



# **REPORT OF GEOTECHNICAL EXPLORATION**

**TUNNEL/BRIDGE  
CENTRAL CHILLER/BOILER PLANT  
DEPARTMENT OF VETERAN AFFAIRS  
3600 30<sup>TH</sup> STREET  
DES MOINES, IOWA**

**FEBRUARY 4, 2013**

**SCHEMMER PROJECT NO. 06054.013**

February 4, 2013

Ms. Cynthia Tabor, Contract Specialist  
Department of Veterans Affairs  
Central Iowa Health Care System – Des Moines Division  
3600 30<sup>th</sup> Street  
Des Moines, Iowa 50310

RE: Report of Geotechnical Exploration  
Tunnel/Bridge for Central Chiller/Boiler Plant  
Central Iowa Health Care System  
3600 30<sup>th</sup> Street, Des Moines, Iowa  
Schemmer Project No. 06054.013

Dear Ms. Tabor:

The Schemmer Associates Inc. has conducted a subsurface exploration program and prepared geotechnical assessment recommendations for the referenced project. This work was performed in accordance with your authorization.

The opinions expressed in this Report are based upon our understanding of the proposed project and the data obtained from our subsurface exploration. Should there be any changes as the project develops, we should be requested to review such new conditions.

Thank you for this opportunity to work with you on this project. Should you have any questions, please contact us.

Sincerely,

THE SCHEMMER ASSOCIATES INC.  
ARCHITECTS | ENGINEERS | PLANNERS

Loras A. Klostermann, P.E.  
Geotechnical Engineer



Copy: Mr. Randall J. Reese, AIA, The Schemmer Associates Inc.  
Mr. Jason Heinze, P.E., S.E., The Schemmer Associates Inc.  
Mr. Gary Norton, P.E., The Schemmer Associates Inc.

## EXECUTIVE SUMMARY

A new tunnel is proposed to support steam and other utility piping between the Kitchen and Administration building and the Warehouse and Shops building at the Central Health Care System campus of the Department of Veterans Affairs in Des Moines, Iowa. This tunnel will cross a natural drainage swale. To reduce excavation costs, the tunnel will become a bridge over the drainage swale. A pedestrian sidewalk will be placed over the bridge and tunnel, through the park-like area of the tunnel alignment.

The base of the bridge portion of the utility pipe conveyance system will be as much as 10 feet above existing grade at the base of the drainage swale. Review of the area topographic map shows that soil fill has been placed over portions of the drainage swale and has resulted in the formation of a small area that is ponded during heavy rainfall. A storm sewer culvert apparently drains this area.

Geotechnical analyses and recommendations have been compiled by The Schemmer Associates Inc. for the proposed bridge and tunnel. The tunnel alignment is oriented in a northeast to southwest direction. Our boring data find the existing soil slope of the tunnel portion located southwest of the swale centerline consists of natural soils. Soil fill has been placed from the base of the natural channel with progressively greater soil fill thickness up the slope to the northeast side of the channel location. Stiff to very stiff soils were encountered within the three borings advanced in this area to a depth of 20 feet below existing surface grade.

Soil at foundation levels consists of compacted clay fill for the northeast bridge abutment, weathered clay placed by water erosion at the base of the swale, and consists of loess and clay placed by water erosion at the southwest abutment. The base of the tunnel will extend into fill and natural soils northeast of the bridge and into natural soils southwest of the bridge. Fill and natural soils found in the borings are suitable for direct support of the base of the tunnel and for support of the bridge with shallow footings. A net allowable bearing pressure of 2,500 pounds per square foot is recommended for footing design, based on the soil data.

No significant site preparation appears necessary for construction of the tunnel/bridge at this location. The upper 4 to 6 inches of soil shall be removed as topsoil, due to numerous roots and other organic matter. In addition, the entire root ball of all trees and shrubs to be displaced by the proposed construction must be removed with the topsoil. Existing surface improvements in the tunnel alignment shall be removed and properly disposed of offsite. There is always a potential to uncover miscellaneous debris in any soil fill section. If debris is found, it shall be removed from the site and properly disposed of. The site soils found at the our boring locations below the thin topsoil layer are generally suitable for reuse as compacted soil fill after proper moisture content adjustments are made.

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## **1.0 INTRODUCTION**

### **1.1 Project Information**

This Report summarizes subsoil exploration work, laboratory findings, and geotechnical engineering conclusions and recommendations by The Schemmer Associates Inc. (Schemmer) for site improvement requirements and foundation design prior to construction of a proposed combination utility tunnel and bridge structure. This structure will span between existing buildings at the Department of Veterans Affairs, Central Iowa Health Care System campus in Des Moines, Iowa. The proposed construction includes a combination pedestrian bridge and utility tunnel, buried utility tunnel, and pedestrian sidewalk over the buried tunnel alignment.

### **1.2 Scope of Service**

The scope of service for this subsoil exploration was limited to:

1. Advance three borings to a depth of 20 feet below existing grade, obtaining soil samples during drilling;
2. Perform laboratory tests to aid in classifying the soils and estimating their engineering properties; and
3. Analyze results of laboratory testing to determine site and foundation-related recommendations, with regard to:
  - a. general discussion of existing conditions and their impact on the proposed construction;
  - b. allowable bearing pressure for foundation design and recommended footing placement for shallow footings;
  - c. recommendations for site improvements below structures and sidewalk pavement areas, as necessary;
  - d. requirements of fill materials and compaction of fill materials beneath construction areas;
  - e. recommendations for densification of subgrade, as necessary;
  - f. recommendations for tunnel subgrade and backfill;
  - g. recommendations for exterior sidewalk subgrade;
  - h. recommendations for automobile drive and parking lot subgrade;
  - i. consolidation magnitudes, surcharge recommendations, and required waiting times due to fill placement;
  - j. seismic design considerations;
  - k. frost-related design considerations;
  - l. comments on soil reactivity, and
  - m. groundwater and surface water considerations.



### **1.3 Report Format**

The purposes of this Report are to describe our field observations; present field and laboratory test results; and provide geotechnical engineering recommendations based on the subsoil conditions encountered. Provided in the Appendix to this Report are a Boring Location Plan showing boring locations with respect to existing features, Logs of Test Borings, a Summary of Soil Test Results, and general notes defining symbols and terms listed on the boring logs and test summary sheets.

## **2.0 EXPLORATION RESULTS**

### **2.1 Scope of Field Exploration**

A total of three test borings, labeled B-1 through Bf-3, were advanced at the site under consideration on January 14, 2013 for the purpose of gathering area subsurface data. Boring locations were determined to coincide with the bridge portion of the project. All borings made are plotted on the Boring Location Plan included in the Appendix to this Report. The borings were placed along the general, currently proposed tunnel/bridge alignment at the locations where the tunnel becomes a bridge over the drainage swale.

### **2.2 Laboratory Test Program**

Tests performed on the soil samples included a limited number of water content, dry unit weight, unconfined compressive strength, Atterberg limits, sieve analyses, and visual classification. A complete table of laboratory test results is included in the Appendix to this Report. Each test was performed in conformance with the current ASTM or state-of-the-art test procedures.

Based on the results of the testing program, the field boring logs were reviewed and supplemented, as presented in the Appendix. These final logs represent our interpretation of the in-place soil conditions.

### **2.3 Site Surface Conditions**

The site is located within the loess-mantled rolling hills of central Iowa. Urban development has existed at this location for many years. We understand the landform has been changed several times to meet the requirements of structures and pavements that currently exist. Natural soils in this area developed on glacial till, colluvium, and a thin layer of loess. Without borings, it is difficult to determine what is natural and what portions of the site have been covered by clay fill. Some of the fill has existed for a long time and large trees have grown upon it over the years.

Lawn grass and trees exist at the project location between existing parking lots, driveways, and buildings. This site is located in the south-central portion of the facility. A wooded creek and drainage floodplain exist to the south of the facility. Urban development consisting of a combination of commercial and housing development surround this complex.

A natural drainage swale exists at the specific location of the three borings. A review of the surface topography suggests the swale extended a short distance to the northwest, to a shallow hill slope that naturally existed there prior to urban development. The swale then extended south and east from the location of the borings to the creek located south of this complex.

However, a dam has effectively been placed across the drainage swale by existing parking and driveway pavement subgrade fill. A storm sewer inlet is noted within the base of the swale, within the project area and apparently provides drainage of surface water that collects in this area. It is estimated that there is a potential from water to be temporarily ponded in the project area, at the base of the swale, during heavy rainfall. However, the grass and tree growth observed in this area indicate no ponding stress has been imparted to the vegetation.

## **2.4 Area Geology**

Natural geologic setting of the area is characterized as loess-mantled, rolling glacial hills of central Iowa. This project crosses a natural drainage swale. Erosion deposits cover the glacial clay soils in this area. Loess soils cover the older water erosion deposits and glacial till on the slope located to the southwest of the center of the drainage swale. Soil fill covers the water erosion deposits and glacial clay on the east side of the drainage swale. Some loess may exist below the fill and the water erosion deposits at other locations on the northeast side of the swale, but away from our boring locations.

Area bedrock consists of sedimentary bedrock layers on the west side of the Des Moines River. The layers consist generally of limestone and shale with sandstone and coal seams. Layers of glacial till exist over the bedrock, placed between naturally occurring periods of global warming and global cooling in the geologic past. The thickness of soil above the bedrock usually allows most foundations to be supported within the soil layers above the bedrock. Three major periods of glaciation left deposits of glacial till and glacial outwash soil upon the bedrock, these are the Nebraskan, Kansan, and Illinoian age glaciers. Mild climate periods existed between these periods of major glaciation and allowed for the development of intermediate topsoil layers. The locations of existing major drainage features including creeks and rivers were generally determined by the locations of natural fractures or faults found within the buried bedrock below the glacial till layers and these streams have existed near existing locations since the Nebraskan and Kansan geologic ages. Some of the ancient drainage channels have been covered by subsequent glaciation and remained buried below the landscape.

One major and several minor periods of loess deposition placed loessial soils above the glacial till in this area. These loess soils were deposited during periods of nearby glaciation. Soil erosion due to wind and water existed during, between, and after the periods of glacial till and loess deposition. Major drainage features within the loessial topography are at the locations of streams that existed on the buried the glacial topography. The loess in this area is rather thin and has naturally eroded from the sides of many hill slopes. Loess-derived alluvium and colluvium are generally found above older deposits of glacial-age colluvium and alluvium in creek and river floodplains of this area.

## **2.5 Subsurface Conditions**

The subsurface conditions encountered in the borings have been used to infer the general soil conditions at the site. We assume the soil conditions between borings are fairly represented by the borings. During construction, if conditions are encountered other than that described below and as shown on the Logs of Test Borings included in the Appendix to this Report, it is important that the geotechnical engineers at Schemmer be informed to evaluate the exposed conditions with respect to their effect on our recommendations.

The following is a brief review of the various layers of soil encountered in current borings advanced for these buildings. All depths given are relative to the ground surface at the time of

drilling. Please refer to the boring logs in the Appendix for a more complete description of soil conditions at each boring location. Separate descriptions are provided for each soil geologic description shown on the boring logs.

**Fill** – Soil placed by human activities was found at the boring B-3 location, on the northeast side of the drainage swale. A review of the site topography finds a consistent fill slope with a gradient of about 5-horizontal to 1-vertical exists. The natural soil surface below the fill apparently was flatter than the fill slope surface. The fill extends to a depth of about 7.5 feet at boring B-3. No fill was found at borings B-1 and B-2, located on the southwest slope and base of the swale, respectively. The fill at boring B-3 consists of sandy lean clay compacted to a very stiff condition. The blocky condition of the fill suggests it was compacted at a water content above the optimum water content for compaction. Our data found the fill to exist with the following measured in-place properties:

- Water contents – 11 to 22%
- Dry unit weight – 101 to 104 pcf
- Unconfined compressive strength – 1.61 tsf
- Passing No. 200 Sieve - 59.7%
- Classification (Unified) – Sandy Lean Clay (CL)
- Standard penetration resistance - 17 blows per foot

**Peoria Loess** – Eolian soil placed as dust by wind during the Medial Wisconsinan geologic age is found at the surface of the boring B-1 location. A review of the site topography suggests the loess thickness decreases to the northeast, towards the drainage swale, and does not exist upon about half of the surface slope between borings B-1 and B-2. The loess extends to a depth of about 3 feet below surface grade at boring B-1, and it consisted of moist and stiff soil at the time boring B-1 was advanced. We estimate a perched water level and a softened loess condition will exist within this soil during periods of extended rainfall. Samples of this soil were found to exist with the following measured in-place properties:

- Water contents – 14%
- Dry unit weight – 97 pcf
- Unconfined compressive strength – 0.94 tsf
- Passing No. 200 Sieve - >95%
- Classification (Unified) – Silt (ML)

**Weathered Colluvium** – Soil deposited by water, resulting from the surface erosion of previously existing nearby soil, was found below the fill and the loess, and at the ground surface of boring B-2 at the base of the drainage swale. The upper 1.5 to 3 feet of the colluvium has been subjected to weathering over many years. This weathered colluvium appears to consist of glacial till erosion deposits and appears to have been naturally placed prior to the deposition of the Peoria loess. Samples of this soil were found with the following in-place properties:

- Water content – 11 to 20%
- Dry unit weight – 109 to 122 pcf
- Unconfined compressive strength – 2.29 to 4.71 tsf
- Liquid limit - 39%
- Plastic limit - 15%



Plasticity index - 24  
Passing No. 200 sieve - 62.6%  
Classification (Unified) – Sandy Lean Clay (CL)

**Colluvium** – Soil resulting from water erosion on the sides of existing slopes is found below the weathered colluvium at each of the three boring locations. This soil layer is 2.5 to 3 feet thick and consists of lean clay without appreciable amounts of sand or other granular materials. This moist and very stiff colluvium exists with the following in-place properties:

Water content – 12 to 15%  
Dry unit weight - 91 to 104 pcf  
Unconfined compressive strength - 0.80 to 1.57 tsf  
Passing No. 200 sieve - >95%  
Classification (Unified) – Lean Clay (CL)  
Standard penetration resistance - 18 blows per foot

**Illinois Glacial Till** – Soil deposited by glacial ice is found below the colluvium of each boring. This soil extends below the base of the 20-foot advancement of borings B-1 and B-3, and extends to a depth of about 12 feet below the ground surface at the base of the drainage swale at boring B-2. This moist and very stiff sandy lean clay exists with the following in-place properties:

Water content – 13 to 26%  
Passing No. 200 sieve - 68.3%  
Classification (Unified) – Sandy Lean Clay (CL)  
Standard penetration resistance - 12 to 19 blows per foot

**Nebraskan Glacial Till** – Soil deposited by glacial ice estimated to be of Nebraskan geologic age was found below a depth of about 14 feet at the base of the swale, at boring B-2. This soil may also exist below the boring B-1 and B-3 locations, but exists at a depth greater than the 20-foot termination of those two borings. This moist and very stiff sandy clay exists with the following in-place properties:

Water content - 16 to 18%  
Classification (Unified) – Sandy Fat Clay (CH)  
Standard penetration resistance - 20 to 21 blows per foot

## 2.6 Groundwater Data

Groundwater levels should be expected to fluctuate seasonally and yearly from the groundwater readings noted on the boring logs. The time of year the borings were drilled and the history of precipitation prior to drilling should be known when using the groundwater readings from the boring logs to extrapolate water levels at other points in time.

A groundwater level was not observed within a depth of 20 feet at any of the boring locations on January 14, 2013. Area experience suggests a perched groundwater level may intermittently develop within the thin loess soil above the glacial and colluvium soils during periods of rainfall.

## **2.7     Seismic Considerations**

Des Moines, Iowa requires seismic building design per the 2012 International Building Code (IBC). Our borings generally encountered stiff to very stiff clay and relatively loose silt deposits within a depth of 20 feet from the existing soil surfaces. Although a 100-foot deep boring was outside the scope of this exploration, an average of the upper 100 feet of soil and rock normally encountered in this area is estimated to provide a Site Class of “D” per Section 1613.3.2 of the 2012 IBC and Chapter 20 of the reference “Minimum Design Loads for Buildings and Other Structures (7-10)”, 2010, published by ASCE. We recommend the project structural engineer shall use this Site Class in seismic evaluation of the proposed structures.

## **3.0 ENGINEERING RECOMMENDATIONS**

### **3.1     Project Data**

The engineering recommendations made in this Report are based on our understanding of the project as discussed in the following paragraphs. The recommendations are valid for a specific set of project conditions. If the characteristics of the project should change from those indicated in this report section, it is important that we be informed so that we can determine whether the new conditions affect our recommendations. The following building data has been provided.

A utility tunnel to convey steam piping and other utilities is proposed. The tunnel will cross a deep drainage swale. One option for construction across the deep swale is to daylight the tunnel on the two sides of the drainage swale and then place a bridge across that portion of the alignment where the base of the tunnel exists above existing grade. A two-span bridge with a total length of 150 feet is proposed.

A sidewalk will be constructed above the utility tunnel as a part of this project. The roof of the bridge portion of the tunnel will be a pedestrian bridge. When completed, this portion of the utility tunnel will appear to be a pedestrian bridge and sidewalk crossing a tree and grass-covered park-like area within the health care complex.

Incidental construction and replacement of some portions of existing sidewalks, drives, and parking surfaces will be required. Our borings were not located over the entire utility tunnel alignment. Except for the bridge location, the tunnel will be excavated into existing soils and be covered. Sidewalks, drives, and parking surfaces that currently exist above the tunnel alignment will be replaced, per the project plans. Some trees will be removed. We expect the removed trees will not be replanted over the new tunnel alignment.

### **3.2     Discussion**

This section provides a short, general discussion of the geotechnical aspects of the site. Each of these items is discussed in greater detail within other sections of this Report.

Site soils exist in a firm to very stiff condition below the entire portion of the tunnel alignment explored by the three borings reported here. Shallow footings placed below the normal area frost protection depth are suitable for support of the bridge pier and abutments using a limited net allowable bearing pressure at each footing location. The abutments of the bridge must be located on the topography to be sure that the base of the tunnel at the abutments remains at least 3.5 feet below finished exterior grade. The soils observed in the borings are suitable for

direct support of the base of the tunnel upon the soil exposed by the tunnel excavation

We understand the site grades will generally not be changed by the proposed construction. We understand that soil fill or cut of no more than one foot from preconstruction grades will occur due to this tunnel and bridge construction project to locate the sidewalk approaches to the bridge.

### **3.3 Site Preparation**

Heavily root-infested topsoil shall be excavated from the ground surface and stockpiled for later covering of the finished grades over landscape areas. Our boring data show from 4 to 6 inches of topsoil covering the site. We recommend the contractor be directed to strip the topsoil to a minimum depth of 6 inches. If the review by the geotechnical engineer finds that additional topsoil thickness exists, the additional topsoil shall also be removed and not used below structure and pavement areas. The vegetation shall be stripped from building and pavement areas before site preparation, placement of utilities, and placement of new fill. The entire root ball shall be removed below trees and shrubs.

Pavement and other bearing surfaces shall be removed at cut joints as shown on the project plans. All existing crushed stone and sand layers shall be stripped from surfaces prior to adding additional soil fill. Areas of stone and sand fill above the clay natural soils will provide a reservoir for water that will weaken the adjoining clay fill soils and provide a reservoir for increased frost heave activity in the area of the granular fill outside the building area. These materials shall be legally disposed of offsite.

Existing surface soils within the depth of excavations consist of medium plasticity sandy lean clay of glacial and colluvial morphology, with a thin layer of silty loess over the lean clay on the southwest slope. The soil boring data suggest that only minimal site preparation is required and generally consist of stripping of topsoil, removing surface improvements, and removing a few trees. The firm soils will provide proper support of the new bridge footings and the base of the proposed utility tunnel.

Additional subgrade preparation is usually recommended below new exterior, grade supported pavements and sidewalks. A layer of uniformly compacted soil at least 12 inches thick is recommended below all pavements and sidewalks. To provide proper compaction of 12 inches of soil subgrade, we recommend the exposed subgrade be excavated to a depth of 8 inches below the base of new exterior concrete in cut areas or areas where less than 6 inches of fill above existing grade is required by the project grading plan. The exposed soil surface shall then be scarified to a depth of 6 inches and uniformly compacted to the requirements of structural fill, at a proper water content. The remaining fill shall then be placed above this recompacted soil layer to the finished subgrade levels. Tunnel backfill shall be properly compacted to the requirements of structural fill, since sidewalk and other pavement will be supported above it.

No overexcavation or other form of soil improvement is required to provide higher bearing value for the foundation and tunnel base subgrade soils at this site. We recommend the base of footings and the base of the tunnel floor slab be poured directly upon the soil exposed at the base of the excavation. The final 8 to 12 inches of subgrade below footings and the tunnel base shall be excavated on the same day that concrete will be placed at the excavated location. Do not dig bearing excavations to the finished subgrade and leave them open for more than 24 hours.

### **3.4 Fill-Related Settlement, Soil Heave**

Placement of additional fill on any site above the level of previous soil elevations will cause the subsoils to compress or consolidate under the new embankment weight. This consolidation occurs when the weight of the new fill exceeds the stress or weight previously applied to the supporting subsoil.

For this project on this site, we understand that fill might be placed to a thickness of no more than one foot above preconstruction grade. Based on past experience, we estimate total subsoil consolidation at this site under one foot of soil fill above existing grade to be less than ¼ inch. This amount of settlement is not expected to be significant and is not expected to cause any fracturing of the proposed construction. No surcharge is recommended to precompress the subsoils. No waiting period is necessary between site grading and the proposed construction.

The soil excavated for the tunnel placement may weigh more than the finished tunnel in some locations. This removal of stress from a soil can, in some cases, cause the subsoils to rebound or swell. The silt and sandy lean clay soils at this site will not rebound a significant amount due to the proposed construction. No site preparation is required to mitigate swell potential.

### **3.5 Foundation and Wall Drains**

No exterior foundation drains are recommended for the proposed bridge supports. We recommend a footing drain be installed on both sides of the tunnel. We understand the base of the tunnel will be a reinforced Portland cement concrete floor slab supported directly upon the soil subgrade after all loose soil has been removed. We recommend the placement of a footing drain placed along both edges of the floor slab, with the base of the drain being at the base of the floor slab concrete. We suggest the drain excavation be made with the floor slab excavation. It is estimated the two perimeter drains will be constructed at the same time the floor reinforcement is placed.

We recommend the drain be at least 6 inches wide with a 2 to 3 inch diameter perforated drain pipe placed at the base of the drain. The drain pipes shall not have a filter sock on them. We recommend the drain excavation be lined with a filtering geotextile, Mirafi 140N or alternate approved by the geotechnical engineer. A thin, impervious form shall be placed on the two edges of the floor to keep the Portland cement from infiltrating the drain materials. The drain shall be protected during concrete placement. No drainage material or sand should be placed below the floor slab. We understand that no coverings will be placed on the floor slab.

The tunnel will tend downward to the southwest. On the east side of the bridge, direct the ends of the perforated drain pipes around the edges of the east abutment to daylight on the side of the slope. At locations away from the footing drain, only solid-wall pipe of the same diameter as the perforated pipe shall be used and the pipe shall be backfilled with compacted clay. The outlet of the drain shall be placed on the slope outside the shadow of the bridge, in an area of grass growth. Due to normal shading below the bridge, grass growth will not occur in the vicinity of the abutment below the bridge.

For that portion of the tunnel west of the bridge, the perimeter drain pipes will slope away from the bridge. Provide storm drain piping from the perimeter drains or sump pits at locations of sags in the tunnel alignment in areas where the base of tunnel does not slope to the existing drainage swale or to an existing drainage feature. Do not ever drain the perimeter drains into an existing building footing drain system.

The type of drainage material used on the exterior walls of the tunnel will be determined by others, based on the degree of moisture infiltration allowed for this structure. If some infiltration is allowed, no drainage material is necessary along the exterior edge of the walls or top of the roof. If no infiltration of moisture is allowed, the exterior of the concrete tunnel walls and top of the tunnel roof may be lined with a thin layer of bentonite clay attached to a positive drainage board with a direct connection at the base of the drainage board to the two perimeter drains. Be sure to promptly backfill bentonite clay boards on the day they are installed to compress the clay in place as the bentonite hydrates.

We estimate that something between these two extremes will be necessary. For ease of construction, we suggest the placement of a preformed drain board on the outer edge of the concrete walls and no water collection system at the top. The wall shall then be backfilled with compacted clay, placed in compacted lifts to the requirements of structural fill. If a drain board is used, the board shall be installed with direct hydraulic connection to the perimeter drain pipes.

An alternative to a preformed drain board is to place sand fill from the base of the wall to the top of the wall as backfill. The sand backfill shall be completely enclosed in the filtering geotextile described above and must be compacted to the requirements of structural fill. At the top of the sand wall backfill, wrap the top edges of the filtering geotextile together.

At the top of the concrete roof of the tunnel, we suggest the placement of a plastic liner to inhibit water flow through the top of the tunnel. This layer is recommended where a top drain is used or not used. Care shall be used when compacting the upper 12 inches of soil backfill on top of the tunnel to protect the plastic from damage.

### **3.6 Foundation Recommendations**

**3.6.1 Footing Depth, Frost Considerations.** Exterior footings and interior footings not heated on all sides shall be placed at a depth of at least 42 inches below the lowest adjacent unheated or exterior grade to inhibit damage from frost action. Interior footings that exist completely surrounded by heated rooms may be placed at any convenient depth, as long as they bear at least 12 inches below the floor subgrade soil surface. However, we understand the floor of the tunnel is the footing for the tunnel.

Structural stoops supported by footings shall be placed at all exterior swinging doors. An expansion joint of sufficient thickness that penetrates the adjoin sidewalk or pavement shall be placed at all locations where exterior pavements or sidewalks abut existing building walls or structural stoops. Exterior sidewalks shall not be supported on the edge of a structural stoop footing. Care shall be used to not allow exterior concrete slabs to extend below siding or other exterior wall coverings.

**3.6.2 Foundation Types.** Shallow footings are suitable for support of proposed bridge footings at abutments and the bridge pier at this site. This statement assumes the recommendations of this Report are completed prior to footing installation. Bearing loads of the bridge have not been provided, but we assume they are rather light. We are aware of no elevator pits or other very heavy building components to be supported by new shallow footings. We are aware of no heavy equipment loads.

**3.6.3 Allowable Bearing Pressure.** A net allowable soil bearing pressure of 2,500 pounds per square foot is available for support of normally constructed shallow footing foundations placed to the recommended depths. A factor of safety of 3 against general



shear failure was utilized when calculating the soil bearing pressure. This bearing pressure value is suitable for bridge and tunnel footings. Footings shall be excavated into firm natural soils or properly compacted fill with the excavation sides being the forms for the footing concrete.

After excavation, care should be taken to avoid wetting soils exposed at the base of the footings. Footing subgrade should not be allowed to freeze before or after footings are poured. Concrete should not be placed upon wetted or frozen soils. If rain or other surface water saturates the exposed soils, the geotechnical engineer should be notified and requested to provide suitable recommendations for construction, based on observed conditions at that time.

Conversely, it is also potentially damaging to the footing support to allow the soils at the base of the footing to dry prior to footing concrete placement. To reduce the potential for excessive wetting or drying of the foundation subgrade and to help keep the footing subgrade from freezing, we recommend the lower 8" of any footing excavation not be dug until the day the footing concrete will be poured or that the contractor protect the footing subgrade from weather conditions.

Construction during winter weather is a concern for shallow footings. Protect the subgrade of shallow footings from frost during winter construction.

**3.6.4 Lateral Earth Pressure.** Lateral soil pressure will develop on the footings due to wind and other lateral forces. Footings supporting lateral loads must be poured in firm contact with the sides of the footing excavation. No forms shall be used on the sides of these footings.

Soil resistance to lateral forces will depend upon the depth of the footing below frost action and other factors that seasonally loosen soils. The following lateral earth pressures, expressed as equivalent fluid pressures without a factor of safety, are recommended in design of foundation walls to support lateral loads:

|                    |         |
|--------------------|---------|
| Passive Resistance | 180 pcf |
| Active Pressure    | 55 pcf  |
| At-Rest Pressure   | 65 pcf  |

Adhesion at the base of the footings supporting lateral load is estimated to be 650 psf. This value does not include a factor of safety.

The lateral load values provided here do not include water pressure loads. We are aware of no situation that would develop a lateral water load on the bridge footings at this site. No footing drains shall be used for the bridge footings. Footing drains for the tunnel have been discussed in a separate section of this Report.

**3.6.5 Excavation Stability.** Some of the proposed footing excavations will extend through properly compacted soil fill. All footings will be supported on natural clay soil or properly compacted soil fill. We have no special excavation stability concerns with excavations within properly compacted fill or the firm natural soils.

In any case, conform to the regulations provided by the U.S. Government and OSHA concerning excavation safety, 29 CFR Part 1926, Occupational Safety and Health Standards - Excavations. Sloped excavations or temporary retaining structures are estimated to be necessary for all cuts into sand. For the clay fill and natural clay deposits expected to be found in the footing and utility excavations at this site, the soil is estimated to generally classify as Type B per 29 CFR Part 1926, Occupational Safety and Health Standards – Excavations. Soil conditions vary and it is necessary for the contractor to have a trained person on-site during construction to determine the actual exposed soil type during excavation, with the authority to properly direct the excavation safety. The geotechnical engineer or his staff is not this person.

Closely spaced parallel excavations should be avoided because an unstable column of soil will be formed between these excavations, especially if one of the excavations is filled before the other. The dangerous effects of closely spaced parallel excavations will remain forever after one excavation is filled prior to digging an adjacent excavation.

**3.6.6 Foundation Settlements.** After the consolidation due to fill placement has been stabilized, foundation settlements of less than 1/4 inch total and less than 1/4 inch differential in a 30-foot span are estimated under the anticipated building loading, as assumed in this Report, using the net allowable bearing pressures listed above for shallow footings. These values do not include any effects of fill placement above preconstruction grades around the structures during and after construction.

### **3.7 Exterior Pavement Recommendations**

We estimate that new Portland cement pavement for sidewalks, drives, and parking lots will be placed as part of the proposed construction. Subgrade treatment is provided in Section 3.3 of this Report. All fill and backfill shall be properly compacted to structural fill quality as discussed in Section 3.9 of this Report. A layer of properly compacted soil subgrade at least 12 inches thick is recommended below all pavements and new sidewalk.

Schemmer recommends the site preparation fill be final prepared with additional surface density compaction testing performed immediately prior to placing the pavement and sidewalk. There is always the potential for rainfall or other inclement weather to occur between fill placement and pavement placement. If the soil surface is wetted by rainfall or disturbed in any way, the affected areas shall be scarified and compacted to the requirements of structural fill.

Immediately prior to driveway and parking lot paving, the rolling stability of the pavement subgrade shall be evaluated in the presence of the geotechnical engineer or his trained representative through the rolling of a fully loaded tandem axle dump truck over the subgrade. The truck should hold about 10 yards of soil during this proof roll test. As the truck is driven slowly back and forth across the subgrade, the engineer will observe the subgrade deflection and rebound under the loaded tires. If excessive deflection is observed, it is an indication that a portion of the subgrade is too wet or otherwise unstable and that subgrade area will need to be overexcavated and replaced with properly conditioned and compacted subgrade soil fill.

We estimate the recommended prepared subgrade compacted in accordance with these recommendations will have a pavement modulus of subgrade reaction of about 120 psi/in of a CBR value of 3. We recommend that the site modulus of subgrade reaction value or CBR value be evaluated during construction, with appropriate laboratory or field tests.

We recommend that granular fill in the form of a base course not be used below exterior pavements or sidewalks in this area. Trench drains that extend to a depth of at least 4 feet and drain to the storm sewer system are required if a granular pavement base layer is used. Water will not drain from the granular base into the rather flat compacted fill subgrade surface resulting below pavements at this site. Water will not readily seep into the compacted soil fill subgrade, but will remain ponded in any granular fill over an extended period of time where sufficient trench drains are not installed. Undrained granular fill will intensify any moisture movement problems and provide a reservoir of water for winter frost heave.

### **3.8 Tunnel Floor Slab**

The floor of the tunnel will be used as the foundation for the tunnel. The tunnel may be designed using the same parameters as the footings, found in Section 3.6 of this Report. All new fill beneath the tunnel floor slabs shall be mechanically densified to at least 95% of the maximum dry unit weight of the soil, as determined by ASTM D698-07e1, standard Proctor test. The water content of clay soil being compacted should be within +4 and -3 percentage points from the optimum water content, also determined by ASTM D698-07e1.

We expect the tunnel floor will be placed on top of the existing clay subgrade consisting of natural soils or fill. Concrete should be placed the same day that portion of the excavation is complete to keep the subgrade soil water content from changing. Any floor subgrade that is wetted or loosened prior to placing concrete should be reconditioned through scarification and water content manipulation prior to being compacted to the requirements of structural fill found in the preceding paragraph, or the base of the excavation deepened to remove the disturbed soils and thicker concrete placed.

Control of the water content of clayey or silty soil being compacted for subgrade is very important in order to reduce the potential for floor slab cracking. Although it is sometimes possible to achieve the recommended compacted soil unit weight when compaction is performed at water contents outside of the recommended water content range, the stability of the resulting subgrade will be significantly less if the soil is compacted too wet or too dry. Compaction of the soil subgrade outside the recommended water content limits can result in uncontrollable floor slab cracking and floor joint failures. These chronic slab movements can only be corrected by removing the pavement and then overexcavating and replacing the upper couple of feet of subgrade fill soil with soil properly compacted at a proper water content before replacing the pavement.

Portland cement shrinks as the material cures. The shrinkage is greater if the concrete surface dries prior to obtaining sufficient setup strength. Always keep the surface of the floor slab moist within the first 72 hours after pouring. Use of a spray-applied curing compound is recommended to hold the moisture within the surface of the concrete during this period. Lack of sufficient curing process that allows the concrete surface to dry will result in curling of the edges of the individual slab panels, resulting in characteristic bumps in the floor near each joint.

### **3.9 Fill Requirements**

Material for use as site fill should be clean, inorganic, medium-plasticity lean clay, CL<sup>1</sup>, or silt ML<sup>2</sup>, or a combination of these two materials both with a liquid limit less than 45 and a plasticity

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<sup>1</sup> Lean clay, lean clay with sand and sandy clay.

<sup>2</sup> Silt, silt with sand and sandy silt.

index less than 25. The near surface site soils below the topsoil are generally suitable for reuse as structural fill.

Sandy or gravelly low to medium plasticity lean clay and sandy or gravelly silt soils are also acceptable, provided no more than 20 percent is retained on the No. 200 Standard US sieve and the sand and gravel are well and completely mixed into the soil. Any granular particles shall have a maximum dimension of 3 inches. Sandy soils with classification of SM<sup>3</sup>, SC<sup>4</sup>, organic soils with classification OH<sup>5</sup> or OL<sup>6</sup>, and highly plastic clays with classification of CH<sup>7</sup> are not approved for general or structure fill below footings, against footings, as backfill, or below exterior pavements and sidewalks at this site. Use of sand as a fill material is not acceptable at this site, except for special drainage layers.

The topsoil strippings will not be suitable for use in embankment fill and should be stockpiled for reuse in covering future vegetated portions of the site after grading and building activities are completed. Stripping soil generally provides greater resistance to water erosion on slopes and provides a better seedbed to grow erosion-resistant plants on slopes and across the entire site.

Proposed fill and backfill materials should be subject to approval by the geotechnical engineer. Representative samples of the proposed fill and backfill materials should be submitted to the geotechnical engineer at least five days prior to placement so the necessary laboratory tests can be performed.

Cohesive structural fill soils being compacted shall also be of proper water content, within +4% and -3% percentage points of optimum water per ASTM D698-07e1, Standard Proctor.

All structural quality fill should be placed in nearly level lifts, not more than 8-inch loose thickness, after the water content has been manipulated to within the levels stated in the previous paragraphs. Attempts to wet or dry soil within the new fill location usually results in formation of layers of wet and dry soil with reduced strength and stability. Prepare the soil prior to placing on the fill area. Each fill lift must be compacted before additional soil is added. When small and hand compaction equipment is used next to existing and new building features, fill layer thickness shall be reduced to 4 inches or less.

New structural fill below and against future buildings, floor slabs, pavements, sidewalk, and footings shall be compacted to not less than 95% of the maximum dry unit weight determined by ASTM D698-07e1, standard Proctor test.

General fill in areas to support vegetation only should be compacted to not less than 85 percent and no more than 92 percent of the maximum dry unit weight determined by ASTM D698-00ae1. Only the upper 2 feet of fill on slopes or anywhere on this site away from pavement or structures can be considered as general fill. All fill below a depth of 2 feet from the finished surface, no matter where it exists on the site, shall be considered structural fill and be properly compacted.

Surface scarification may be required for planting in fill to allow initial root penetration. Since fill soil has rather low permeability, we recommend that transplanted trees or other plants that have

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<sup>3</sup> Silty sand.

<sup>4</sup> Clayey sand.

<sup>5</sup> Elastic Silt

<sup>6</sup> Organic Clay or Organic Silt

<sup>7</sup> Fat clay, fat clay with sand, and/or sandy fat clay

root balls not be placed in excavations that extend into the fill materials. The roots are many times drowned in the water-filled basin that results in the hole placed into compacted soil fill. Place the plant on top of the finished grade and mound some soil around it. The roots will then grow into the fill soil over the next couple of years.

### **3.10 Backfill**

Backfill over exterior footings and next to walls shall be compacted to not less than 95% of the maximum dry unit weight determined by ASTM D698-07e1, standard Proctor test. Backfill soils should also be of proper water content, within +4% and -3% of optimum water, per ASTM D698-07e1, Standard Proctor. Sand wall backfill, if used, shall be compacted at any convenient water content that does not cause sand bulking to occur. We suggest that thin fill lifts be used and the walls be properly braced prior to backfill placement. For the tunnel, the backfill shall proceed equally on the two sides.

### **3.11 Loessial Collapse Potential**

Some undisturbed soils of Peoria loess geologic origin are susceptible to loss of strength due to increases in water content through a process termed “loessial collapse”. Loessial collapse occurs in low water content and low-unit weight loess. Collapse does not generally occur in colluvium derived from Peoria loess. The loess must have both a low water content and low in-place unit weight to have a significant loessial collapse potential. The soil water content generally needs to be less than 10% and the in-place dry unit weight of undisturbed the natural loess generally needs to be less than 80 pcf. As low-water content and low-unit weight loess soils are wetted to saturation, the internal structure of the soil is softened, the softened soils consolidate to cause significant settlement of all things supported on them, and the resulting devastating increase in soil pore pressure significantly reduces the soil shear strength resulting in complete foundation failures. It is noted that wet loess and compacted fill soil derived from loess have no potential for loessial collapse, although these soils are capable of consolidation under added fill or bearing loads.

No areas of significant loessial collapse potential are indicated by the current boring data below the proposed construction areas. No special provisions to reduce loessial collapse are recommended.

### **3.12 Additional Considerations**

Soils in this area have a high potential for heaving due to winter frost action. Depending upon the subsurface moisture available and permeability of the soils, these soils can heave in excess of 1 inch during the normal winter season. Eventual frost heave potential is not significantly altered by degree of soil fill compaction or reduced by heavy compaction. After several winter seasons, previously compacted soil fill will heave nearly as much as soil of similar type that has not been compacted. Providing efficient and complete drainage of the surface water runoff can decrease frost heave potential by decreasing the amount of water that soaks into the ground and is, therefore, available for future frost heaving. Provide a full-depth expansion joint between exterior pavements and building components to keep frost heave occurring below the pavement from lifting the adjacent building components.

External slab heaving due to winter frost action can cause serious access problems at exterior swinging doors. Appropriate measures should be taken to stabilize pavements and walks at doorways. Structural stoops are recommended at all exterior swinging doorways.



Final site grade should provide positive drainage away from structures. A minimum gradient of 0.5% is recommended for pavement surfaces next to and around buildings. For vegetation-covered areas, a minimum gradient of 2.0% is recommended within 10 feet of the exterior of structures. Proper placement and compaction of utility and wall trench backfills will reduce moisture migration to foundation levels. Grass covered drainage swales should use a minimum gradient of at least 3.0% if the grass is irrigated to allow water drainage between water applications.

Any proposed landscape feature that exists in an area of potential ponding and is surrounded by concrete curbs should be separately drained. Perforated pipes and connections to a storm sewer or other gravity drainage system should be provided. Any irrigation system should be constructed and operated to prevent accumulation of water ponds near foundations.

The soils found at this site are typical of the area. Past experience indicates that corrosion of buried metallic pipes will occur and corrosion protection is recommended. Sulfate corrosion potential of Portland cement is generally minimal, and Type I Portland cement is allowable for use. Exterior concrete shall be air-entrained to reduce damage from frost action. Air-entrainment chemicals in concrete can decrease the adhesive effect of some interior concrete coverings.

## **4.0 CONSTRUCTION CONSIDERATIONS**

All excavation work should be completed in accordance with OSHA standards. Where safe back-slopes cannot be provided, bracing designed by competent professionals should be installed. The results of our subsurface water measurements indicate that dewatering during construction will not be necessary for normal excavation at this site. The compaction of fill and backfill should be tested to determine compliance with the construction documents. Fresh concrete shall be tested for compliance with the construction documents. Schemmer is available to assist with construction materials testing and special inspection of structural items.

## **5.0 OBSERVATION AND TESTING**

Since a project of this nature requires many soil-related judgments and decisions, we recommend that Schemmer geotechnical engineering be retained as part of the design and construction team. Schemmer should be requested to monitor fill placement. We recommend that a geotechnical engineer from Schemmer visually inspect all footing trenches prior to placing concrete. We recommend that Schemmer review the base of overexcavation to determine that the recommendations of this Report are followed. Any unsuitable or wet soil conditions existing at footing level can then be delineated for removal and replacement. We also recommend that a limited number of compaction tests be performed to document the degree of compaction obtained in backfill and structural fill.

Schemmer is also available to provide trained and certified professionals to perform special inspections of building structural components. Our inspectors are also cross-trained to perform tests of concrete, mortar, and other building materials.

## **6.0 FIELD EXPLORATION PROCEDURES**

### **6.1 Soil Sampling**

The test borings were made with truck-mounted CME 55 drilling and sampling rig using 3.25-inch internal diameter hollow-stem flight auger to advance the borings. Relatively undisturbed samples of cohesive soils were obtained with thin-walled tube samplers. These samples were packaged in appropriate containers and brought to our laboratory. Select samples were evaluated for in-place unit weight and strength.



Split barrel sampling was performed on very stiff glacial till deposits in accordance with ASTM D 1586. Using this procedure, a 2-inch outside diameter split-barrel sampler is driven into the soil by successive blows of a 140-pound weight falling 30 inches. After an initial set penetration of 6 inches, the number of blows required to drive the sampler an additional 12 inches was recorded as the “penetration resistance” or “N value”. The N value is an index of the relative density of cohesionless soils and the relative consistency or strength of cohesive clay soils.

### **6.2 Soil Classification**

As the samples were obtained in the field, they were visually and manually classified by the drill crew chief in general accordance with ASTM D2487-06 and D2488-06. Representative portions of the samples were then returned to the laboratory for further examination and verification of field classification. Logs of the borings indicating the depth and identification of the various strata, water level information, and pertinent information regarding the method of maintaining and advancing the drill holes are included in the Appendix. Charts illustrating the soil classification procedure are also included in the Appendix.

## 7.0 STANDARD OF CARE

This Report has been prepared for the exclusive use of our client. The recommendations contained in this Report represent our professional opinions. These opinions were arrived at in accordance with currently accepted engineering procedures at this time and location. Other than this, no warranty, either expressed or implied, is intended.

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|  | <b>THE SCHEMMER ASSOCIATES INC.</b>  |
|   | <p>I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Nebraska.</p> <p> Date: <u>2/4/2013</u></p> <p><b>LORAS A. KLOSTERMANN, P.E.</b> #E-6498<br/>Geotechnical Engineer</p> <p>My license renewal date is <b>December 31, 2013</b></p> <p>Pages or sheets covered by this seal: All pages</p> |

# **APPENDIX**







|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|---|-------------------------|-----------------------------|------------|---|-----------|------------|---|---------------|-----------|-------------------------|-------------------------|------------------------------------|-------------|---------------------------------|---------------|----|--|----|--|
| <div>SCHEMMER</div> <div>ARCHITECTS   ENGINEERS   PLANNERS</div> <div>GEOTECHNICAL ENGINEERING DIVISION</div> |                         |                             |            | PROJECT: Tunnel/Bridge for Central Chiller/Boiler Plant               |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            | LOCATION: 3600 30th Street, Des Moines, Iowa                          |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            | CLIENT: Department of Veteran Affairs - Des Moines, Iowa              |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            | JOB No. : 06054.013   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            | DATE: 01/14/13  |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
| BORING LOG  |                         |                             |            |   |           |            | BORING No. : B-2  |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
| WEATHER CONDITIONS  |                         |                             |            | BORING LOCATION   |           |            |   | SURFACE ELEV. |           | ELEVATION DATUM         |                         | DRILLER                            |             | LOGGER                          |               |    |  |    |  |
| 25° F, Partly Cloudy<br>Southwest Breeze  |                         |                             |            | See Boring Location Plan  |           |            |   | 110.4         |           | Site                    |                         | Ryan O'Malley<br>O'Malley Drilling |             | Shawn Gray<br>O'Malley Drilling |               |    |  |    |  |
| GROUNDWATER LEVEL OBSERVATIONS  |                         |                             |            | TYPE OF SURFACE   |           |            |   |               |           | DRILL RIG               |                         |                                    |             |                                 |               |    |  |    |  |
| WHILE DRILLING  | END OF DRILLING         | 24 HOURS AFTER DRILLING     | - HOURS    | Grass   |           |            |   |               |           |                         |                         | CME-55                             |             |                                 |               |    |  |    |  |
|   |                         |                             |            | DRILLING METHOD   |           |            |   |               |           | BIT USED                |                         | TOTAL DEPTH                        |             |                                 |               |    |  |    |  |
| None  | None                    |                             |            | 3.25" I. D. Hollow-Stem Auger<br>3" Thin-Walled Tube, 2" Split-Barrel |           |            |   |               |           | Finger                  |                         | 20.0 feet                          |             |                                 |               |    |  |    |  |
| SAMPLE DATA   |                         |                             |            | DESCRIPTION OF SOIL   |           |            |   |               |           | LABORATORY RESULTS      |                         |                                    |             |                                 |               |    |  |    |  |
| DEPTH<br>FT   | SAMPLE<br>TYPE &<br>NO. | "N"<br>BLOWS<br>PER<br>FOOT | %<br>REC.  | COLOR   | MOIST     | CONS       | GEOLOGICAL DESCRIPTION  |               | MC<br>(%) | DRY<br>DENSITY<br>(PCF) | q <sub>u</sub><br>(tsf) | SOIL<br>CLASS                      | DEPTH<br>FT |                                 |               |    |  |    |  |
| 5   | U-1                     |                             | 100        | dark gray   | moist     | stiff      | 4" thick, Weathered soil surface  |               | 11        | 122                     | 4.71<br>*4.5+           | CL                                 | 5           |                                 |               |    |  |    |  |
|   |                         |                             |            | gray  | very damp | very stiff | Weathered colluvium, sandy lean clay, medium plasticity, carbon nodules, ferrous stains, calcareous nodules, blocky, fine to medium sand grains with some gravel and few cobbles, earthy odor, few root holes |               |           |                         |                         | CL                                 |             |                                 |               |    |  |    |  |
|   | U-2                     |                             | 100        | brown   | moist     | very stiff | Colluvium, lean clay, low plasticity, carbon nodules, ferrous stains, root holes, layered, very blocky, few tree roots, earthy odor   |               |           |                         |                         | 14                                 |             | 91                              | 0.80<br>*4.5+ | CL |  |    |  |
|   |                         |                             |            | gray and brown mottled  | moist     | very stiff | Illinoisian glacial till, sandy lean clay with gravel and some cobbles, medium plasticity, carbon nodules, ferrous stains, calcareous nodules, fine to coarse sand, fine gravel, earthy odor                  |               |           |                         |                         | 13                                 |             |                                 | *4.5+         | CL |  |    |  |
| SB-4  | 19                      | 100                         | gray brown |   |           |            |   |               |           |                         | 10                      |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             | red brown  |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
| 15  | SB5                     | 21                          | 100        | dark gray   | moist     | very stiff | Nebraskan glacial till, sandy fat clay, high plasticity, fine to medium sand grains, carbon nodules   |               | 16        |                         |                         |                                    |             |                                 |               | 15 |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   | SB6                     | 20                          | 100        |   |           |            |   |               |           |                         |                         | 14                                 |             |                                 |               |    |  | 20 |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
| 20  |                         |                             |            |   |           |            | BOTTOM OF BORING @ 20.0'  |               |           |                         |                         |                                    |             |                                 |               | 25 |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
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|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |
|   |                         |                             |            |   |           |            |   |               |           |                         |                         |                                    |             |                                 |               |    |  |    |  |

|   |                   |                    |        |  |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
|---|-------------------|--------------------|--------|--|-------|-----------------|---|---|--|-----------------|-------------------|------------------------------------|------------|---------------------------------|--|--|
| <div>SCHEMMER</div> <div>ARCHITECTS   ENGINEERS   PLANNERS</div> <div>GEOTECHNICAL ENGINEERING DIVISION</div> |                   |                    |        | PROJECT: Tunnel/Bridge for Central Chiller/Boiler Plant  |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
|   |                   |                    |        | LOCATION: 3600 30th Street, Des Moines, Iowa             |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
|   |                   |                    |        | CLIENT: Department of Veteran Affairs - Des Moines, Iowa |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
|   |                   |                    |        | JOB No. : 06054.013                                      |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
|   |                   |                    |        | DATE: 01/14/13   |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
| BORING LOG  |                   |                    |        |  |       |                 |   | BORING No. : B-3  |  |                 |                   |                                    |            |                                 |  |  |
| WEATHER CONDITIONS  |                   |                    |        | BORING LOCATION  |       |                 |   | SURFACE ELEV.   |  | ELEVATION DATUM |                   | DRILLER                            |            | LOGGER                          |  |  |
| 30° F, Partly Cloudy<br>Southwest Breeze  |                   |                    |        | See Boring Location Plan                                 |       |                 |   | 128.3   |  | Site            |                   | Ryan O'Malley<br>O'Malley Drilling |            | Shawn Gray<br>O'Malley Drilling |  |  |
| GROUNDWATER LEVEL OBSERVATIONS  |                   |                    |        |  |       | TYPE OF SURFACE |   |   |  |                 |                   | DRILL RIG                          |            |                                 |  |  |
| WHILE DRILLING  |                   | END OF DRILLING    |        | 24 HOURS AFTER DRILLING                                  |       | - HOURS         |   | Grass   |  |                 |                   | CME-55                             |            |                                 |  |  |
|   |                   |                    |        |  |       | DRILLING METHOD |   |   |  | BIT USED        |                   | TOTAL DEPTH                        |            |                                 |  |  |
| None  |                   | None               |        |  |       |                 |   | 3.25" I. D. Hollow-Stem Auger<br>3" Thin-Walled Tube, 2" Split-Barrel |  |                 |                   | Finger                             |            | 20.0 feet                       |  |  |
| SAMPLE DATA   |                   |                    |        | DESCRIPTION OF SOIL                                      |       |                 |   |   |  |                 |                   | LABORATORY RESULTS                 |            |                                 |  |  |
| DEPTH   | SAMPLE TYPE & NO. | "N" BLOWS PER FOOT | % REC. | COLOR  | MOIST | CONS            | GEOLOGICAL DESCRIPTION  |   |  | MC (%)          | DRY DENSITY (PCF) | q <sub>u</sub> (tsf)               | SOIL CLASS | DEPTH                           |  |  |
| FT  |                   |                    |        |  |       |                 |   |   |  |                 |                   |                                    |            | FT                              |  |  |
| 5   | U-1               |                    | 100    | dark gray  | moist | stiff           | 4" thick, Weathered soil surface  |   |  | 22              | 104               | 1.61<br>*4.5+                      | CL         | 5                               |  |  |
|   |                   |                    |        | dark gray  | moist | very stiff      | Fill, sandy lean clay, medium plasticity, carbon nodules, ferrous stains, seams of silty sand, brick fragments, layered, fine to medium sand grains, blocky, earthy odor                    |   |  |                 |                   |                                    | CL         |                                 |  |  |
|   | U-2               |                    | 100    | light brown and gray mottled                             |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
|   | SB-3              | 17                 | 100    |  |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
| 10  | SB-4              | 18                 | 100    | dark gray brown  | moist | very stiff      | Weathered colluvium, lean clay, medium plasticity, carbon nodules, ferrous stains, blocky, few root holes, earthy odor  |   |  | 12              |                   |                                    | CL         | 10                              |  |  |
|   |                   |                    |        | light gray brown   | moist | very stiff      | Colluvium, lean clay, low plasticity, carbon nodules, ferrous stains, root holes, layered, blocky, earthy odor  |   |  |                 |                   |                                    | CL         |                                 |  |  |
| 15  | SB-5              | 12                 | 89     | gray and brown mottled                                   | moist | very stiff      | Illinoisan glacial till, sandy lean clay with gravel and some cobbles, medium plasticity, carbon nodules, ferrous stains, calcareous nodules, fine to coarse sand, fine gravel, earthy odor |   |  | 18              |                   |                                    | CL         | 15                              |  |  |
|   |                   |                    |        |  |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
| 20  | SB-6              | 16                 | 78     |  |       |                 | BOTTOM OF BORING @ 20.0'  |   |  | 16              |                   |                                    |            | 20                              |  |  |
|   |                   |                    |        |  |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |
| 25  |                   |                    |        |  |       |                 |   |   |  |                 |                   |                                    |            | 25                              |  |  |
|   |                   |                    |        |  |       |                 |   |   |  |                 |                   |                                    |            |                                 |  |  |

**SUMMARY OF SOIL TEST RESULTS**

PROJECT: Tunnel/Bridge for Central Chiller/Boiler Plant

TSA JOB NO: 06054.013

CLIENT: Department of Veterans Affairs - Des Moines, Iowa

DATE: 01/23/13

LOCATION: 3600 30th Street, Des Moines, Iowa

| BORING<br>No. | SAMPLE<br>NO. | SAMPLE<br>DEPTH | SAMPLE<br>DIAM. | SAMPLE<br>LENGTH | WATER<br>CONTENT | UNIT WT.<br>WET | UNIT WT.<br>DRY | VOID<br>RATIO | SAT. | UNCONFINED              |                  | SOIL CLASSIFICATION |    |    |                 | REMARKS |                 |
|---------------|---------------|-----------------|-----------------|------------------|------------------|-----------------|-----------------|---------------|------|-------------------------|------------------|---------------------|----|----|-----------------|---------|-----------------|
|               |               |                 |                 |                  |                  |                 |                 |               |      | COMPRESSION             |                  | ATTERBERG<br>LIMITS |    |    | PASSING<br>#200 |         | SYMBOL          |
|               |               |                 |                 |                  |                  |                 |                 |               |      | q <sub>u</sub><br>(tsf) | STRAIN<br>(€, %) | LL                  | PL | PI |                 |         |                 |
|               |               | (ft.)           | (in.)           | (in.)            | (%)              | (pcf)           | (pcf)           | (e)           | (%)  |                         |                  |                     |    |    |                 |         |                 |
| B-1           | U-1           | 1-2.5           | 2.826           | 5.8              | 13.8             | 110.9           | 97.4            | 0.72          | 52   | 0.943                   | 15.1             | 39                  | 15 | 24 | 62.60           | CL      | Sandy Lean Clay |
|               | U-2           | 3.5-5           | 2.862           | 5.7              | 19.8             | 130.8           | 109.2           | 0.53          | 100  | 2.294                   | 10.8             |                     |    |    |                 |         |                 |
|               | U-3           | 6-7.5           | 2.849           | 4.1              | 15.0             | 119.3           | 103.7           | 0.61          | 66   | 1.566                   | 1.6              |                     |    |    |                 |         |                 |
|               | SB-4          | 8.5-10          |                 |                  | 25.8             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-5          | 13.5-15         |                 |                  | 15.5             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-6          | 18.5-20         |                 |                  | 13.7             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
| B-2           | U-1           | 1-2.5           | 2.840           | 4.4              | 10.5             | 134.3           | 121.6           | 0.38          | 75   | 4.711                   | 2.6              |                     |    |    | 68.30           |         | Sandy Lean Clay |
|               | U-2           | 3.5-5           | 2.814           | 5.7              | 14.2             | 104.0           | 91.0            | 0.84          | 46   | 0.798                   | 1.3              |                     |    |    |                 |         |                 |
|               | U-3           | 6-7.5           |                 |                  |                  |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-4          | 8.5-10          |                 |                  | 12.6             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-5          | 13.5-15         |                 |                  | 16.3             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-6          | 18.5-20         |                 |                  | 13.7             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
| B-3           | U-1           | 1-2.5           | 2.871           | 5.4              | 21.7             | 126.3           | 103.7           | 0.61          | 95   | 1.608                   | 7.2              |                     |    |    | 59.70           |         | Sandy Lean Clay |
|               | U-2           | 3.5-5           | 2.812           | 4.6              | 22.1             | 123.4           | 101.0           | 0.65          | 90   |                         |                  |                     |    |    |                 |         |                 |
|               | SB-3          | 6-7.5           |                 |                  | 11.1             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-4          | 8.5-10          |                 |                  | 12.2             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-5          | 13.5-15         |                 |                  | 18.2             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |
|               | SB-6          | 18.5-20         |                 |                  | 15.7             |                 |                 |               |      |                         |                  |                     |    |    |                 |         |                 |

## GENERAL NOTES


### DRILLING AND SAMPLING SYMBOLS

|             |  |
|-------------|--|
| SB          | : Split-Barrel - 2" O.D., Unless Otherwise Noted                                     |
| U           | : Thin-Walled Tube - 3" O.D., Unless Otherwise Noted                                 |
| B           | : Bag Sample - From Cutting, Unless Otherwise Noted                                  |
| T           | : Test Pit Grab Sample   |
| REC         | : Sample Recovery, Percent   |
| NSR         | : No Sample Recovered  |
| NMR         | : No Measurement Recorded, Due to Drilling Fluid                                     |
| NONE        | : No Groundwater Level Encountered Within Drilling Depth                             |
| MOIST       | : Moisture Condition   |
| CONS        | : Consistency  |
| SOIL CLASS: | Soil Classification per ASTM D 2487, Unless Otherwise Noted (Unified System Symbols) |
| Fish        | : Fish Tail Drilling Bit   |
| CFA         | : Continuous Flight Auger  |
| HSA         | : Hollow Stem Auger  |

### SOIL DESCRIPTION ABBREVIATIONS

|      |  |
|------|--|
| med. | : Medium, as in Medium Stiff or Medium Dense |
| sl.  | : Slightly, as in Slightly Moist             |

### TEST SYMBOLS

|   |   |
|---|---|
| MC  | : Moisture Content - % of Dry Soil Weight (ASTM D 2216) |
| SAT.  | : Saturation of Sample - %                              |
| qu  | : Unconfined Compressive Strength (ASTM D 2166)         |
| STRAIN  | : Strain at Maximum Strength (ASTM D 2166)              |
| LL  | : Liquid Limit (ASTM D 4318)                            |
| PL  | : Plastic Limit (ASTM D 4318)                           |
| PI  | : Plasticity Index (ASTM 4318)                          |
| PASSING No. 200   | : Passing No. 200 Sieve (ASTM D 422)                    |
|  | : Groundwater Level Measurement                         |

### ADDITIONAL SYMBOLS

|  |  |
|--|--|
| Pq   | : Penetrometer Reading - tons per square foot  |
| Ts   | : Torvane Reading - tons per square foot       |
| SPG  | : Specific Gravity (ASTM D 854)                |
| SHL  | : Shrinkage Limit (ASTM D 427)                 |
| OC   | : Organic Content                              |
| pH   | : Hydrogen Ion Content                         |
| SC   | : Sulfate Ion Content - Parts/Million or mg/L  |
| CC   | : Chloride Ion Content - Parts/Million or mg/L |
| C*   | : One-Dimensional Consolidation (ASTM D 2435)  |
| Qc*  | : Triaxial Compression                         |
| DS*  | : Direct Shear (ASTM D 3080)                   |
| K*   | : Coefficient of Permeability - cm/sec         |
| LR   | : Laboratory Resistivity - Ohm-cm (ASTM G 57)  |
| RQD  | : Rock Quality Designation - Percent           |
| * See attached data sheet or graph, if used. |  |

### Notes:

- Standard "N" Penetration (ASTM D 1586): Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split-barrel sampler.
- Water levels shown on the boring logs are the levels measured in the borings at the time and under the conditions indicated. In pervious soils, the indicated levels may reflect the location of the groundwater. In low permeability soils, the accurate determination of the groundwater levels is not possible with only short term observations. Please note that groundwater levels vary with time and location.

### CONSISTENCY OF COHESIVE (CLAY) SOILS (SILT AND SAND)

#### Unconfined Compressive

| Strength, qu (tsf) | Consistency  | N - blows / foot |
|--------------------|--------------|------------------|
| < 0.25             | Very Soft    | < 2              |
| 0.25 - 0.50        | Soft         | 2 - 4            |
| 0.50 - 1.00        | Medium Stiff | 5 - 8            |
| 1.00 - 2.00        | Stiff        | 9 - 15           |
| 2.00 - 4.00        | Very Stiff   | 16 - 30          |
| > 4.00             | Hard         | > 30             |

### RELATIVE DENSITY OF GRANULAR SOILS

| N - blows / foot | Relative Density |
|------------------|------------------|
| 0 - 3            | Very Loose       |
| 4 - 9            | Loose            |
| 10 - 29          | Medium Dense     |
| 30 - 50          | Dense            |
| > 50             | Very Dense       |

### RELATIVE PARTICLE SIZES

| Description  | Sieve Size  |                       |
|--|-------------|-----------------------|
| Boulder  | > 12"       | (+ 300 mm)            |
| Cobble   | 3" - 12"    | (75 mm - 300 mm)      |
| Gravel   |             |                       |
| Coarse   | 3/4" - 3"   | (19 mm - 75 mm)       |
| Fine   | #4 - 3/4"   | (4.75 mm - 19.0 mm)   |
| Sand   |             |                       |
| Coarse   | #10 - #4    | (2.0 mm - 4.75 mm)    |
| Medium   | #40 - #10   | (0.425 mm - 2.0 mm)   |
| Fine   | #200 - #40  | (0.075 mm - 0.425 mm) |
| Silt and Clay                                      | Passes #200 | (< 0.075 mm)          |
| Classification as Silt or Clay Based on Plasticity |             |                       |

### TERMINOLOGY DEFINITIONS

|                |  |
|----------------|--|
| Dry            | Powdery, No apparent moisture  |
| Slightly Moist | Can feel moisture, but soil won't retain shape when remolded           |
| Moist          | Can feel moisture, Will remold easily, yet crumbles upon kneading      |
| Very Moist     | Can feel much moisture, Molds easily and does not crumble when kneaded |
| Wet            | Saturated, Above liquid limit moisture content                         |
| Water-Bearing  | Pervious soil below water level  |



# CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

(Based on Unified Soil Classification System)

ASTM: D 2487

| Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests <sup>A</sup> |   |  |  | Soil Classification |  |
|--|---|--|--|---------------------|--|
|  |   |  |  | Group Symbol        | Group Name <sup>B</sup>  |
| Coarse-Grained Soils<br>More than 50% retained on No. 200 sieve                          | Gravels<br>More than 50% of coarse fraction retained on No. 4 sieve | Clean Gravels<br>Less than 5% fines <sup>C</sup>                 | $Cu \geq 4$ and $1 \leq Cc \leq 3^E$                             | GW                  | Well-graded gravel <sup>F</sup>  |
|  |   |  | $Cu < 4$ and/or $1 > Cc > 3^E$                                   | GP                  | Poorly graded gravel <sup>F</sup>  |
|  |   | Gravels with Fines<br>More than 12% fines <sup>C</sup>           | Fines classify as ML of MH                                       | GM                  | Silty gravel <sup>F, G, H</sup>  |
|  |   |  | Fines classify as CL or CH                                       | GC                  | Clayey gravel <sup>F, G, H</sup>   |
|  | Sands<br>50% or more of coarse fraction passes No. 4 sieve          | Clean Sands<br>Less than 5% fines <sup>D</sup>                   | $Cu \geq 6$ and $1 \leq Cc \leq 3^E$                             | SW                  | Well-graded sand   |
|  |   |  | $Cu < 6$ and/or $1 > Cc > 3^E$                                   | SP                  | Poorly graded sand <sup>I</sup>  |
|  |   | Sands with Fines<br>More than 12% fines <sup>D</sup>             | Fines classify as ML or MH                                       | SM                  | Silty sand <sup>G, H, I</sup>  |
|  |   |  | Fines classify as CL or CH                                       | SC                  | Clayey sand <sup>G, H, I</sup>   |
| Fine-Grained Soils<br>50% or more passes the No. 200 sieve                               | Silts and Clays<br>Liquid limit less than 50                        | Inorganic  | $PI > 7$ and plots on or above "A" line <sup>J</sup>             | CL                  | Lean clay <sup>K, L, M</sup>   |
|  |   |  | $PI < 4$ or plots below "A" line <sup>J</sup>                    | ML                  | Silt <sup>K, L, M</sup>  |
|  |   | Organic  | Liquid limit -- oven dried<br>Liquid limit -- not dried $< 0.75$ | OL                  | Organic clay <sup>K, L, M, N</sup><br>Organic silt <sup>K, L, M, O</sup> |
|  |   |  | Silts and Clays<br>Liquid limit 50 or more                       | Inorganic           | $PI$ plots on or above "A" line  |
|  | $PI$ plots below "A" line   | MH   |  |                     | Elastic silt <sup>K, L, M</sup>  |
|  | Organic   | Liquid limit -- oven dried<br>Liquid limit -- not dried $< 0.75$ |  | OH                  | Organic clay <sup>K, L, M, P</sup><br>Organic silt <sup>K, L, M, O</sup> |
|  |   | Highly organic soils   |  |                     | PT   |
|  | Primarily organic matter, dark in color, and organic odor           |  |  |                     |  |

<sup>A</sup> Based on the material passing the 3-in. (75-mm) sieve.

<sup>B</sup> If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to the group name.

<sup>C</sup> Gravels with 5 to 12% fines require dual symbols:

GW-GM well-graded gravel with silt  
GW-GC well-graded gravel with clay  
GP-GM poorly graded gravel with silt  
GP-GC poorly graded gravel with clay

<sup>D</sup> Sands with 5 to 12% fines require dual symbols:

SW-SM well-graded sand with silt  
SW-SC well-graded sand with clay  
SP-SM poorly graded sand with silt  
SP-SC poorly graded sand with clay

$$^E Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

<sup>F</sup> If soil contains  $\geq 15\%$  sand, add "with sand" to group name.

<sup>G</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>H</sup> If fines are organic, add "with organic fines" to group name.

<sup>I</sup> If soil contains  $\geq 15\%$  gravel, add "with gravel" to group name.

<sup>J</sup> If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

<sup>K</sup> If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

<sup>L</sup> If soil contains  $\geq 30\%$  plus No. 200, predominantly sand, add "sandy" to group name.

<sup>M</sup> If soil contains  $\geq 30\%$  plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>N</sup>  $PI \geq 4$  and plots on or above "A" line.

<sup>O</sup>  $PI < 4$  or plots below "A" line.

<sup>P</sup>  $PI$  plots on or above "A" line.

<sup>Q</sup>  $PI$  plots below "A" line.

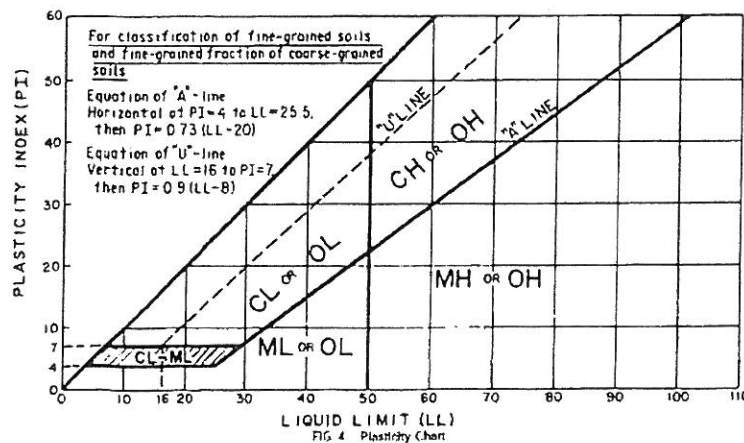
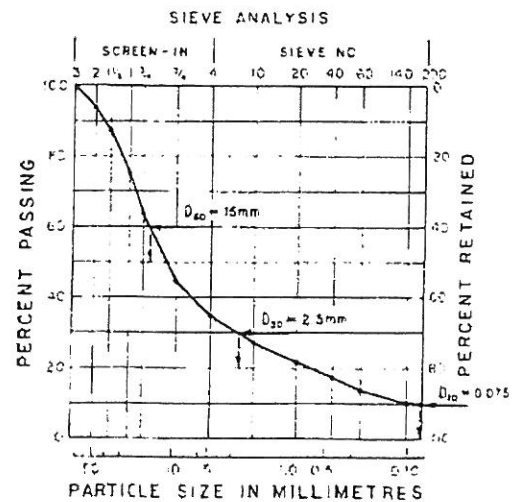


FIG. 4 Plasticity Chart



$$Cu = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

FIG. 5 Cumulative Particle-Size Plot

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