gravelly, silty SAND with roots.
S-2	18	3–5	(Stiff), moist, orange, gray and tan, sandy SILT with trace roots in top.
S-3	19	5–15	(Hard), moist, brownish gray, slightly gravelly, sandy SILT.
		12	Increasing density with depth.
		15	Bottom of Test Pit at 15 Feet. Completed 5/2/00.

No groundwater seepage observed.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1=1 CHARLI-8PC2
TESTPITS

HARTCROWSER
J-4978-28 5/00
Figure A-24

Test Pit Log HC00-TP304

N 19855
E 10748

Ground Surface Elevation in Feet: 284

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS
S-1	10	0	(Medium dense), moist, brown, slightly gravelly SAND with roots.
S-2	17	3.5	(Stiff to hard), moist, gray, tan, and orange, slightly gravelly, sandy SILT.
		7	Increasing sand and decreasing silt, gravel sizes up to 6 inches.
S-3	13	10	Wet, gray, slightly silty, gravelly SAND.
S-4	13	11	(Very dense), moist, gray, slightly gravelly, silty SAND.
		15	Bottom of Test Pit at 15 Feet. Completed 5/2/00. Groundwater seepage observed at a depth of 10½ feet.

Test Pit Log HC00-TP305

N 19427
E 10922

Ground Surface Elevation in Feet: 279

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS
S-1	7	0	3 inches of roots over (medium dense), moist, brown, fine to medium SAND.
S-2	13	1.5	(Dense), moist, gray and orange, gravelly, silty SAND.
		4.5	Grading to very dense, gray-brown.
		11	Bottom of Test Pit at 11 Feet. Completed 5/2/00. Refusal at 11 feet. No groundwater seepage observed.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1=1 CHART1-B PC2
TESTPITS

HARTCROWSER
J-4978-26 **5/00**
Figure A-25

Test Pit Log HC00-TP306

N 18861
E 10496

Ground Surface Elevation in Feet: 236

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS
S-1	27	0–2	(Stiff), moist, brown, gravelly, very sandy SILT with large asphalt debris. (FILL)
S-2	10	2–6	(Dense), moist, gray, sandy GRAVEL.
S-3	20	6–8.5	(Medium dense), moist, gray SAND with organic material.
S-4	25	8.5–10.5	(Stiff), moist, gray, slightly sandy SILT.
S-5	22	10.5–15	(Very stiff), moist, gray, sandy, clayey SILT with trace cobbles.
S-6	21		

Bottom of Test Pit at 15 Feet.
Completed 5/3/00.

Groundwater seepage observed at depth of 5½ and 8 feet.

Test Pit Log HC00-TP307

N 18771
E 10524

Ground Surface Elevation in Feet: 235

Sample	Water Content	Lab Test	Depth in Feet	SOIL DESCRIPTIONS
S-1	20		0–2	(Medium dense to dense), moist, brown, slightly silty, very gravelly, SAND with large asphalt debris. (FILL)
S-2	15		2–4.5	(Medium dense to dense), moist, gray, slightly clayey, slightly silty SAND with thin clay lenses.
S-3	41		4.5–7	(Soft), moist, dark brown-black, sandy PEAT.
S-4	30	GS	7–9	(Medium dense), moist, gray, very silty SAND with organic material.
S-5	29		9–11	(Medium stiff to stiff), moist, gray, sandy, clayey SILT.
S-6	29	AL	11–12.5	(Stiff), moist, gray, slightly sandy SILT.
S-7	23		12.5–15	(Stiff), moist, gray SILT.

Bottom of Test Pit at 15 Feet.
Completed 5/3/00.

Groundwater seepage observed at a depth of 7 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

HARTCROWSER
J-4978-26 5/00
Figure A-26

DIN 8/30/00 1=1 CHART1-8 PC2 11STPIIS

AR 045864

Test Pit Log HC00-TP308

N 18537
E 10671

Sample	Water Content
S-1	8
S-2	18
S-3	15
S-4	14

Depth in Feet — SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 240

(Medium dense), moist, brown SAND with scattered gravel, silt pockets, and roots in top 6 inches. (FILL)

(Stiff), moist, gray to orange, very sandy SILT.

(Dense), moist, gray, gravelly SAND.

(Very dense), moist, brown-gray, slightly gravelly, very silty SAND. (Weathered)

Grades to gray.

Bottom of Test Pit at 15 Feet.
Completed 5/3/00.

Slight groundwater seepage observed at a depth of 9½ feet.
Slight petroleum-like odor coming from excavation.

Test Pit Log HC00-TP309

N 18468
E 10704

Sample	Water Content
S-1	11
S-2	14
S-3	12

Depth in Feet — SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 240

(Medium dense), moist, brown, slightly silty, fine to medium SAND with organic material and roots to 3 ½feet. (FILL)

(Dense), moist, orange and gray, very silty SAND.

(Very dense), moist, brownish gray, gravelly, silty SAND. (Weathered)

Grades to gray.

Bottom of Test Pit at 15 Feet.
Completed 5/3/00.

Groundwater seepage observed at a depth of 9½ feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1=1 CHART 8PC2
HSIPITS

HARTCROWSER
J-4978-26 5/00
Figure A-27

Test Pit Log HC00-TP310

N 17575
E 10809

Ground Surface Elevation in Feet: 263

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS
S-1	15	0–3.5	(Medium dense), moist, brown, slightly silty SAND with roots.
S-2	16	3.5–5	(Medium dense), moist, brown, gravelly SAND.
S-3	19	5–11	(Dense), moist, gray, gravelly, silty SAND. Grades to (very dense).
S-4	23	11–14	(Hard), moist, gray SILT.

Bottom of Test Pit at 14 Feet.
Completed 5/3/00.

Groundwater seepage observed at a depth of 9½ feet.

Test Pit Log HC00-TP311

N 16634
E 10938

Ground Surface Elevation in Feet: 354

Sample	Water Content	Lab Test	Depth in Feet	SOIL DESCRIPTIONS
			0–1.5	(Medium dense), moist, brown, slightly silty SAND with large debris. (FILL)
S-1	128		1.5–3.5	(Medium stiff), moist, dark brown SILT with organic material.
S-2	22	GS	3.5–6	(Medium dense), moist to wet, gray, slightly gravelly, silty SAND with 3-foot boulder.
S-3	9		6–11	(Very dense), moist, brown to gray, slightly gravelly, silty SAND.

Bottom of Test Pit at 11 Feet.
Completed 5/4/00.

Refusal at 11 feet.
Moderate to strong groundwater seepage observed at a depth of 5 feet.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1=1 CHART 8PC2
TESTPITS

HARTCROWSER
J-4978-26 5/00
Figure A-28

AR 045866

Test Pit Log HC00-TP312

N 16490
E 11153

Sample	Lab Tests	Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 363
		0–4	6 inches of roots over (medium dense to dense), moist, brown, slightly silty, gravelly SAND.
S-1	11	2	
S-2	12	4–9	(Very dense), moist, gray, slightly gravelly, silty SAND.
		9	Bottom of Test Pit at 9 Feet. Completed 5/4/00. Refusal at 9 feet. No groundwater seepage observed.

Test Pit Log HC00-TP313

N 16339
E 10993

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 361
S-1	14	0–2.5	(Medium dense), moist, brown, gravelly, slightly silty SAND with roots. (FILL)
S-2	10	2.5–9	(Dense to very dense), moist, gray, slightly silty SAND.
		9	Bottom of Test Pit at 9 Feet. Completed 5/4/00. No groundwater seepage observed.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1=1 CHARLI-8PC2 TESTPITS

HARTCROWSER
J-4978-26 5/00
Figure A-29

Test Pit Log HC00-TP314

N 16203
E 11060

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 366
S-1	19	0–3	(Medium dense to dense), moist, brown, gravelly, silty SAND with roots.
S-2	14	3–9	(Dense to very dense), moist, gray and orange, slightly gravelly, silty SAND.
S-3	9	6	Grades to slightly silty SAND.
		9	Bottom of Test Pit at 9 Feet. Completed 5/4/00. Refusal at 9 feet. No groundwater seepage observed.

Test Pit Log HC00-TP315

N 16114
E 11017

Sample	Water Content	Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 363
S-1	25	0–2	(Medium dense), moist, brown, gravelly, slightly silty SAND with roots. (FILL)
S-2	17	2–4	(Medium dense), moist, gray, slightly gravelly, silty SAND with silt and sand lenses.
S-3	9	4–10	(Dense to very dense), moist, brown to gray, slightly gravelly, silty SAND.
		10	Bottom of Test Pit at 10 Feet. Completed 5/4/00. No groundwater seepage observed.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1=1 CHART1 8PC2
TESTPITS

HARTCROWSER
J-4978-26 5/00
Figure A-30

Test Pit Log HC00-TP316

N 15920
E 10996

Sample	Water Content
S-1	11
S-2	26
S-3	17
S-4	9

SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 360

Depth in Feet	Soil Descriptions
0–2	(Loose), moist, brown, very gravelly, slightly silty SAND with roots and organic material.
2–3.5	(Loose to medium dense), moist to wet, light brown, gravelly, silty SAND with roots, and organic material.
3.5–5	(Medium dense), wet, light gray-brown, gravelly, silty SAND.
5–7	(Very dense), damp, gray, slightly silty SAND.
7	Bottom of Test Pit at 7 Feet. Completed 5/5/00. No groundwater seepage observed.

Test Pit Log HC00-TP317

N 15857
E 11167

Sample	Water Content
S-1	10
S-2	13
S-3	10

SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 371

Depth in Feet	Soil Descriptions
0–2	(Medium dense to dense), damp, gray, sandy GRAVEL. (FILL)
2–6.5	(Medium dense), moist, gray-brown, slightly gravelly, slightly silty SAND.
6.5–8	(Very dense), damp, gray, slightly silty SAND.
8	Bottom of Test Pit at 8 Feet. Completed 5/5/00. No groundwater seepage observed.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1:1 CHARLI-8PC2
TESTPITS

HARTCROWSER
J-4978-26 5/00
Figure A-31

Test Pit Log HC00-TP318

N 15364
E 10859

Sample	Water Content	Lab Test	Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 360
S-1	10		0–3	(Medium dense), damp to moist, light brown, gravelly, slightly silty to silty SAND with organic material and roots to 3 feet. (FILL) Large roots.
S-2	10		4–6	(Medium dense to dense), damp to moist, gray, slightly gravelly, slightly silty SAND.
S-3	16	GS	6–13	(Stiff), moist, gray and red alternating bedding, very sandy SILT.
S-4	10		13–14	(Very dense), damp, gray, gravelly, silty SAND.
			14	Bottom of Test Pit at 14 Feet. Completed 5/5/00. No groundwater seepage observed.

Test Pit Log HC00-TP319

N 15206
E 10698

Sample	Water Content	Lab Test	Depth in Feet	SOIL DESCRIPTIONS Ground Surface Elevation in Feet: 351
S-1	14		0–1	(Loose to medium dense), damp to moist, brown, gravelly, silty SAND with roots and organic material.
S-2	15		1–4	(Medium dense), moist, light brown and tan alternating bedding, gravelly, silty SAND. Roots.
S-3	13	GS	4–8	(Medium dense to dense), damp, gray with red-brown bedding, slightly gravelly, very silty SAND.
S-4	10		8–9	(Dense to very dense), damp, gray, gravelly, silty, fine to medium SAND.
			9	Bottom of Test Pit at 9 Feet. Completed 5/5/00. No groundwater seepage observed.

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DIN 8/30/00 1=1 CHART 8 PC2
TESTPITS

HARTCROWSER
J-4978-26 5/00
Figure A-32

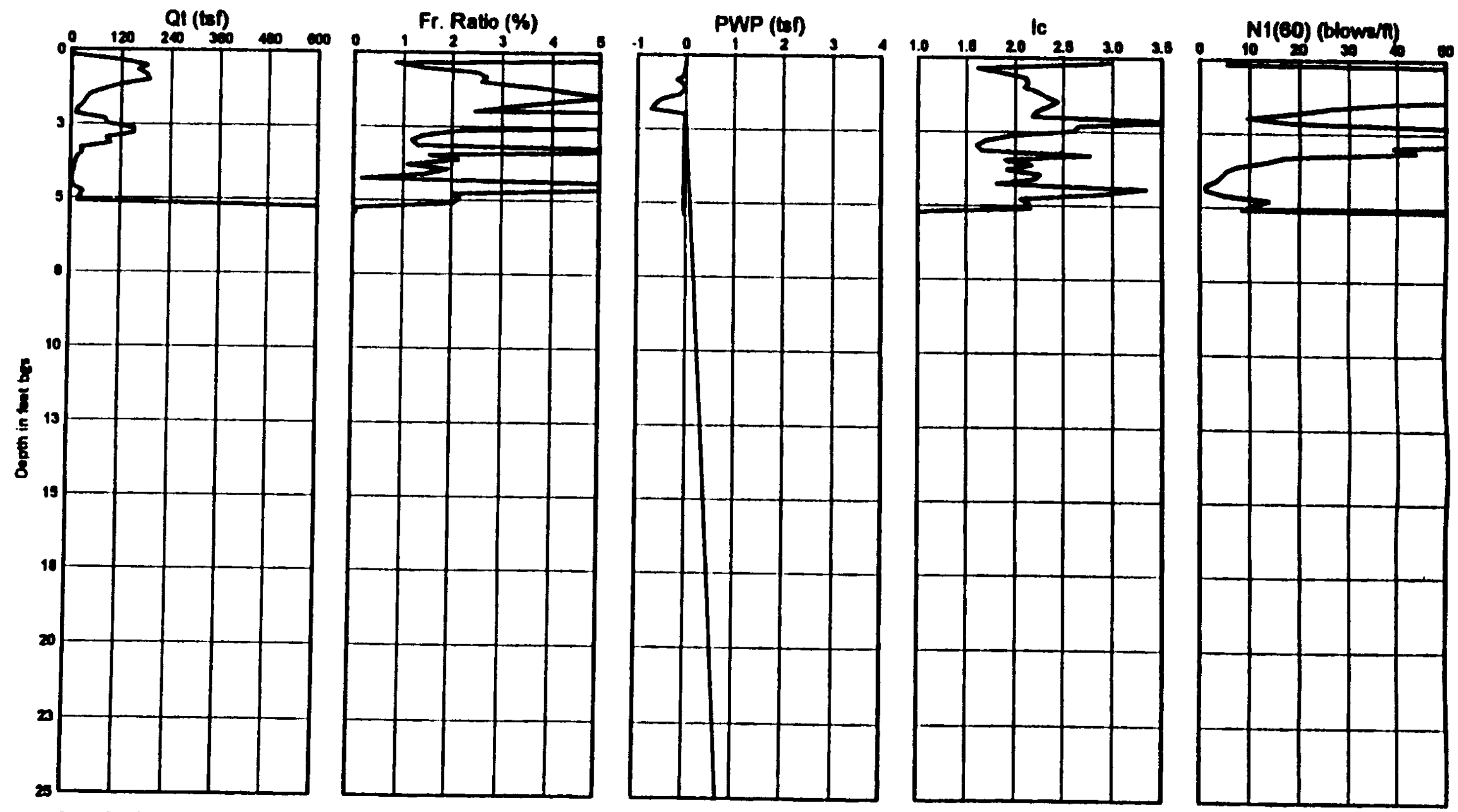
Cone Penetration Probe Log HC00-P22A

N 18507 E 10928

Test Date : May 18, 2000
Location : Third Runway Embankment Refused at 5 feet depth.

Operator : Northwest Cone Exploration

Ground Surf. El 253 0.00
Water Table Depth : 2.00



Qt normalized for unequal end area effects

Fr Ratio = 100*F/(Qt-Sigmav)
Gamma = 115.2 pcf

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

After Jefferies and Davies (1993)

PROJECT NO J-4978-27 DATE May 24, 2000 DRAWN BY: Keith Brown

Hart Crowser

CVD 6/16/00 4978270 cdr

HARTCROWSER
J-4978-27 6/00
Figure A-33

AR 045871

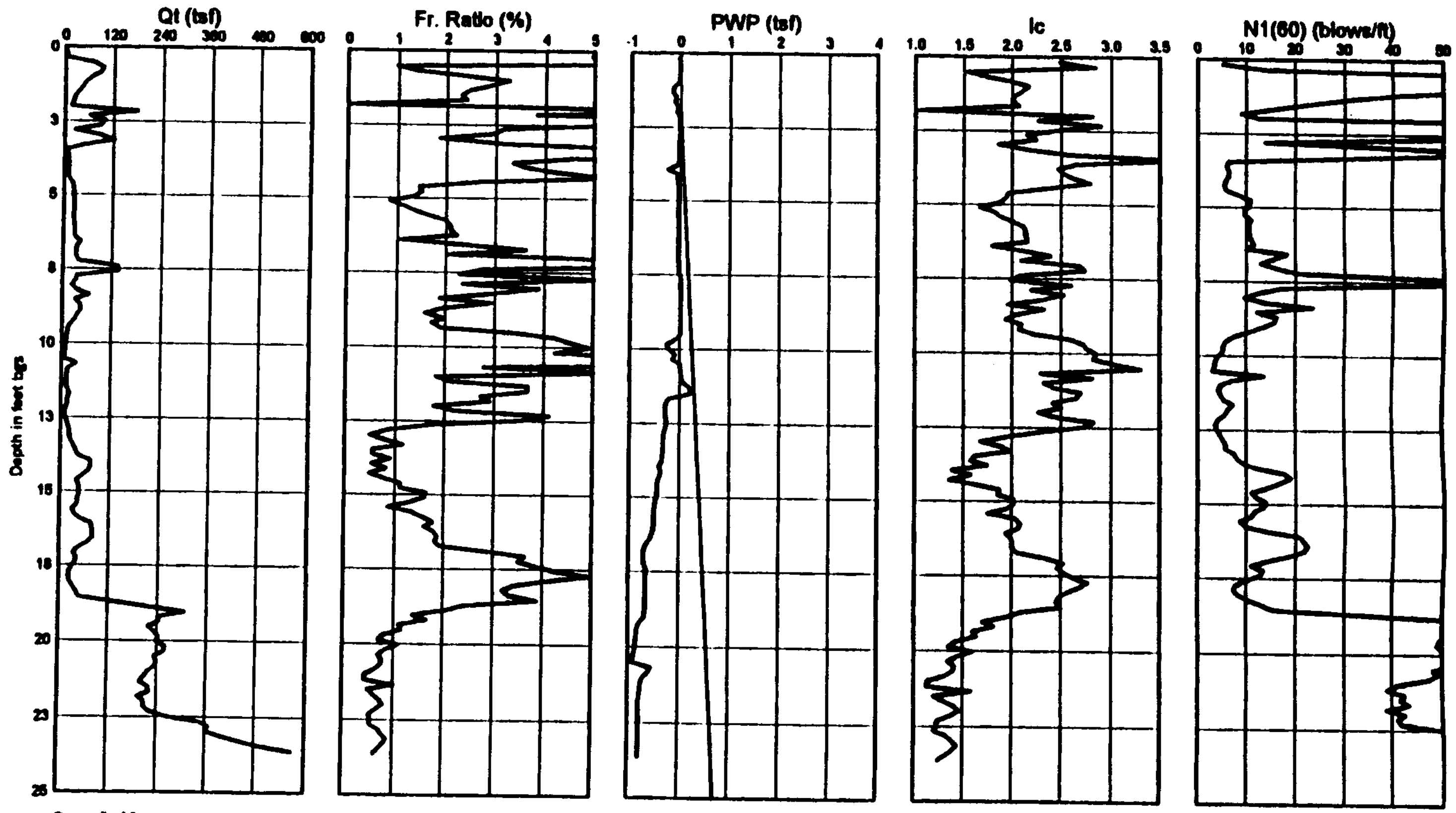
Cone Penetration Probe Log HC00-P22B

N 18504 E 10917

Test Date : May 18, 2000
Location : Third Runway Embankment   Repeat of 22A.

Operator : Northwest Cone Exploration

Ground Surf. Elev. : 256
Water Table Depth : 2.00



Qt normalized for
unequal end area effects

Fr Ratio = 100*F/(Qt-Sigmav)
Gamma = 115.2 pcf

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

After Jefferies and Davies (1993)

PROJECT NO. J-4978-27   DATE: May 24, 2000   DRAWN BY: Keith Brown

Hart Crowser

DTN 8/30/00 497826Pcdr

HARTCROWSER
J-4978-26   6/00
Figure A-34

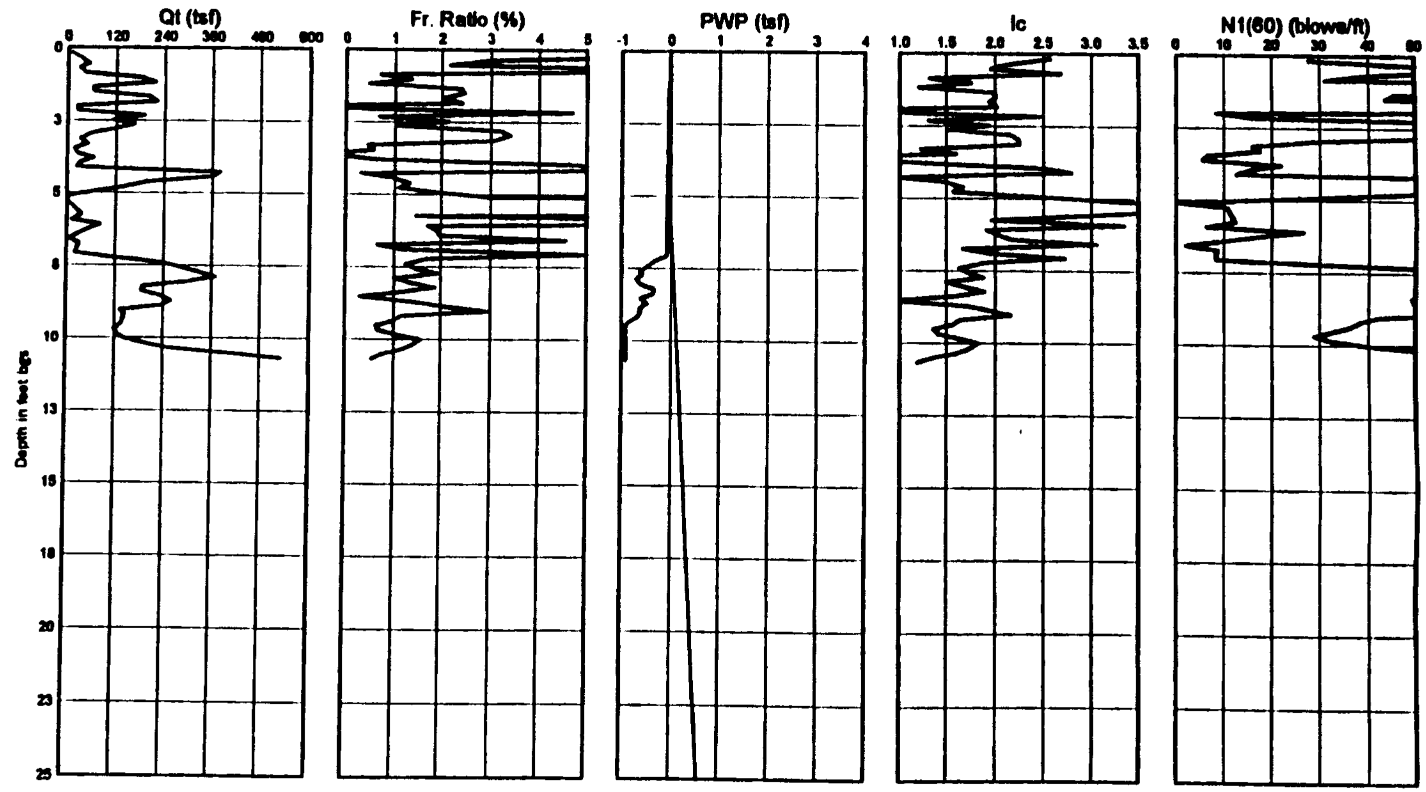
Cone Penetration Probe Log HC00-P23

N 18590 E 11000

Test Date : May 18, 2000
Location : Third Runway Embankment

Operator : Northwest Cone Exploration

Ground Surf. Elev. : 261' Apprx.
Water Table Depth : 6.00



Qt normalized for unequal end area effects

Fr Ratio = 100*F/(Qt-Sigma v)
Gamma = 115.2 pcf

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

After Jefferies and Davies (1993)

PROJECT NO J-4978-27 DATE May 24, 2000 DRAWN BY: Keith Brown

Hart Crowser

CVD 6/16/00 497827C cdr

HARTCROWSER
J-4978-27 6/00
Figure A-35

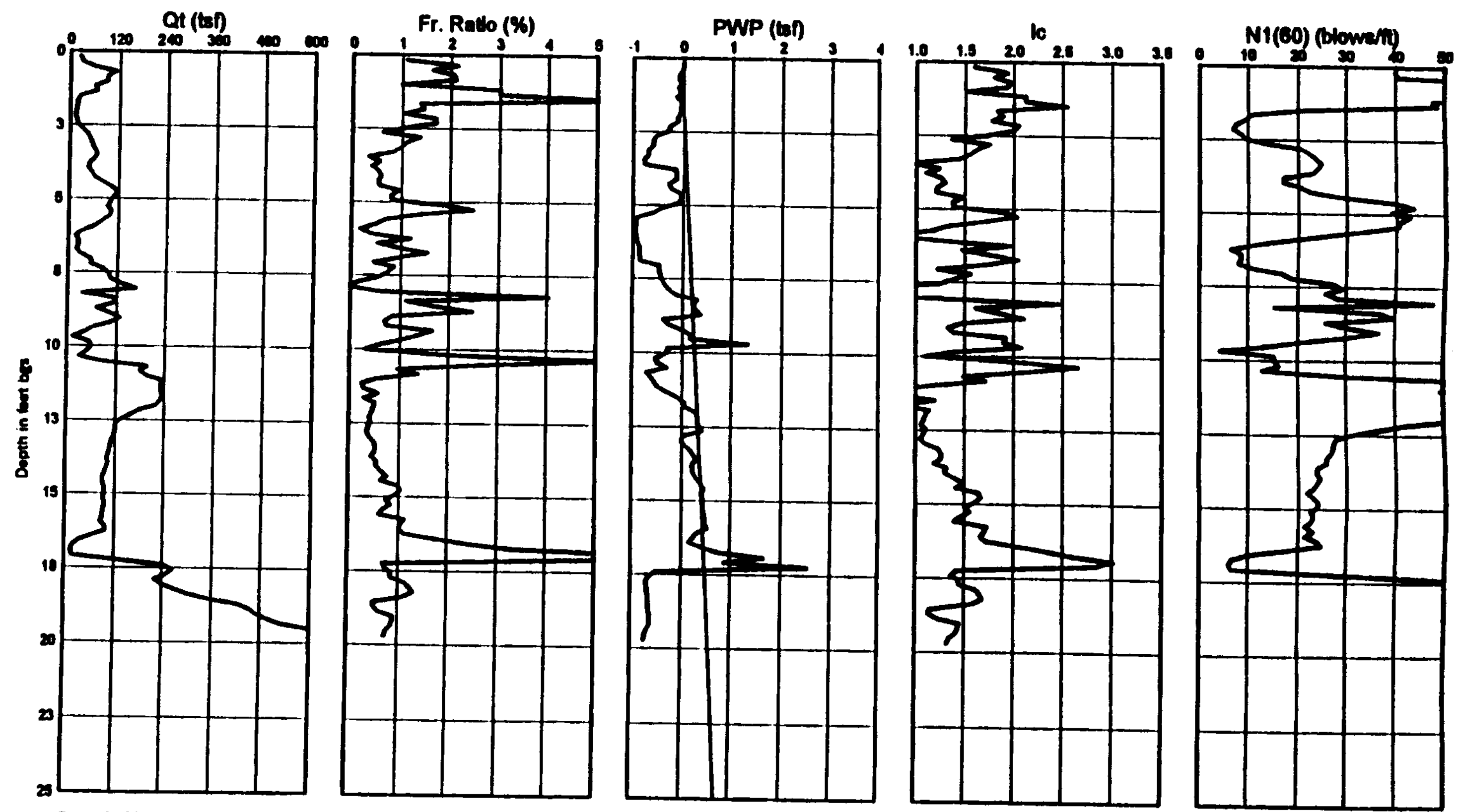
Cone Penetration Probe Log HC00-P24

N 18199 E 11050

Test Date : May 18, 2000
Location : Third Runway Embankment

Operator : Northwest Cone Exploration

Ground Surf. Elev. 246' Apprx.
Water Table Depth : 2.00



Qt normalized for unequal end area effects

Fr Ratio = 100*F/(Qt-Sigmav)
Gamma = 115.2 pcf

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

After Jefferies and Davies (1993)

PROJECT NO J-4978-27 DATE May 24, 2000 DRAWN BY. Keith Brown

Hart Crowser

DTN 8/30/00 4978260 cdr

HARTCROWSER
J-4978-27 6/00
Figure A-36

AR 045874

Cone Penetration Probe Log HC00-P25

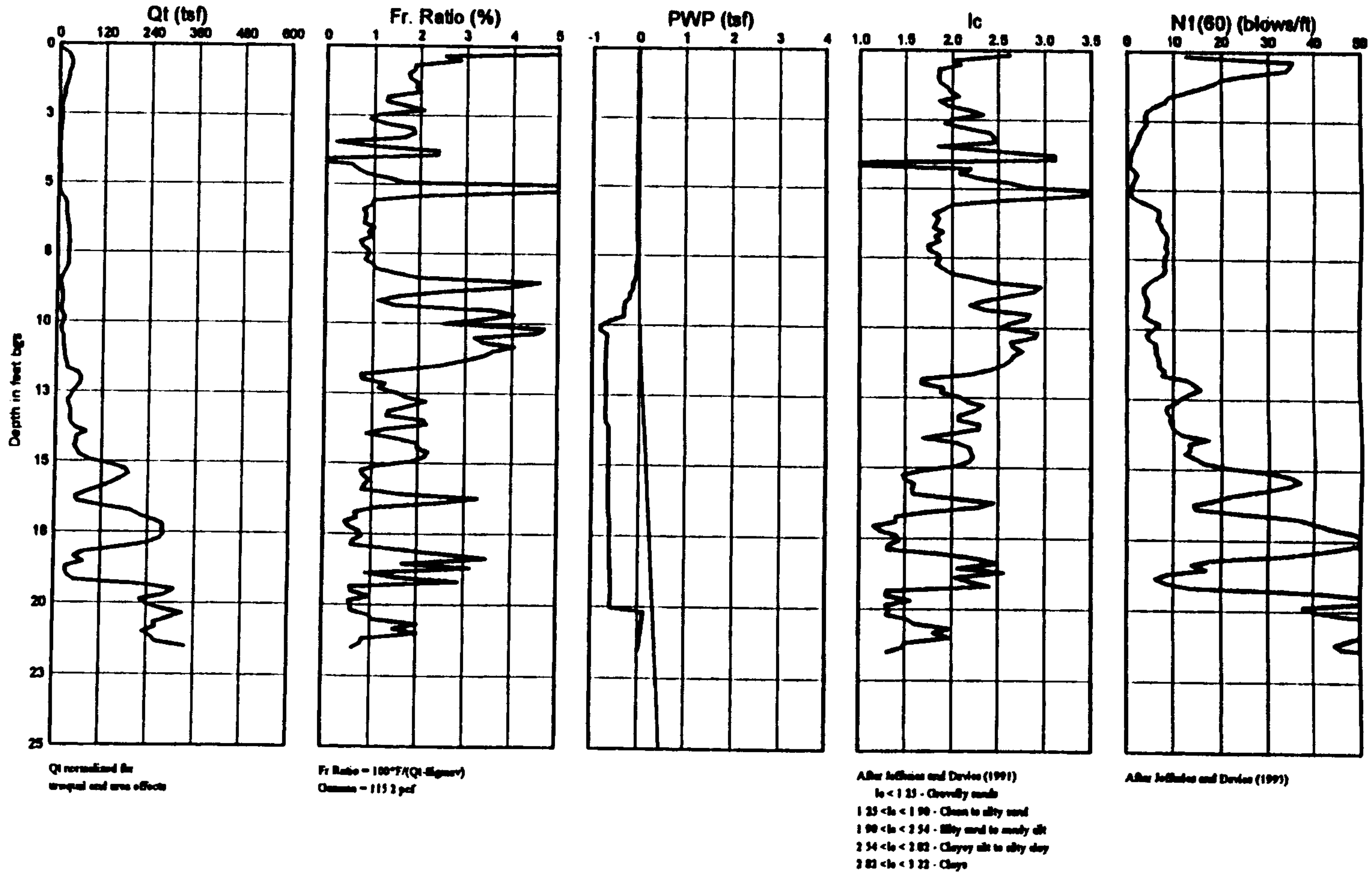
N 17595 E 10989

Test Date : May 19, 2000
Location : Third Runway Embankment

Test near edge of existing fill embankment.

Operator : Northwest Cone Exploration

Ground Surf. Elev. : 283
Water Table Depth : 10.00



PROJECT NO J-4978-27 DATE May 24, 2000 DRAWN BY: Keith Brown

Hart Crowser

CVD 6/16/00 4978270 cdr

HARTCROWSER

J-4978-27 6/00

Figure A-37

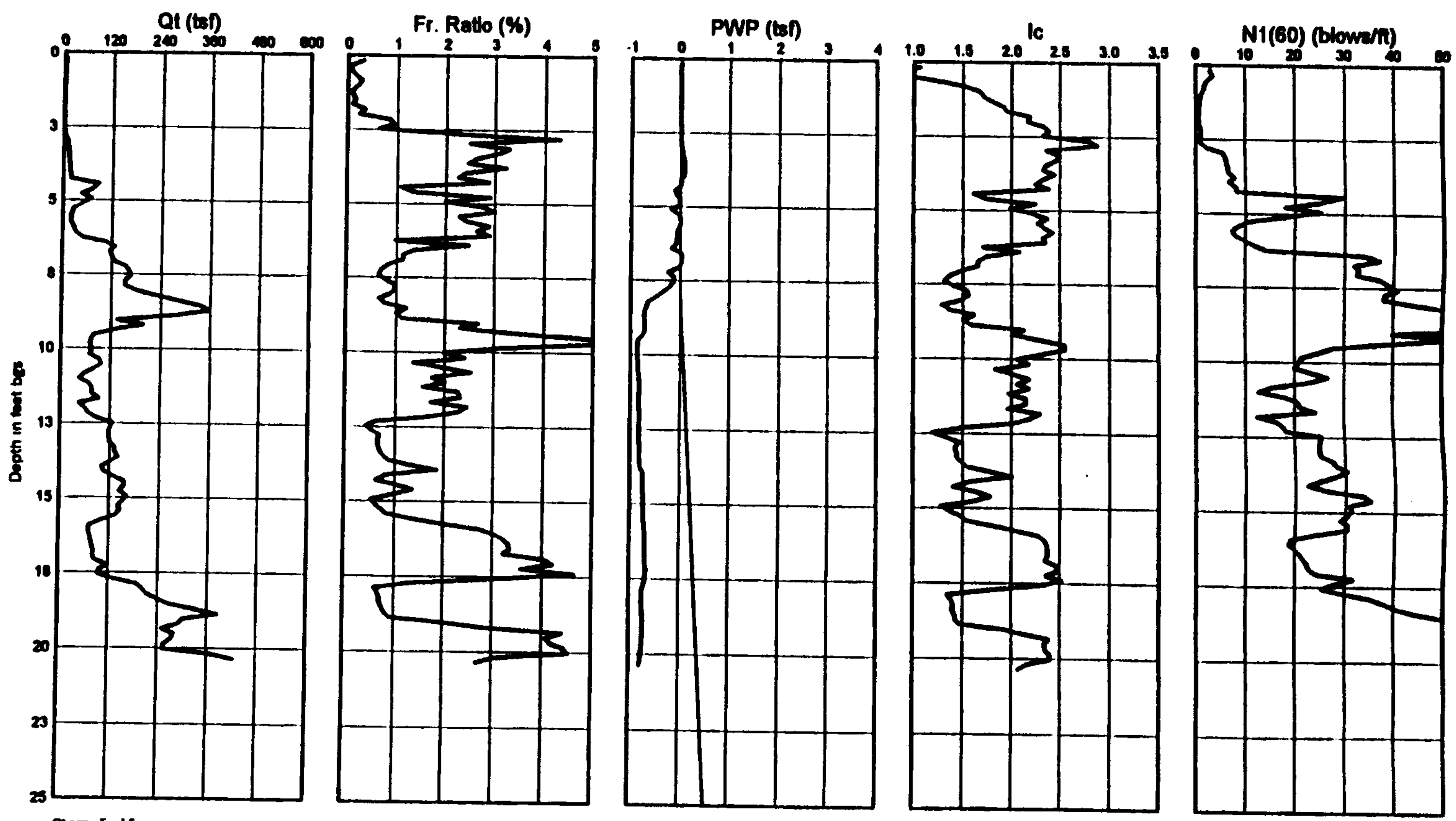
Cone Penetration Probe Log HC00-P26

N 17526 E 11048

Test Date : May 19, 2000
Location : Third Runway Embankment

Operator : Northwest Cone Exploration
Test in driveway of residence. Hand auger to 36 inch depth.

Ground Surf. Elev. : 286
Water Table Depth : 8.00



Qt normalized for
unequal end area effects

Fr Ratio = 100*F/(Qt-Sigmav)
Gamma = 115.2 pcf

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 <Ic < 1.90 - Clean to silty sand
1.90 <Ic < 2.54 - Silty sand to sandy silt
2.54 <Ic < 2.82 - Clayey silt to silty clay
2.82 <Ic < 3.22 - Clays

After Jefferies and Davies (1993)

PROJECT NO J-4978-27 DATE: May 24, 2000 DRAWN BY: Keith Brown

Hart Crowser
DTN 8/30/00 497826R cdr

HARTCROWSER
J-4978-27 6/00
Figure A-38

AR 045876

APPENDIX B
LABORATORY TESTING PROGRAM

APPENDIX B
LABORATORY TESTING PROGRAM

A laboratory testing program was performed for this study to evaluate the basic index and geotechnical engineering properties of the site soils. Disturbed and relatively undisturbed samples were tested. The tests performed and the procedures followed are outlined below.

Soil Classification

Field Observation and Laboratory Analysis. Soil samples from the explorations were visually classified in the field and then taken to our laboratory where the classifications were verified in a relatively controlled laboratory environment. Field and laboratory observations include density/consistency, moisture condition, and grain size and plasticity estimates.

The classifications of selected samples were checked by laboratory tests such as Atterberg limits determinations and grain size analyses. Classifications were made in general accordance with the Unified Soil Classification (USC) System, ASTM D 2487, as presented on Figure B-1.

Note that the term "trace" used on exploration logs generally indicate a material within the soil matrix that constitutes a relatively small fraction by weight of the total soil. The usage of this term in not associated with the ASTM simplified classification procedure.

Water Content Determinations

Water contents were determined for most samples recovered in the explorations in general accordance with ASTM D 2216, as soon as possible following their arrival in our laboratory. The results of these tests are plotted or recorded at the respective sample depth on the exploration logs. In addition, water contents are routinely determined for samples subjected to other testing. These are also presented on the exploration logs.

Grain Size Analysis (GS)

Grain size distribution was analyzed on representative samples in general accordance with ASTM D 422. Wet sieve analysis was used to determine the size distribution greater than the U.S. No. 200 mesh sieve. The results of the tests are presented as curves on Figures B-2 through B-8 plotting percent finer by weight versus grain size.

Atterberg Limits (AL)

We determined Atterberg limits for selected fine-grained soil samples. The liquid limit and plastic limit were determined in general accordance with ASTM D 4318-84. The results of the Atterberg Limits analyses and the plasticity characteristics are summarized in the Liquid and Plastic Limits Test Report, Figures B-9 to B-11. This relates the plasticity index (liquid limit minus the plastic limit) to the liquid limit. The results of the Atterberg limits tests are also shown graphically on the boring logs.

Unconsolidated Undrained Triaxial Compression Test (UU)

The unconsolidated undrained triaxial compression test estimates the total strength of the soil at various stress levels. The test was performed in general accordance with ASTM D 2850. A relatively undisturbed fine-grained sample was trimmed to a length of about 6 inches, encased in a rubber membrane, and placed in the triaxial cell. With the sample in the triaxial test cell, an all-around pressure was applied hydraulically, although the drainage valves remained closed. Thus the sample was not allowed to consolidate. The sample was loaded to failure under undrained conditions by application of increasing axial load at a constant strain rate.

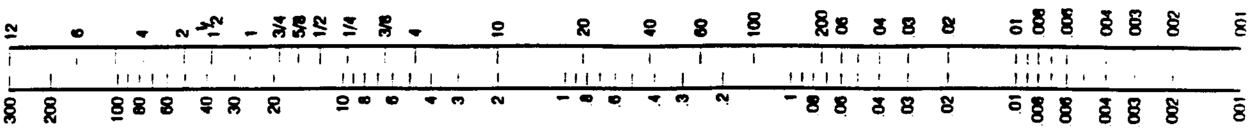
The data are plotted using shear stress versus principal stress as Mohr's circles. Because the test is a measure of the total stress strength of a soil, the tangent to the Mohr's circles for a test series extends to the vertical axis in a straight line. The intercept along the vertical axis is the cohesion (c), but also is equal to the undrained shear strength (τ) of the soil. The test results are shown on Figures B-12 and B-13.

F:\docs\jobs\497826\DataReport.doc

Unified Soil Classification (USC) System

Soil Grain Size

Size of Opening in Inches	Number of Mesh per Inch (US Standard)	Grain Size in Millimetres



Grain Size in Millimetres

COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines		* GRAVEL with >12% fines		Clean SAND <5% fines		* SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right) \begin{matrix} >4 \text{ for G W} \\ >6 \text{ for S W} \end{matrix}$ & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A line with PI <4

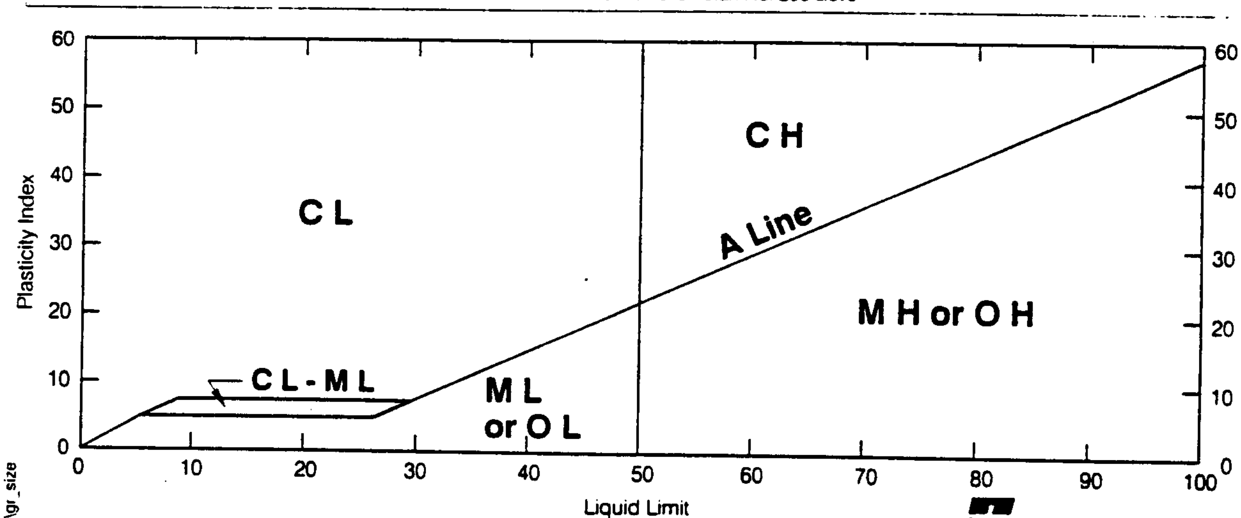
G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases required use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particles diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						



Core\forms\gr_size

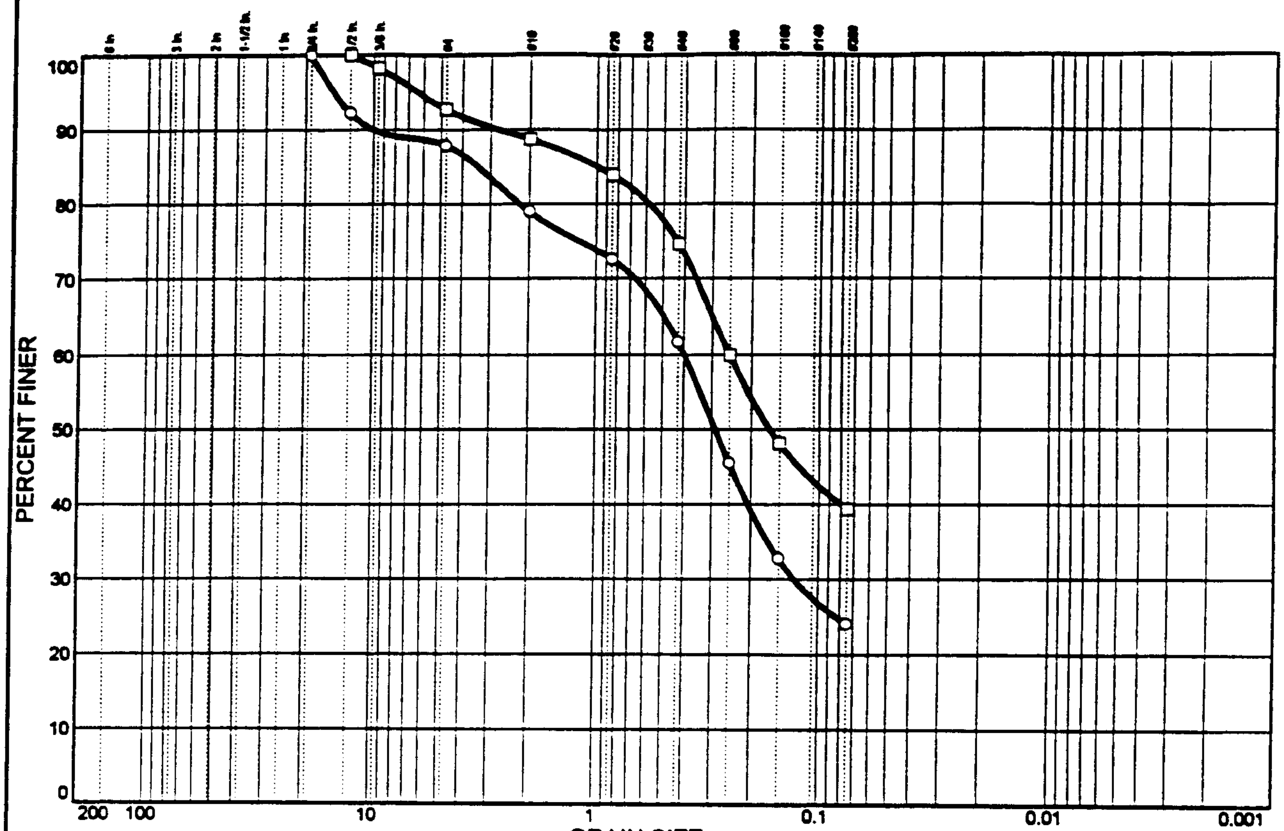
HARTCROWSER

J-4978-26 6/00

Figure B-1

AR 045880

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% + 3"	% GRAVEL		% SAND			% FINES	
		CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	12.1	8.9	17.2	37.7	24.1	
□	0.0	0.0	7.2	4.1	14.1	35.3	39.3	

☒	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			3.39	0.397	0.288	0.128				
□			0.989	0.250	0.165					

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
○ Gravelly, silty SAND	SM	9%
□ Slightly gravelly, very silty,medium to coarse SAND	SM	14%

Remarks:

○

□

Project: Third Runway

Client: HNTB

○ **Source:** HC00-B138 **Sample No.:** S-5

□ **Source:** HC00-B300 **Sample No.:** S-4

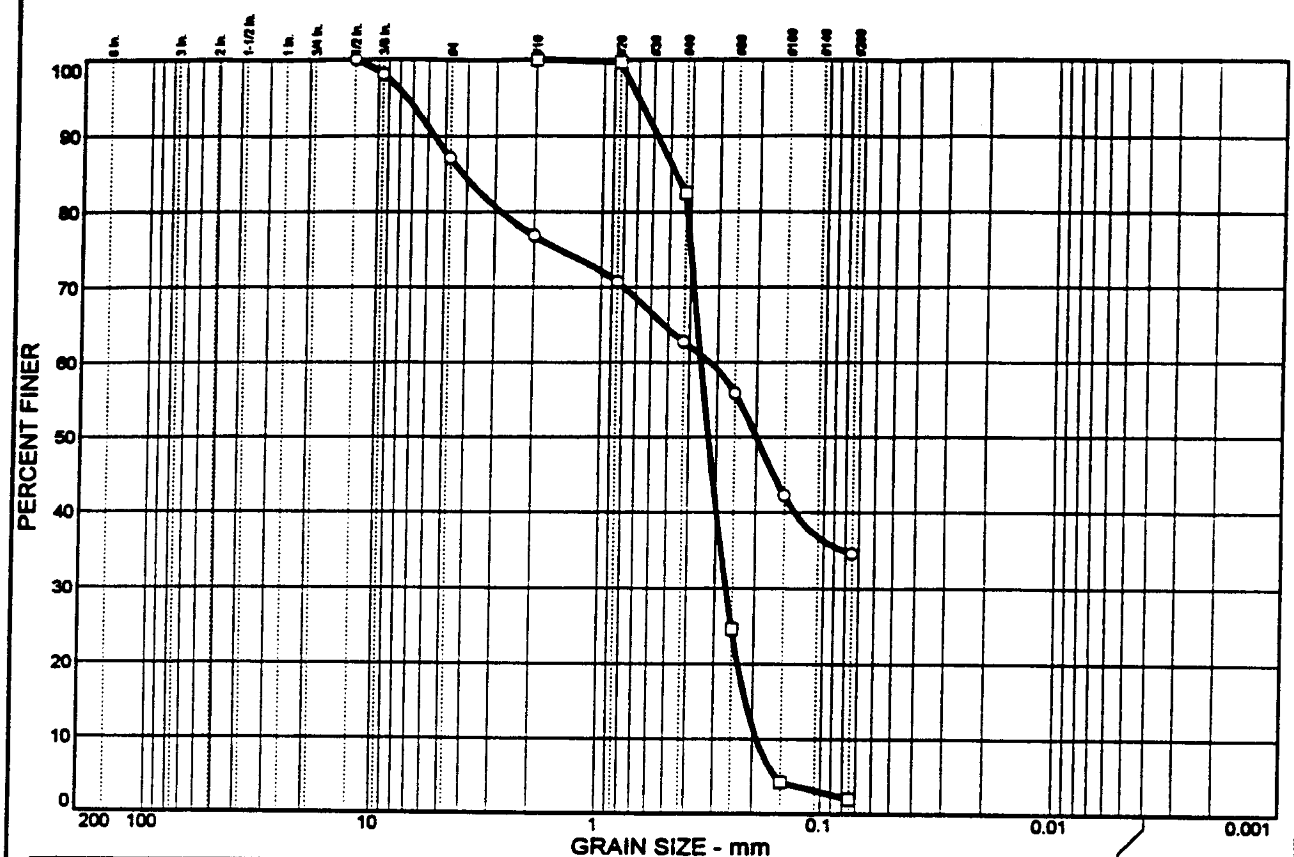
HARTCROWSER

J-4978-26 6/14/2000

Figure No. B-2

AR 045881

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% + 3"	% GRAVEL		% SAND			% FINES	
		CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	12.8	10.3	14.1	28.3	34.5	
□	0.0	0.0	0.0	0.0	17.4	80.6	2.0	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			4.13	0.323	0.200					
□			0.468	0.354	0.325	0.267	0.215	0.191	1.05	1.85

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
○ Gravelly, very silty SAND	SM	22%
□ Medium to fine SAND	SP	9%

Remarks:

○

□

Project: Third Runway South End

Client: HNTB

○ **Source:** HC00-TP221 **Sample No.:** S-2

□ **Source:** HC00-TP224 **Sample No.:** S-1

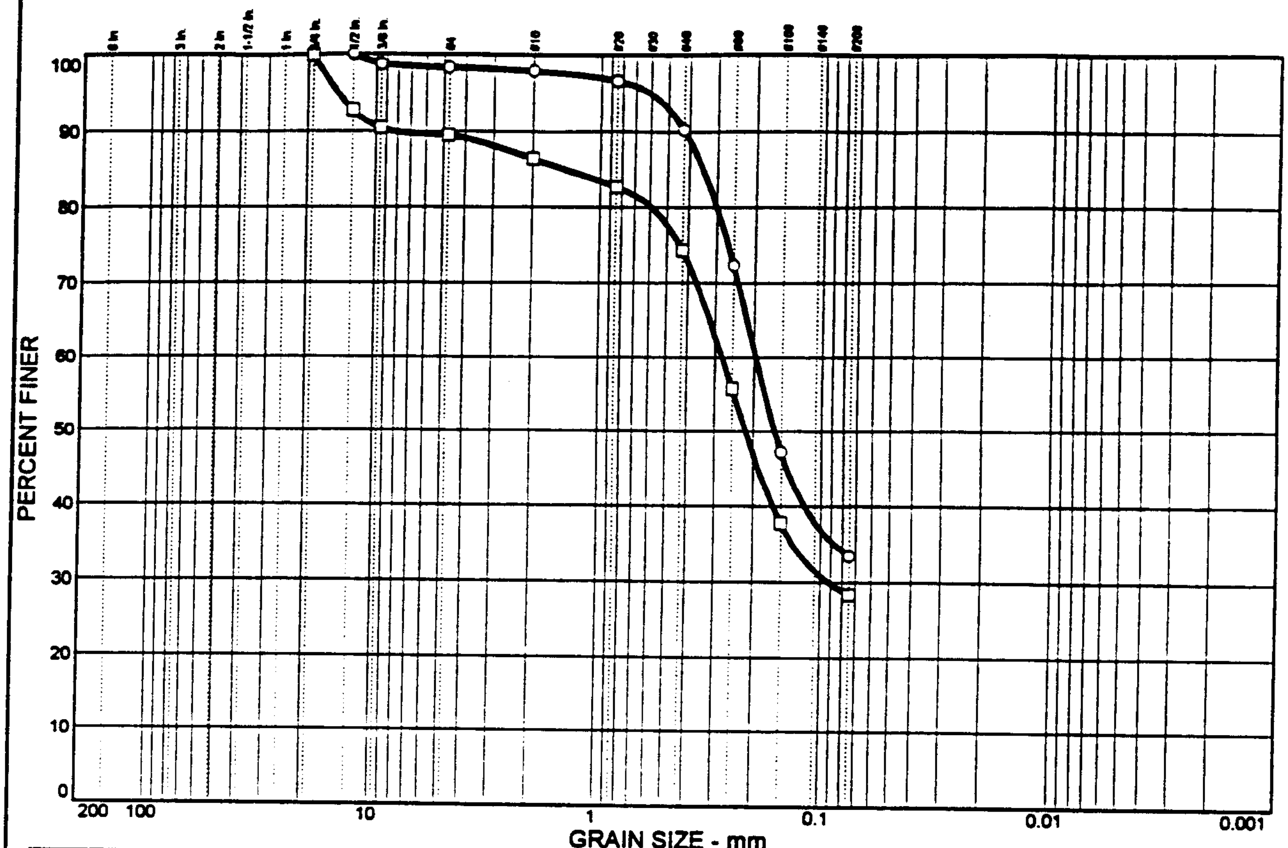
HARTCROWSER

J-4978-23 6/15/2000

Figure No. B-3

AR 045882

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% + 3"	% GRAVEL		% SAND			% FINES	
		CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	1.7	0.4	7.6	56.9	33.4	
□	0.0	0.0	10.5	3.0	12.2	45.9	28.4	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.346	0.196	0.160					
□			1.39	0.278	0.216	0.0920				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
○ Very silty, medium to fine SAND	SM	30%
□ Slightly gravelly, silty, medium to fine SAND	SM	22%

Remarks:
○
□

Project: Third Runway

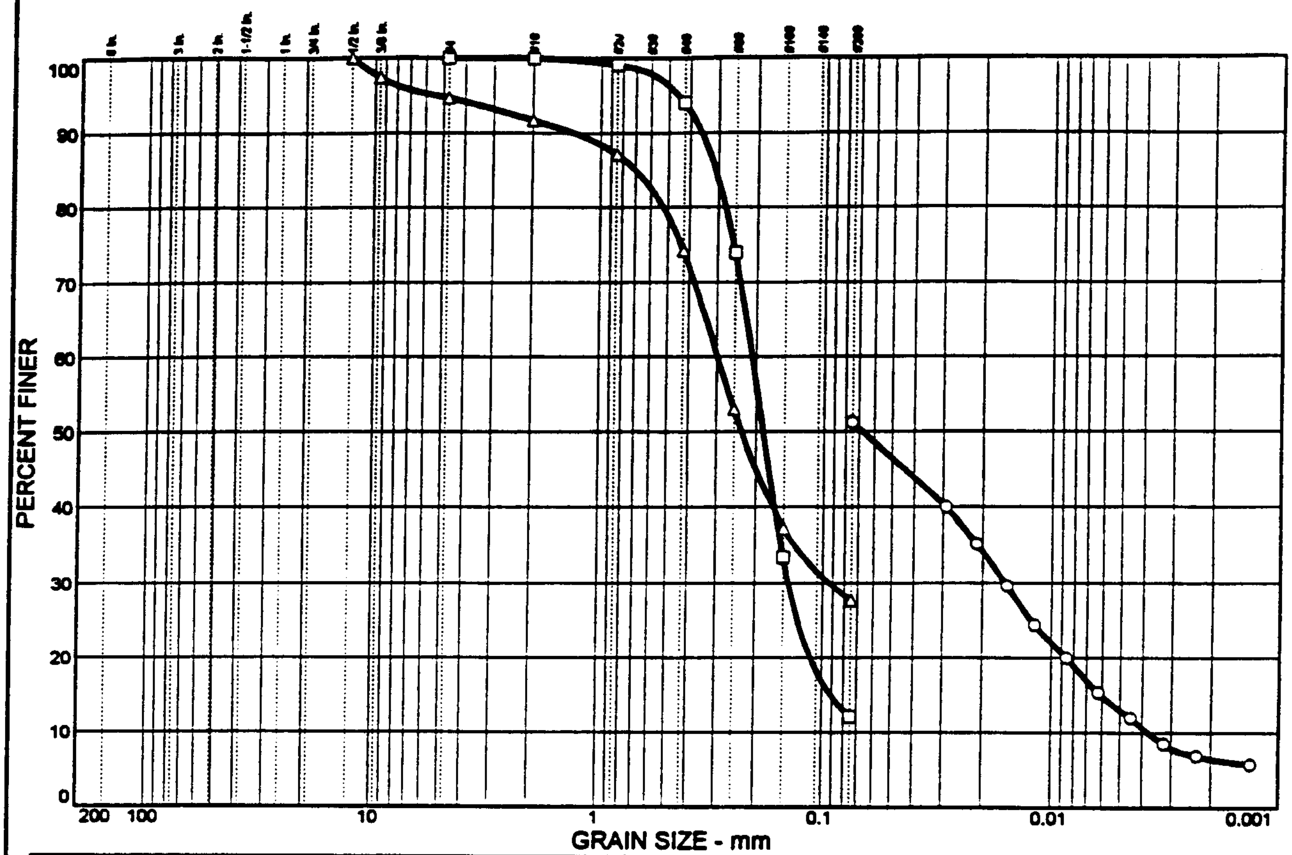
Client: HNTB
○ **Source:** *HC00-TP307* **Sample No.:** S-4
□ **Source:** *HC00-TP311* **Sample No.:** S-2

HARTCROWSER

J-4978-26 5/11/2000
Figure No. B-4

AR 045883

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% + 3"	% GRAVEL		% SAND			% FINES	
		CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
○							38.1	13.1
□	0.0	0.0	0.0	0.1	5.9	81.8	12.2	
△	0.0	0.0	5.3	3.0	17.5	46.5	27.7	

☒	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○					0.0674	0.0160	0.0060	0.0038		
□			0.307	0.209	0.186	0.142	0.0909			
△			0.695	0.297	0.231	0.0935				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
○		15%
□ Silty, medium to fine SAND	SM	6%
△ Slightly gravelly, silty, medium to fine SAND	SM	15%

Remarks:

○

□

△

Project: Third Runway

Client: HNTB

○ **Source:** HC00-B302 **Sample No.:** S-5

□ **Source:** HC00-B303 **Sample No.:** S-2

△ **Source:** HC00-B303 **Sample No.:** S-7

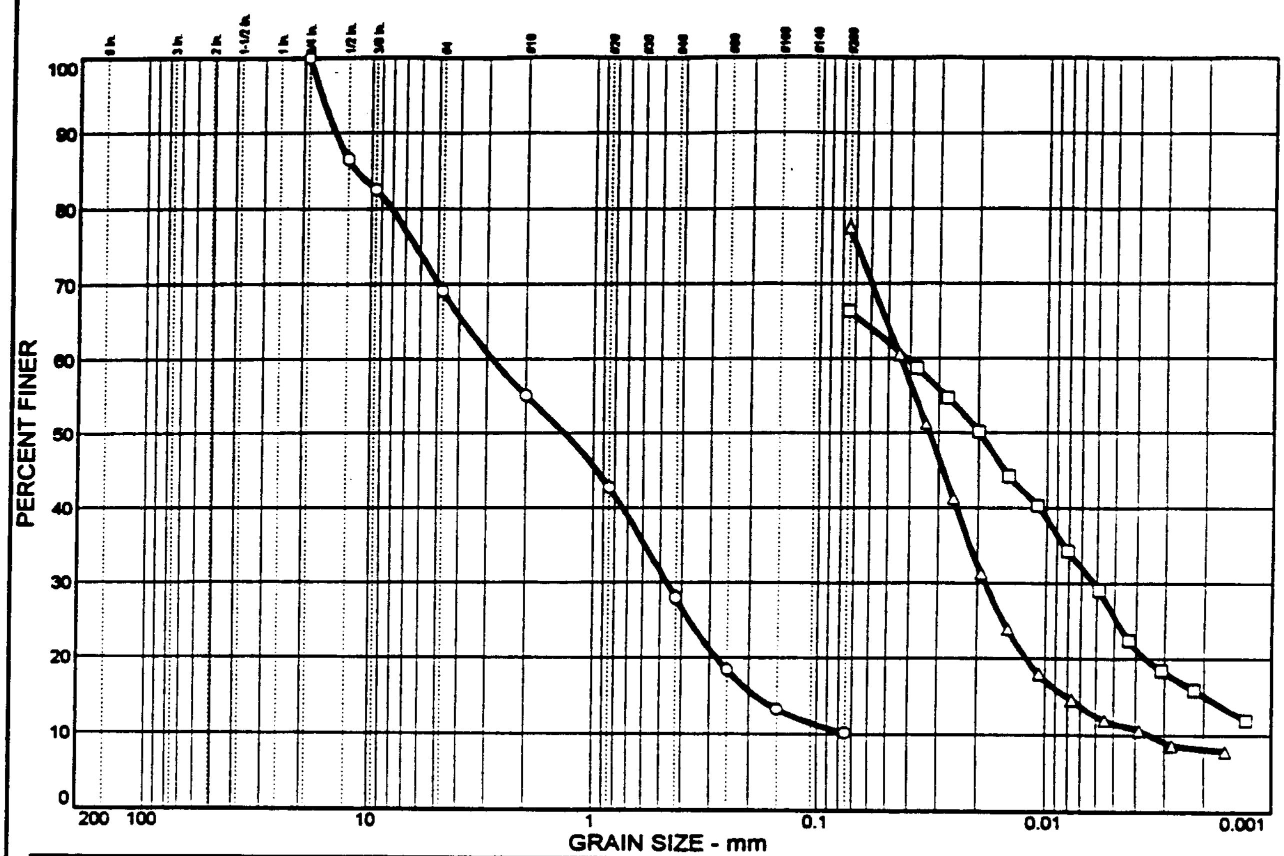
HARTCROWSER

J-4978-31 8/18/2000

Figure No. B-6

AR 045884

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% + 3"	% GRAVEL		% SAND			% FINES	
		CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	30.9	13.9	27.2	17.8	10.2	
□							40.8	25.6
△							66.2	11.6

☒	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			11.6	2.82	1.34	0.466	0.185			
□	26	10		0.0415	0.0198	0.0062	0.0019			
△	28	6		0.0441	0.0328	0.0185	0.0079	0.0034	2.26	12.84

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
○ Slightly silty, very gravelly SAND	SP-SM	3%
□	CL	19%
△	CL-ML	30%

Remarks:
○
□
△

Project: Third Runway

Client: HNTB

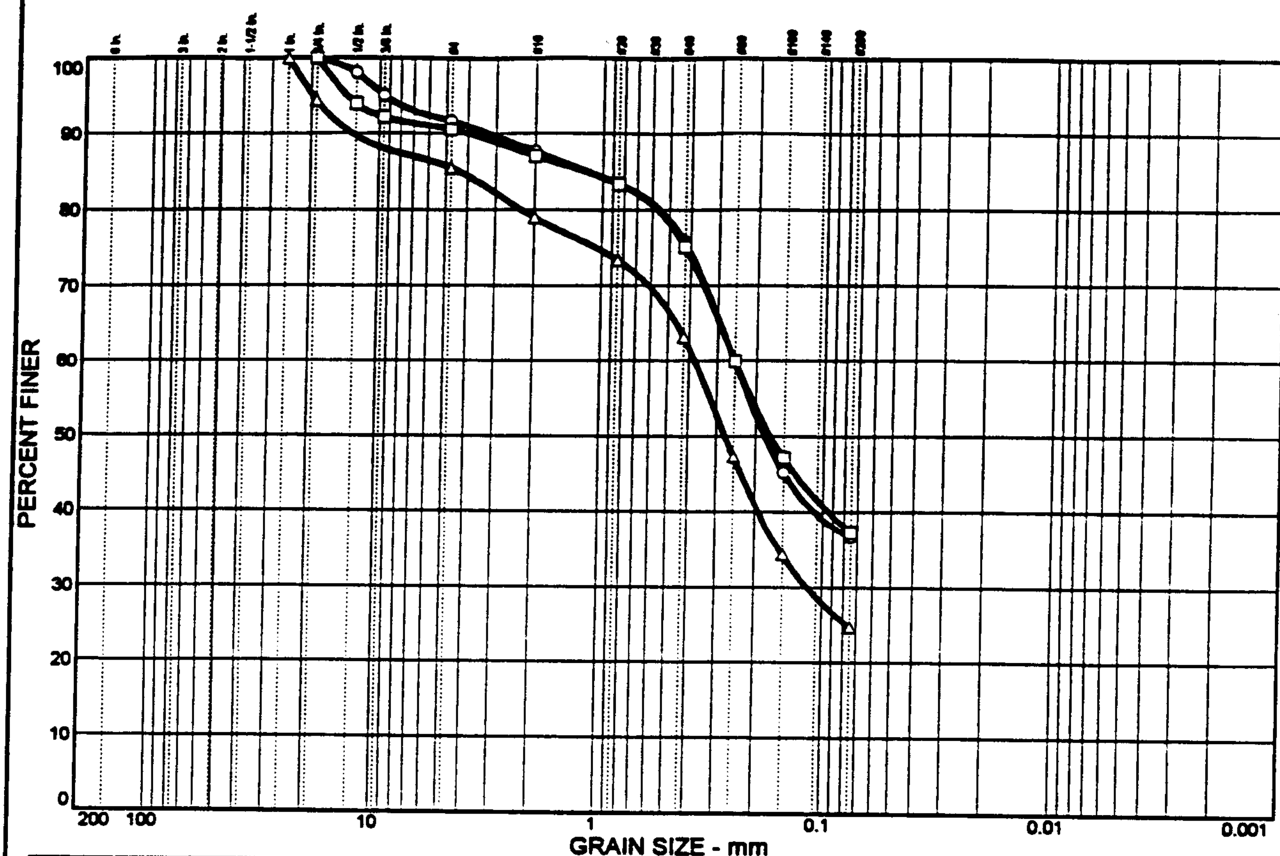
○ **Source:** HC00-B305 **Sample No.:** S-2
□ **Source:** HC00-B305 **Sample No.:** S-4
△ **Source:** HC00-B306 **Sample No.:** S-3

HARTCROWSER

J-4978-31 8/18/2000
Figure No. B-7

AR 045885

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% + 3"	% GRAVEL		% SAND			% FINES	
		CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
○	0.0	0.0	8.3	4.1	11.9	39.0	36.7	
□	0.0	0.0	9.4	3.6	11.9	37.7	37.4	
△	0.0	5.5	9.0	6.5	15.8	38.4	24.8	

☒	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			1.17	0.251	0.182					
□			1.19	0.250	0.172					
△			4.35	0.377	0.273	0.116				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
○ Slightly gravelly, very silty, medium to fine SAND	SM	16%
□ Slightly gravelly, very silty, medium to fine SAND	SM	15%
△ Gravelly, silty SAND	SM	8%

Remarks:
○
□
△

Project: Third Runway

Client: HNTB

○ **Source:** HC00-B306 **Sample No.:** S-4
□ **Source:** HC00-B306 **Sample No.:** S-5
△ **Source:** HC00-B307 **Sample No.:** S-3

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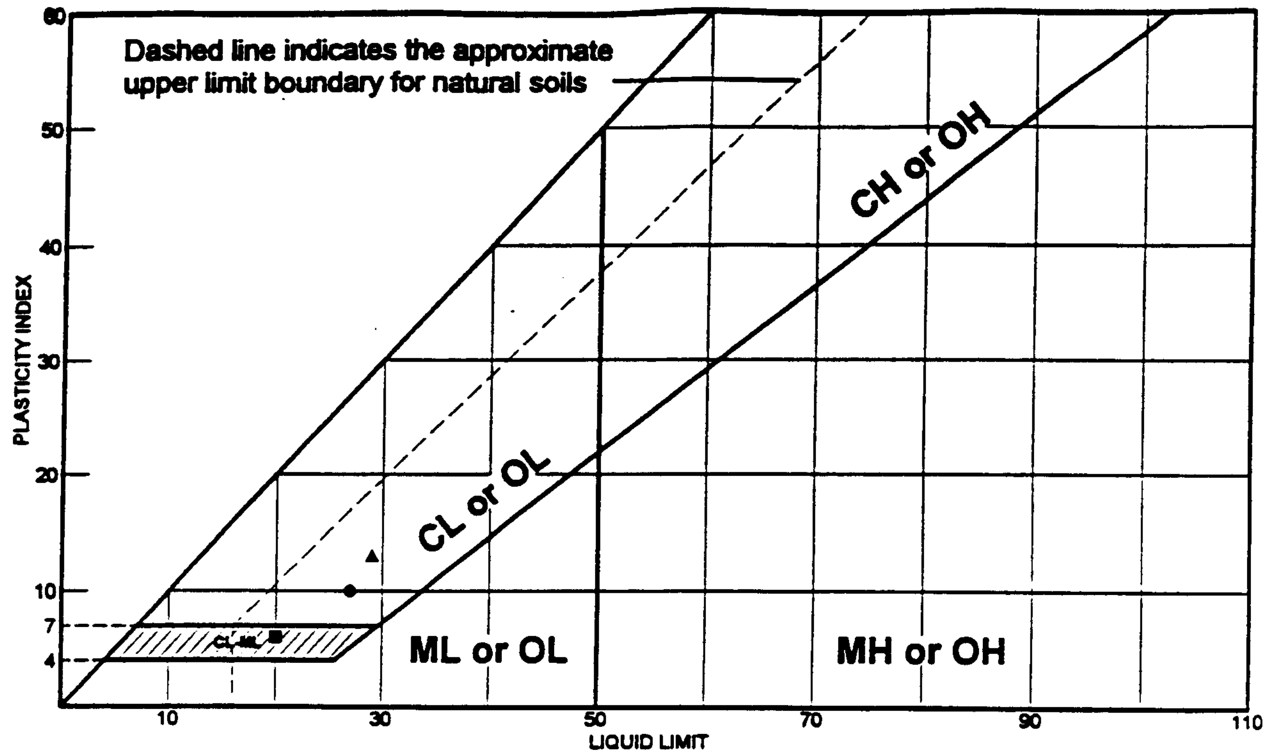
Figure No. B-8

AR 045886

LIQUID AND PLASTIC LIMITS TEST REPORT



Location + Description		LL	PL	PI	-200	USCS
● Source: HC00-B137 Lean CLAY	Sample No.: S-2	27	17	10		CL
■ Source: HC00-B138 CLAY-SILT	Sample No.: S-3	20	14	6		CL-ML
▲ Source: HC00-B300 Lean CLAY	Sample No.: S-3	29	16	13		CL

Remarks:
●
■
▲

Project: Third Runway

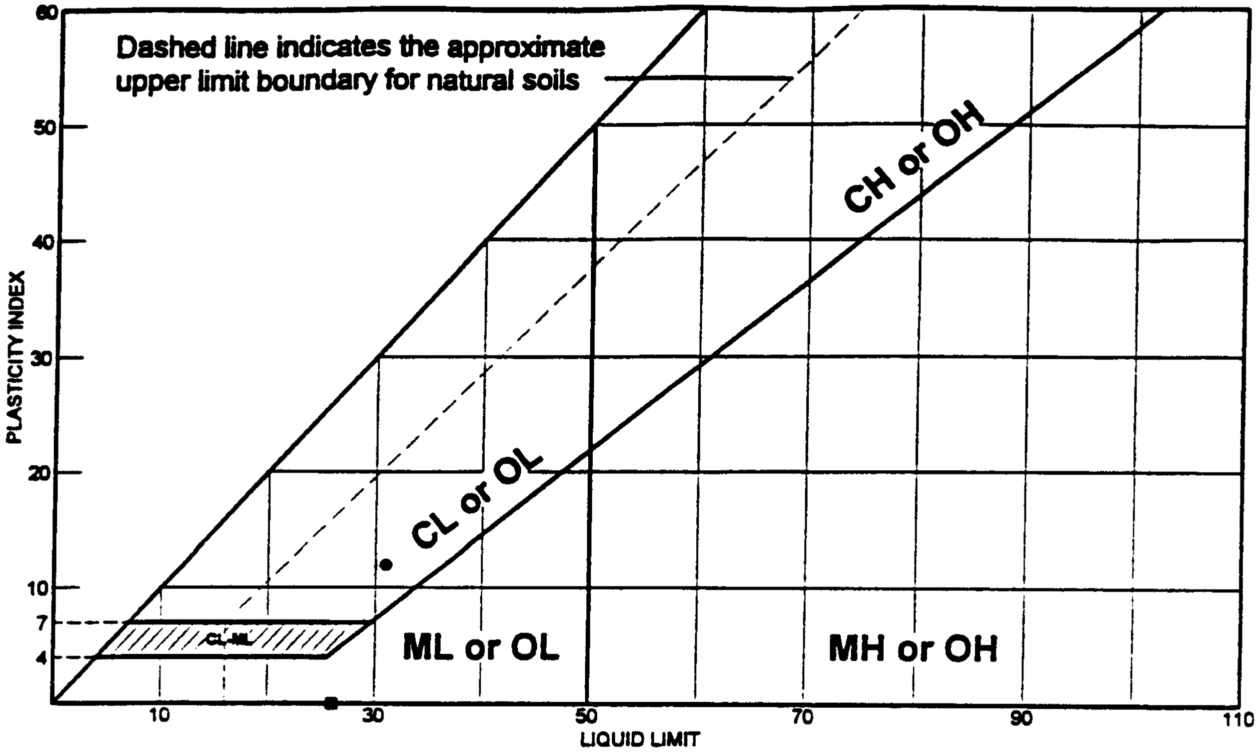
Client: HNTB

Location:

HARTCROWSER

J-4978-26 6/14/2000
Figure No. B-9

LIQUID AND PLASTIC LIMITS TEST REPORT



Location + Description	LL	PL	PI	-200	USCS
● Source: TP-301 Sample No.: S-3 Lean CLAY	31	19	12		CL
■ Source: TP-307 Sample No.: S-6 SILT	26	26	0		ML

Remarks:
●
■

Project: Third Runway

Client: HNTB

Location:

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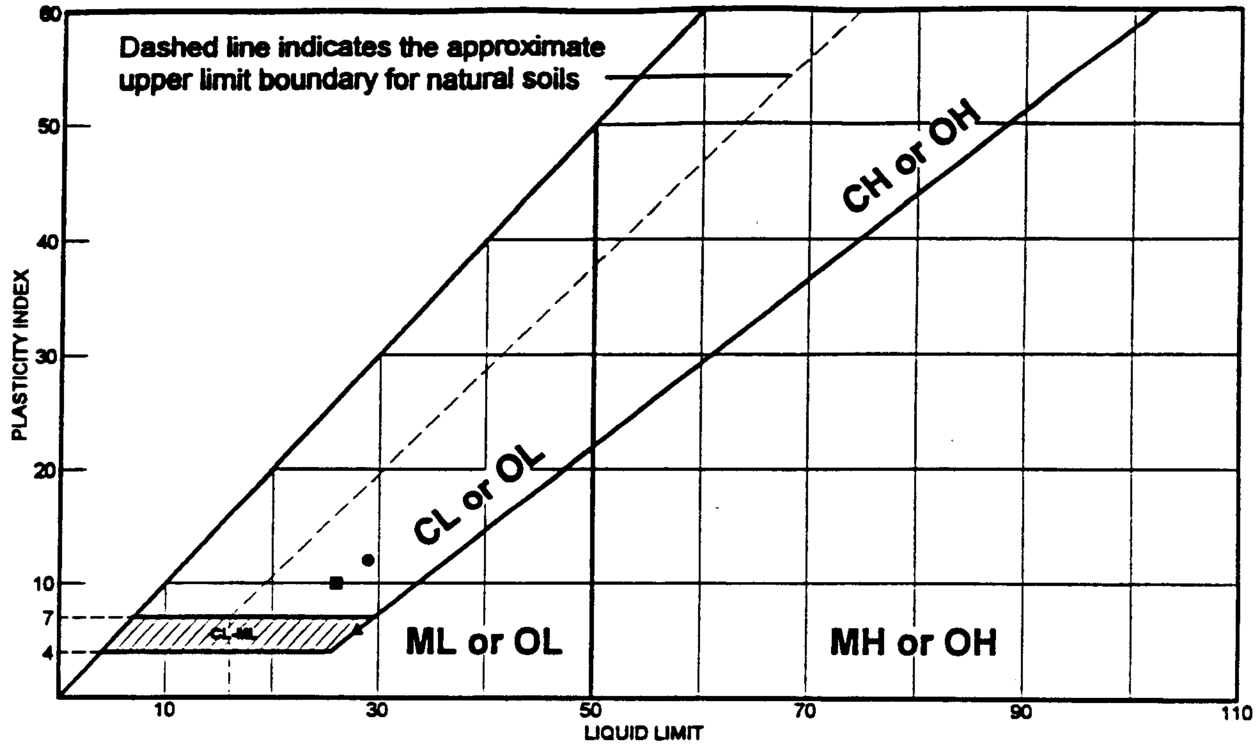
Figure No. B-10

LIQUID AND PLASTIC LIMITS TEST REPORT



Location + Description		LL	PL	PI	-200	USCS
● Source: HC00-B302	Sample No.: S-4	29	17	12		
■ Source: HC00-B305	Sample No.: S-4	26	16	10	66.4	CL
▲ Source: HC00-B306	Sample No.: S-3	28	22	6	77.7	CL-ML

Remarks:
●
■
▲

Project: Third Runway

Client: HNTB

Location:

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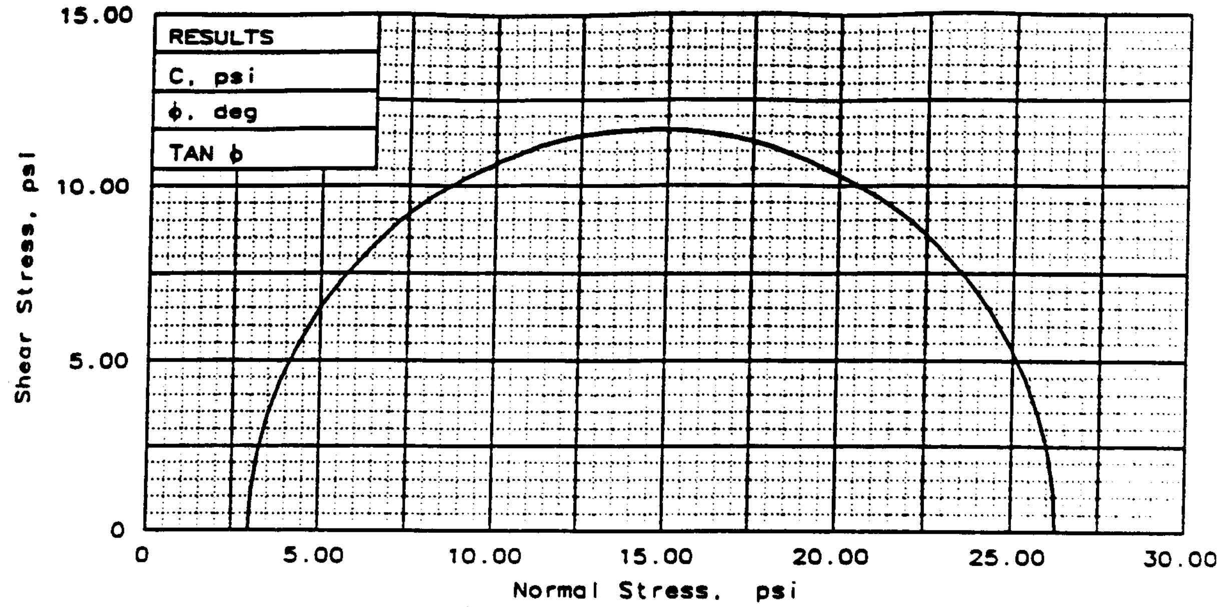
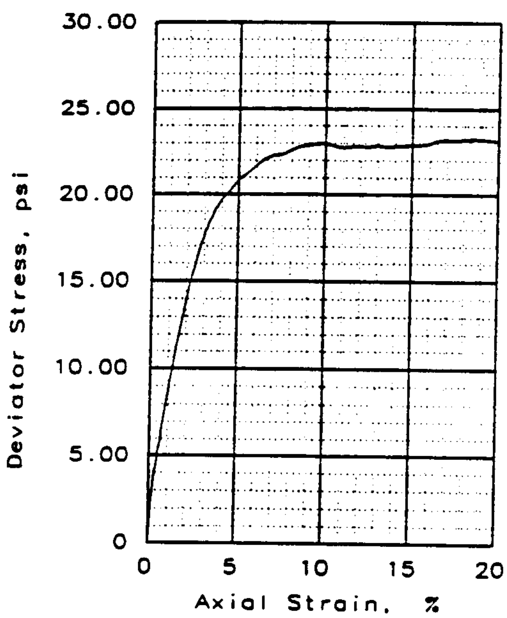
Figure No. B-11

AR 045889





SAMPLE NO.		1
INITIAL	WATER CONTENT, %	22.4
	DRY DENSITY, pcf	106.9
	SATURATION, %	108.5
	VOID RATIO	0.547
	DIAMETER, cm	7.20
	HEIGHT, cm	15.59
AT TEST	WATER CONTENT, %	22.3
	DRY DENSITY, pcf	106.9
	SATURATION, %	108.1
	VOID RATIO	0.547
	DIAMETER, cm	7.20
	HEIGHT, cm	15.59
BACK PRESSURE, psi		0.00
CELL PRESSURE, psi		3.00
FAILURE STRESS, psi		23.27
PORE PRESSURE, psi		
STRAIN RATE, %/min.		0.300
ULTIMATE STRESS, psi		
PORE PRESSURE, psi		
σ_1 FAILURE, psi		26.27
σ_3 FAILURE, psi		3

TYPE OF TEST:
Unconsolidated undrained
SAMPLE TYPE: Shelby Tube
DESCRIPTION: Lean CLAY

LL= 29 PL= 16 PI= 13.0
SPECIFIC GRAVITY= 2.65
REMARKS:

CLIENT: HNTB

PROJECT: Third Runway Wetlands

SAMPLE LOCATION: HC00-B300

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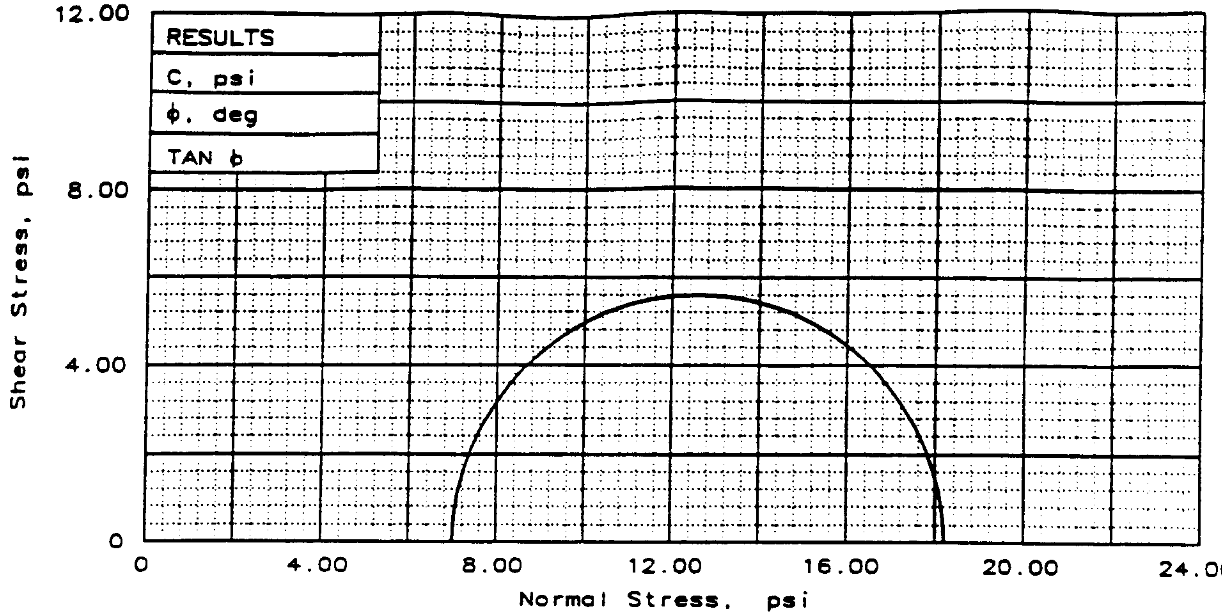
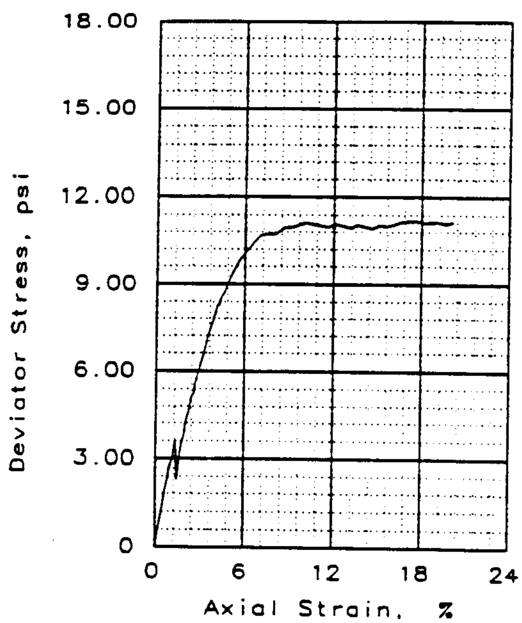
J4978-26 6/12/00

Figure B-12





SAMPLE NO.		1
INITIAL	WATER CONTENT, %	182.1
	DRY DENSITY, pcf	25.4
	SATURATION, %	92.9
	VOID RATIO	3.922
	DIAMETER, in	2.84
	HEIGHT, in	6.01
AT TEST	WATER CONTENT, %	182.1
	DRY DENSITY, pcf	25.4
	SATURATION, %	92.9
	VOID RATIO	3.922
	DIAMETER, in	2.84
	HEIGHT, in	6.01
BACK PRESSURE, psi		0.00
CELL PRESSURE, psi		7.00
FAILURE STRESS, psi		11.19
PORE PRESSURE, psi		
STRAIN RATE, %/min.		0.300
ULTIMATE STRESS, psi		
PORE PRESSURE, psi		
σ_1 FAILURE, psi		18.19
σ_3 FAILURE, psi		7

TYPE OF TEST:
Unconsolidated undrained
SAMPLE TYPE: Shelby Tube
DESCRIPTION: PEAT

LL= NV PL= NP PI=
SPECIFIC GRAVITY= 2
REMARKS:

CLIENT: HNTB

PROJECT: Third Runway

SAMPLE LOCATION: HC00-B151/S-4

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J-4978-26 6/19/00
Figure B-13

AR 045891

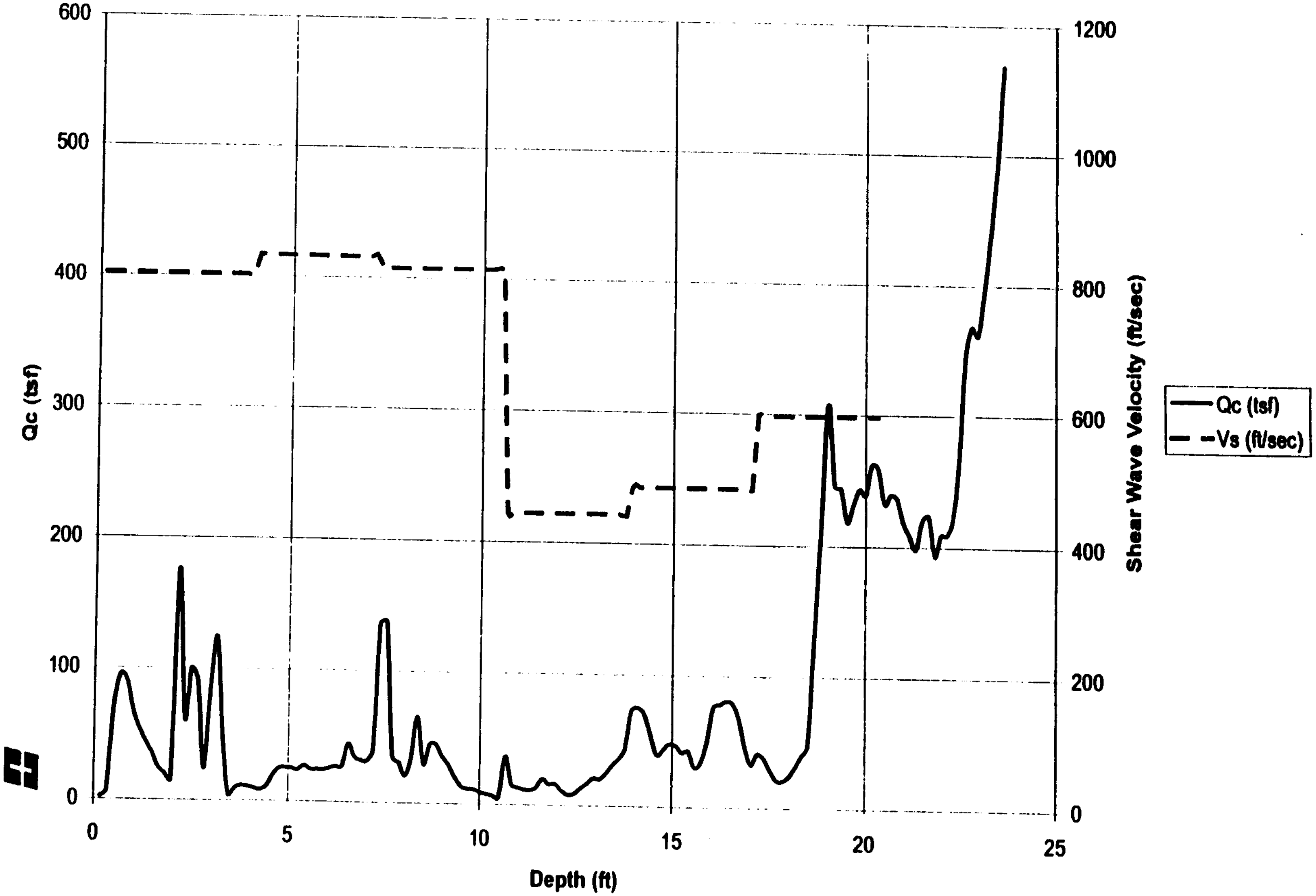
APPENDIX C
ADDITIONAL PIEZOCONE DATA

APPENDIX C
ADDITIONAL PIEZOCONE DATA

In addition to the piezocone results described and shown in Appendix A, shear wave velocity and dissipation tests were performed. Downhole shear wave velocity testing was performed in each of the piezocone holes. The resulting shear wave velocity profiles are shown on Figures C-1 through C-5. Dissipation testing was preformed in piezocones HC00-P23, HC00-P24, and HC00-P26. The results of the dissipations testing are shown on Figures C-6 though C-8. Northwest Cone Exploration, a subconsultant to Hart Crowser, performed these tests and compiled the results.

F:\docs\jobs\497826\DataReport.doc

Cone Penetration Probe Shear Wave Velocity Profile HC00-P22B

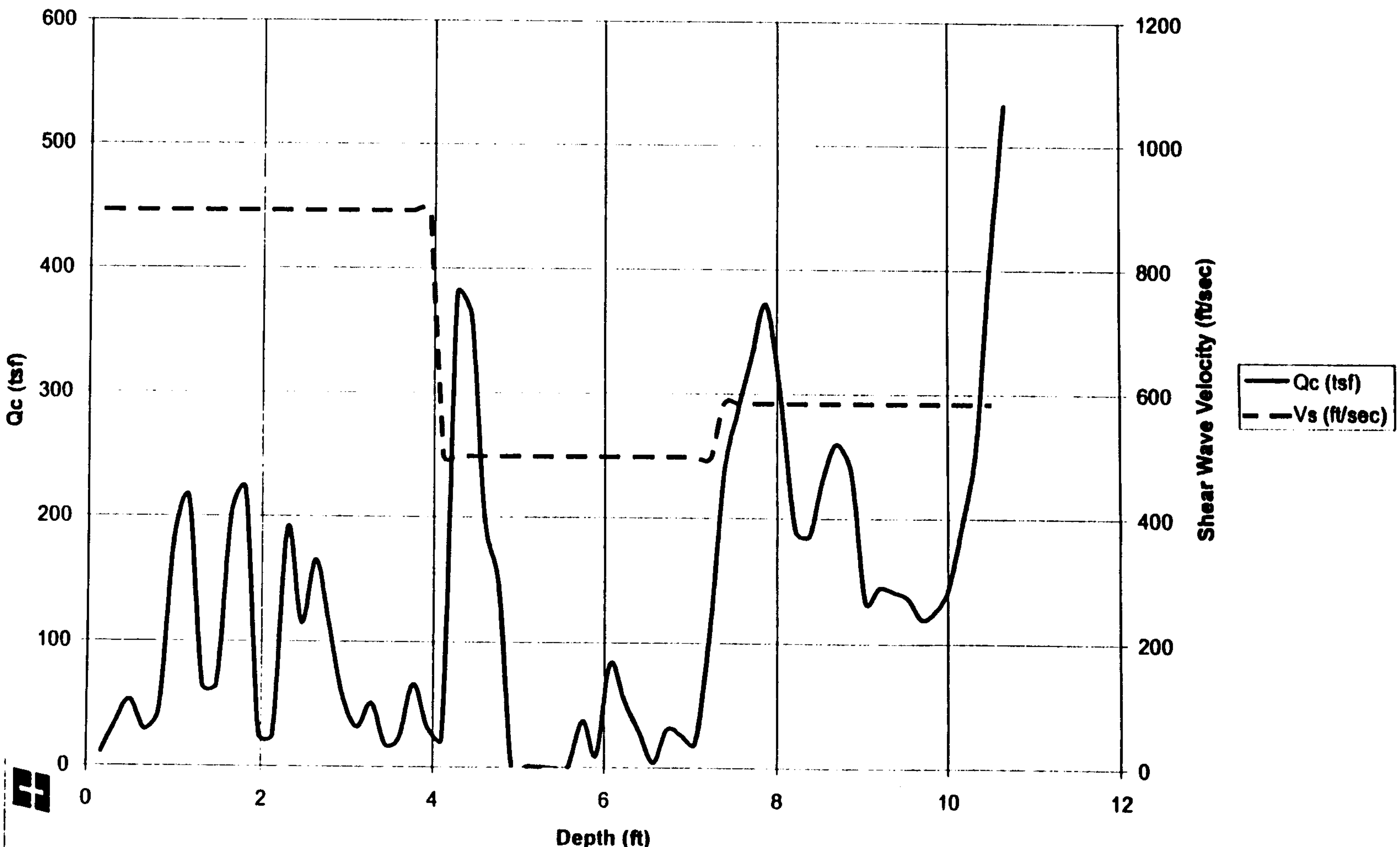


CVD 6/23/00 497827H CDR

HARTCROWSER
J-4978-27 6/00
Figure C-1

AR 045894

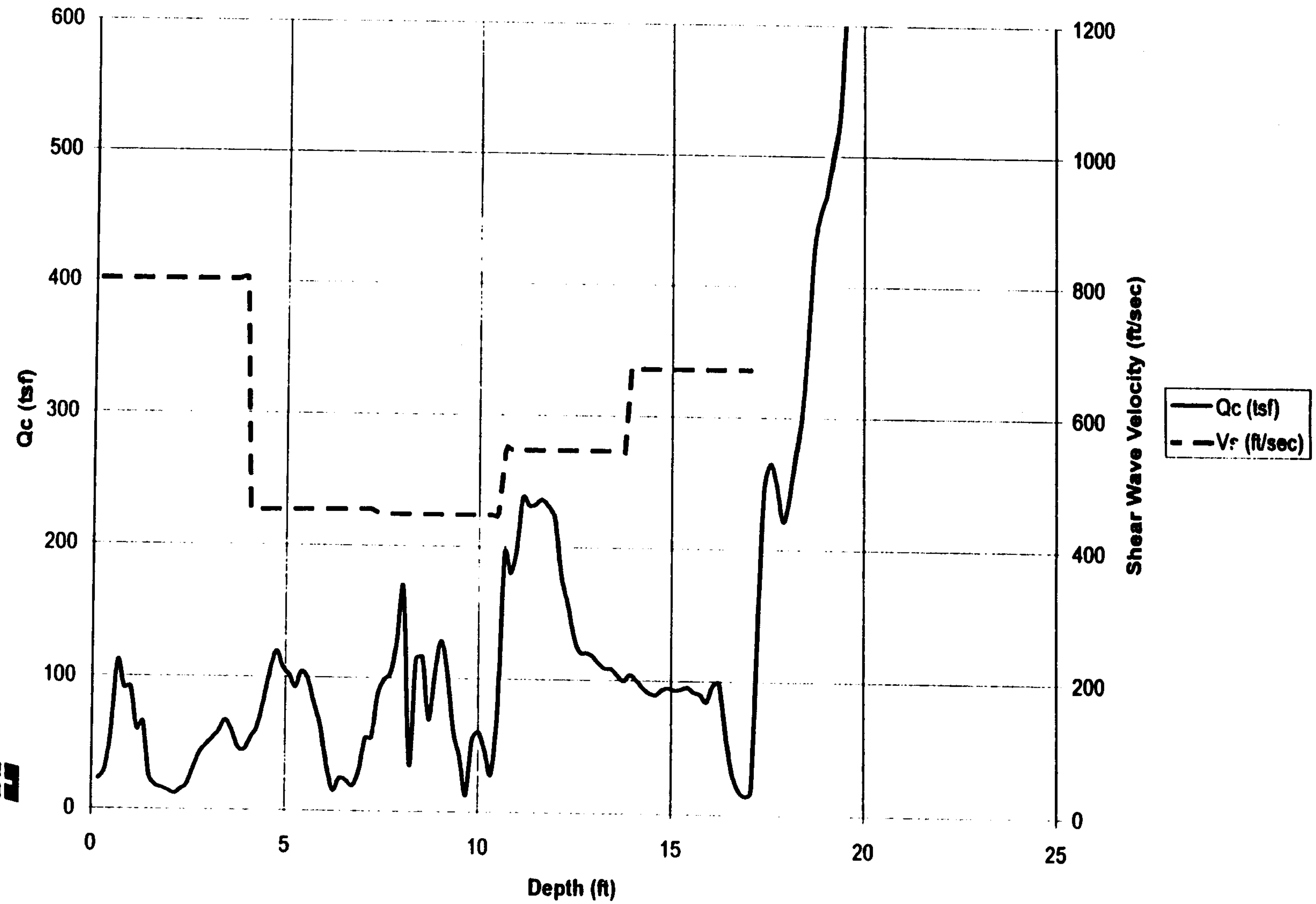
Cone Penetration Probe Shear Wave Velocity Profile HC00-P23



HARTCROWSER
J-4978-27 6/00
Figure C-2

CVD 6/23/00 497827I CDR

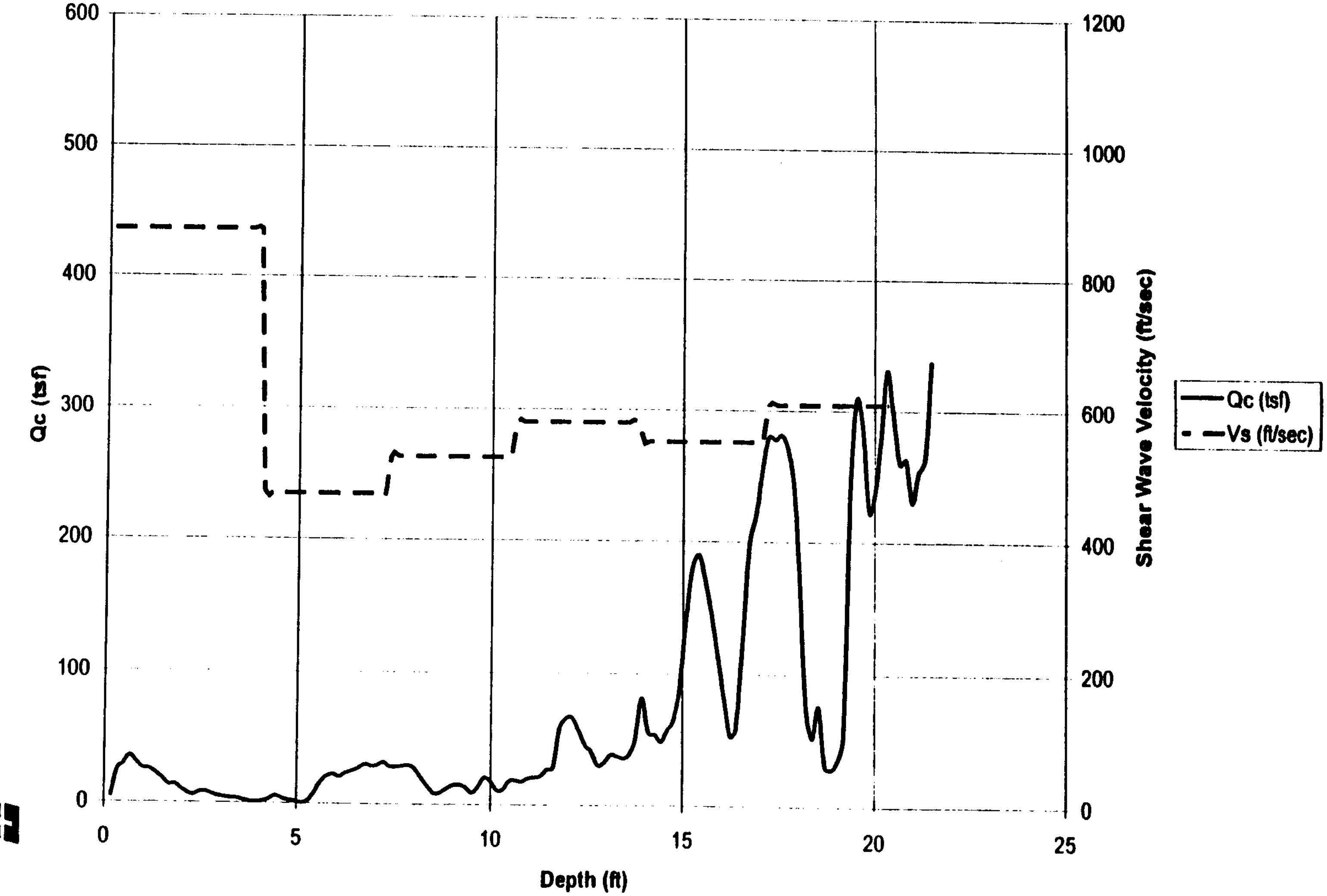
Cone Penetration Probe Shear Wave Velocity Profile HC00-P24



HARTCROWSER
J-4978-27 6/00
Figure C-3

CVD 6/23/00 497827G CDR

Cone Penetration Probe Shear Wave Velocity Profile HC00-P25



CVD 6/23/00 497827J CDR

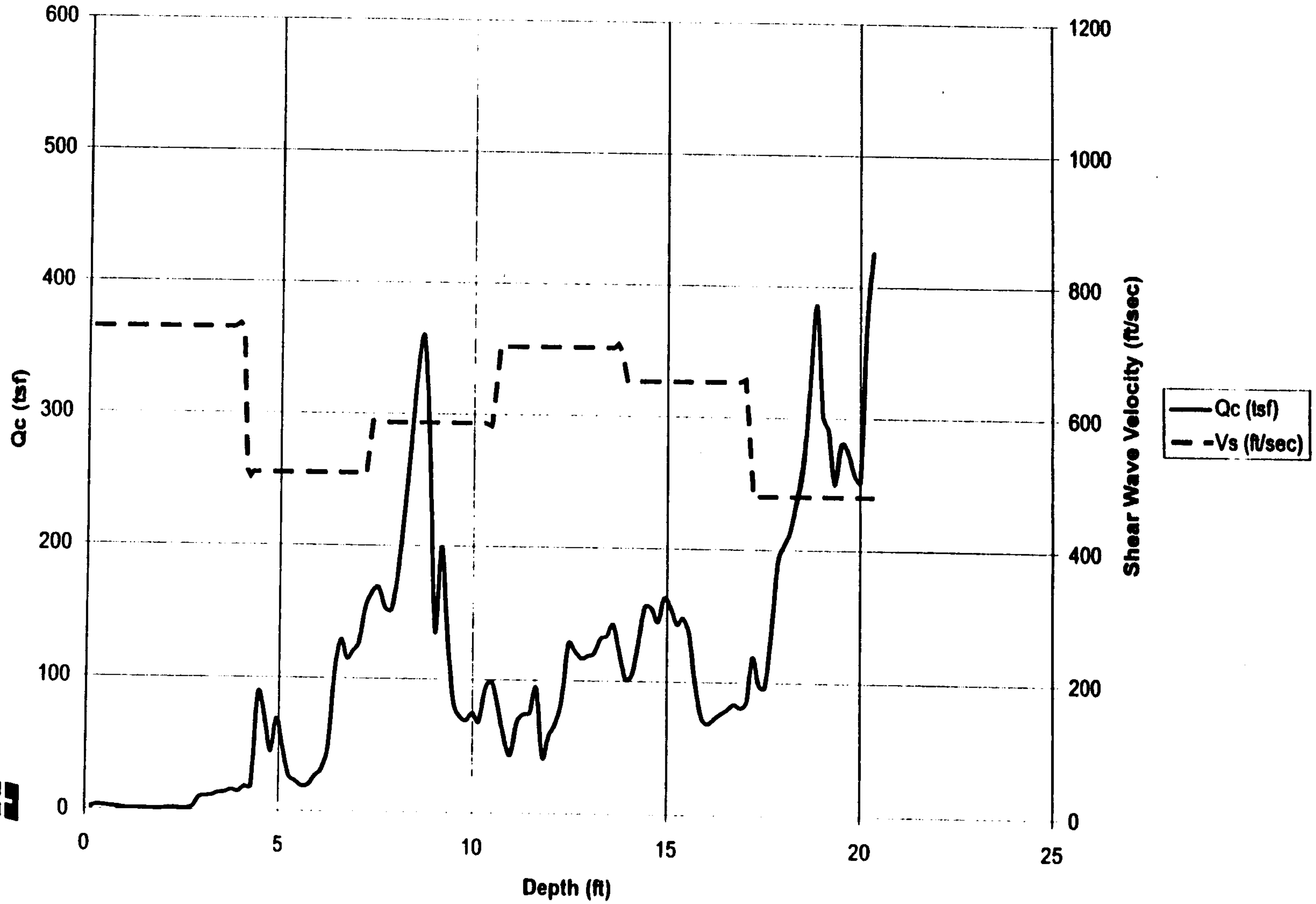
HARTCROWSER

J-4978-27 6/00

Figure C-4

AR 045897

Cone Penetration Probe Shear Wave Velocity Profile HC00-P26



HARTCROWSER

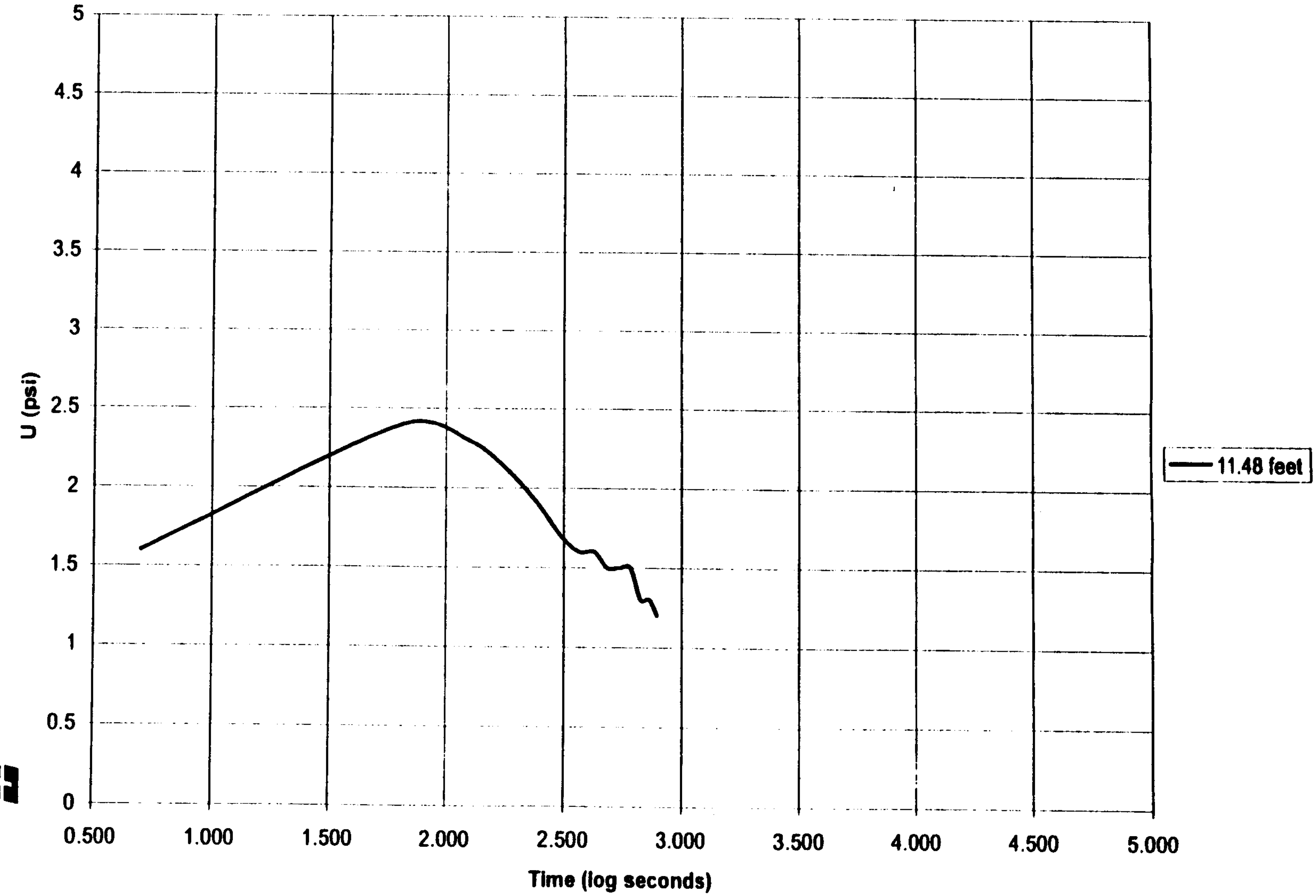
J-4978-27 6/00

Figure C-5

AR 045898

CVD 6/23/00 497827K CDR

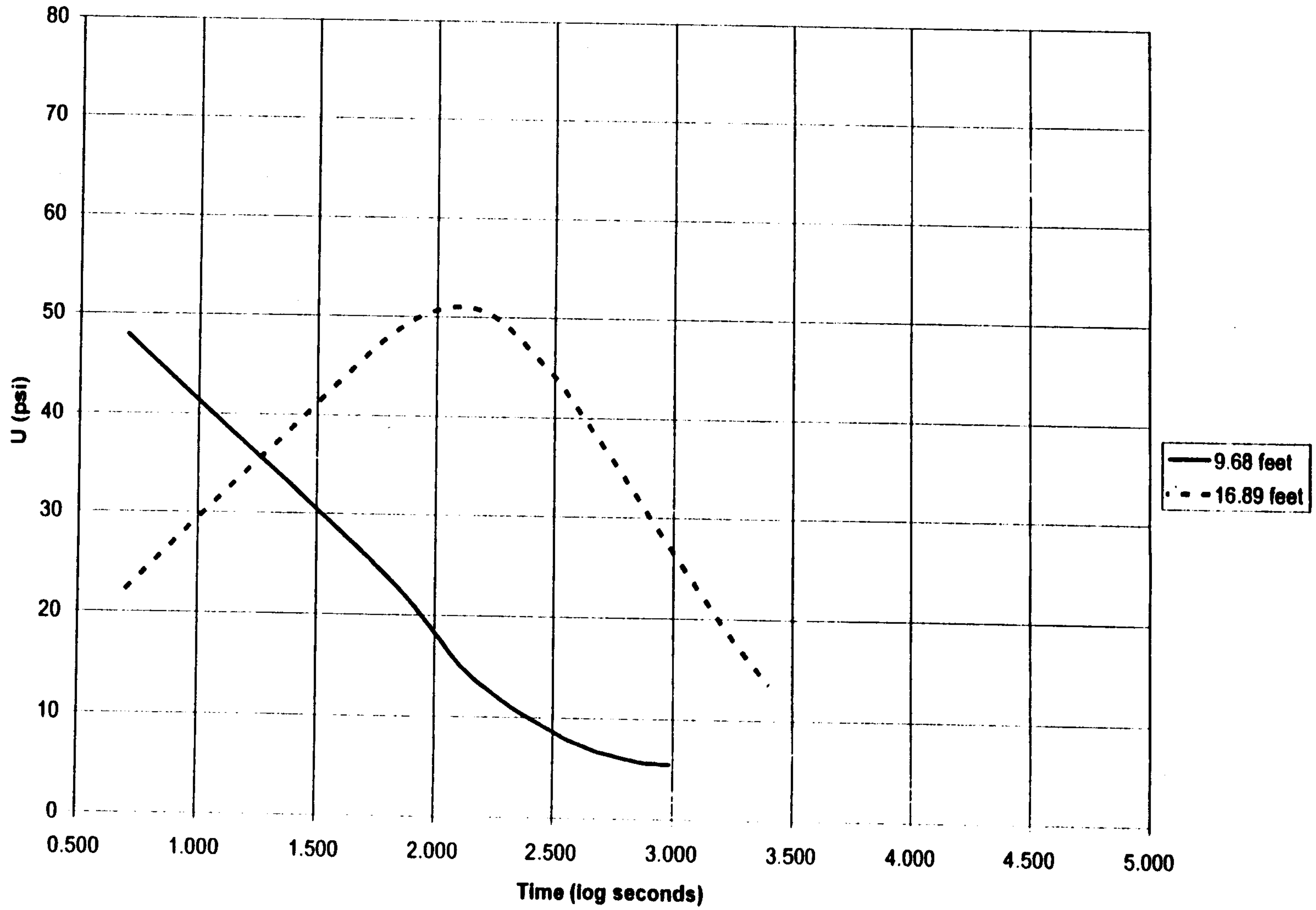
Cone Penetration Probe Dissipation Test Data HC00-P23



CVD 6/23/00 497827L CDR

HARTCROWSER
J-4978-27 6/00
Figure C-6

Cone Penetration Probe Dissipation Test Data HC00-P24



CVD 6/23/00 497827M CDR

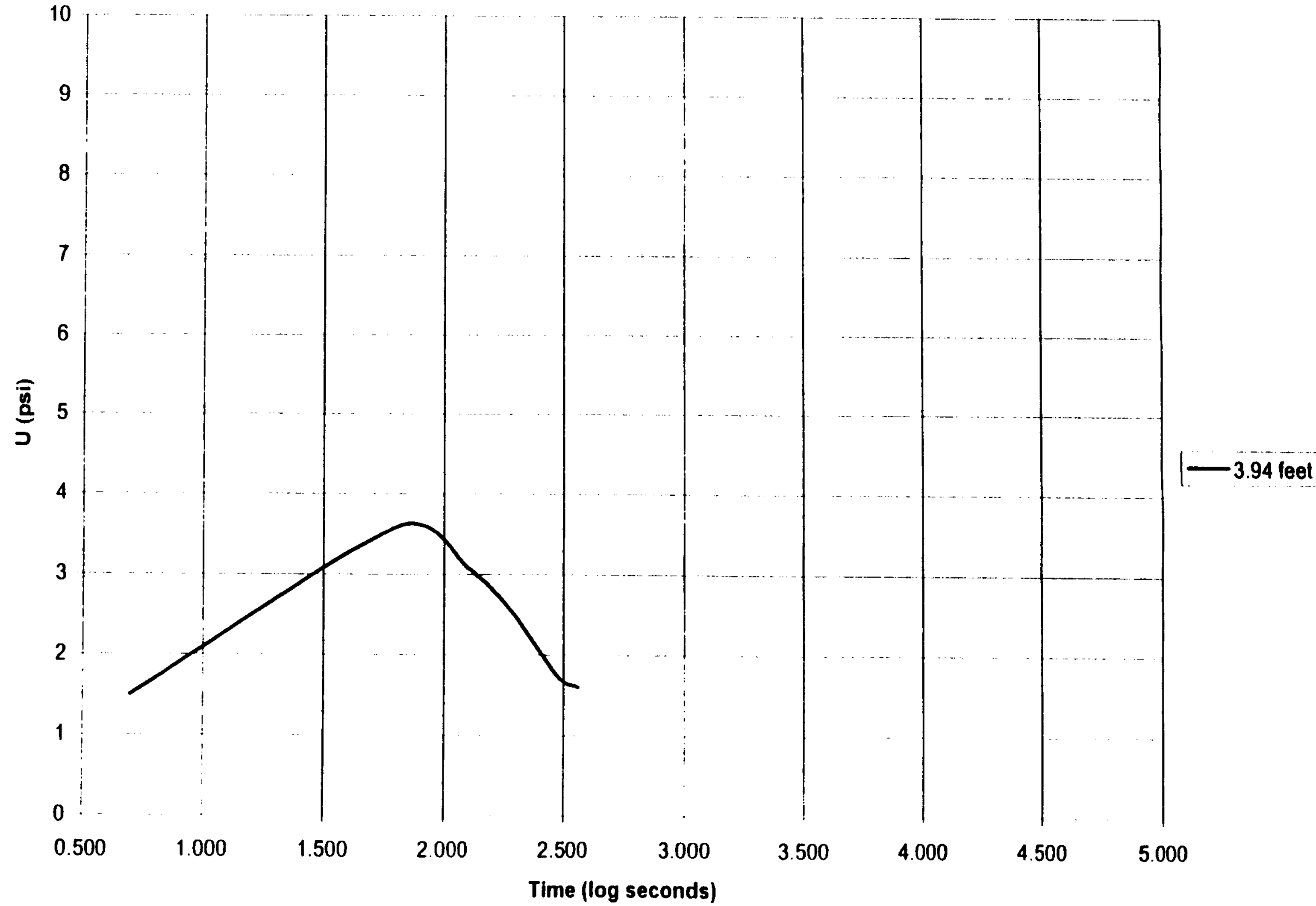
HARTCROWSER

J-4978-27 6/00

Figure C-7

AR 045900

Cone Penetration Probe Dissipation Test Data HC00-P26



CVD 6/23/00 497827N CDR

HARTCROWSER
J-4978-27 6/00
Figure C-8

APPENDIX D
SHEAR WAVE VELOCITY TESTING REPORT
GEO-RECON INTERNATIONAL

GEO RECON INTERNATIONAL
applied geophysics

June 9, 2000
J00-704

HartCrowser Inc
1910 Fairview Avenue East
Seattle, WA 98102

Compressional and Shear Wave Velocity Measurements
Proposed Retaining Wall Structure, Sea-Tac Airport 3rd Runway Project

This report present the results of the geophysical measurements in three bore holes located on alignment of the Proposed Retaining Wall Structure for the 3rd Runway at the Seattle-Tacoma Airport. Down-hole Compressional and Shear wave velocities for soil dynamic moduli determinations were measured in the three borings. The boreholes are HC00 B-220 on the South, HC00 B-221 in the Middle and HC00 B-222 on the North of the proposed alignment. The fieldwork was completed between May 24 and June 5, 2000.

COMPRESSIONAL AND SHEAR WAVE VELOCITIES

The borings were cased with threaded, 2-inch Schedule 40 PVC pipe. The 2-inch casings were grouted in the bore hole annulus with a weak cement grout. The PVC casings were enclosed in monument casings at ground surface.

The measured compressional and shear wave velocities are presented on the tables attached to this report. The tables show the averaged velocities calculated from the interval velocities for the boring, the calculated interval velocities, the interval times, converted time arrivals, the measured time arrivals and depths down the bore hole. When the velocity boundary does not coincide with a measurement depth, the velocity calculation of that point is not accurate from the preceding point of measurement, and the velocity computation between those two points is not included in the velocity average.

Figures 1 through 3 are the time-depth plots for the borings. The plots are the corrected down-hole time arrivals of the measured Compressional (P) and Shear (S) wave particle motion, plotted against the depth of measurement. The velocities of the P and S waves are computed from the slopes of the time arrivals on the Figures, or as the averaged velocities

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of the interval velocities. These figures were utilized to determine the depth of the velocity changes in the attached tables and summary presented below.

The velocity and thickness of the immediate top layer (above the depth of 5 feet) was not determined. The top layer above 5 feet varied from road sub-grade (B-221 and B-222) to a possible fill/cut section (B-220).

The summaries of the measured P and S wave velocities in the borings are as follows:

Boring HC00 B-220

Depth of Data (feet)	P-wave Velocity (feet/second)	S-wave Velocity (feet/second)	Poisson's Ratio
5 to 15	2776	476	0.4849
15 to 40	5814	1023	0.4840
40 to 80	6588	1619	0.4679
80 to 100	7189	1844	0.4648

Boring HC00 B-221

Depth of Data (feet)	P-wave Velocity (feet/second)	S-wave Velocity (feet/second)	Poisson's Ratio
5 to 15	3554	640	0.4832
15 to 40	6055	1242	0.4780
40 to 55	5229	1078	0.4778
55 to 100	6661	1641	0.4677

Boring HC00 B-222

Depth of Data (feet)	P-wave Velocity (feet/second)	S-wave Velocity (feet/second)	Poisson's Ratio
5 to 10	2018	289	0.4895
10 to 40	4903	1137	0.4716
40 to 60	7292	1462	0.4791
60 to 100	6838	1620	0.4703

Poisson's Ratio is calculated as follows:

$$\mu = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)}$$

Where: μ = Poisson's Ratio
Vp = Compressional Wave Velocity
Vs = Shear Wave Velocity

The Compressional (P) wave energy was a vertical hammer blow to a metal plate on the ground surface, offset from the borehole. The zero time of the hammer blow was determined from an impact switch taped to the hammer. Multiple hammer blows were stacked to enhance the energy arrivals. A minimum of two, separate measurements were made at each depth point to verify the time history of the particle motion at that depth.

The Shear (S) wave energy source was a horizontal wood plank placed beneath the wheels of a vehicle. The orientation of the plank was normal to a line through the center of the boring. The shear wave source was offset approximately 10 feet from the borehole, as noted in the attached tables. An impact switch taped to the handle of the hammer determined the zero time.

Three detectors, spaced at 10-foot intervals in the borehole, were used to detect the generated S wave energy. To minimize the effect of the detector spiral as they are lowered down the borehole; each detector package contains four sets of horizontal geophones (8 Hz geophones) placed on axes of 45 degrees. The axis of sensitivity of the geophones is 20 degrees. Utilizing the three detector packages, a minimum of two separate measurements was collected at each depth point. The first and final data points, however, are single measurements.

For the S wave data, two recordings were made at each data point. The two separate recordings were made with reversed (polarized) energy inputs utilizing the opposite ends of the wooden plank. The time arrival of the shear wave energy was determined by comparing the times and direction of particle motion of the recorded wave motion of the two recordings.

The particle motion of the shear wave energy is polarized and is dependent on the direction of the energy input. On Blow 1, the particle motion is reversed from that produced by Blow 2. The polarization of the energy helps the interpreter to separate S wave arrivals from other energy arrivals. Reversed particle motion, however, can also occur in other ways such as out-of-phase noise or shear energy generated in the boring annulus and casing (tube waves) and/or P to S conversion from the tube waves.

Tube wave energy arrivals from energy propagation through the grout and casing generate early arrivals at the detector, particularly when the grout/casing velocity is greater than the formation velocity. Distinction between the early arrivals and the arrival of the generated direct wave was largely determined by the continuity of the arrival times down the borehole and comparison to the material changes and blow counts logged in the boring. Excessive tube wave energy was enhanced by the requirement to maintain a minimum of a 2-inch annulus around the casing.

The picked arrival times were converted from the "slant distance" travel path to the vertical travel path down the borehole. The "slant distance" travel path is a result of the source to borehole offset. The formula used for the conversion to the 'Corrected Time' vertically down the borehole is:

DH Time = Record Time x [Cos(Arctan (offset/detector depth))]

Borehole drift was not measured in the borings, and no corrections have been applied for potential drift. The velocity changes generally correspond to the logged material changes and/or blow counts, so that extreme drift of the borings off of vertical is not expected.

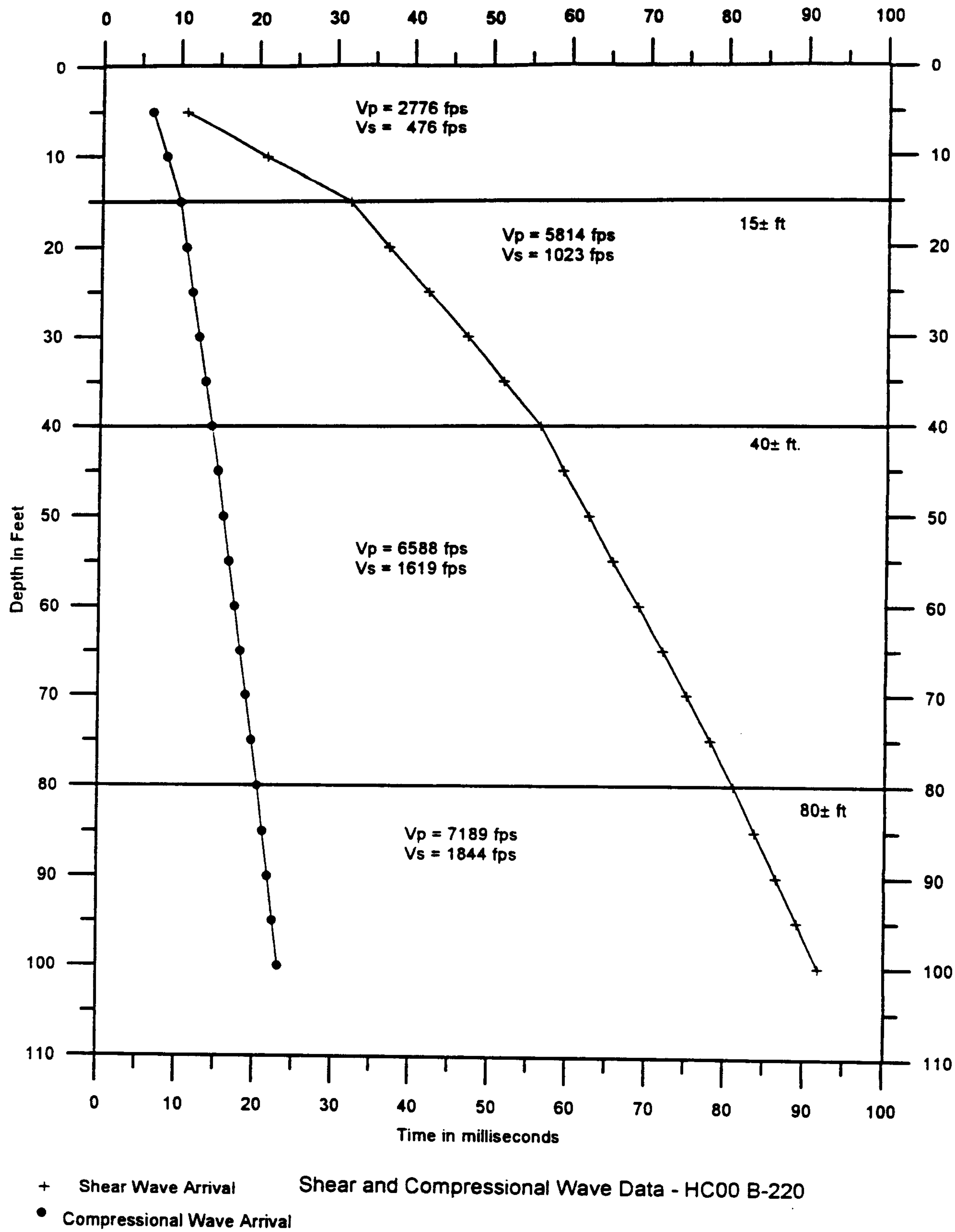
The recording equipment was an EG&G 1225, a 12-channel signal enhancement digital recording seismograph. The P wave was measured with a 25 milli-second record length and the S wave was measured with a 100 milli-second record length. The sampling rate was 1000 samples per record length. For the P wave records the data was picked to from 0.025 milliseconds. For the S wave records the data was picked to from 0.1 milliseconds. Varying amounts of time delays were used in the measurements.

The information presented in this report is based upon geophysical measurements made by generally accepted methods and field procedures, and our interpretation of these data. The presented information is based upon our best estimate of subsurface conditions considering the geophysical results and all other information available to us. These results are interpretive in nature and are considered to be a reasonably accurate presentation of the existing conditions within the limitations of the method or methods employed.

For Geo-Recon International:

John M Musser Jr

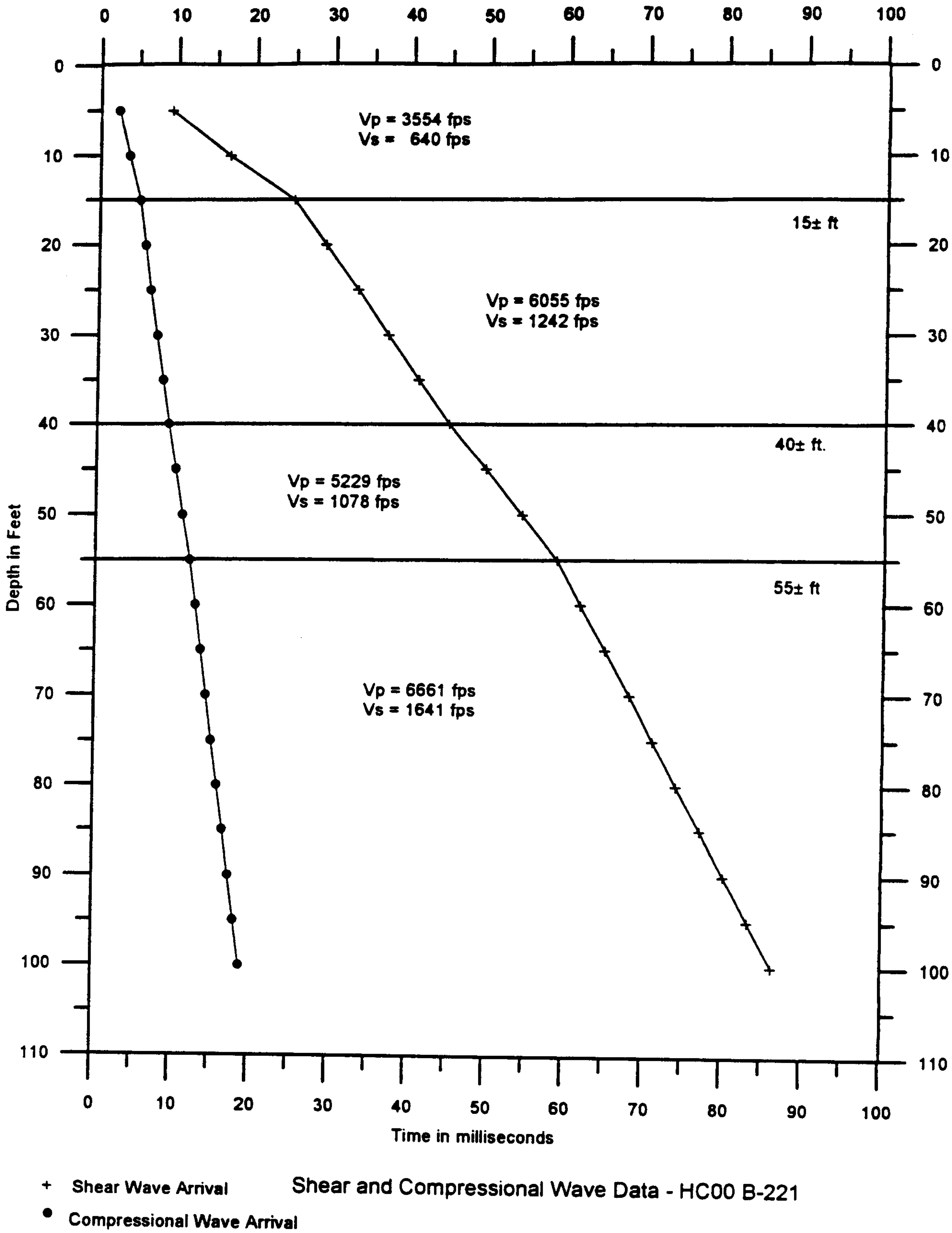
John M. Musser Jr.
Principal Geophysicist



Shear and Compressional Wave Data - HC00 B-220

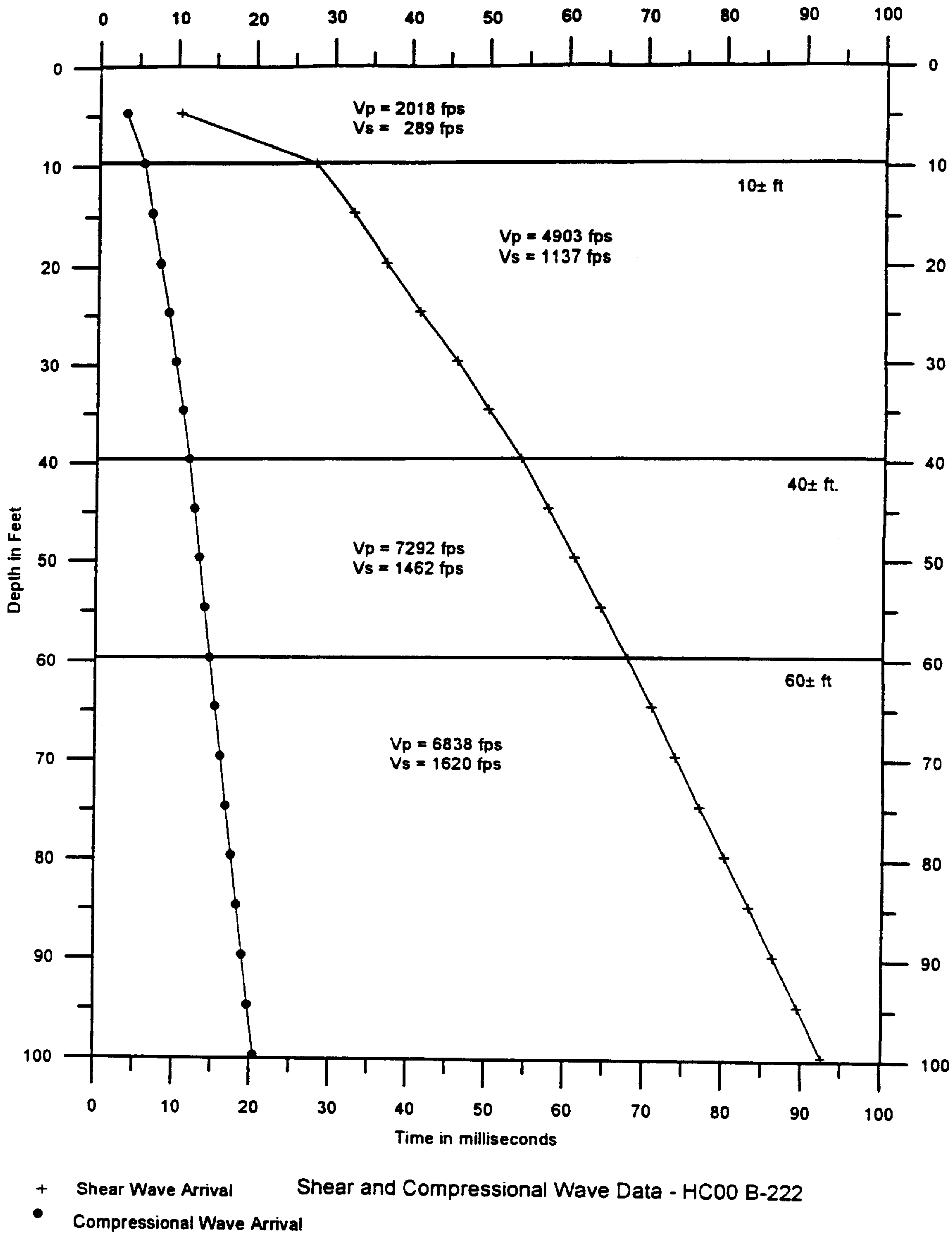
Fig. 1

AR 045907



Shear and Compressional Wave Data - HC00 B-221

Fig. 2



Shear and Compressional Wave Data - HC00 B-222

Fig. 3

Downhole Compressional and Shear Wave Velocity Measurements

Borehole: HC00-B-220 - Retaining Wall Structure, SeaTac 3rd Runway

Compressional Wave Data - Interval Velocity Computations

Depth of Data	Recorded Time	Corrected Time	Interval Time	Interval Velocity		Average Velocity
5.0	13.150	6.386	-----	-----	n/a	
10.0	11.050	8.213	1.827	2736		
15.0	11.650	9.990	1.776	2815		2776
Velocity Change at 15 feet						
20.0	11.875	10.829	0.839	5958		
25.0	12.400	11.667	0.838	5967		5814
30.0	13.100	12.548	0.881	5678		
35.0	13.875	13.438	0.890	5616		
40.0	14.650	14.293	0.855	5849		
Velocity Change at 40 feet						
45.0	15.400	15.101	0.808	6186		
50.0	16.075	15.821	0.720	6946		
55.0	16.775	16.555	0.734	6811		
60.0	17.525	17.331	0.776	6441		6588
65.0	18.250	18.078	0.746	6699		
70.0	19.000	18.845	0.767	6516		
75.0	19.750	19.609	0.764	6541		
80.0	20.500	20.371	0.762	6560		
Velocity Change at 80 feet						
85.0	21.200	21.082	0.711	7036		
90.0	21.900	21.791	0.709	7051		7189
95.0	22.550	22.449	0.658	7597		
100.0	23.250	23.156	0.707	7073		

Bottom of Casing at 100.7 feet.

Source to Borehole offset: 9 feet.
Casing stickup above ground: 0 feet.
n/a - Not included in Velocity Average.

Velocities in feet per second.
Depths in feet - Times in milli-seconds.
Velocity Breaks from Time-Depth Plot.

Downhole Compressional and Shear Wave Velocity Measurements

Borehole: HC00-B-220 - Retaining Wall Structure, SeaTac 3rd Runway

Shear Wave Data - Interval Velocity Computations

Depth of Data	Recorded Time	Corrected Time	Interval Time	Interval Velocity		Average Velocity
5.0	22.700	10.794	-----	-----	n/a	
10.0	28.700	21.069	10.274	487		
15.0	37.400	31.834	10.765	464		476
	Velocity Change at 15 feet					
20.0	40.600	36.850	5.016	997		
25.0	44.800	42.016	5.167	968		1023
30.0	49.200	47.016	5.000	1000		
35.0	53.400	51.627	4.612	1084		
40.0	57.800	56.314	4.686	1067		
	Velocity Change at 40 feet					
45.0	60.500	59.261	2.947	1697		
50.0	63.600	62.539	3.278	1525		
55.0	66.500	65.579	3.040	1645		
60.0	69.700	68.886	3.307	1512		1619
65.0	72.700	71.975	3.089	1619		
70.0	75.700	75.048	3.073	1627		
75.0	78.700	78.108	3.061	1634		
80.0	81.600	81.060	2.952	1694		
	Velocity Change at 80 feet					
85.0	84.300	83.805	2.745	1821		
90.0	87.000	86.544	2.739	1826		1844
95.0	89.600	89.178	2.634	1898		
100.0	92.300	91.908	2.729	1832		

Bottom of Casing at 100.7 feet.

Source to Borehole offset: 9.25 feet.
Casing stickup above ground: 0 feet.
n/a - Not included in Velocity Average.

Velocities in feet per second.
Depths in feet - Times in milli-seconds.
Velocity breaks from Time-Depth Plot.

Downhole Compressional and Shear Wave Velocity Measurements

Borehole: HC00-B-221 - Retaining Wall Structure, SeaTac 3rd Runway

Compressional Wave Data - Interval Velocity Computations

Depth of Data	Recorded Time	Corrected Time	Interval Time	Interval Velocity		Average Velocity
5.0	4.800	2.331	2.331	——	n/a	
10.0	5.025	3.735	1.404	3561		3554
15.0	6.000	5.145	1.410	3546		
Velocity Change at 17 feet						
20.0	6.500	5.927	0.783	6390		
25.0	7.100	6.680	0.753	6642		6055
30.0	7.925	7.591	0.910	5492		
35.0	8.725	8.450	0.859	5819		
40.0	9.525	9.293	0.843	5934		
Velocity Change at 40 feet						
45.0	10.425	10.223	0.930	5377		
50.0	11.350	11.170	0.948	5275		5229
55.0	12.325	12.163	0.993	5037		
Velocity Change at 55 feet						
60.0	13.075	12.930	0.767	6518		
65.0	13.800	13.670	0.739	6764		
70.0	14.525	14.406	0.737	6786		6661
75.0	15.225	15.117	0.710	7041		
80.0	15.975	15.875	0.758	6594		
85.0	16.750	16.657	0.782	6394		
90.0	17.500	17.413	0.756	6611		
95.0	18.250	18.169	0.755	6618		
100.0	19.000	18.924	0.755	6624		

Bottom of Casing at 101.2 feet.

Source to Borehole offset: 9 feet.
Casing stickup above ground: 0 feet.
n/a - Not included in Velocity Average.

Velocities in feet per second.
Depths in feet - Times in milli-seconds.
Velocity Breaks from Time-Depth Plot.

Downhole Compressional and Shear Wave Velocity Measurements

Borehole: HC00-B-221 - Retaining Wall Structure, SeaTac 3rd Runway

Shear Wave Data - Interval Velocity Computations

Depth of Data	Recorded Time	Corrected Time	Interval Time	Interval Velocity	Average Velocity
5.0	20.600	9.213	9.213	——	n/a
10.0	23.600	16.688	7.475	669	640
15.0	29.900	24.878	8.191	610	
	Velocity Change at 15 feet				
20.0	32.400	28.979	4.101	1219	
25.0	35.700	33.147	4.167	1200	
30.0	39.100	37.094	3.947	1267	1242
35.0	42.700	41.057	3.964	1261	
40.0	46.400	45.015	3.958	1263	
	Velocity Change at 40 feet				
45.0	51.000	49.786	4.771	1048	
50.0	55.500	54.422	4.637	1078	1078
55.0	59.900	58.934	4.512	1108	
	Velocity Change at 55 feet				
60.0	62.800	61.946	3.012	1660	
65.0	65.900	65.134	3.188	1568	
70.0	68.900	68.208	3.074	1627	
75.0	71.800	71.170	2.963	1688	1641
80.0	74.800	74.222	3.052	1638	
85.0	77.800	77.267	3.045	1642	
90.0	80.800	80.306	3.039	1645	
95.0	83.800	83.340	3.034	1648	
100.0	86.800	86.369	3.030	1650	

Bottom of Casing at 101.2 feet.

Source to Borehole offset: 10 feet.
Casing stickup above ground: 0 feet.
n/a - Not included in Velocity Average.

Velocities in feet per second.
Depths in feet - Times in milli-seconds.
Velocity breaks from Time-Depth Plot.

Downhole Compressional and Shear Wave Velocity Measurements

Borehole: HC00-B-222 - Retaining Wall Structure, SeaTac 3rd Runway

Compressional Wave Data - Interval Velocity Computations

Depth of Data	Recorded Time	Corrected Time	Interval Time	Interval Velocity	Average Velocity
4.6	8.175	3.416	3.416	----	n/a
9.6	8.225	5.696	2.280	2018	2018
	Velocity Change at 10 feet				
14.6	8.250	6.806	1.110	4503	
19.6	8.850	7.883	1.077	4644	
24.6	9.725	9.009	1.126	4441	4903
29.6	10.525	9.971	0.962	5196	
34.6	11.375	10.928	0.956	5228	
39.6	12.225	11.853	0.925	5404	
	Velocity Change at 40 feet				
44.6	12.850	12.539	0.686	7291	
49.6	13.500	13.234	0.695	7194	7292
54.6	14.150	13.918	0.685	7302	
59.6	14.800	14.596	0.677	7380	
	Velocity Change at 60 feet				
64.6	15.500	15.318	0.722	6929	
69.6	16.200	16.035	0.718	6966	
74.6	16.900	16.750	0.715	6995	
79.6	17.625	17.488	0.737	6781	6838
84.6	18.350	18.223	0.736	6797	
89.6	19.075	18.957	0.734	6810	
94.6	19.800	19.690	0.733	6821	
99.6	20.550	20.447	0.757	6606	

Bottom of Casing at 100 feet.

Source to Borehole offset: 10 feet.
Casing stickup above ground: 0.45 ft.
n/a - Not included in Velocity Average.

Velocities in feet per second.
Depths in feet - Times in milli-seconds.
Velocity Breaks from Time-Depth Plot.

Downhole Compressional and Shear Wave Velocity Measurements

Borehole: HC00-B-222 - Retaining Wall Structure, SeaTac 3rd Runway

Shear Wave Data - Interval Velocity Computations

Depth of Data	Recorded Time	Corrected Time	Interval Time	Interval Velocity		Average Velocity
4.6	25.300	10.401	10.401	----	n/a	
9.6	40.400	27.689	17.288	289		289
	Velocity Change at 10 feet					
14.6	39.800	32.626	4.938	1013		
19.6	41.600	36.902	4.276	1169		1137
24.6	44.600	41.199	4.297	1164		
29.6	48.700	46.043	4.844	1032		
34.6	52.200	50.070	4.027	1242		
39.6	56.000	54.230	4.160	1202		
	Velocity Change at 40 feet					
44.6	59.200	57.710	3.480	1437		
49.6	62.400	61.121	3.411	1466		1462
54.6	65.600	64.484	3.363	1487		
59.6	68.900	67.913	3.428	1458		
	Velocity Change at 60 feet					
64.6	71.900	71.020	3.108	1609		
69.6	74.800	74.009	2.989	1673		
74.6	77.800	77.083	3.073	1627		
79.6	80.900	80.244	3.161	1582		1620
84.6	84.000	83.396	3.152	1586		
89.6	87.000	86.442	3.046	1642		
94.6	90.000	89.481	3.040	1645		
99.6	93.100	92.616	3.134	1595		
	Bottom of Casing at 100 feet.					

Source to Borehole offset: 10.2 feet.
Casing stickup above ground: 0.45 ft.
n/a - Not included in Velocity Average.

Velocities in feet per second.
Depths in feet - Times in milli-seconds.
Velocity breaks from Time-Depth Plot.

APPENDIX E
PRESSUREMETER TESTING REPORT
HUGHES INSITU ENGINEERING, INC.

Data Summary of

Pressuremeter Testing

at

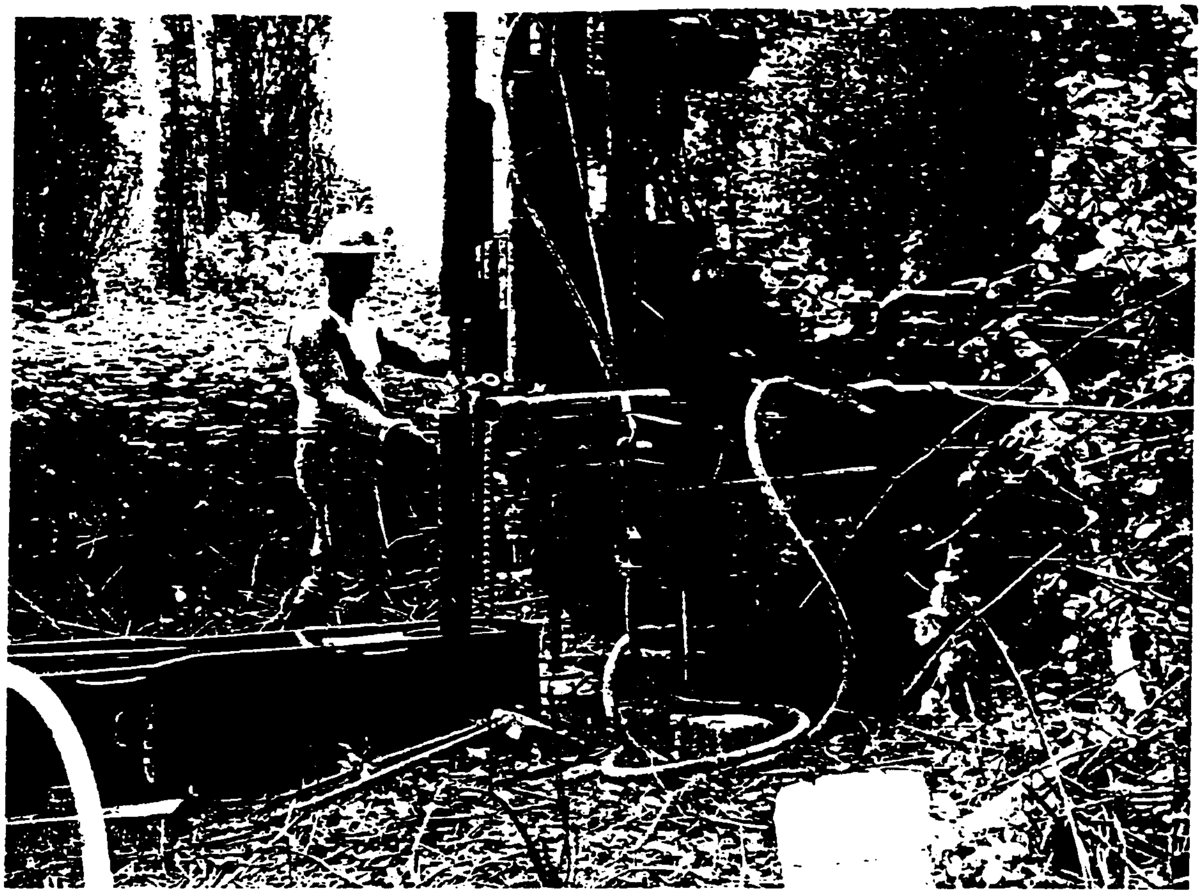
SeaTac Airport, Third Runway
Seattle, Washington

submitted to

Hart Crowser, Inc.
Seattle, Washington

June, 2000
Report # C-219

HUGHES INSITU ENGINEERING INC.
Suite 804, 938 Howe Street, Vancouver B.C. Canada V6Z-1N9
Phone (604) 331-4451 Fax (604) 331-4452



Holt Drilling, Inc. track mounted rig at location HC00-B225.

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Photographs

Figures

Tables

Appendices

1 Introduction

During the period May 17-24, 2000, pressuremeter testing along with a standard geotechnical investigation was conducted at six locations on the proposed location of retaining walls for the SeaTac Third Runway. The field investigation was under the direction of Mr. Doug Lindquist, P.E. of Hart Crowser, Inc. Seattle, Washington. The drilling for this testing was performed by Holt Drilling , Inc., Washington, using both a truck-mounted mobile auger drill rig and a track-mounted rig. The pressuremeter testing was conducted by Hughes Insitu Engineering Inc.

2 Site conditions

In general, the conditions at the four locations were geologically similar and of glacial origin. There were several feet of recent soft materials over sandy gravels and dense till with some silty layers. At most locations, the sandy gravels contained only a low percentage of cohesive fines. The general material descriptions of the pressuremeter test locations are presented in Table I.

3 Formation of the hole for the pressuremeter

In order to conduct a pressuremeter test, the pressuremeter must be inserted into the ground with minimal disturbance. In dense material, a hole has to be drilled which is as close as possible to the diameter of the pressuremeter. In materials which have only a limited amount of fines to act as a binder, it is very difficult to cut a hole which will both remain open and not collapse, and be of the appropriate diameter for a good pressuremeter test to be performed. As the displacement range of the three-inch diameter pressuremeter used was limited to a maximum diameter of four inches, a hole had to be cut and remain open at no larger than 3.3 inches to obtain useful data. To cut this hole, a 2-$^{15}/16$" tricone was used with thick drilling mud.

Because of the rapidly varying soil conditions, it was difficult to establish a procedure which was successful on all occasions. As a result, some 36 attempts were made. Only about half of these tests produced useful data. In many cases, the hole cut for the pressuremeter was either greater than four inches in diameter, or it collapsed such that the pressuremeter could not be placed in the pocket.

With the deeper tests below 30 feet in holes B222 and B223, the hole above the nominal three-inch diameter test pocket, which was drilled with a four-inch bit, collapsed or squeezed in at the 20-foot level, such that there was considerable difficulty withdrawing the pressuremeter from the hole. In both holes the outer shield was destroyed.

(In granular materials that are free from gravel, and have a SPT blowcount less then 20, a three-inch diameter self-boring pressuremeter can be used, in which the material displaced by the pressuremeter is washed or drilled up the inside of the pressuremeter. The self-boring pressuremeter would not have been able to penetrate in these dense materials, particularly with the presence of gravel.)

4 Pressuremeter

The pressuremeter used for this study is a monocell pressuremeter. At the center of the pressuremeter are three electronic displacement sensors, spaced 120 degrees apart. Over these sensors is the flexible membrane, clamped at each end, which is pressurized to deform the adjacent material. The membrane is covered by a protective sheet of stainless steel strips. The essential details of the instrument are shown in Figure 1. The electronic signals from displacement sensors and the pressure sensor are transmitted by cable to the surface. During the test, the average expansion against pressure curve is displayed on a computer screen.

Photograph 1 shows the pressuremeter assembled and ready to go be lowered into the hole. Photograph 2 shows the pressuremeter with the membrane and protective shield removed. One of the covers over a displacement sensor is visible in the middle of the pressuremeter.

The pressuremeter was expanded by controlling the flow of compressed nitrogen.

5 The pressuremeter test

In view of the difficulties in forming the test pocket, the pressuremeter test was varied, in an attempt to coax as much information out of the test before one of the displacement sensors reached its limit.

For discussion purposes, consider the two tests shown in Figure 2 – one in silty sand, and the other in silt/clay, both at about the same depth. The maximum pressure for the silty sand is over 300 psi. whereas that for the silty clay is lower (less than 200 psi). The slope of the unload-reload loops in the silty sand steepen as the strain and pressure increases. However, the last two loops tend to be parallel. In ideal tests, in which there is little disturbance, all these loops tend to be parallel. In disturbed material, successive slopes steepen and tend to reach a limit close to the undisturbed state. In Figure 2a the last two loops are similar, between 12,000 and 13, 000 psi. In Figure 2b, the two loops are almost parallel, between 4,000 and 4,500 psi. Hence, there is possibly less disturbance in Figure 2b.

Therefore, the aim is to try and determine the likely maximum slope of the unload-reload loops from which the shear modulus can be calculated. These values have been tabulated in Table II. In this table some of the tests are still in very disturbed material, particularly in Hole HC00-B222. Hence, the modulus presented can only be considered a lower limit in these materials.

The other feature of the Figure 2 test is to note that the pressure in the silt/clay tends to a limit pressure at 170 psi, whereas the pressure in the silty sand test is still rising. In cohesive material, the pressure tends to a limit pressure at much less strain than a purely frictional material. This tends to confirm that the test in Figure 1b is indeed in a more cohesive material, as indicated by the drill logs.

To gain some indication of the strength properties the field data is compared to the ideal pressuremeter test derived from a frictional or a cohesive model. In Figure 3 the field pressuremeter test in the silty clay test shown in Figure 2b is compared with a frictional model (Figure 3a) and a cohesive model (Figure 3b). If the material surrounding the pressuremeter has not been disturbed, then in general the shape of the ideal pressuremeter curve follows the same form as shown in Figure 5 in Appendix II. However, as illustrated in Figure 3, the match is poor. Hence, this modeling process essentially can only be used to develop an ideal pressuremeter curve which envelops the field data.

Hence this simple analysis would indicate that the silt/clay has a friction angle of 38 degrees and no cohesion or a cohesive strength of 48 psi and no friction. Using this process limits can be set on the possible mechanical properties. However as some judgement is required in this curve matching process the results should be viewed with caution.

6 References

General Reference on Pressuremeter Tests

Mair, R.J. and Wood, D.M. 1987. Pressuremeter testing: methods and interpretation. CIRIA Ground Engineering Report. Butterworths, London.

Hughes, J.M.O. 1999. Pressuremeter testing in tills and glacially-consolidated granular materials. 52nd Canadian Geotechnical Conference, Regina, Saskatchewan.

Table 1. Material types and SPT values at pressuremeter locations					
Date	**Hole**	**Test**	**Depth (ft)**	**Material** [5]	**SPT** [5]
May 17	HC00-B222				
		HC2	15.5	Gravelly clay	29
		HC3	14	Gravelly clay	29
		HC4	23.5	Gravel	66
		HC6	36.5	Gravel sand outwash	50/5"
May 18	HC00-B225				
		HC7	9	clayey silt	23
		HC8	14	sandy silt	32
		HC9	19	till	50/6"
		HC10	24	till	50/6"
		HC11	33	till	50/6"
May 19	HC00-B221				
		HC12	9.5	till	65
		HC16	17	silty sand	23
		HC17	30	silt/clay	34
		HC18	28.5	silt/clay	34
		HC19	40	silt/clay	36
May 22	HC00-B224				
		HC24	24	till	50/4"
		HC25	35	till	50/3"
May 23	HC00-B220				
		HC26	8	silty clay	42
		HC28	30	silty/sand	50/5"
		HC29	40	sand	89/11"
May 24	HC00-B223				
		HC31	9	silty sand	16
		HC34	24	till	50/2"

Table II. Unload-reload shear modulus and estimate of strength properties					
Date	**Hole**	**Test**	**Depth [1] (ft)**	**Shear modulus [3] (psi)**	**Friction angle [4]**
May 17	HC00-B222				
		HC2	15.5	>1,000 [2]	-
		HC3	14	>1,000 [2]	-
		HC4	23.5	>5,500 [2]	>38
		HC6	36.5	>5,000 [2]	>38
May 18	HC00-B225				
		HC7	9	12,000	40
		HC8	14	4,000	>40
		HC9	19	9,500	>40
		HC10	24	25,000	>40
		HC11	33	17,000	>40
May 19	HC00-B221				
		HC12	9.5	2,500	>40
		HC16	17	>1,200 [2]	-
		HC17	30	5,500	38
		HC18	28.5	4,500	38
		HC19	40	11,000	>40
May 22	HC00-B224				
		HC24	24	>10,000	>40
		HC25	35	12,000	>40
May 23	HC00-B220				
		HC26	8	>1,200	38
		HC28	30	12,000	>40
		HC29	40	10,000	>40
May 24	HC00-B223				
		HC31	9	>1,000	>40
		HC34	24	17,000	>40

Notes:

1 Depth recorded in Table is at the bottom of the pressuremeter. The center of the pressuremeter is 1.5 feet back.

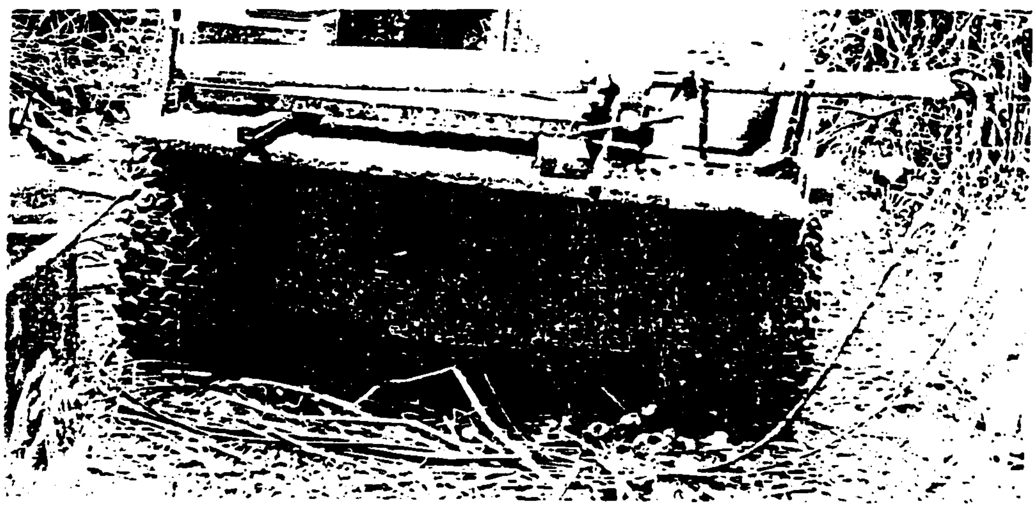
2 These tests are in disturbed material. The modulus measured will be lower than the undisturbed modulus.

3 The shear modulus has been determined form the unload reload portions of the pressuremeter curve. This shear modulus is the secant shear modulus which is applicable over a strain range of 0 to 0.5 %.

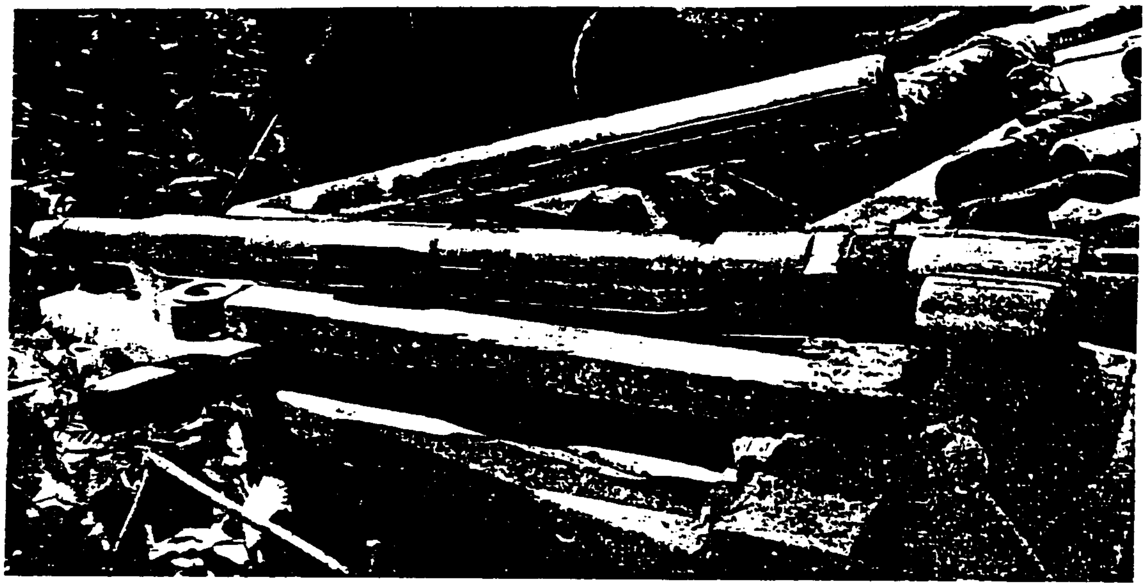
4 The friction angle has been estimated by comparing an ideal pressuremeter curve to the field data. In view of the disturbance in many of the tests, the match is not well defined. Hence, the frictional angle cannot be determined with certainty. The lower limit of the friction angle has been presented in the table.

In Test HC18, a simple cohesive model would indicate a shear strength of 48 psi and no cohesion. However, this cohesion would be applicable for short-term loading only.

5 The material identification has been estimated from the samples taken either above or below the pressuremeter test level.



Photograph 1 Pressuremeter on back of all-terrain support vehicle



Photograph 2 Pressuremeter with membrane removed. Displacement sensor cover in center of the pressuremeter and stainless steel shield in background behind instrument.

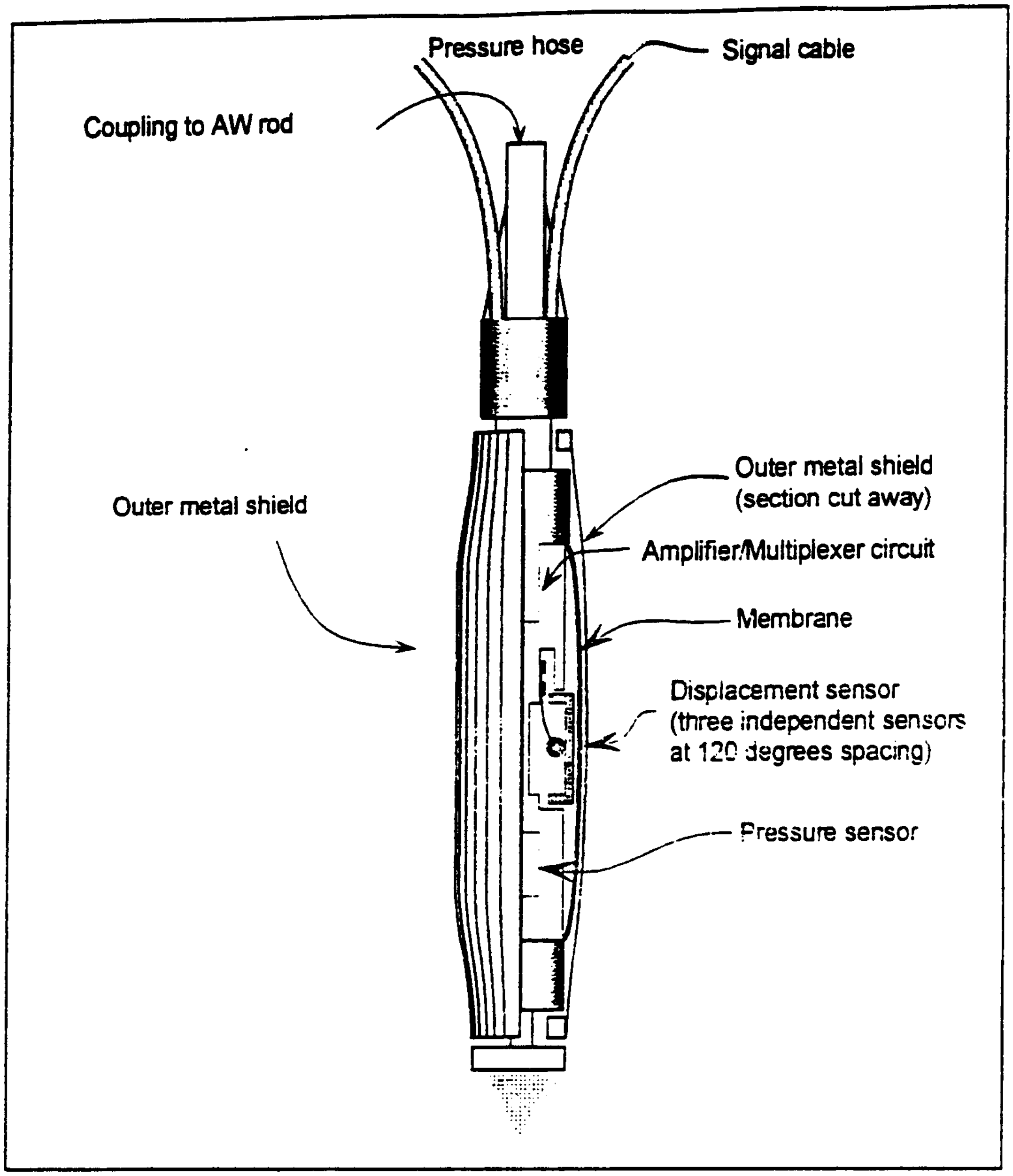


Figure 1

Schematic Outline of Pressuremeter

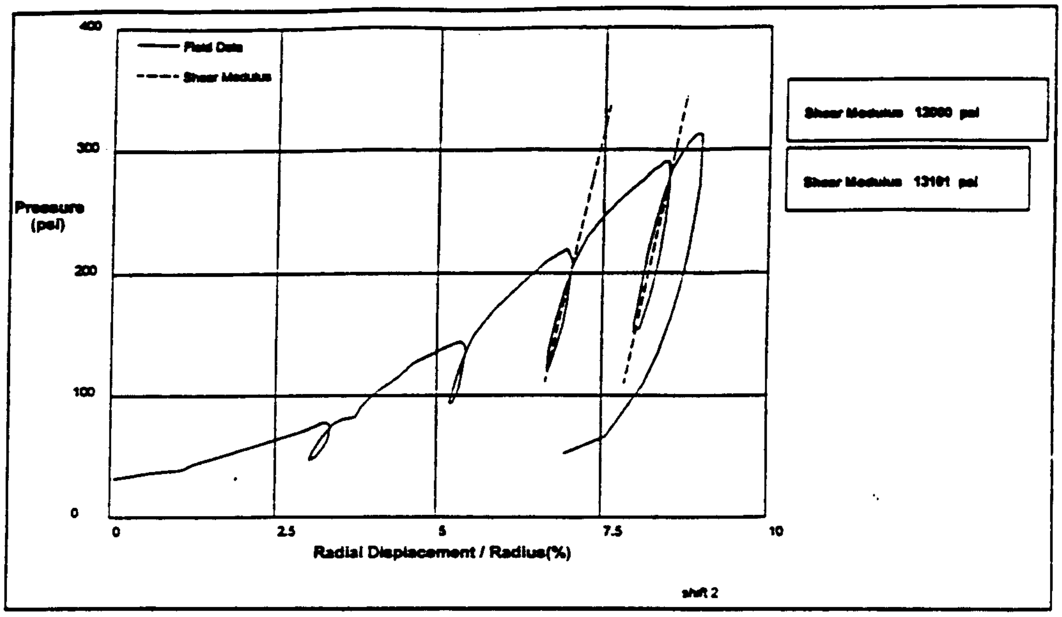


Figure 2a Test HC28 in silty sand at 30 ft in hole HC00-220

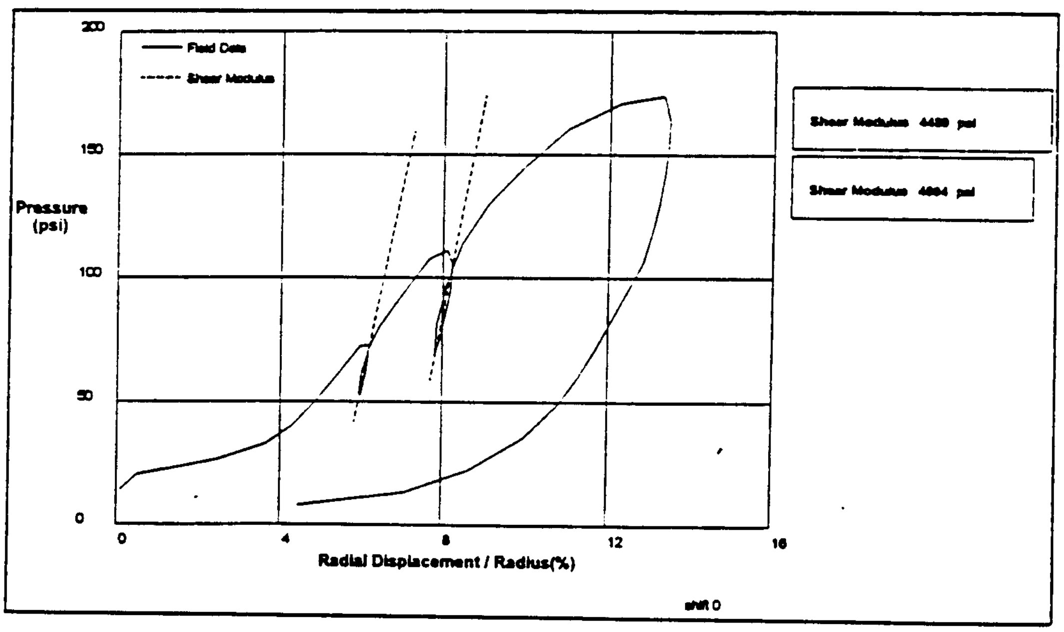


Figure 2b Test HC18 in silt/ clay at 28.5 ft in hole HC00-221

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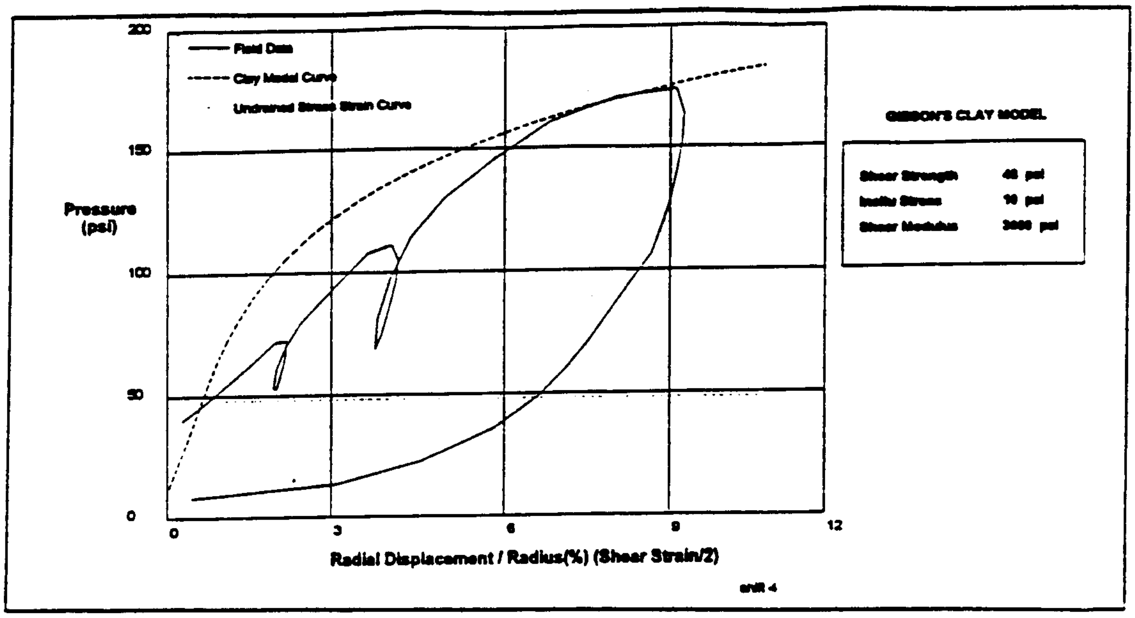

Figure 3a Cohesive model analysis for test HC18

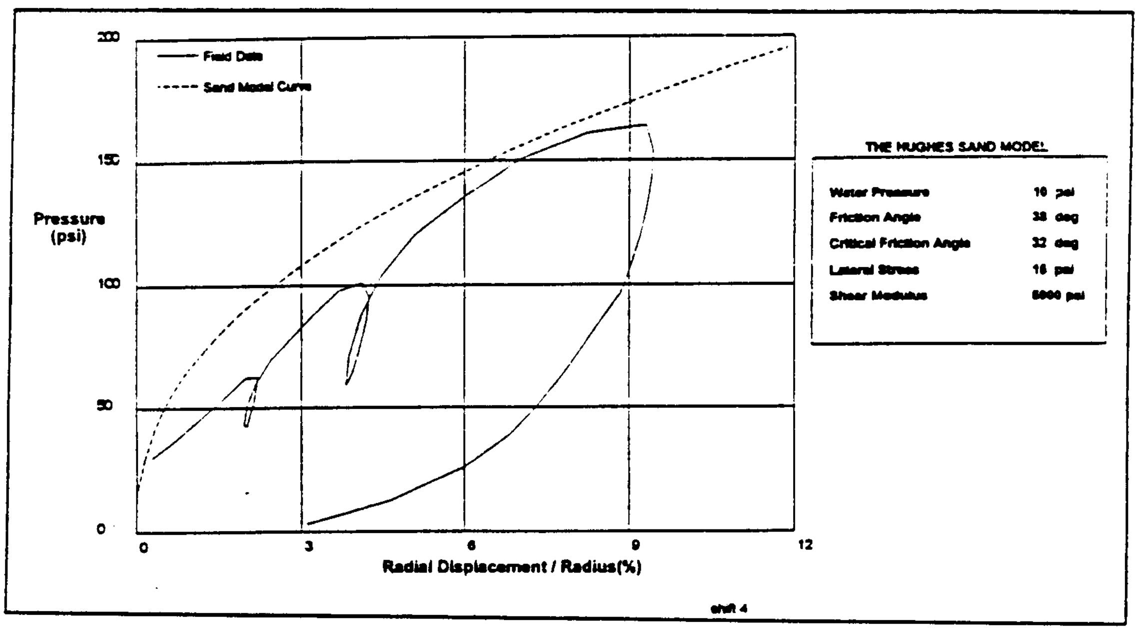

Figure 3b Frictional model analysis for test HC18

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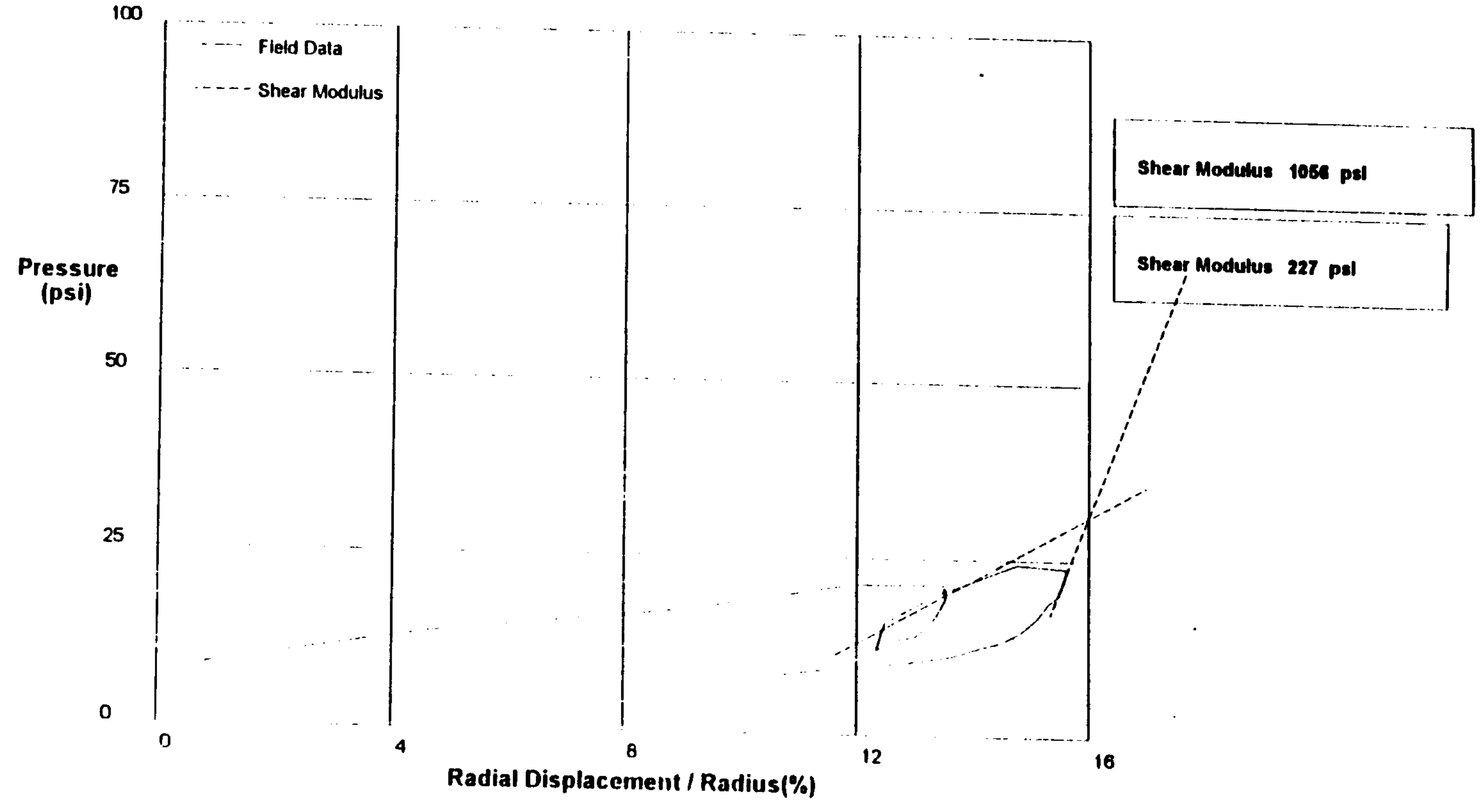
Appendix I

Basic pressuremeter data and strength determination.

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 17, 2000**

Hole No. HC00-B222 Depth 15.5 ft **File C:\DATA\C-219\HC2.P**

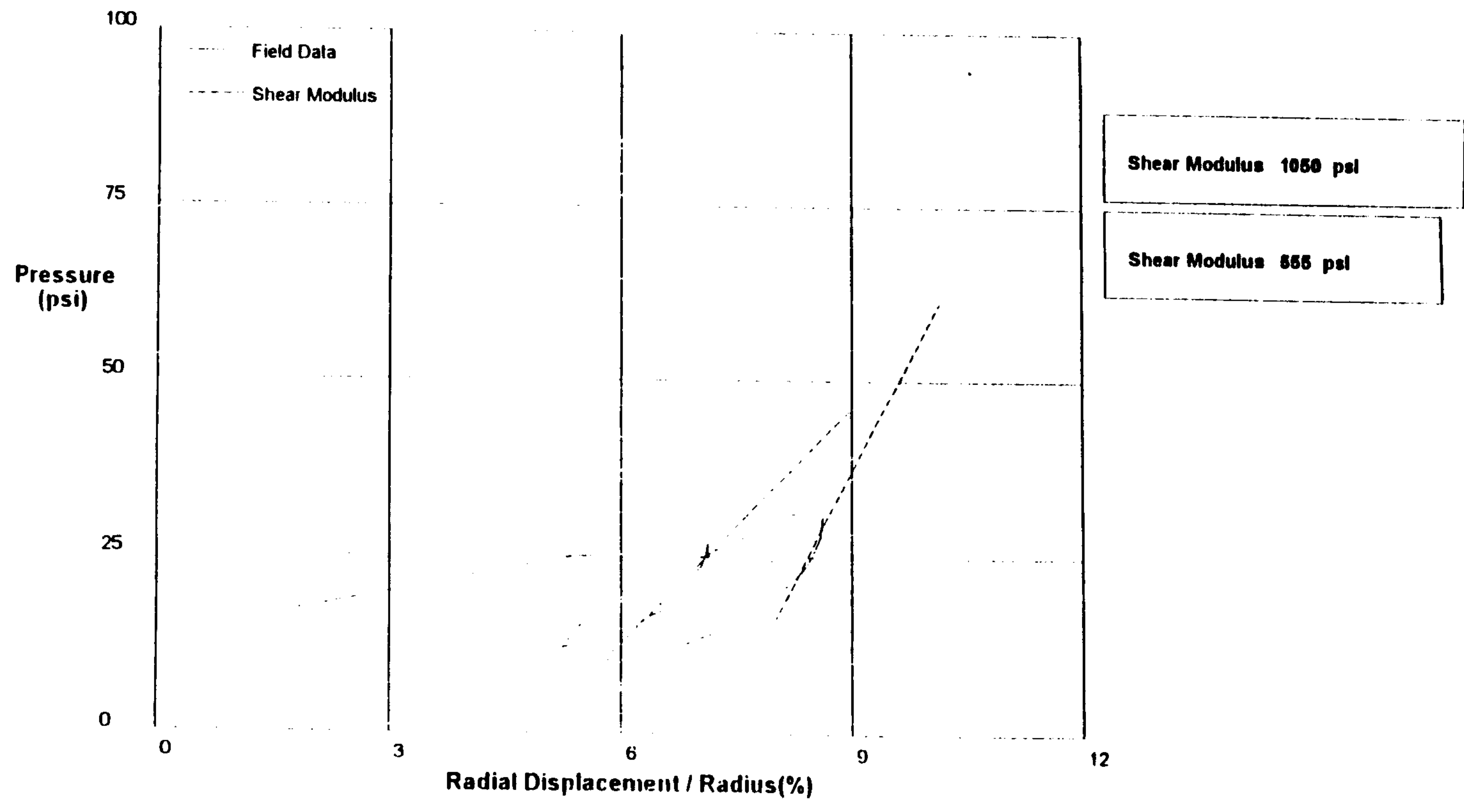


HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 17, 2000**

Hole No. HC00-B222 Depth 14 ft **File C:\DATA\C-219\HC3.P**



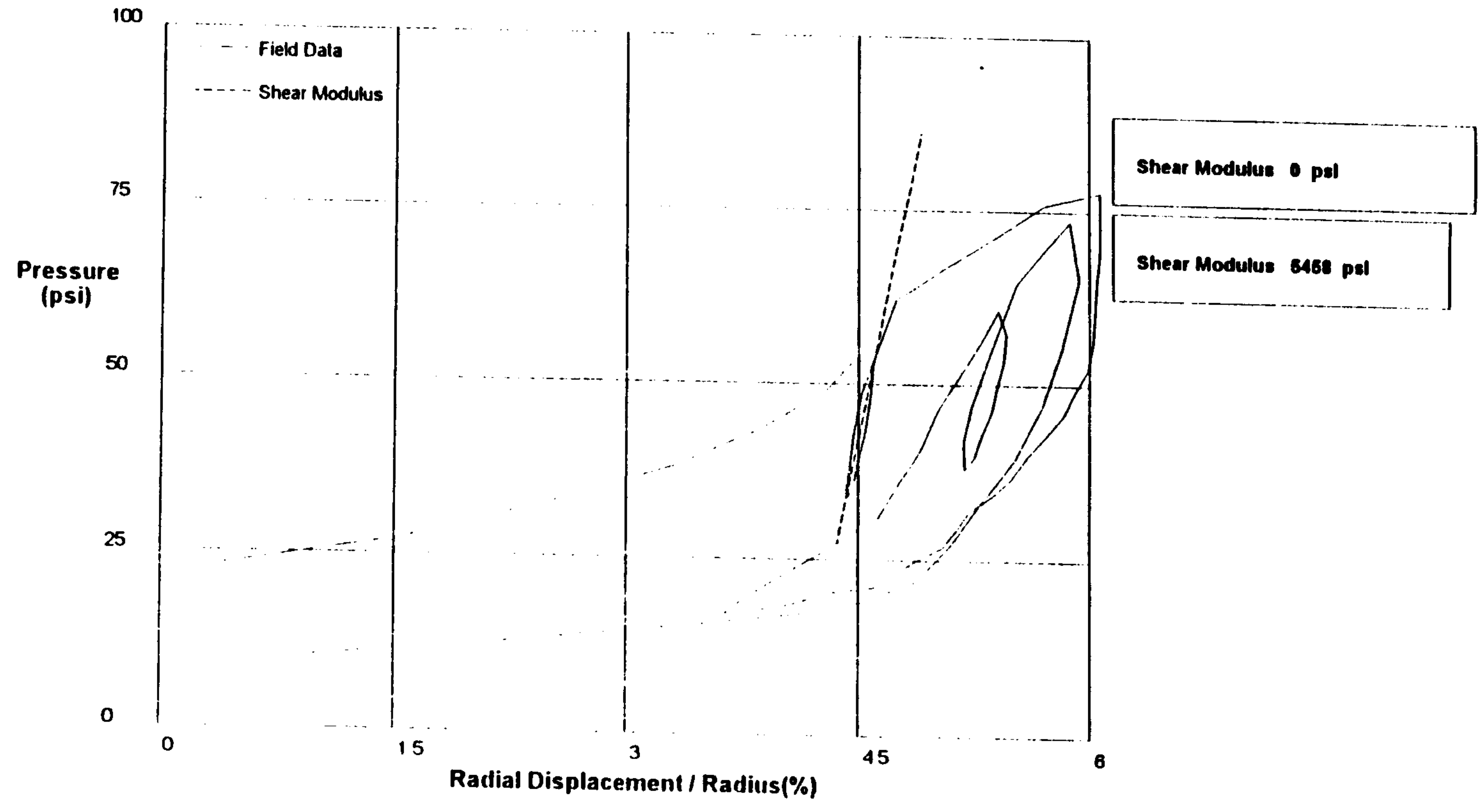
shift 8

HUGHES

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 17, 2000

Hole No. HC00-B222 Depth 23.6 ft File C:\DATA\C-219\HC4.P



shift 2

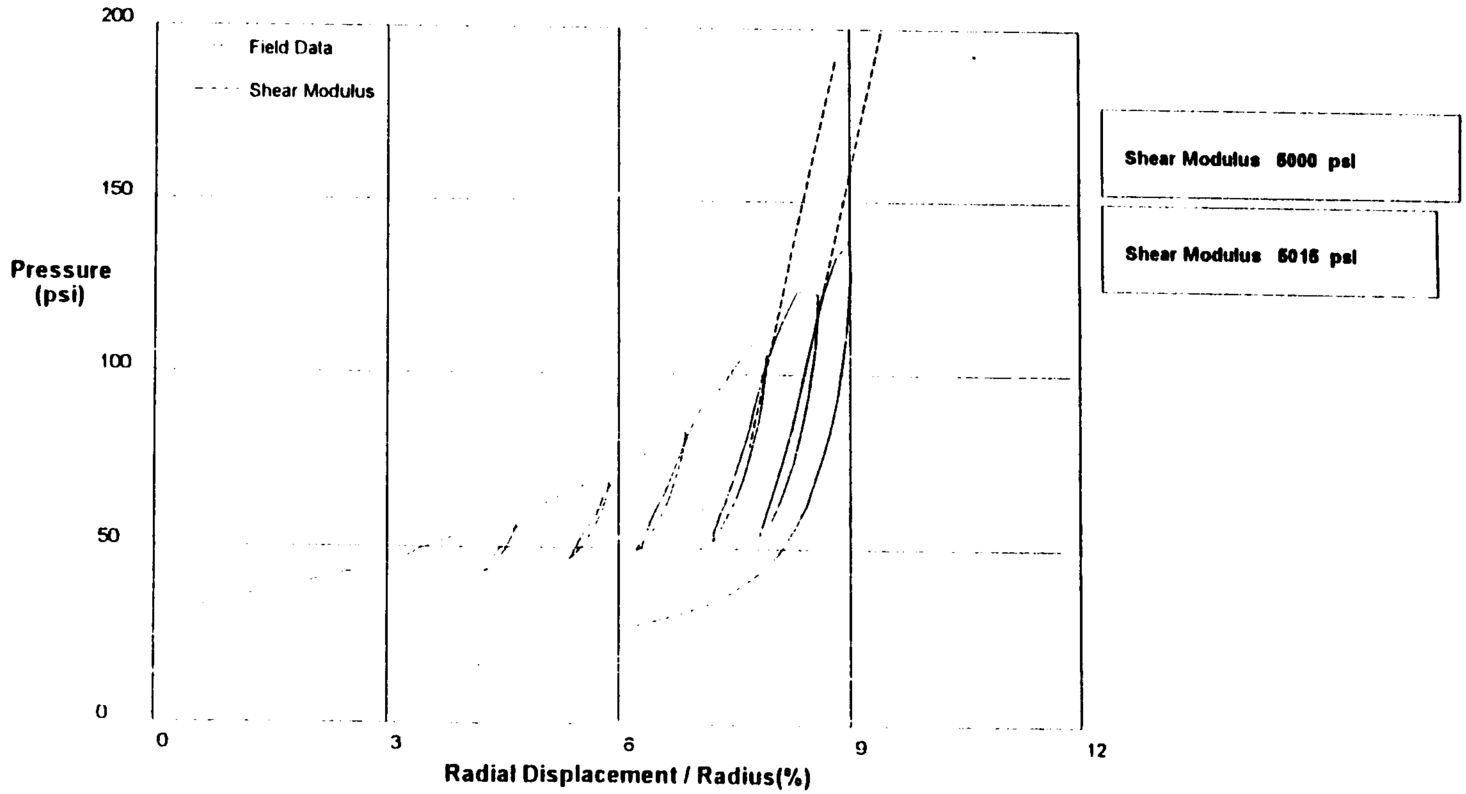
HUGHES

AR 045932

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 17, 2000

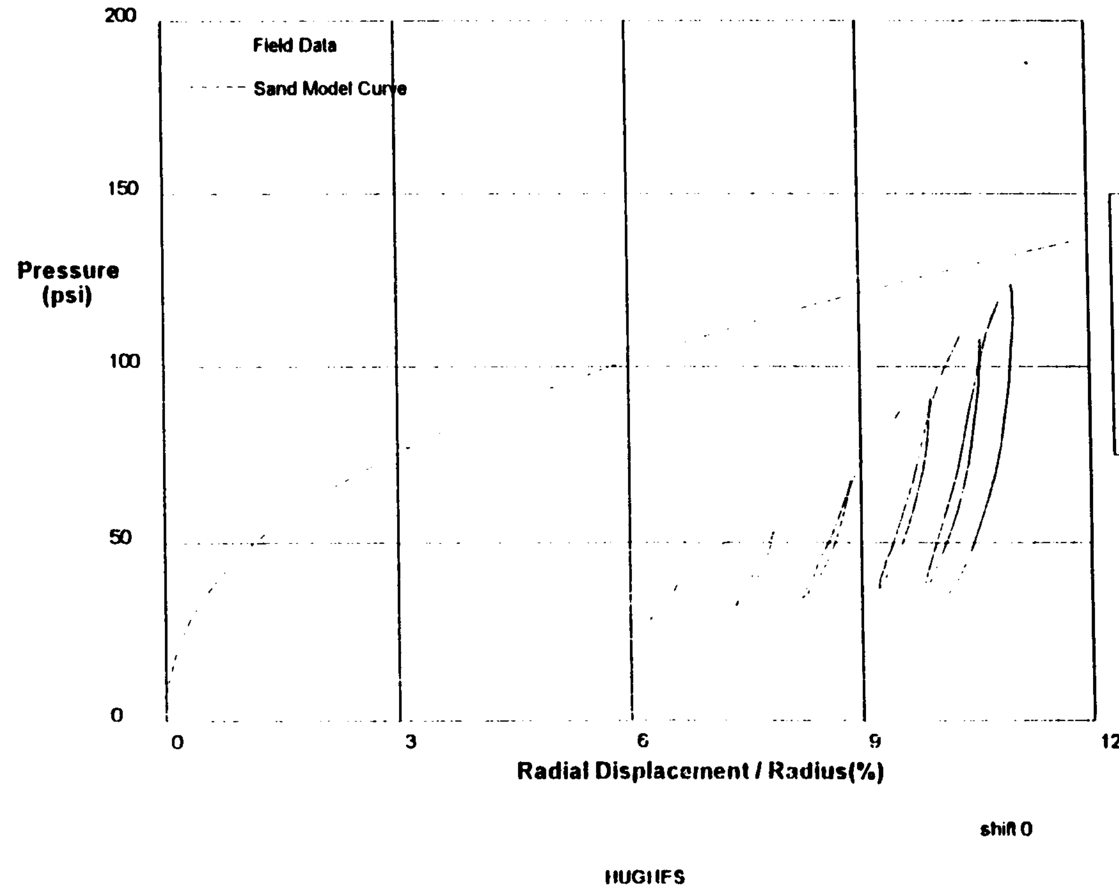
Hole No. HC00-B222 Depth 36.5 ft File C:\DATA\C-219\HC6.P



shift 2

HUGHES

PRESSUREMETER DATA	**Hart Crowser, Inc.**	
Seatac Airport Third Runway		**May 17, 2000**
Hole No. HC00-B222	**Depth 36.5 ft**	**File C:\DATA\C-219\HC6.P**



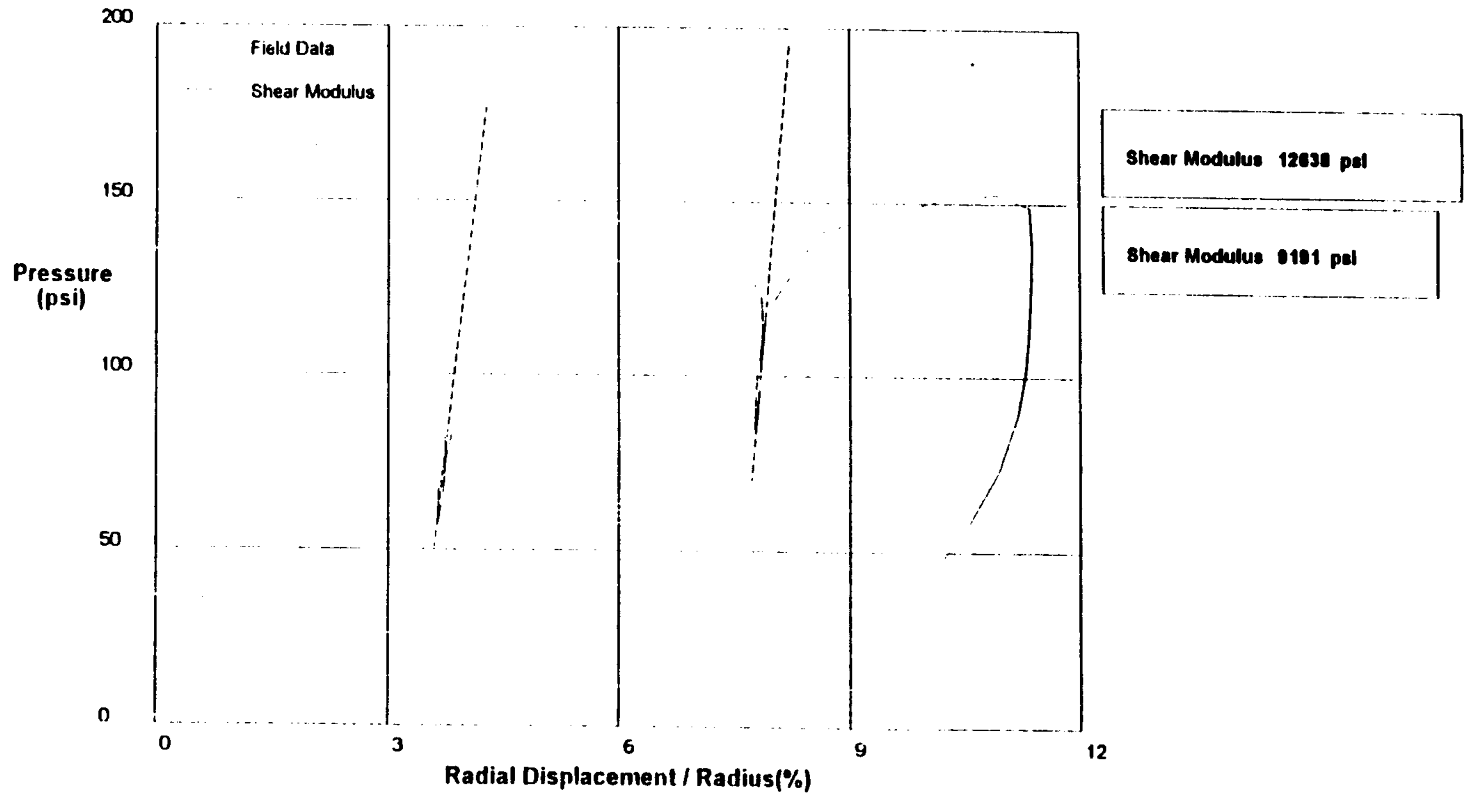
THE HUGHES SAND MODEL

Water Pressure	16 psi
Friction Angle	38 deg
Critical Friction Angle	32 deg
Lateral Stress	8 psi
Shear Modulus	5000 psi

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 18, 2000

Hole No. HC00-B226 Depth 9 ft File C:\DATA\C-219\HC7.P



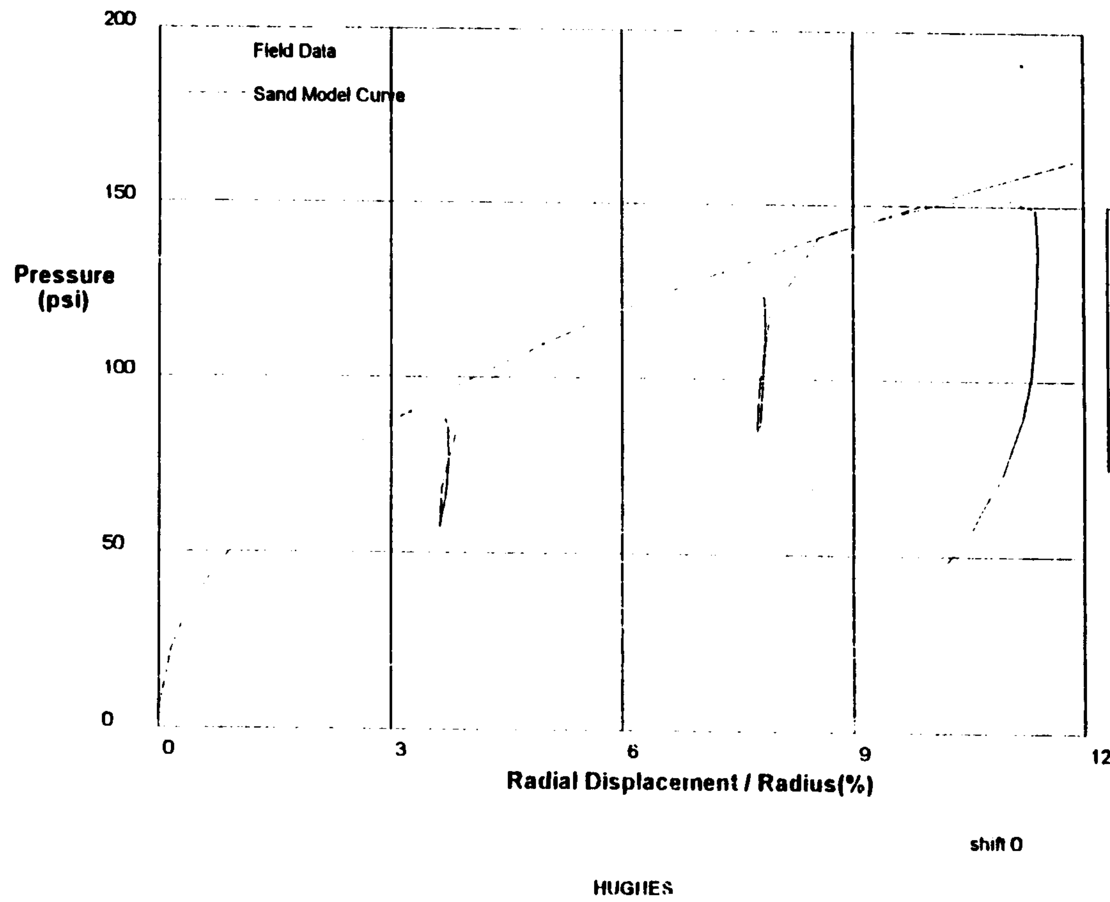
shift 0

HUGHES

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 18, 2000

Hole No. HC00-B225 Depth 9 ft File C:\DATA\C-219\HC7.P



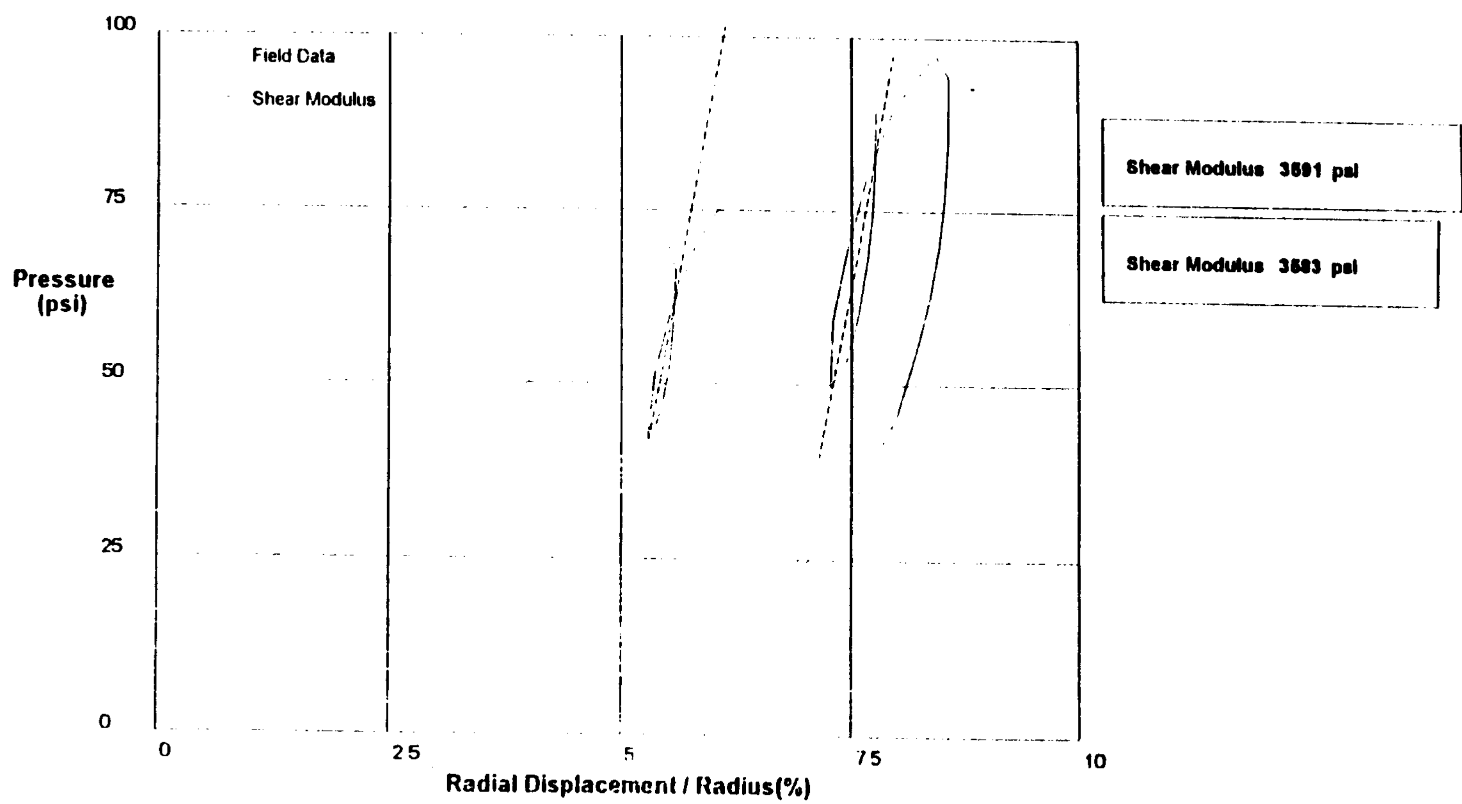
THE HUGHES SAND MODEL

Water Pressure	0 psi
Friction Angle	40 deg
Critical Friction Angle	32 deg
Lateral Stress	5 psi
Shear Modulus	9191 psi

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway **May 18, 2000**

Hole No. HC00-B225 Depth 14 ft **File C:\DATA\C-219\HC8.P**



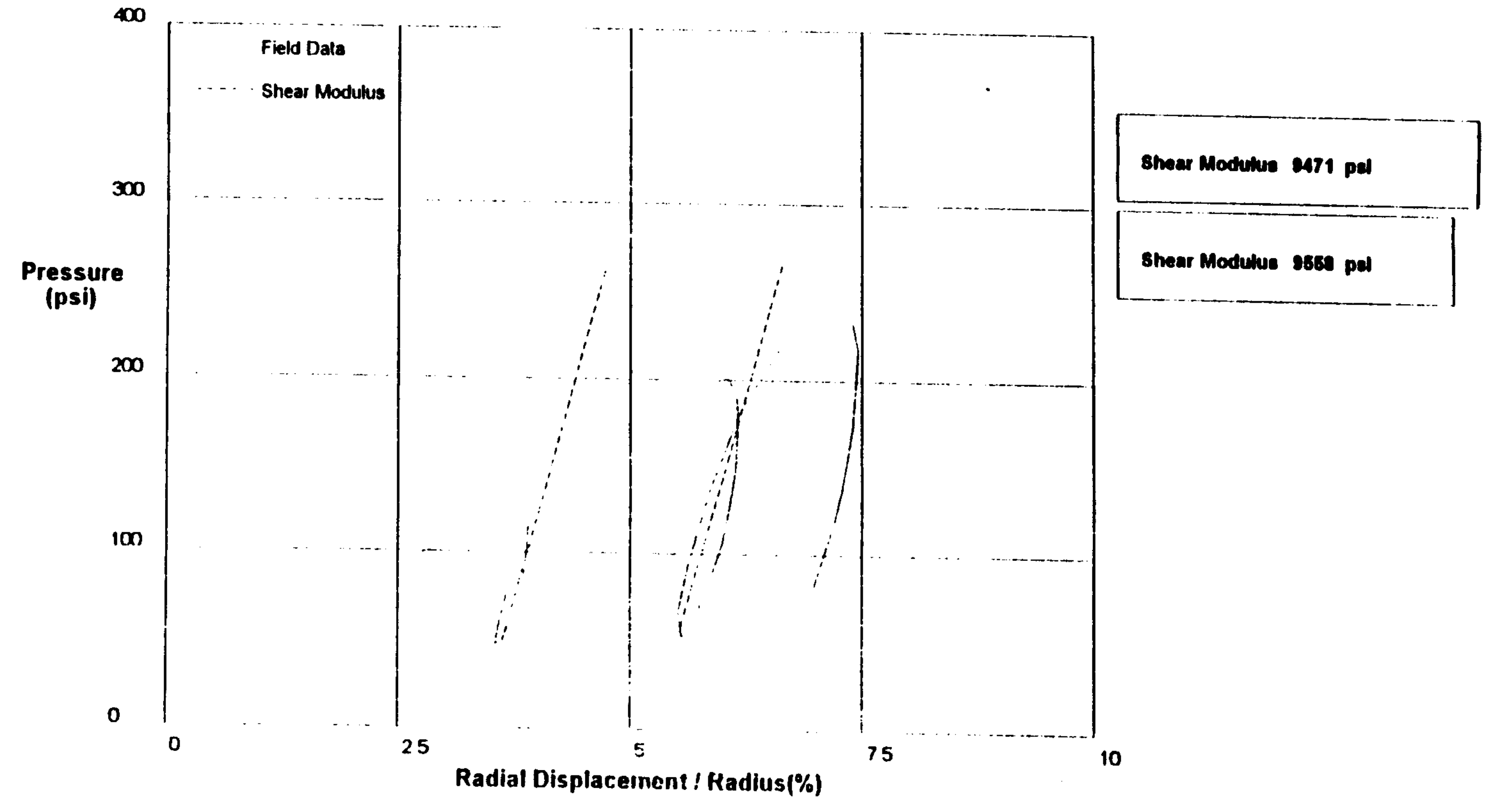
shift 7

HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway May 18, 2000

Hole No. HC00-B225 Depth 19 ft File C:\DATA\C-219\HC9.P



shift 6

HUGHES

PRESSUREMETER DATA

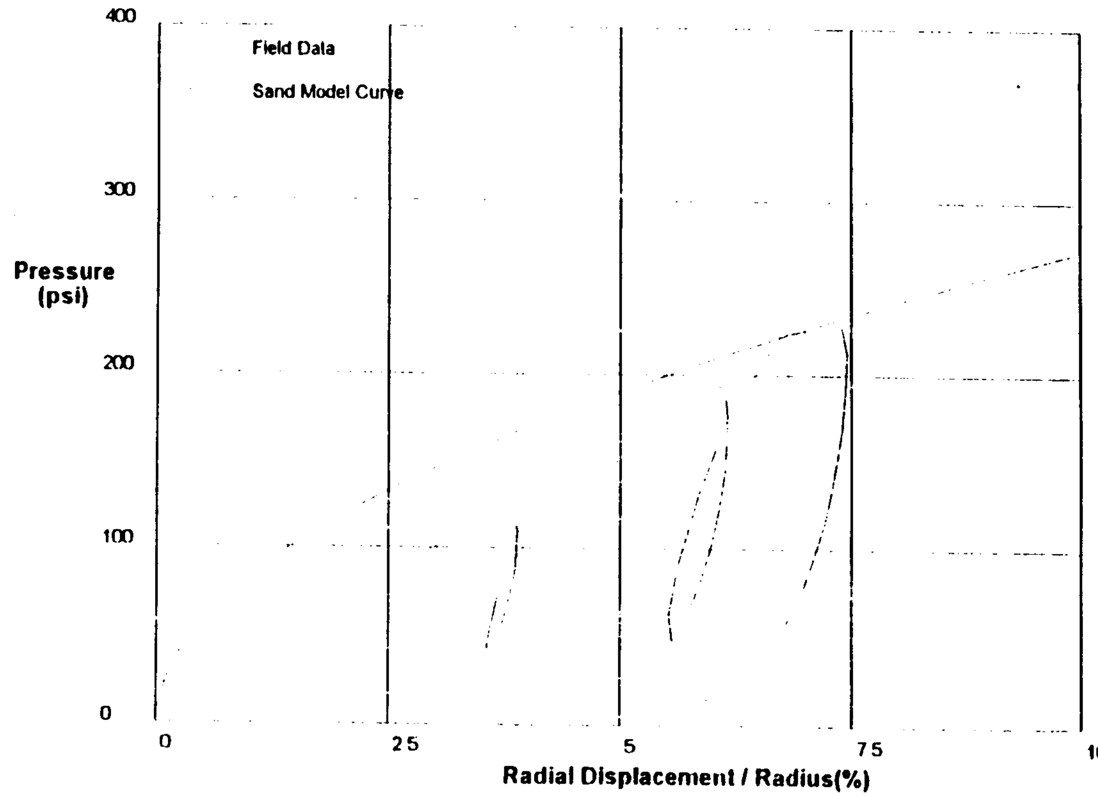
Hart Crowser, Inc.

Seatac Airport Third Runway

May 18, 2000

Hole No. HC00-B226 Depth 19 ft

File C:\DATA\C-219\HC9.P



THE HUGHES SAND MODEL

Water Pressure	6 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	8 psi
Shear Modulus	9191 psi

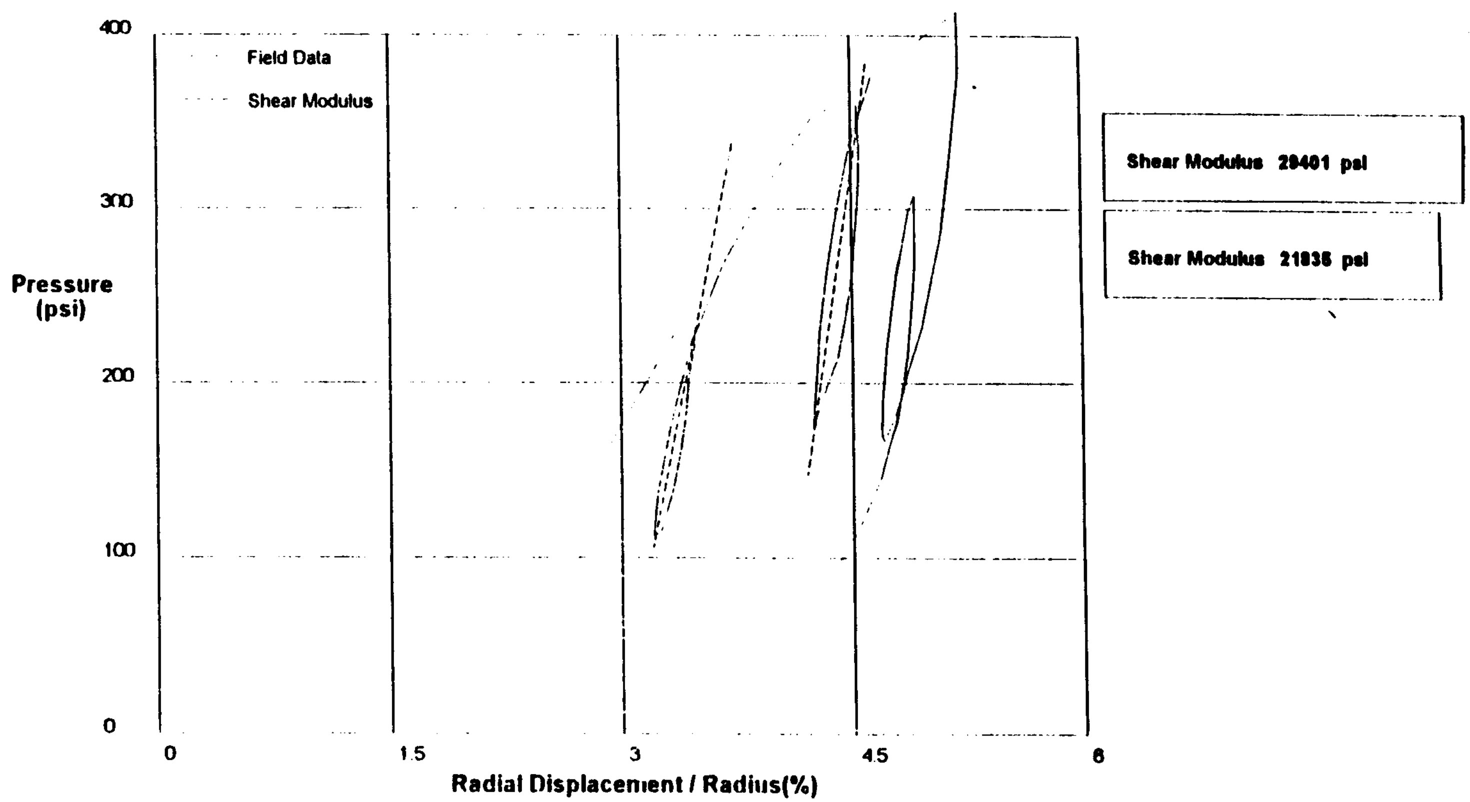
shift 6

HUGHES

PRESSUREMETER DATA — Hart Crowser, Inc.

Seatac Airport Third Runway — May 18, 2000

Hole No. HC00-B225 — Depth 24 ft — File C:\DATA\C-219\HC10Z.P



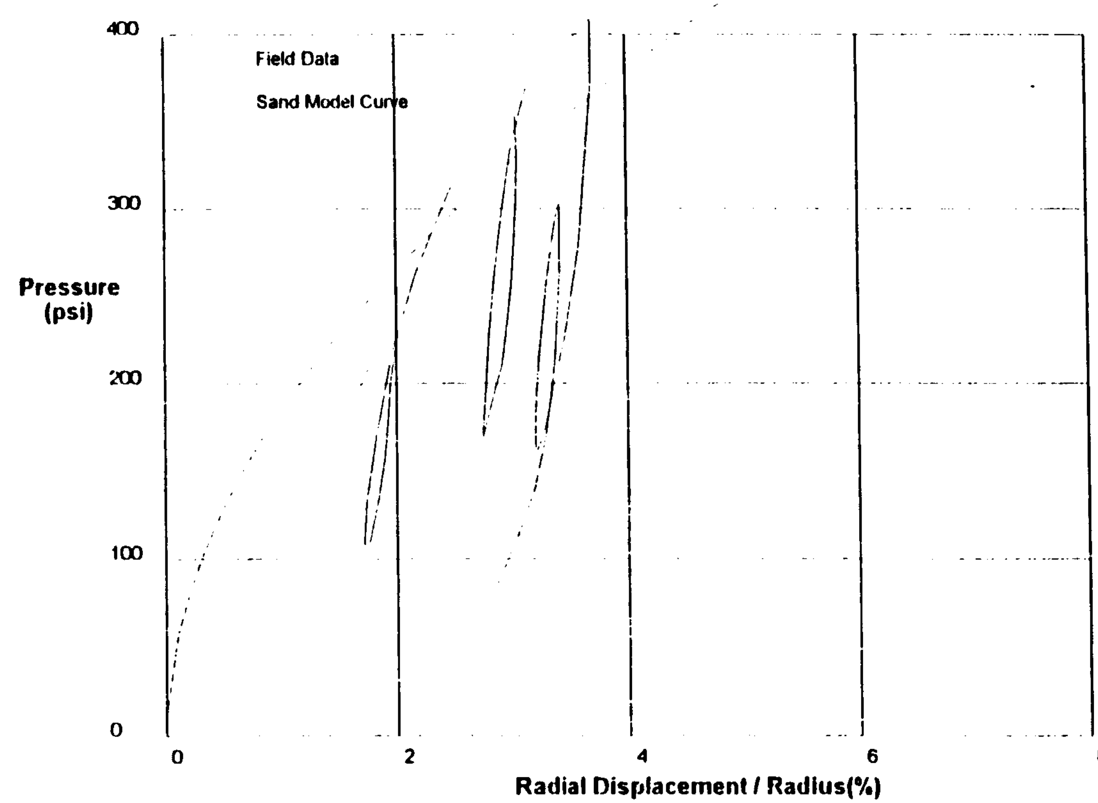
shift 2

HUGHES

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 18, 2000

Hole No. HC00-B225 Depth 24 ft File C:\DATA\C-219\HC10Z.P



THE HUGHES SAND MODEL

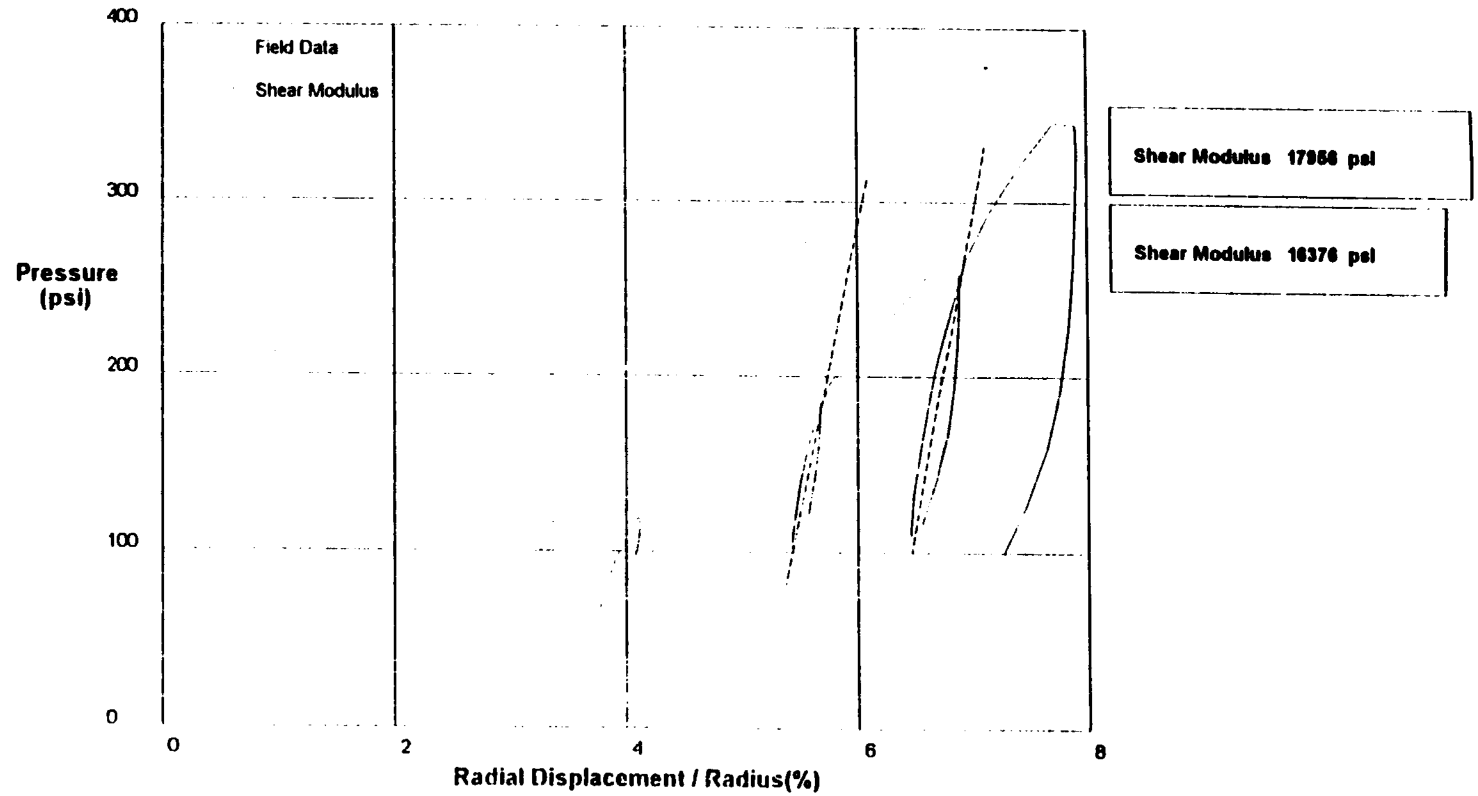
Water Pressure	6 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	12 psi
Shear Modulus	30000 psi

shift 3 5

HUGHES

AR 045941

PRESSUREMETER DATA	Hart Crowser, Inc.
Seatac Airport Third Runway	May 18, 2000
Hole No. HC00-B226 Depth 33 ft	File C:\DATA\C-219\HC11.P



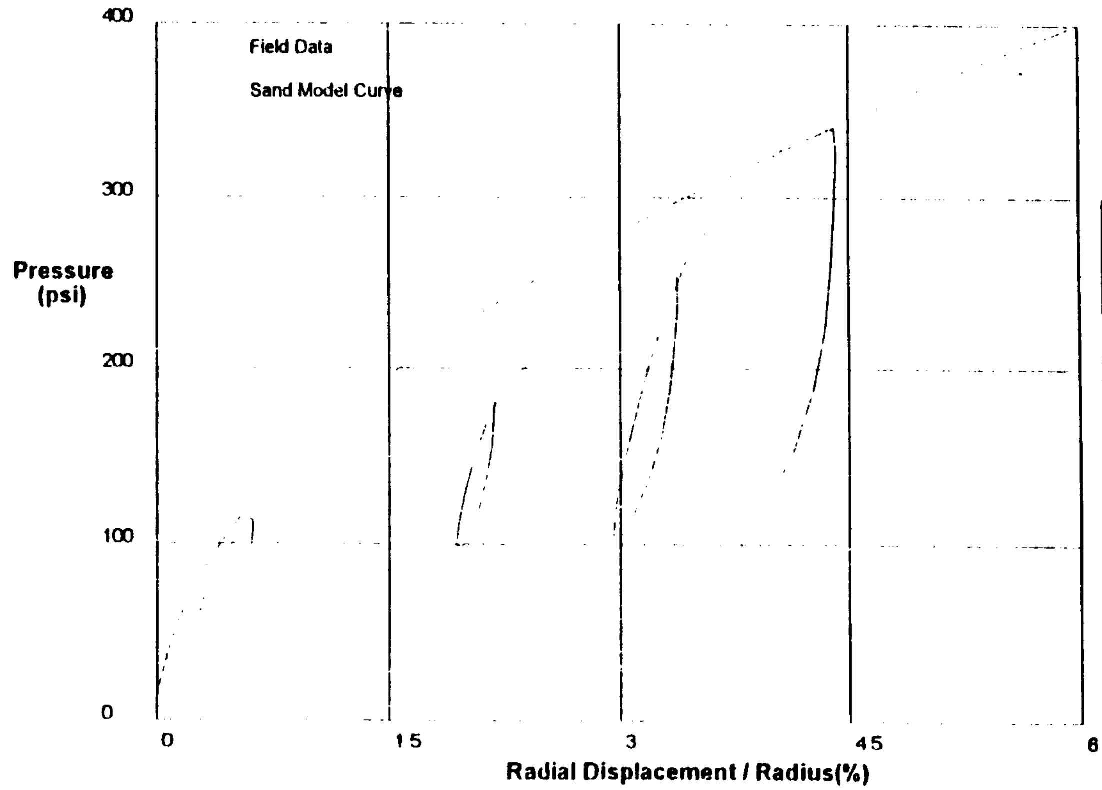
HUGHES

AR 045942

PRESSUREMETER DATA | **Hart Crowser, Inc.**

Seatac Airport Third Runway | May 18, 2000

Hole No. HC00-B226 Depth 33 ft | File C:\DATA\C-219\HC11.P

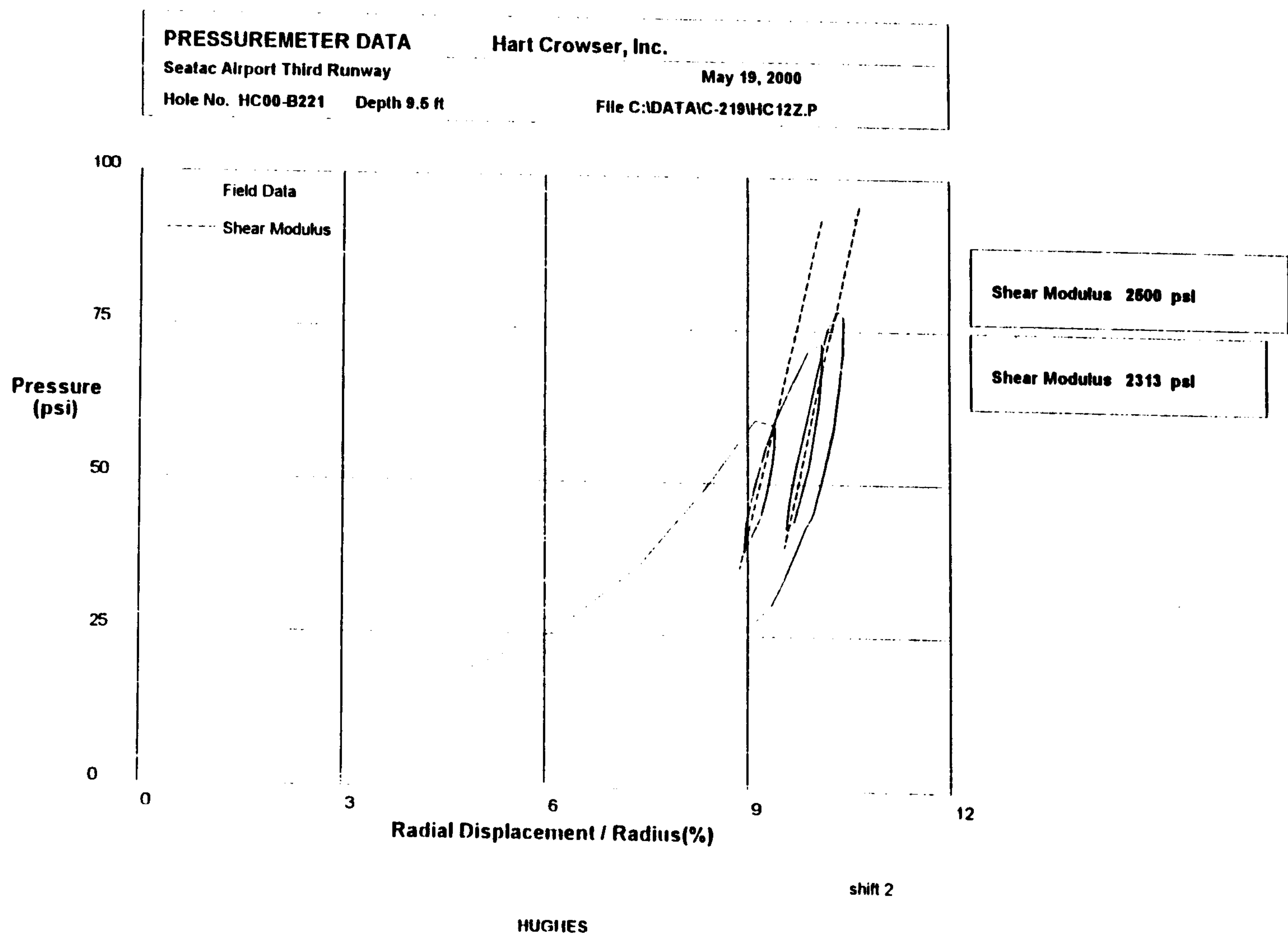


THE HUGHES SAND MODEL

Water Pressure	5 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	16 psi
Shear Modulus	18000 psi

shift 7

HUGHES

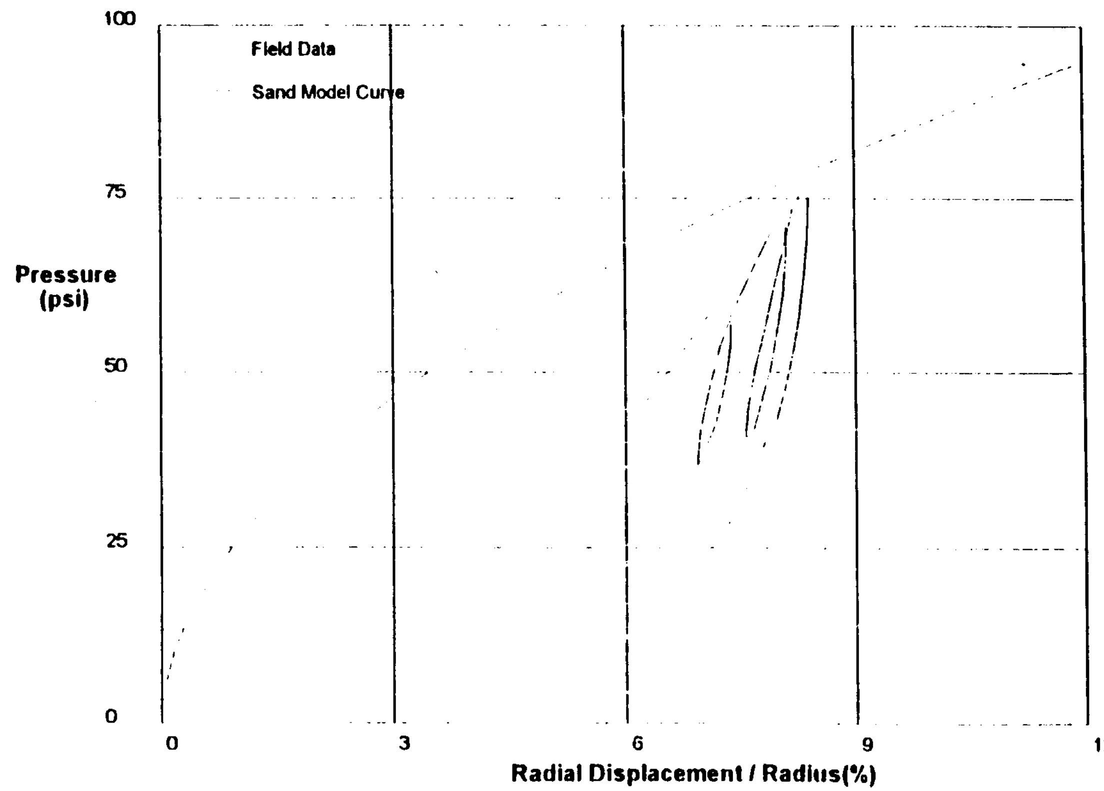


PRESSUREMETER DATA
Hart Crowser, Inc.
Seatac Airport Third Runway
May 19, 2000
Hole No. HC00-B221
Depth 9.5 ft
File C:\DATA\C-219\HC12Z.P
Field Data
Shear Modulus
Shear Modulus 2500 psi
Shear Modulus 2313 psi
Pressure (psi)
100
75
50
25
0
0
3
6
9
12
Radial Displacement / Radius(%)
shift 2
HUGHES

PRESSUREMETER DATA | **Hart Crowser, Inc.**

Seatac Airport Third Runway | May 19, 2000

Hole No. HC00-B221 | Depth 9.5 ft | File C:\DATA\C-219\HC12Z.P



THE HUGHES SAND MODEL

Water Pressure	2 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	3 psi
Shear Modulus	2600 psi

shift 4

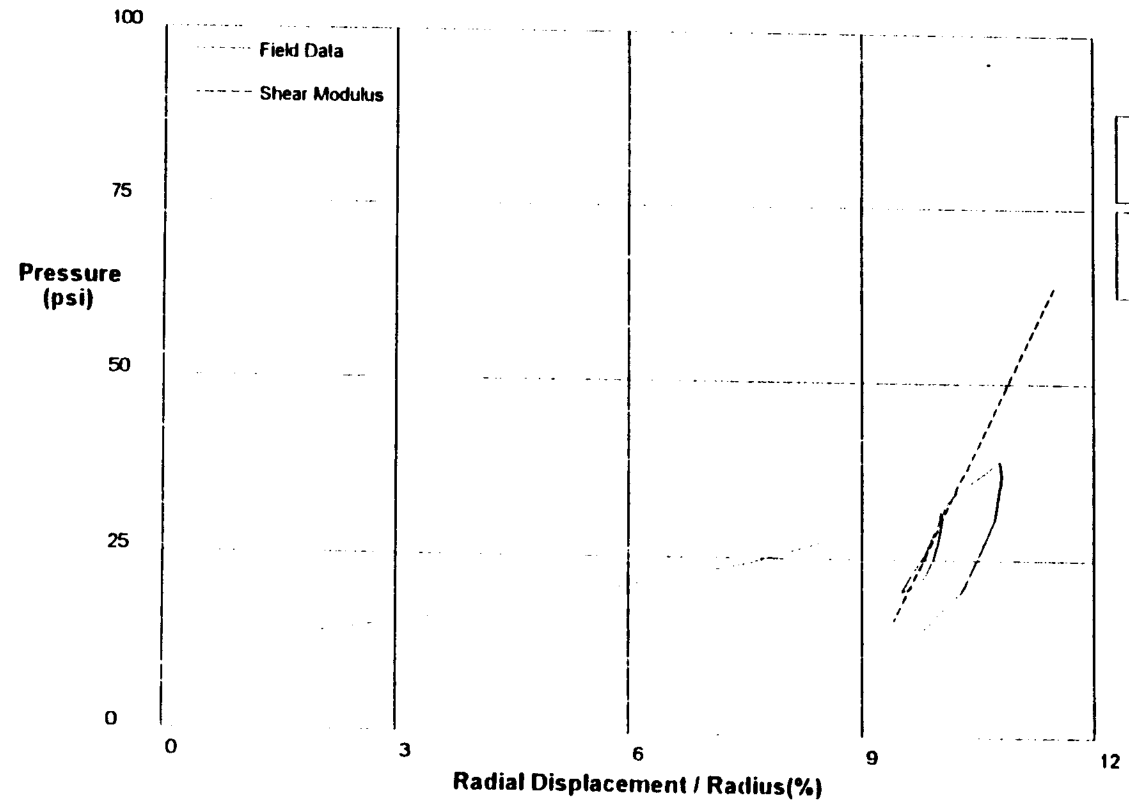
HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway

May 19, 2000

Hole No. HC00-B221 Depth 17 ft File C:\DATA\C-219\HC16.P



Shear Modulus 0 psi

Shear Modulus 1135 psi

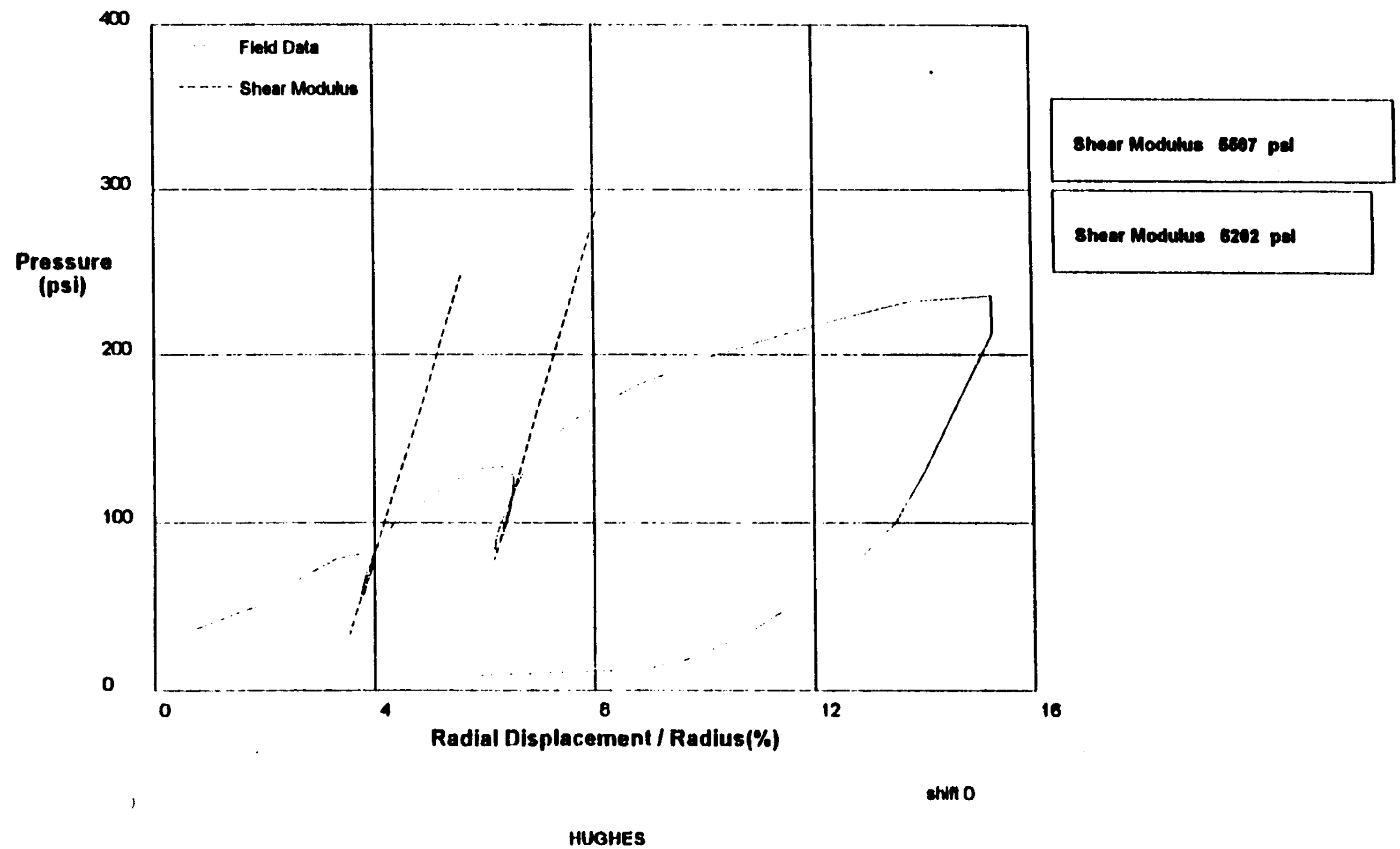
shift 2

HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 19, 2000**

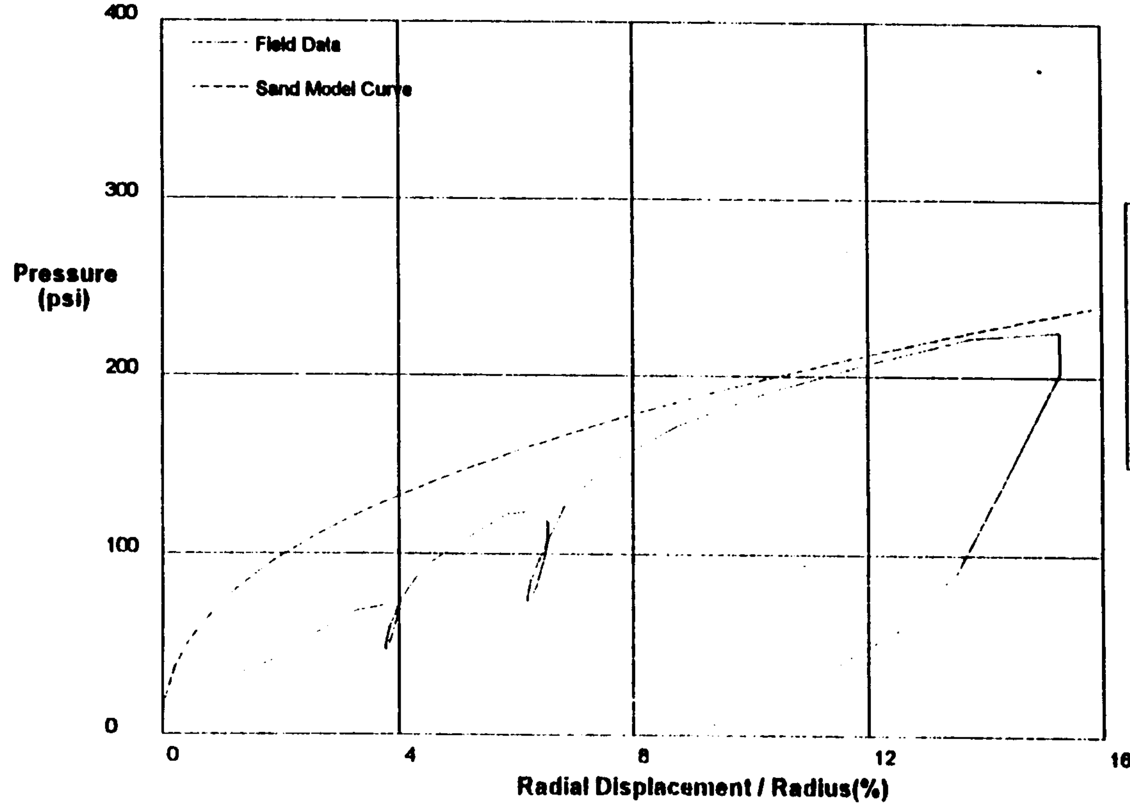
Hole No. HC-221 **Depth 30 ft** **File C:\DATA\C-219\HC17.P**



PRESSUREMETER DATA — Hart Crowser, Inc.

Seatac Airport Third Runway — May 19, 2000

Hole No. HC-221 — Depth 30 ft — File C:\DATA\C-219\HC17.P



shift 0

HUGHES

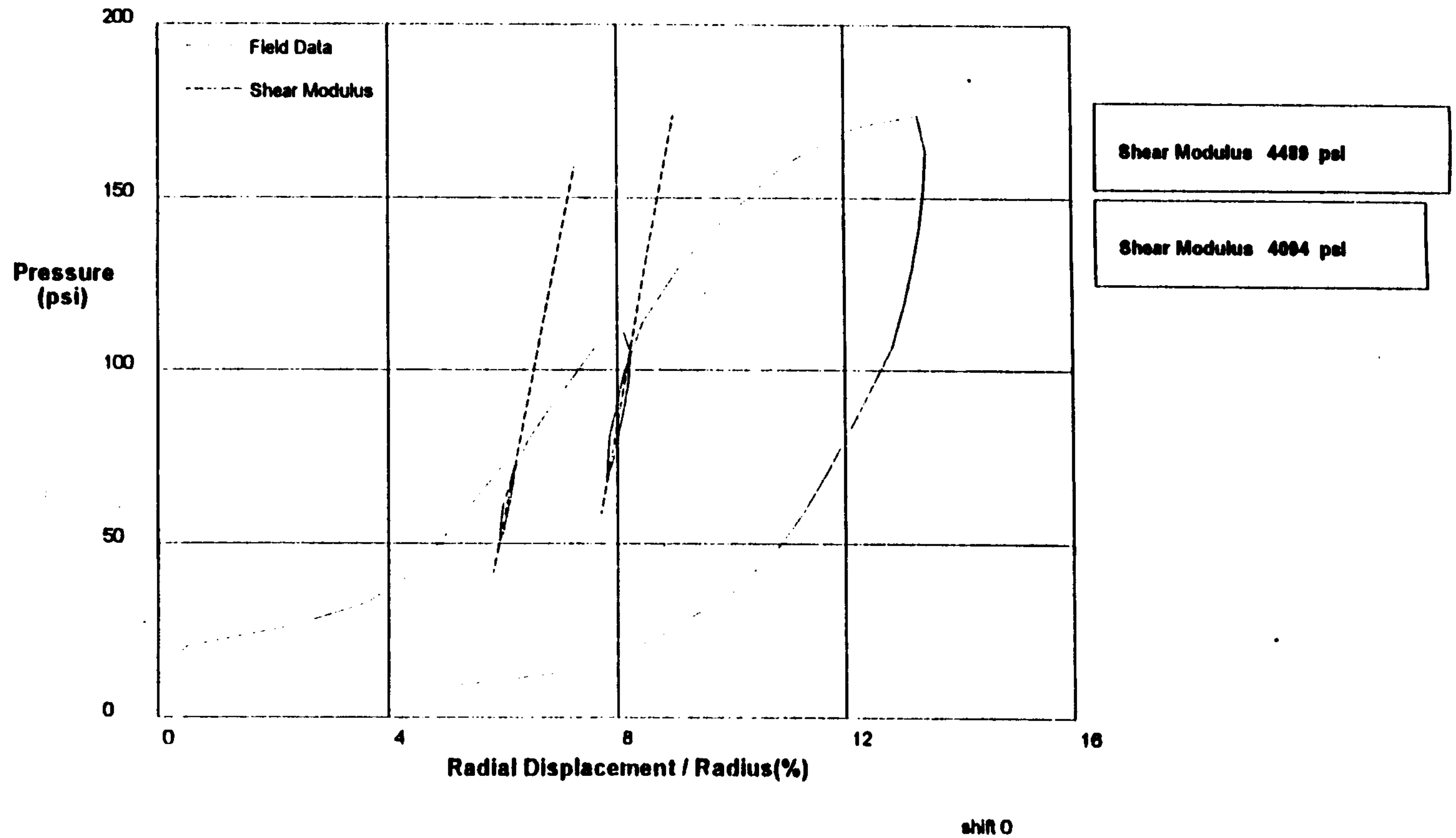
THE HUGHES SAND MODEL

Water Pressure	10 psi
Friction Angle	38 deg
Critical Friction Angle	32 deg
Lateral Stress	16 psi
Shear Modulus	6000 psi

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway May 19, 2000

Hole No. HC00-B221 Depth 28.5 ft File C:\DATA\C-219\HC18.P

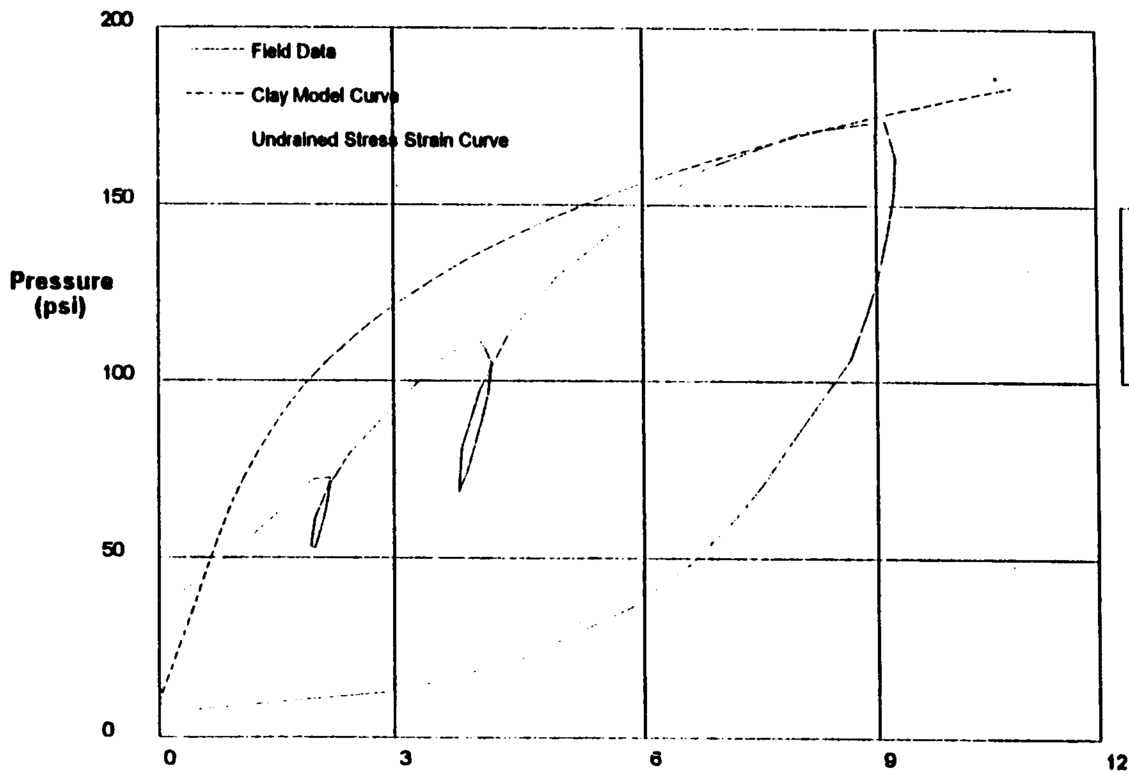


HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 19, 2000**

Hole No. HC00-B221 **Depth 28.5 ft** **File C:\DATA\C-219\HC18.P**



GIBSON'S CLAY MODEL

Shear Strength	48 psi
Insitu Stress	18 psi
Shear Modulus	3000 psi

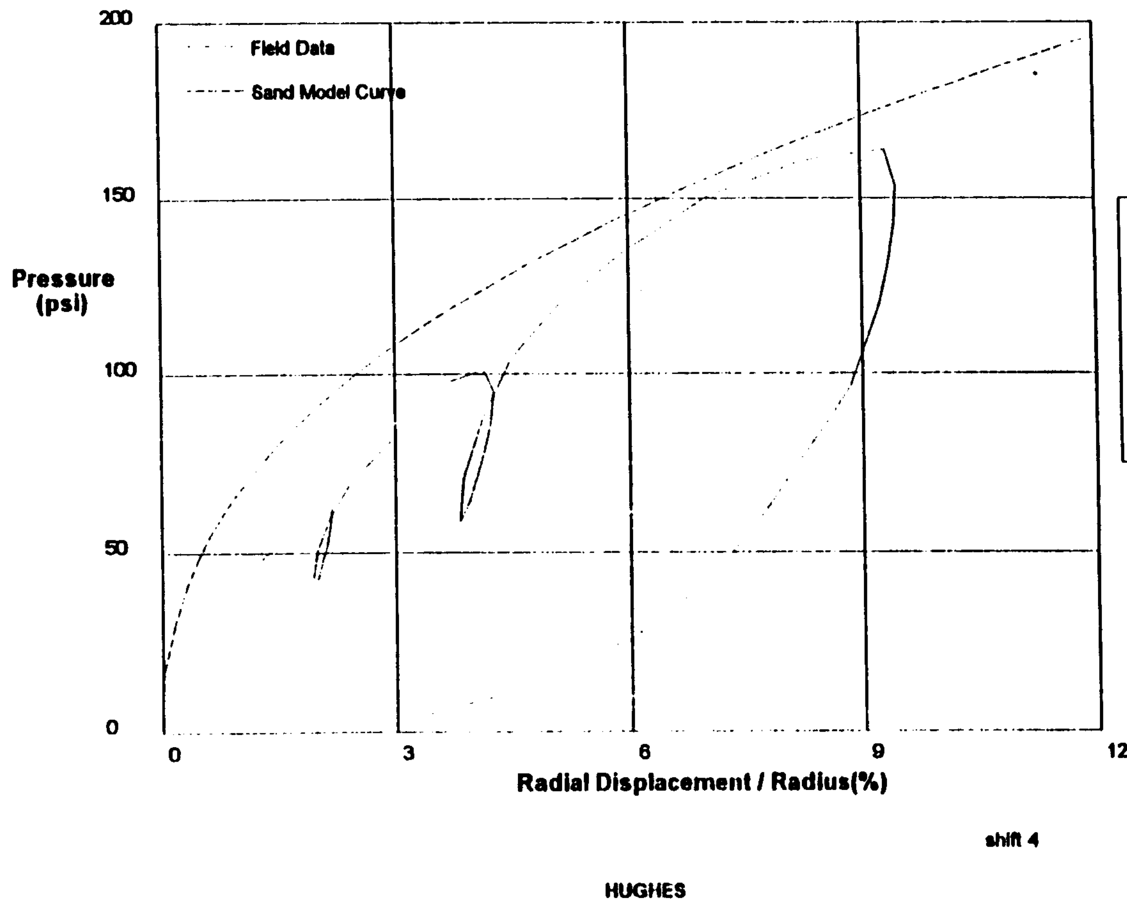
shift 4

HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway May 19, 2000

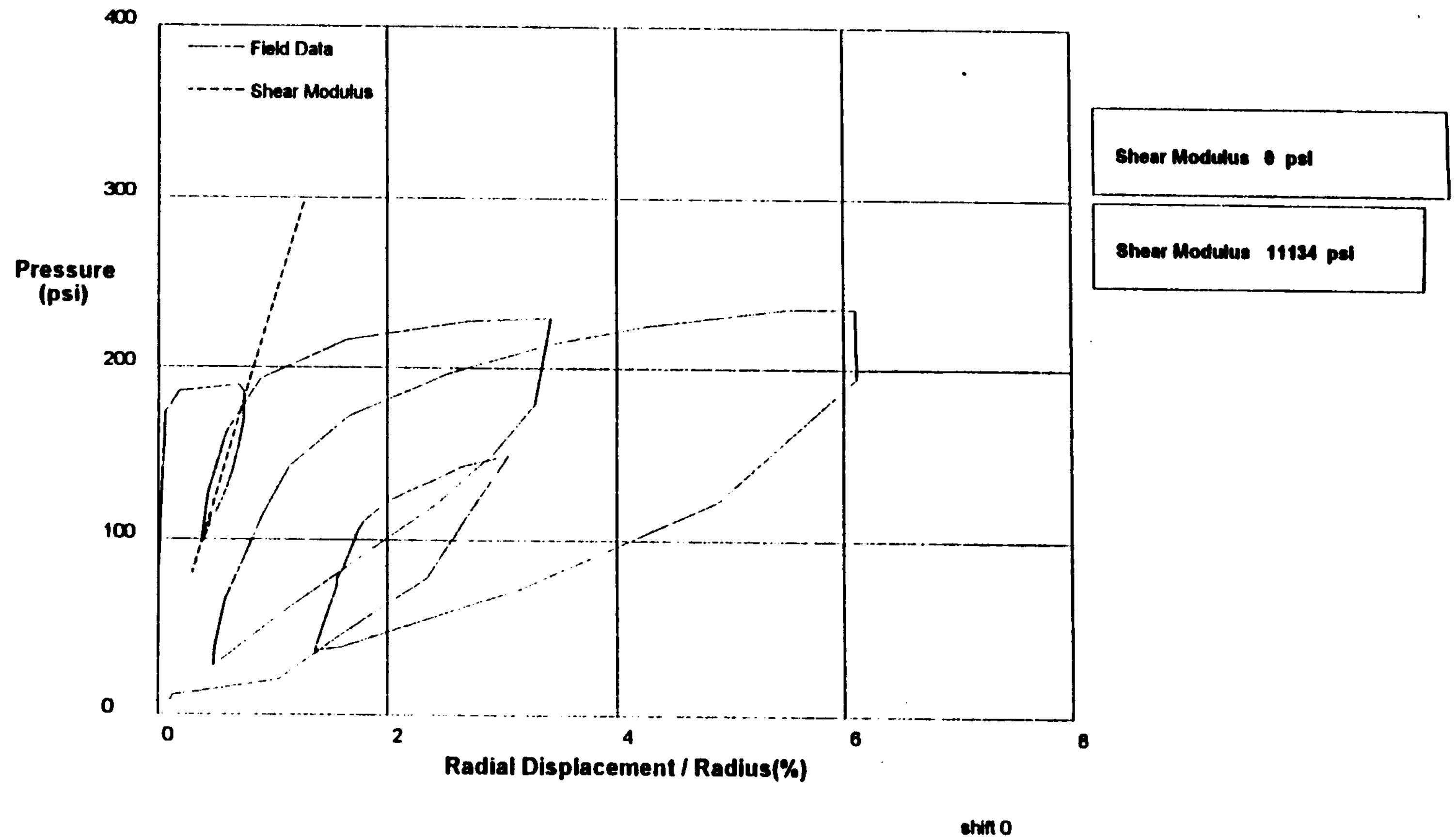
Hole No. HC00-B221 Depth 28.5 ft File C:\DATA\C-218\HC18.P



THE HUGHES SAND MODEL

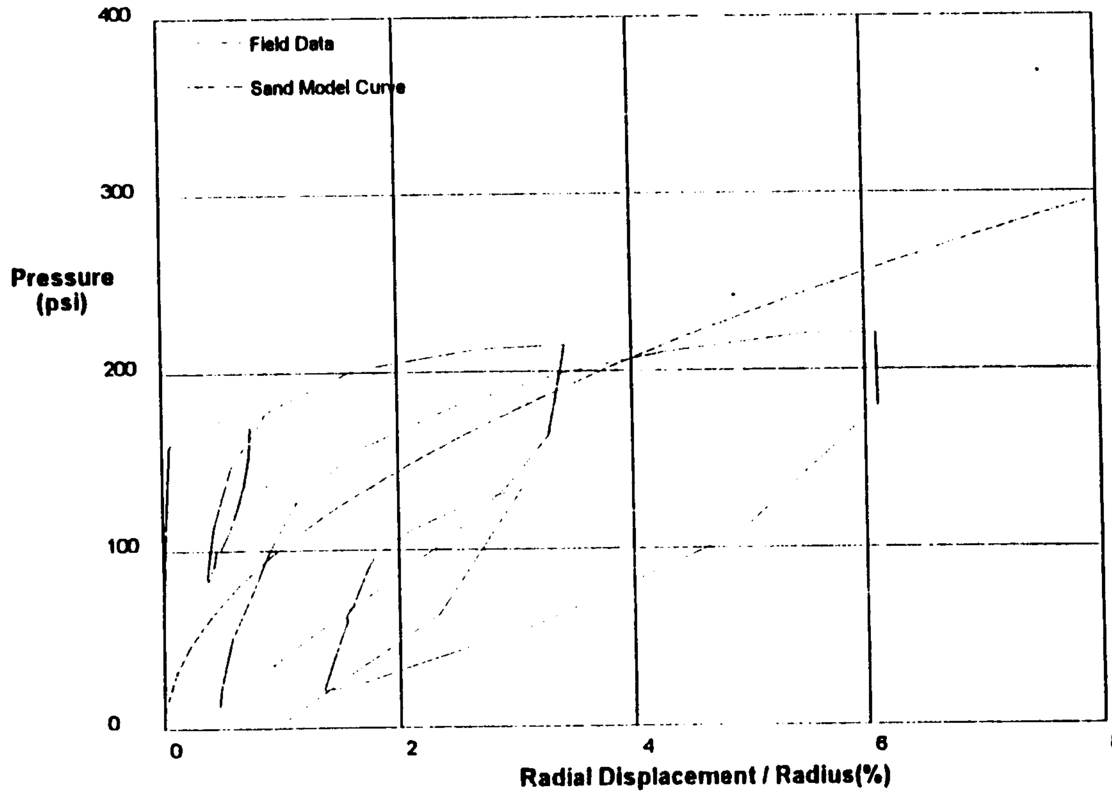
Water Pressure	10 psi
Friction Angle	38 deg
Critical Friction Angle	32 deg
Lateral Stress	15 psi
Shear Modulus	5000 psi

PRESSUREMETER DATA	Hart Crowser, Inc.	
Seatac Airport Third Runway		May 19, 2000
Hole No. HC00-B221	Depth 40 ft	File C:\DATA\C-219\HC19.P



HUGHES

PRESSUREMETER DATA	Hart Crowser, Inc.	
Seatac Airport Third Runway		May 19, 2000
Hole No. HC00-B221 Depth 40 ft		File C:\DATA\C-219\HC19.P



THE HUGHES SAND MODEL

Water Pressure	16 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	10 psi
Shear Modulus	11000 psi

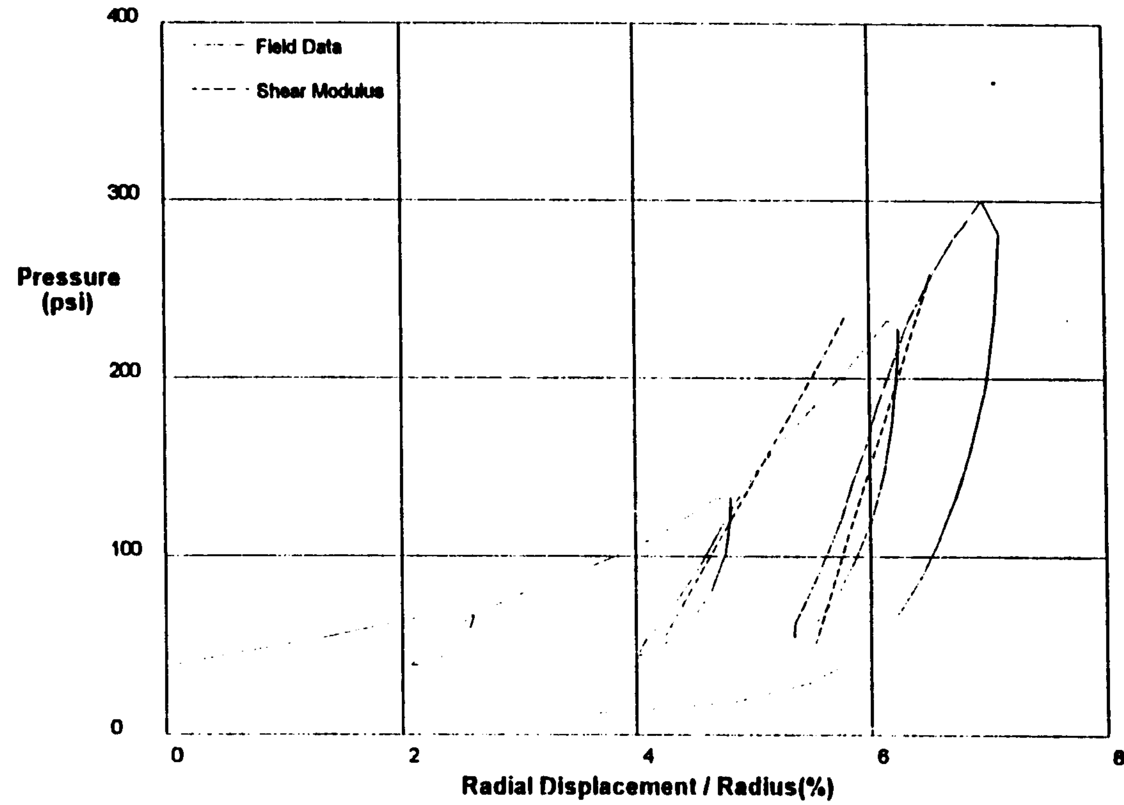
shift 0

HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 22, 2000**

Hole No. HC00-B224 **Depth 24 ft** **File C:\DATA\C-219\HC24.P**



Shear Modulus 10274 psi

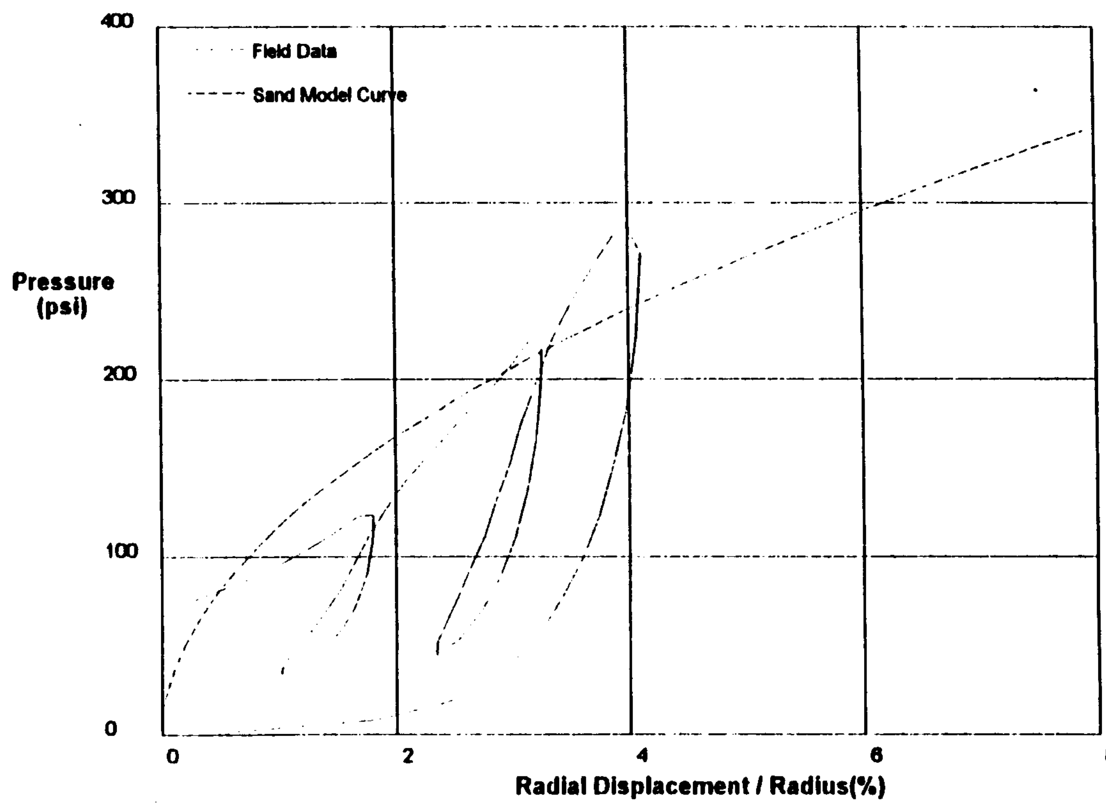
Shear Modulus 5794 psi

shift 4

HUGHES

AR 045954

PRESSUREMETER DATA	Hart Crowser, Inc.	
Seatac Airport Third Runway		May 22, 2000
Hole No. HC00-B224 Depth 24 ft		File C:\DATA\C-219\HC24.P



shift 7

HUGHES

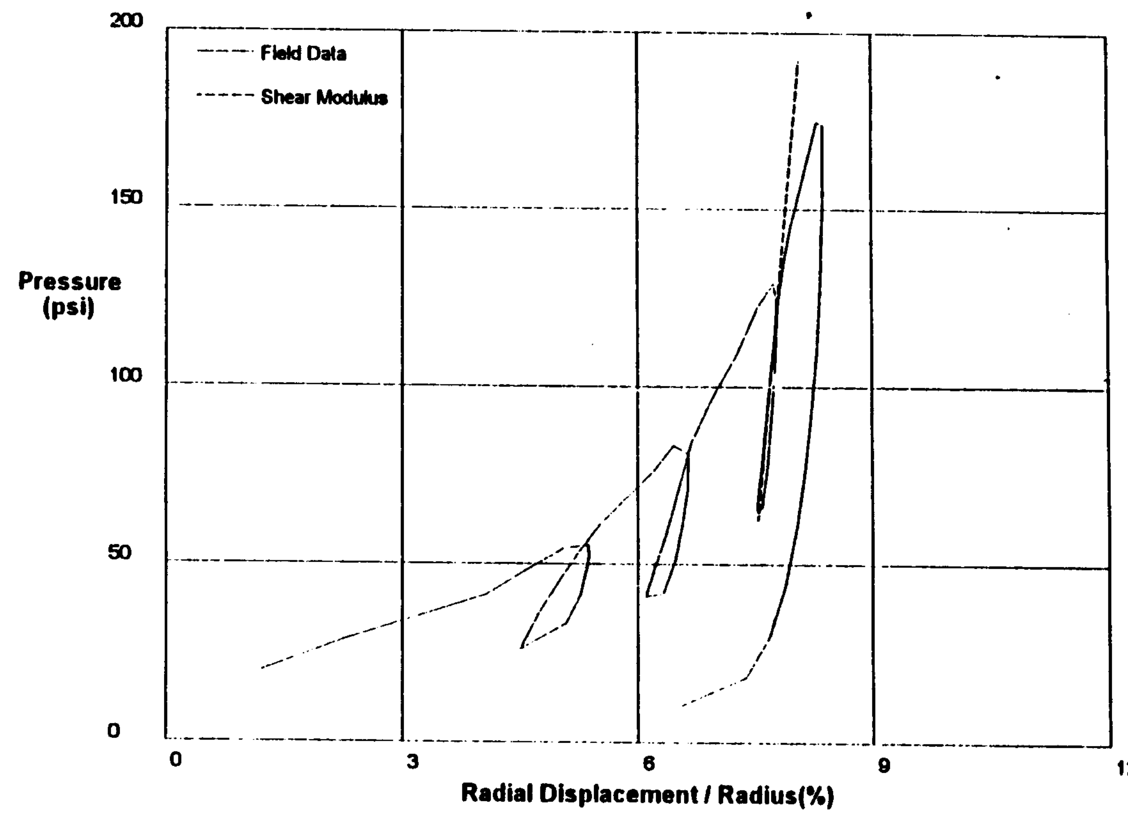
THE HUGHES SAND MODEL

Water Pressure	10 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	16 psi
Shear Modulus	10000 psi

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 22, 2000

Hole No. HC00-B224 Depth 33.5 ft File C:\DATA\C-219\HC28.P



Shear Modulus 0 psi

Shear Modulus 12222 psi

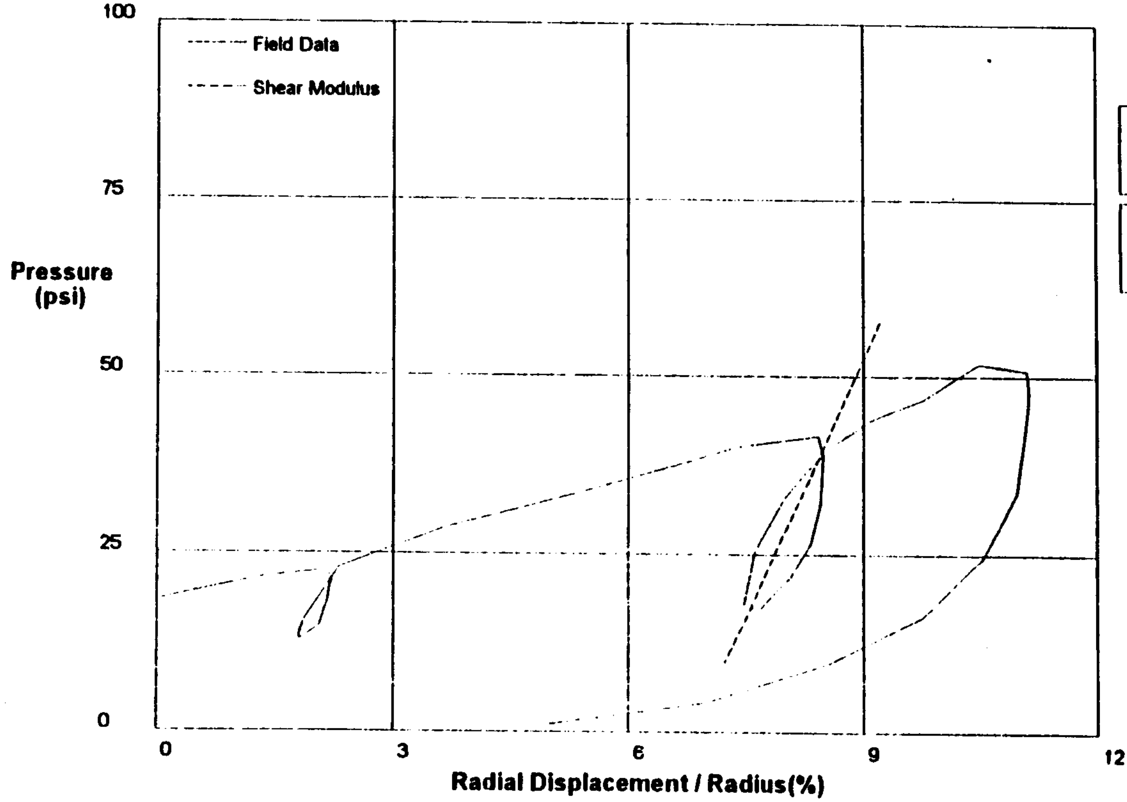
shift 4

HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 23, 2000**

Hole No. HC00-B220 **Depth 9 ft** **File C:\DATA\C-219\HC26.P**



Shear Modulus 0 psi

Shear Modulus 1201 psi

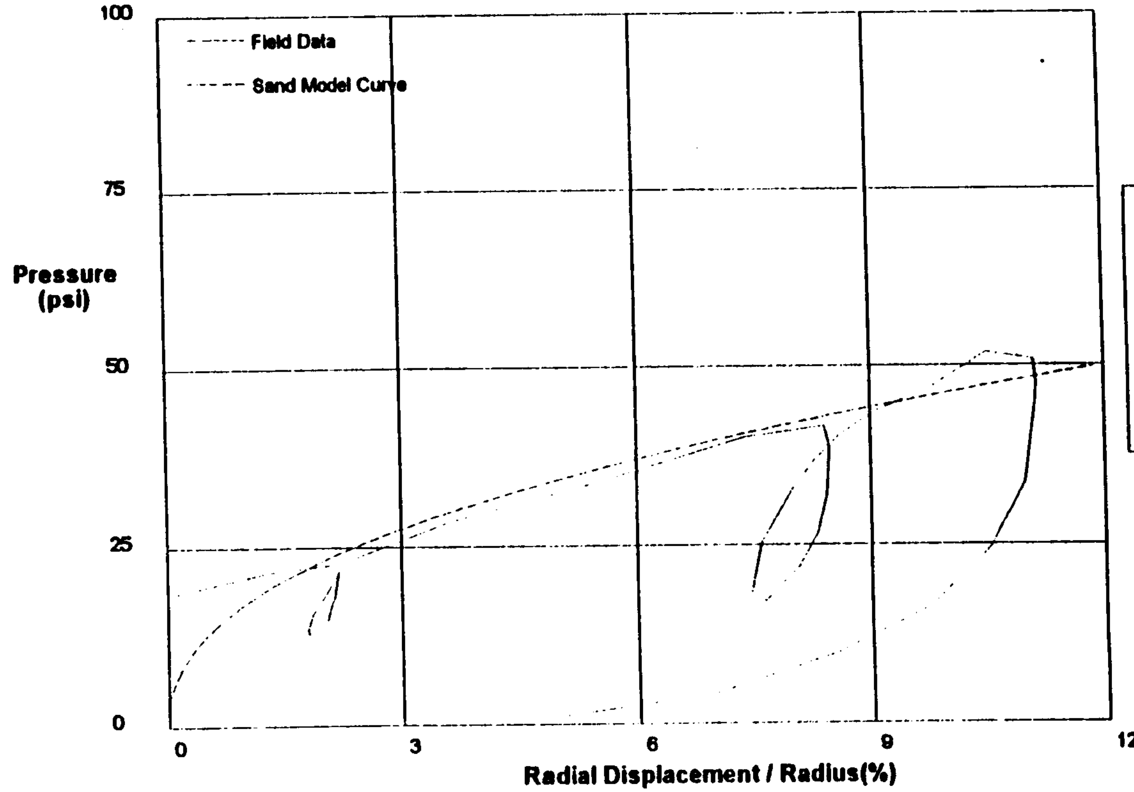
shift 4

HUGHES

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 23, 2000

Hole No. HC00-B220 Depth 9 ft File C:\DATA\C-219\HC26.P



THE HUGHES SAND MODEL

Water Pressure	0 psi
Friction Angle	38 deg
Critical Friction Angle	32 deg
Lateral Stress	4 psi
Shear Modulus	1200 psi

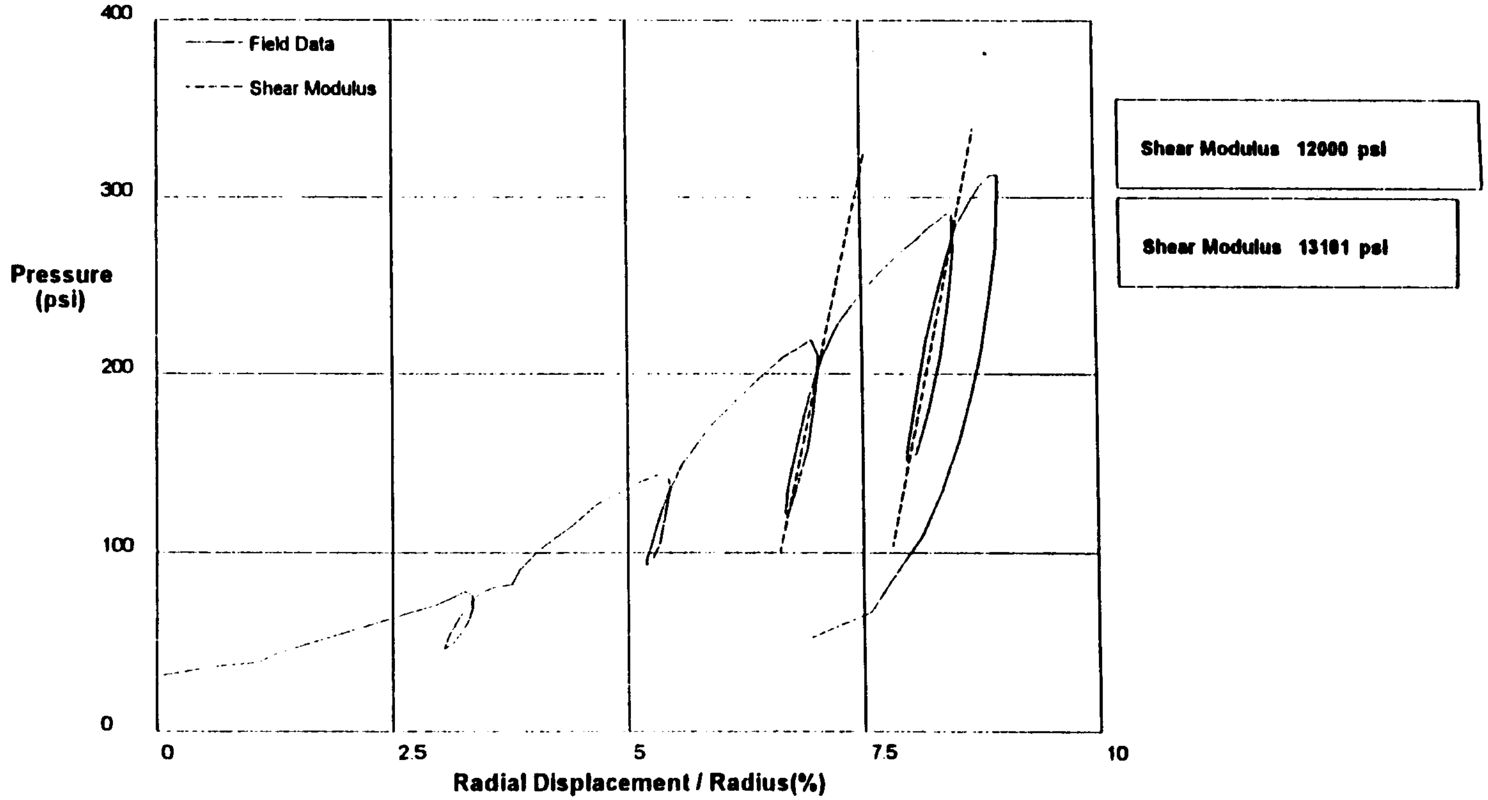
shift 4

HUGHES

PRESSUREMETER DATA — Hart Crowser, Inc.

Seatac Airport Third Runway — May 23, 2000

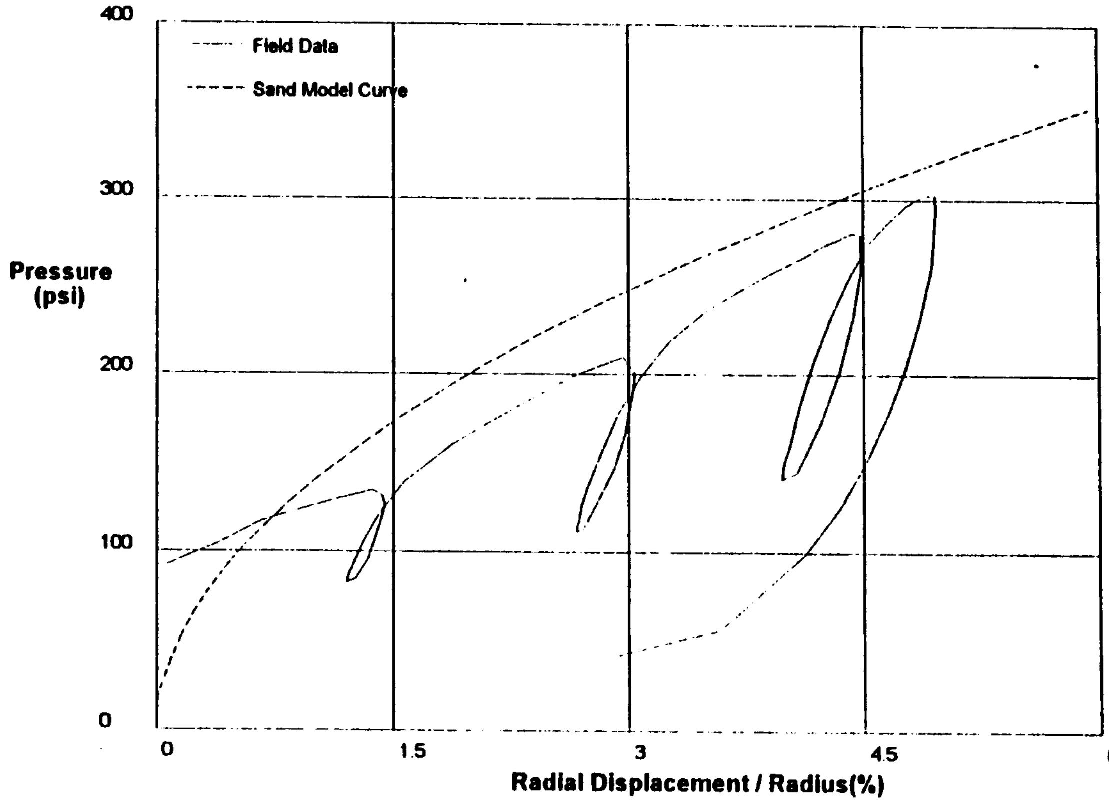
Hole No. HC00-B220 — Depth 30 ft — File C:\DATA\C-219\HC28Z.P



shift 2

HUGHES

PRESSUREMETER DATA	Hart Crowser, Inc.	
Seatac Airport Third Runway		May 23, 2000
Hole No. HC00-B220	Depth 30 ft	File C:\DATA\C-219\HC28Z.P



THE HUGHES SAND MODEL

Water Pressure	10 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	18 psi
Shear Modulus	12000 psi

shift 6

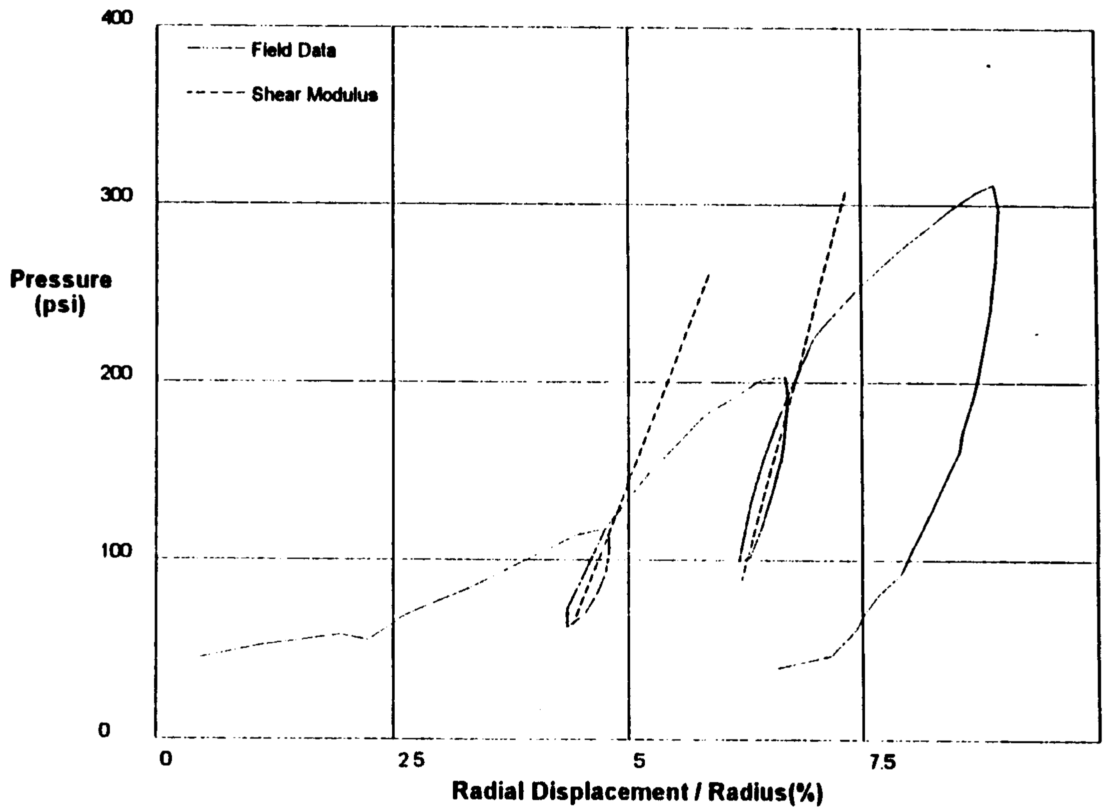
HUGHES

AR 045960

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 23, 2000**

Hole No. HC00-B220 **Depth 40 ft** **File C:\DATA\C-219\HC29.P**



Shear Modulus 6761 psi

Shear Modulus 9658 psi

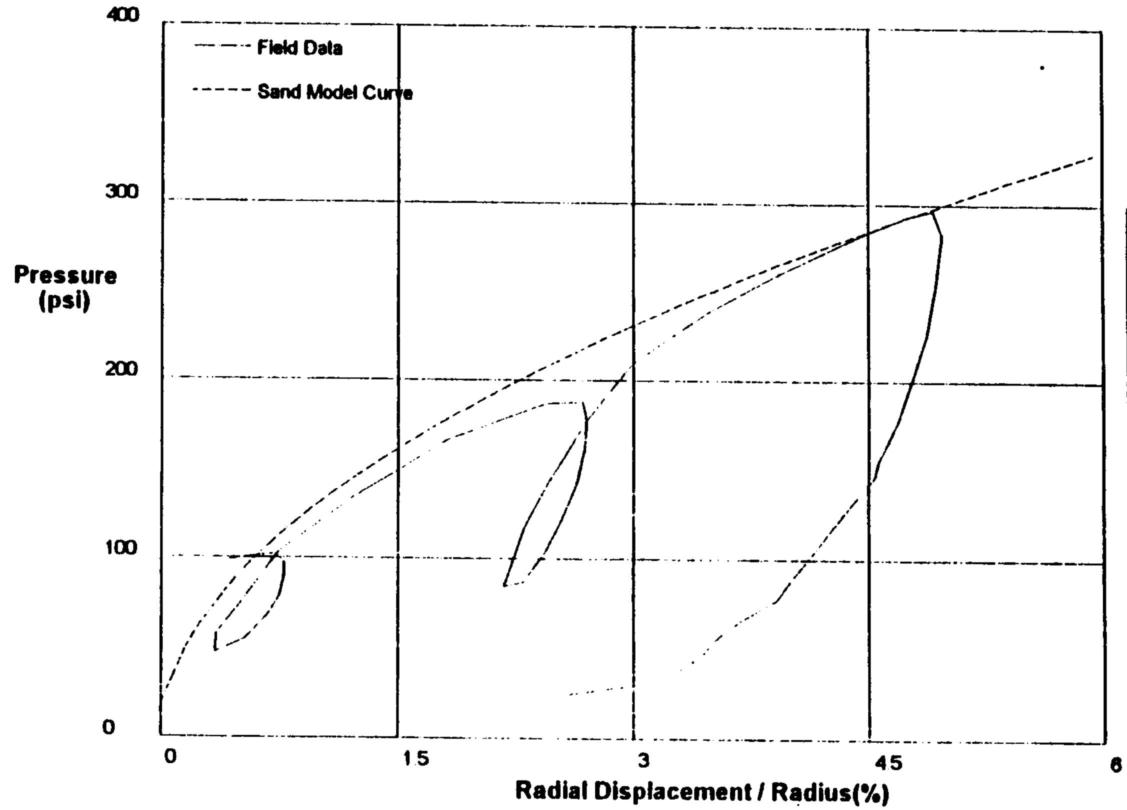
shift 2

HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 23, 2000**

Hole No. HC00-B220 **Depth 40 ft** **File C:\DATA\C-219\HC29.P**



THE HUGHES SAND MODEL

Water Pressure	15 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	28 psi
Shear Modulus	9500 psi

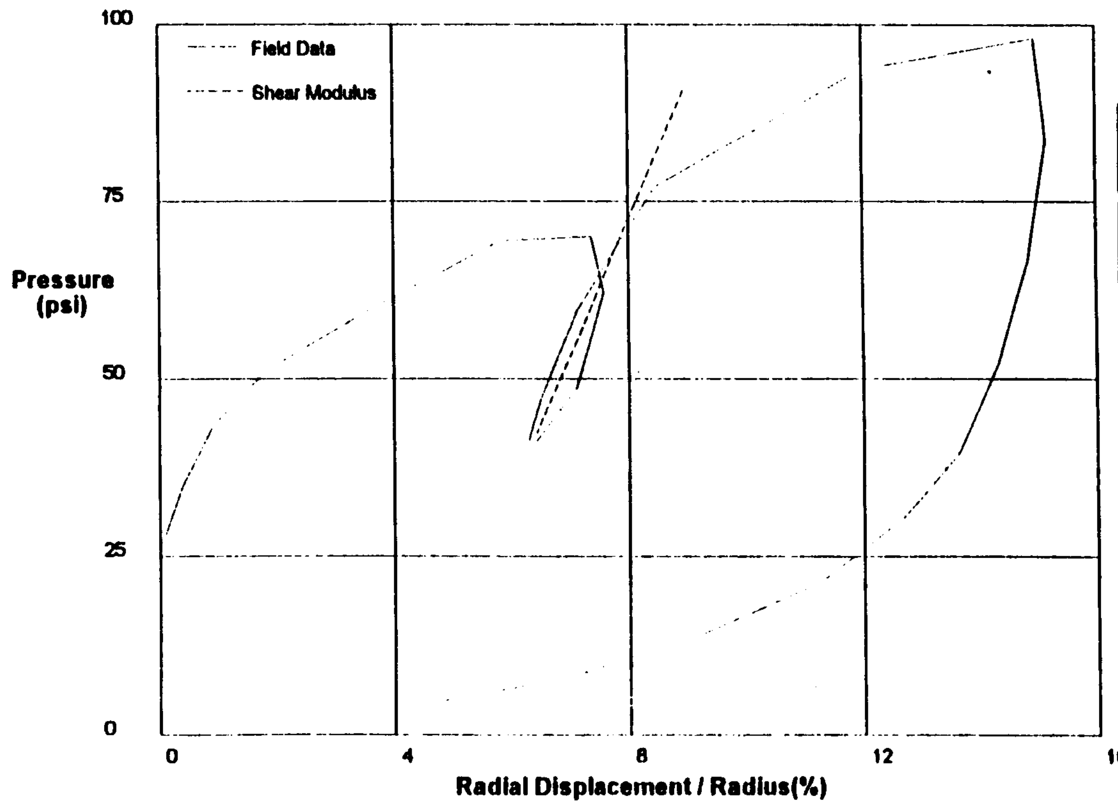
shift 6

HUGHES

PRESSUREMETER DATA **Hart Crowser, Inc.**

Seatac Airport Third Runway **May 24, 2000**

Hole No. HC00-B223 **Depth 9 ft** **File C:\DATA\C-219\HC31.P**



Shear Modulus 0 psi

Shear Modulus 954 psi

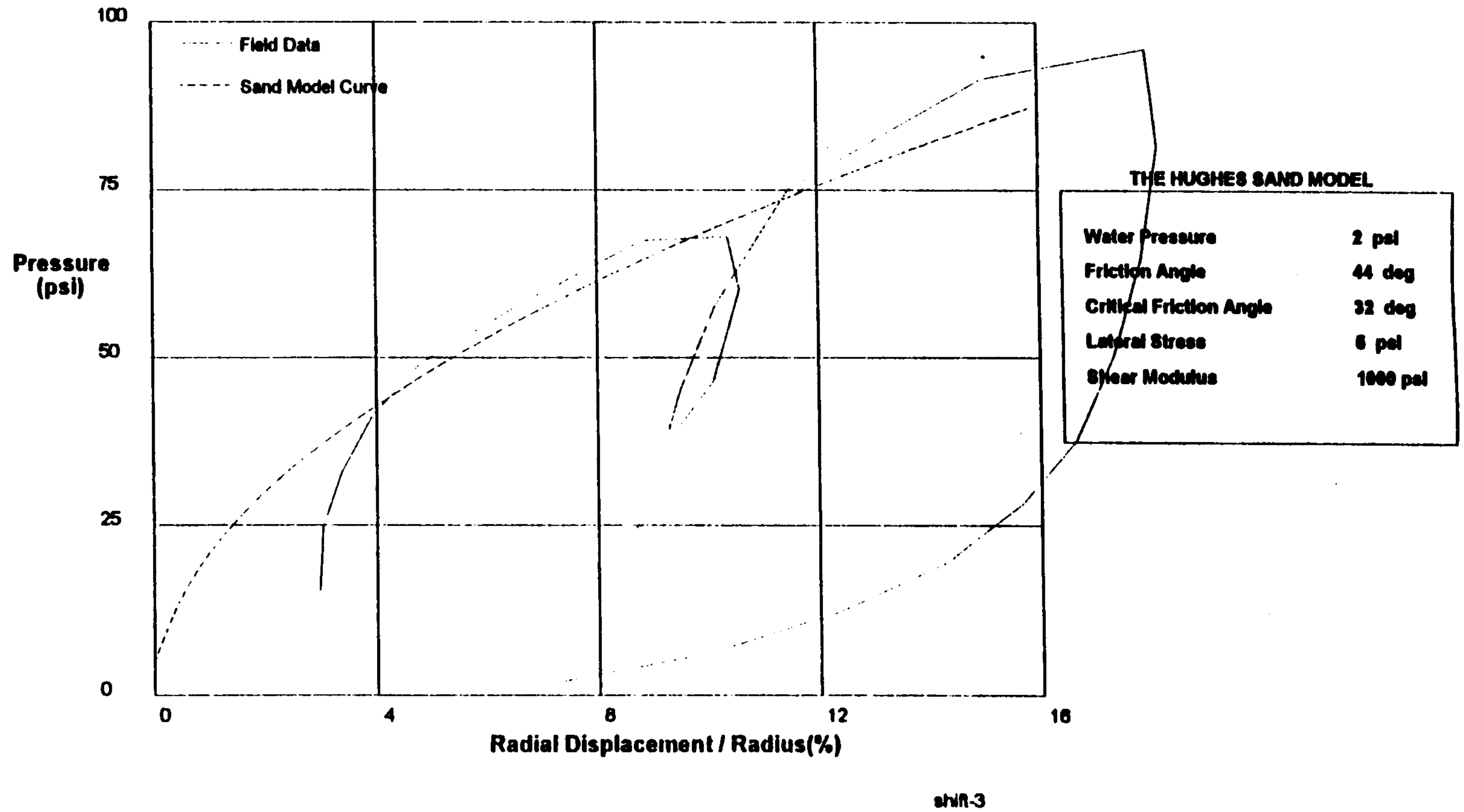
shift 0

HUGHES

PRESSUREMETER DATA Hart Crowser, Inc.

Seatac Airport Third Runway May 24, 2000

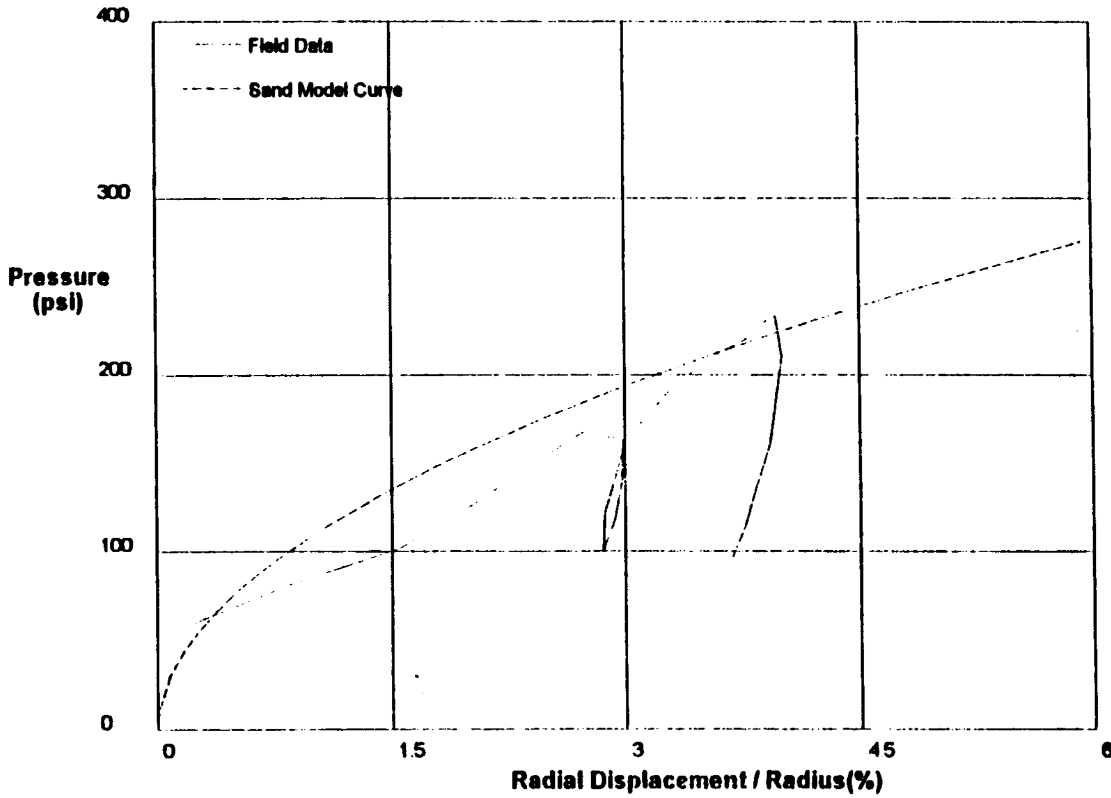
Hole No. HC00-B223 Depth 9 ft File C:\DATA\C-219\HC31.P



HUGHES

AR 045964

PRESSUREMETER DATA	Hart Crowser, Inc.	
Seatac Airport Third Runway		May 24, 2000
Hole No. HC00-B223 Depth 24 ft		File C:\DATA\C-219\HC34.P



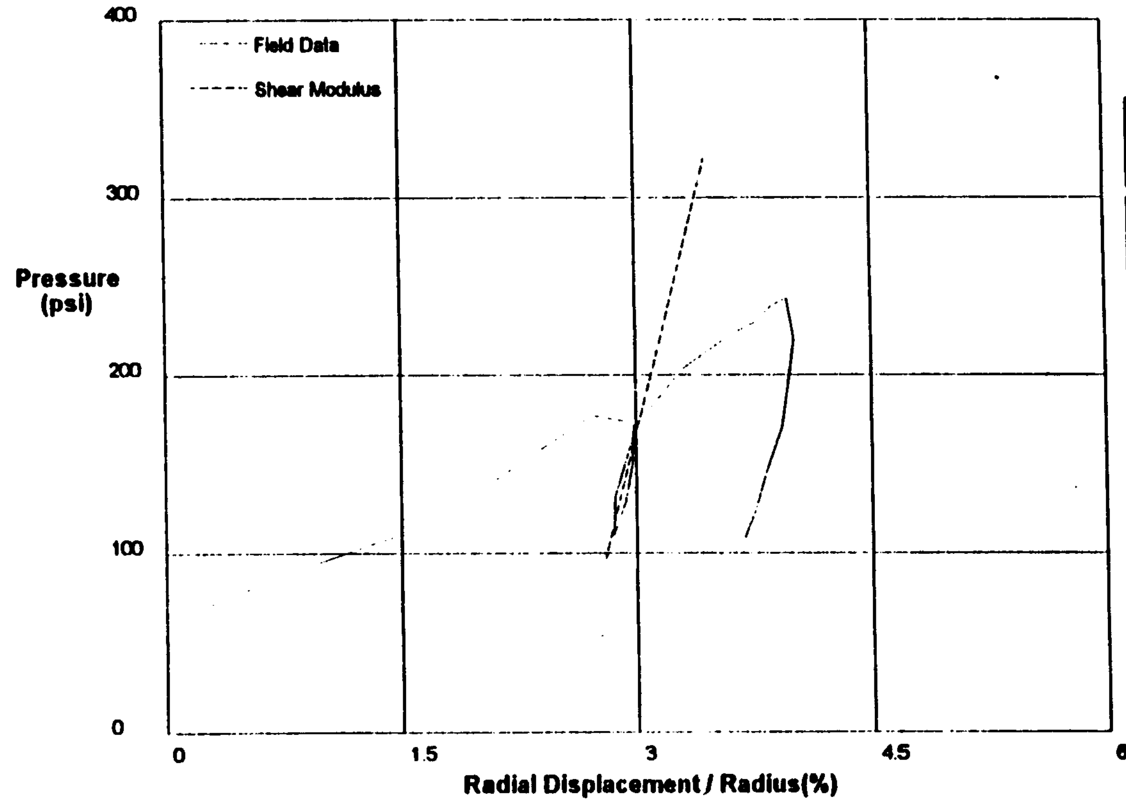
THE HUGHES SAND MODEL

Water Pressure	10 psi
Friction Angle	44 deg
Critical Friction Angle	32 deg
Lateral Stress	7 psi
Shear Modulus	18000 psi

shift 6

HUGHES

PRESSUREMETER DATA	Hart Crowser, Inc.
Seatac Airport Third Runway	May 24, 2000
Hole No. HC00-B223 Depth 24 ft	File C:\DATA\C-219\HC34.P



Shear Modulus 8 psi

Shear Modulus 17142 psi

shift 6

HUGHES

AR 045966

Appendix II

Pressuremeter testing in tills and glacially-consolidated granular materials

PRESSUREMETER TESTING IN TILLS AND GLACIALLY-CONSOLIDATED GRANULAR MATERIALS

J.M.O.Hughes, President, Hughes Insitu Engineering Ltd., 804-938 Howe Street, Vancouver, Canada

ABSTRACT: In general, granular tills and glacially-consolidated outwash materials are strong, and present few problems in geotechnical engineering where deformation is a concern. These materials are very stiff. However, in heavily-loaded structures a more detailed understanding of the material properties may be required. Conventional site investigation techniques often rely on laboratory testing of samples, which in these materials are difficult to obtain. The pressuremeter offers an alternative method of obtaining in-situ stiffness and strength parameters.

RÉSUMÉ: En général, les terrains érratiques granuleux et matériaux constitués d'eaux de fusion glaciarement consolidées sont résistants, et présentent peu de problèmes au niveau de l'ingénierie géotechnique où la déformation est concernée. Ces matériaux sont très rigides. Cependant dans les structures lourdement chargées, une comprehension plus detaillée des propriétés du matériau, peut être requise. Les techniques des recherches dans les sites conventionnels, se fient souvent aux tests d'échantillons au laboratoire, ce qui dans ces mêmes matériaux est difficile d'obtenir. La pressiomètre offre une méthode alternative pour obtenir les paramètres de rigidité et résistance.

1. THE PRESSUREMETER TEST .

The pressuremeter test, as developed by Ménard, has been available for a long time. In many materials, such as stiff clays, it is a particularly useful tool for obtaining in-situ properties. However, it is not always easy to use successfully in dense glacial materials. If there is a major void present in the test pocket, the membrane can expand in an uncontrolled manner and possibly rupture before the test is completed. This problem can be overcome using heavy reinforced membranes. However, the compressibility and the stiffness of these membranes can in some circumstances have a significant influence on the results.

To a certain extent, this problem can be overcome. Relatively flexible and incompressible membranes can be used, provided that the onset of potential rupture can be recognized. If the displacement measurements are made electronically at several points inside the membrane, and further, if the expansion process is by injection fluid in an incremental manner into the pressuremeter, then it is often possible to recognize the onset of rupture by observing the non-uniformity of the cavity expansion and the movement of the strain sensors relative to the volume of fluid injected.

The pressuremeter described in this paper is shown in Figure 1. The displacements are measured electrically at three locations at the centre of the pressuremeter, and the pressure is measured electrically inside the probe. With this arrangement, the signals from the sensors are monitored continuously during the test on a computer screen. The membrane requires only 250 kPa to expand fully. Further, it is rigid enough to measure shear modulus up to 2 GPa. In good material, the pressure range is in the order of 20 Mpa. Pressuremeters of this pressure range are often referred to as high-pressure dilatometers.

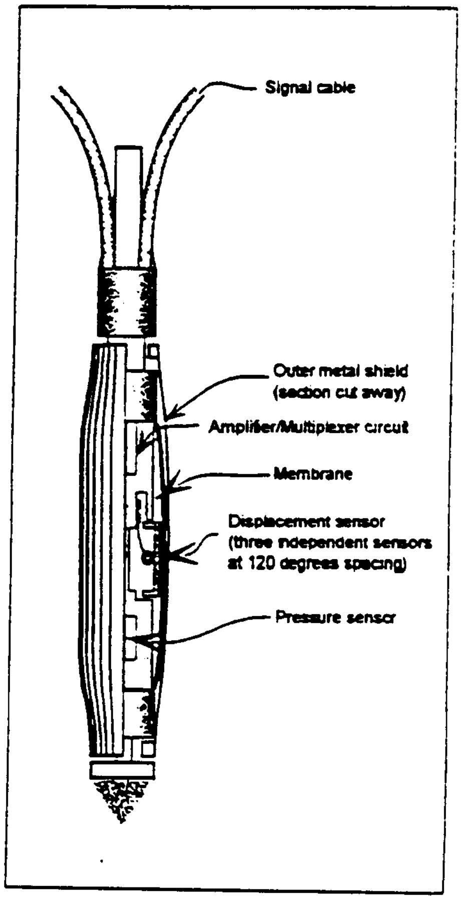


Figure 1. Schematic details of pressuremeter

AR 045968

2. FORMATION OF THE TEST POCKET

The formation of the test pocket is critical to the success of the test. For the instrument shown in Figure 1, a hole 76 mm in diameter is required. Commonly, a hole of diameter 85 mm or more is drilled to just above the test level. A pocket, 1.5 m diameter long, is then drilled below the base of the larger hole. The method of formation of this pilot hole depends on the expected material. In very dense tills, in which rocks are not present, or where the materials are so dense that they are firmly held in the till, a core barrel can produce a satisfactory hole. However, in more gravelly material, a tricone bit 74 mm in diameter can be successful. However, it is particularly important to stabilize the wall of the pilot hole using thick mud. Drillers are experienced in making holes, but are usually not concerned about the absolute amount the holes is oversize. Some experimentation is required to determine the appropriate rates of mud flow and rotation.

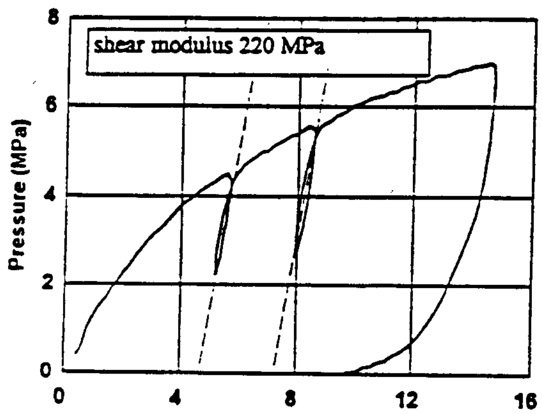


Figure 2. Pressuremeter test in dense out-wash sands.

Figure 2 is an almost perfect example of a test in coarse out-wash sand which has subsequently been overloaded by glaciation. This test was done at a depth of 14 m, at a site in Washington State. The nearby cliffs on the river bank of this material stand about 15 m in height on a slope of 70 degrees. The material is very dense with an SPT blow count of over 100. It is likely that obtaining a sample for laboratory strength tests from a borehole would be very difficult.

The hole for the pressuremeter was drilled with a tricone bit 2mm smaller than the required hole size (76mm). The resulting hole is almost the ideal size, as the gap between the wall and the pressuremeter is less than 1 mm. It should be stressed that this success is not always achieved in glacial material. But with experience, the number of aborted tests in glacial material is usually well under 10%. Figure 2 shows the pressure against the average strain as measured on the three displacement sensors. As all of these measurements are made electronically, down hole, they are known with considerable accuracy.

3. OBSERVATIONS

The general shape of the curve is smooth, with the curvature slowly decreasing with strain. Clearly, the pressure is tending to a limit. The final unloading curve is also very smooth. However, the rate of change in the movement inwards increases rapidly as the pressure reduces and the material fails inwards.

The general slope of the unload-reload loops as measured along the axes of the loops are very close to each other. The shear modulus, which is 0.5 times the slope, is 220 MPa and 218 MPa respectively. Further, the slope of these unload-reload loops is much steeper than the general slope of the pressuremeter curve.

As a first approximation, the slope of these lines is a measure of the low-strain elastic shear modulus. In some instances, this value is also close to the seismic G_{max}. Seismic methods could probably be used more economically to obtain the maximum shear modulus if this was the only information required. However with good definition of the unload-reload loop the shear modulus can be defined as a function of shear strain.

The general shape of the pressuremeter curve can be used to give an indication of the fundamental material properties. The slope of both the loading section of the pressuremeter curve (plotted on a log scale) and the unloading curve (again plotted to a log scale) can be used to give a estimate of the frictional characteristics of the material.

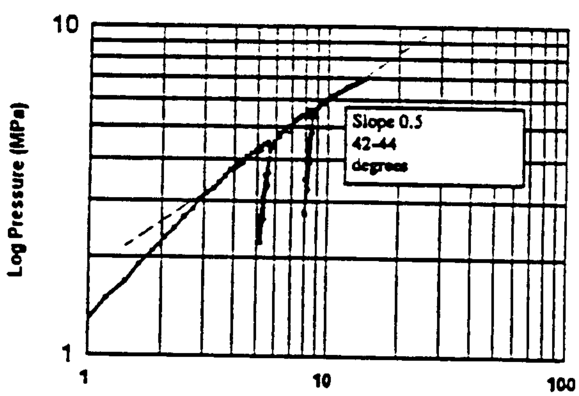


Figure 3. Initial loading analysis by Hughes et al. (1977)

The analysis of the loading curve, presented in Figure 3, is based on a very simple closed-form solution developed over 20 years ago (Hughes, Wroth and Windle, 1977). The analysis of the unloading curve, developed by Yu (1996) is performed in the same manner. The slope of the unload curve, plotted on a log scale (with the strain origin taken as zero at the maximum strain) is related to the friction angle and to the state parameter. With the above test, both methods give results in the same order (a friction angle of about 43 degrees).

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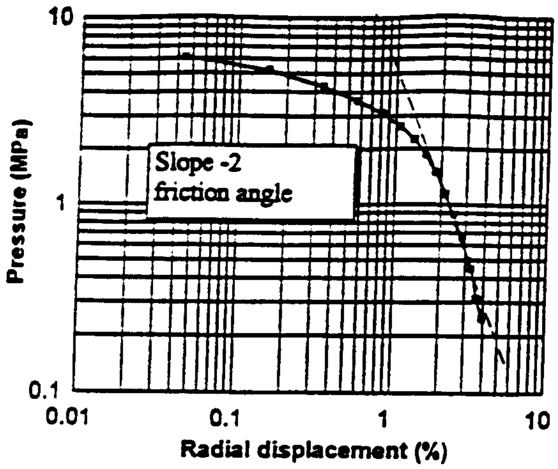

Figure 4. Analysis of final unloading curve (Yu, 1996)

A more powerful method of analysis is available by using a very simple inversion technique with computer modeling. If the material is assumed to deform according to a simple model, with few parameters, then an ideal pressuremeter curve can be developed, based on an assumed set of material parameters. This ideal curve can then be compared to the field data. Adjustments to the parameters can be made until a reasonable match is made. If the simple model of Hughes, Wroth and Windle (1977) is used, only four parameters — friction angle, critical state friction angle, secant modulus and lateral stress — are required. The model assumes that the material deforms under plane strain conditions. This is a very simple model, which does not take into account three-dimensional effects or elastic compression. Both these effects are present. However they act in opposite directions of almost equal amounts.

The model is used to predict a pressuremeter curve based on an assumed set of parameters, which is then compared to the actual field curve using interactive computer graphics. This inversion process can be conducted very rapidly. The parameters in the ideal curve which give a reasonable match to the data are likely to be close to the material parameters for the in-situ material. In general, there is not a unique set of parameters which match the curve. However, for well-formed tests, they lie usually within a very narrow band. The best ideal pressuremeter curve for the pressuremeter test discussed is presented in Figure 5. The parameters assumed are friction angle = 43 degrees, critical state friction angle 32 degrees, lateral stress 0.34 MPa and secant shear modular (from zero strain until onset of failure) of 117 Mpa. The same approach can be extended to the unloading curve of Yu et al. (1996).

If the data is very well formed, the inversion process can be used with more complex models such as developed by Roy (1997). Alternatively, finite element or FLAC programs can be used to develop an ideal pressuremeter curve.

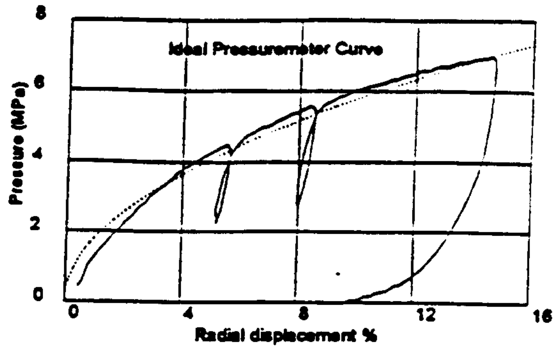

Figure 5. Ideal pressure-expansion curve with friction angle of 43 degrees

4. CONCLUSION

In many instances, in hard glacial material it is very difficult to obtain a sample which can be tested under laboratory conditions. However, it is often possible to drill a hole in these materials in which the walls are relatively smooth. It is then possible to conduct pressuremeter tests which can be analyzed to obtain some fundamental material properties.

5. ACKNOWLEDGMENTS

The testing of dense glacial material using the pressuremeter has been developed by our Company over several years, on civil engineering projects primarily in British Columbia and in Washington State.

The help of the following Companies, who have supported this work in using the pressuremeter to obtain material properties is very much appreciated, particularly in view of the high drilling costs at many of these sites.
Agra Earth and Environmental Ltd. Vancouver, B.C.
Klohn Crippen Ltd., Vancouver, B.C.
Macleod Geotechnical Ltd., Vancouver, B.C.
Golder Associates, Inc. Seattle, WA
Shannon & Wilson, Inc., Seattle, WA
Washington Department of Transportation, Olympia,WA

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HUGHES, J.M.O., WROTH, C.P., and WINDLE, D.1977. Pressuremeter Tests in Sands. Geotechnique, 27(2), pp. 455-477.

ROY, D. 1997. Deformation behaviour of granular deposits from self-boring pressuremeter. Ph.D. thesis, Department of Civil Engineering, University of British Columbia, Vancouver, B.C.

YU, H.S. 1996. Interpretation of pressuremeter unloading tests in sands. Geotechnique, 46 (1), pp. 17-31.

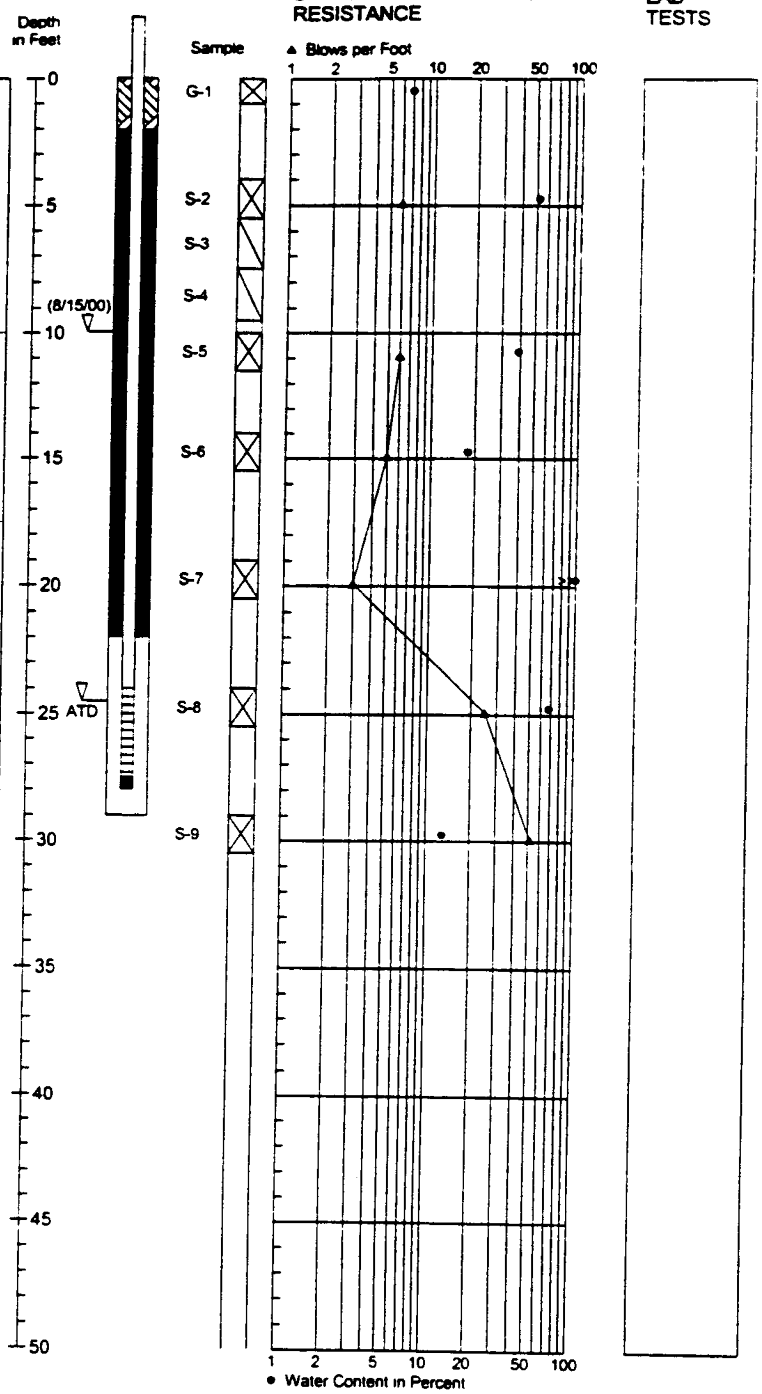
AR 045970

APPENDIX F
EXPLORATIONS AND TEST RESULTS
MILLER CREEK RELOCATION AND PROPOSED MILLER CREEK DETENTION FACILITY

Monitoring Well Log HC00-B308

N 22291
E 12160
Soil Descriptions
Ground Surface Elevation in Feet: 279
Top of Casing Elevation in Feet: 282.21

Depth in Feet	Soil Descriptions
0	Medium stiff, damp to moist, brown, gravelly PEAT (FILL). Trace of brick debris noted.
10	Medium stiff, moist, dark brown and gray, slightly sandy to sandy, silty PEAT with some wood debris.
17.5	Soft to stiff, moist to wet, dark brown to gray, slightly sandy PEAT.
25	Medium dense to dense, moist to wet, dark brown to gray, fine to coarse SAND.
30.5	Bottom of Boring at 30.5 Feet. Completed 08/14/00.



BORING LOG 497831F GPJ HC_CORP GDT 9/5/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

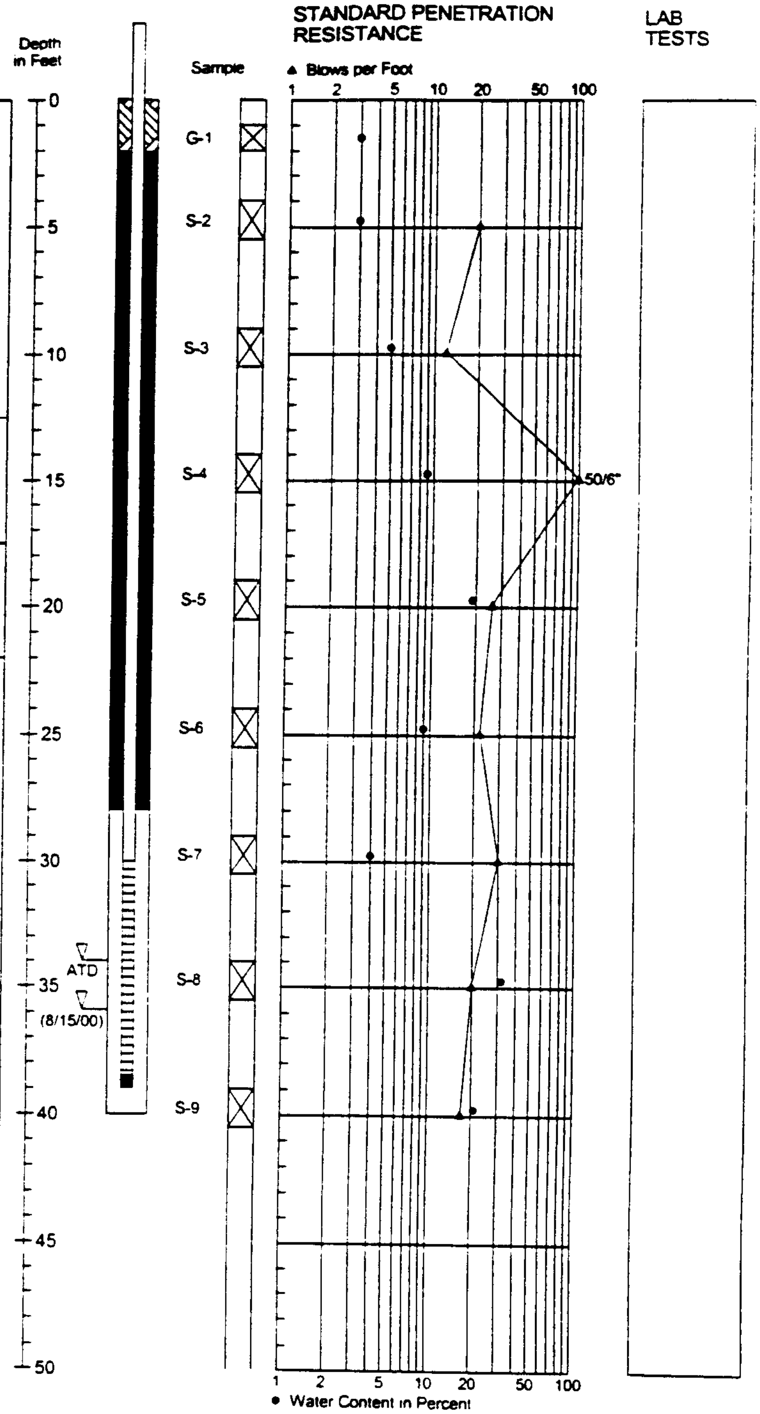
HARTCROWSER
4978-31 08/00
Figure F-1

AR 045972

Monitoring Well Log HC00-B309

N 22239
E 12340
Soil Descriptions
Ground Surface Elevation in Feet: 311
Top of Casing Elevation in Feet: 313.69

Soil Descriptions
Medium dense, damp to moist, brown to gray, slightly gravelly, slightly silty to silty, fine to coarse SAND with asphalt debris and abundant organic material (FILL).
Very dense, moist, gray, slightly gravelly, slightly silty, fine to medium SAND with organic material (FILL).
Very stiff, moist, dark brown, gravelly, slightly sandy PEAT.
Medium dense to dense, moist, gray, slightly gravelly to gravelly, fine to coarse SAND.
Medium dense, wet, brown, silty, fine SAND.
Bottom of Boring at 40.5 Feet. Completed 08/14/00.



BORING LOG 49783IF GPJ HC CORP GDT 9/1/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
4978-31 08/00
Figure F-2

Monitoring Well Log HC00-B310

N 22648
E 11521

Soil Descriptions

Ground Surface Elevation in Feet: 276

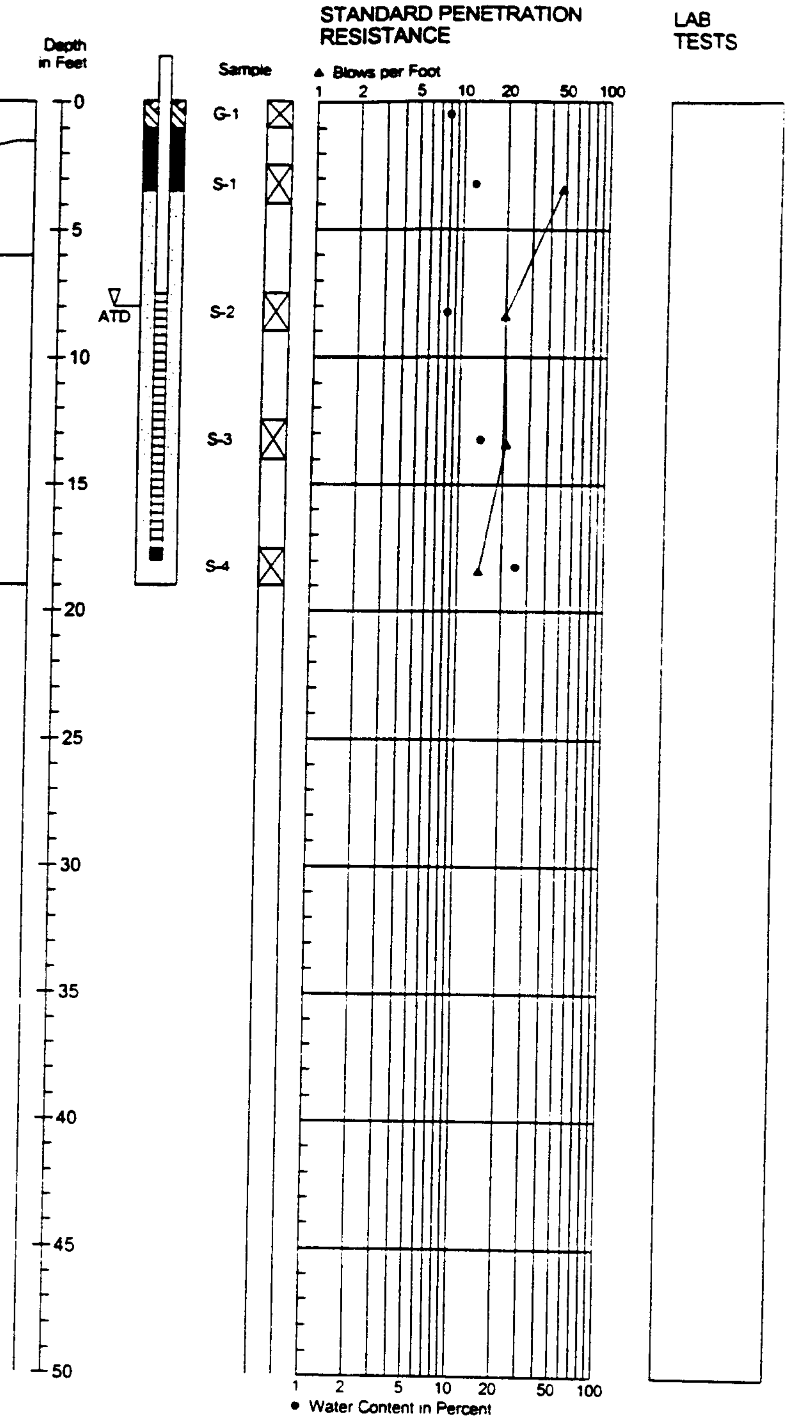
Top of Casing Elevation in Feet: 278.09

(Stiff), moist, brown, slightly gravelly, sandy SILT with organic material (FILL).

Dense, moist, brown to gray, silty, gravelly fine to medium SAND with trace organics and asphalt pieces (FILL).

Medium dense, moist to wet, brown to gray, slightly silty to silty, non-gravelly to gravelly, fine to medium SAND.

Bottom of Boring at 19.0 Feet.
Completed 08/16/00.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

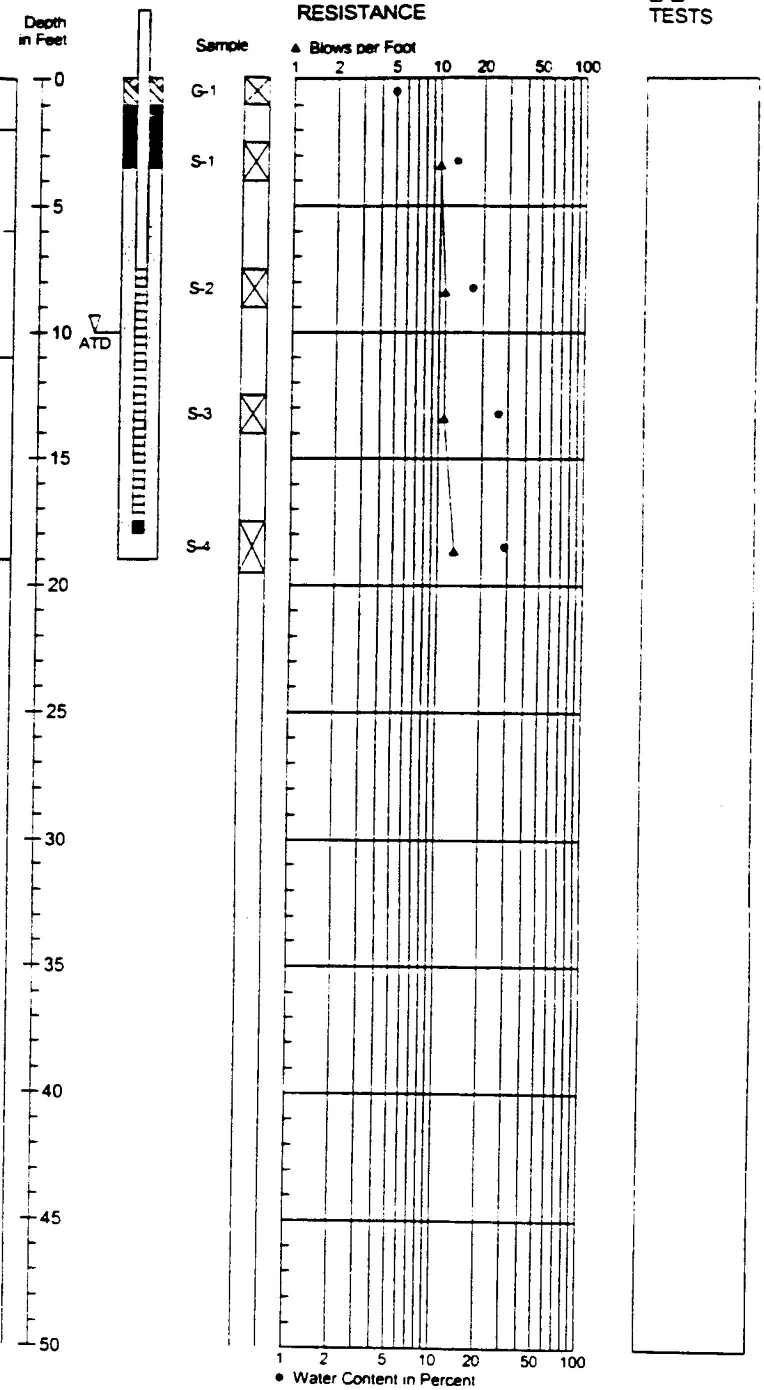
4978-31 08/00

Figure F-3

Monitoring Well Log HC00-B311

N 22417
E 11370
Soil Descriptions
Ground Surface Elevation in Feet: 274
Top of Casing Elevation in Feet: 277.48

Soil Descriptions
(Stiff), dry to moist, brown, gravelly, sandy SILT with organics.
Medium dense, moist, brown to gray, slightly gravelly, silty, fine to coarse SAND with organic material.
Medium dense, moist to wet, gray, silty, fine to medium SAND.
Stiff, wet, brown, sandy SILT.
Bottom of Boring at 19.0 Feet. Completed 08/16/00.



BORING LOG 497831F.GPJ HC_CORP.GDT 9/1/00

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
4978-31 08/00
Figure F-4

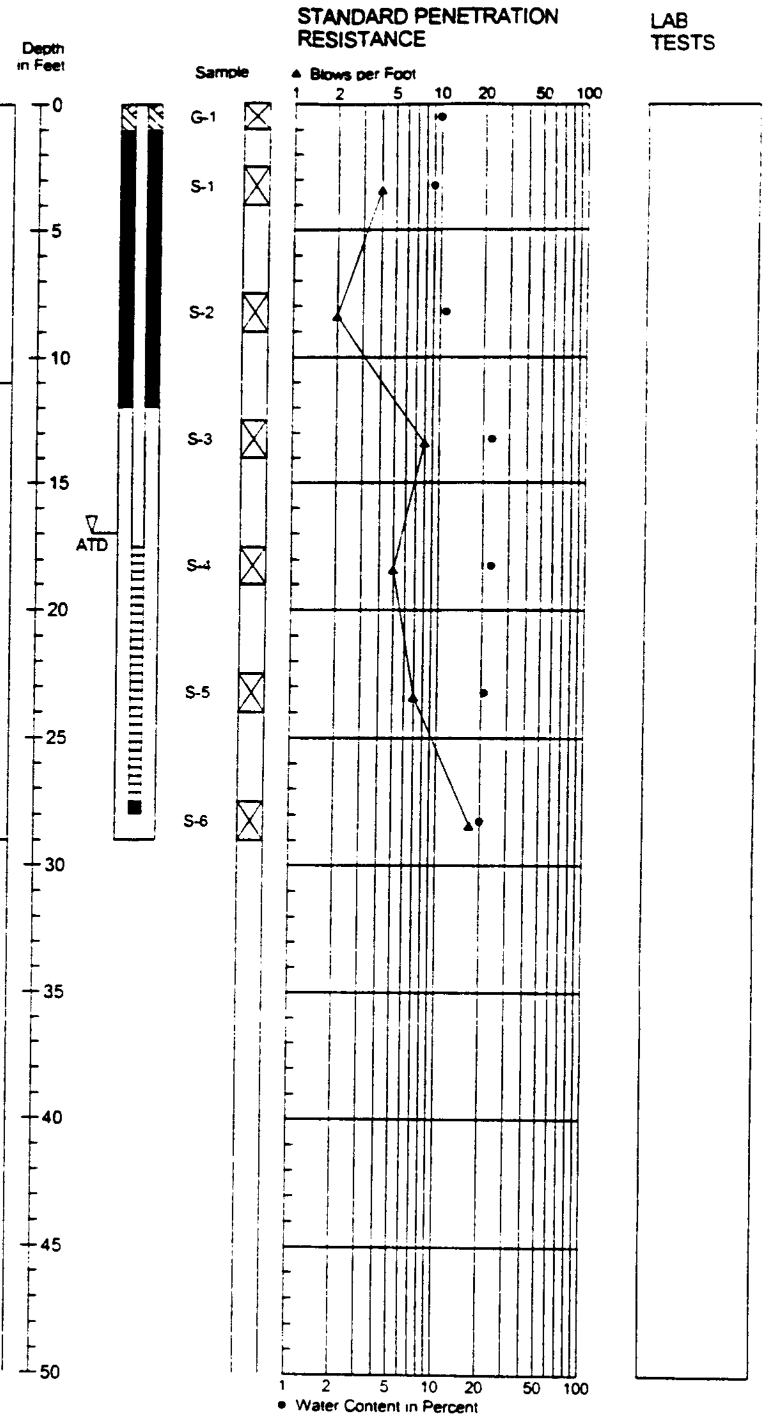
AR 045975

Monitoring Well Log HC00-B312

N 22773
E 11192

Soil Descriptions
Ground Surface Elevation in Feet: 284
Top of Casing Elevation in Feet: 283.79

Soil Descriptions	Depth in Feet
Very loose to (medium dense), moist, brown, slightly gravelly, silty, fine to coarse, SAND with clay lumps (possible FILL).	0–10
Loose to medium dense, moist to wet, brown, slightly silty, fine to medium SAND. Water added to counter heave. Water added to counter heave.	10–29
Bottom of Boring at 29.0 Feet. Completed 08/16/00.	29



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

4978-31 08/00

Figure F-5