GEOTECHNICAL INVESTIGATION

Proposed Highway 892 Reconstruction
Within Portions of E ½ 24-64-4 W4M and W ½ 19-64-3 W4M
North of Ardmore, Alberta

Prepared for:

Municipal District of Bonnyville
c/o SE Design and Consulting Inc.

Date:
18 October 2017

Project File #: PG17-1351
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1.0 INTRODUCTION

This report presents the results of the geotechnical investigation conducted for the proposed reconstruction of a portion of Highway 892, within E ½ 24-64-4 W4M and W ½ 19-64-3 W4M, north of Ardmore, Alberta. The geotechnical investigation was carried out by SolidEarth Geotechnical Inc. (SolidEarth) at the request of Mr. Steve Engman, P.Tech.(Eng.) of SE Design and Consulting Inc. (SE Design).

The purpose of the geotechnical investigation was to assess the subsurface conditions at selected locations along the existing roadway alignment and to provide geotechnical recommendations and considerations associated with the roadway reconstruction.

2.0 PROJECT DESCRIPTION AND INVESTIGATION SCOPE

Based on information provided to SolidEarth, it was understood that the Municipal District of Bonnyville (MD of Bonnyville) is planning the reconstruction of an approximately 800 m section of Highway 892. It was further understood that widening and minor vertical grade adjustments may be required.

The scope of work completed by SolidEarth included drilling boreholes along the existing roadway alignment, conducting laboratory review and testing on recovered soil samples, undertaking geotechnical engineering analysis, and preparation of this report.

3.0 PROJECT LOCATION AND SITE DESCRIPTION

The section of Highway 892 included in this project was approximately 12 km north of Highway 55, and just south of the Imperial Oil Cold Lake Operations, within E ½ 24-64-4 W4M and W ½ 19-64-3 W4M. The project alignment was approximately 800 m in length. The key plan on a 2016 airphoto is presented as Figure 1.

The existing roadway was generally surfaced with a thick layer of cold mix asphalt. The road was generally elevated 1 to 3 m above the surrounding grades.

Photographs showing site conditions that existed at the time of the field investigation are presented in Appendix A.

4.0 FIELD AND LABORATORY INVESTIGATION

4.1 GROUND DISTURBANCE AND SAFETY PERFORMANCE

Prior to field drilling, a SolidEarth representative completed internal ground disturbance procedures, which included placing an Alberta One Call. Before starting onsite work, a daily field level hazard assessment was conducted by the SolidEarth representative, and was
Geotechnical Investigation  
Proposed Highway 892 Reconstruction  
Within Portions of E ½ 24-64-4 W4M and W ½ 19-64-3 W4M  
North of Ardmore, Alberta

communicated with all workers involved during the tailgate meeting. The field program was successfully completed without any near misses or incidents.

4.2 FIELD DRILLING AND TESTING

The borehole locations were selected and marked in the field by SolidEarth personnel. The boreholes were spaced approximately 100 to 150 m apart. The borehole location plan on a 2015 airphoto is presented as Figure 2.

SolidEarth subcontracted Top Gear Contracting Ltd., of Lloydminster, Saskatchewan to drill the boreholes. Drilling was completed using a truck-mounted auger drill rig utilizing 150 mm solid-stem continuous flight augers.

The field investigation was undertaken on 21 September 2017 and consisted of drilling a total of seven boreholes (BH17-1 through -7) along the project alignment. The boreholes were drilled to approximate depths ranging between 4.6 to 7.6 m below the existing road surface.

During drilling, soil samples were collected at approximately 0.75 m intervals along the depth of the boreholes. Pocket penetrometer testing was conducted on selected cohesive soil samples to obtain an indication of the unconfined compressive strength of disturbed soil samples from the auger. Standard Penetration Tests (SPT) were conducted at selected depths (typically every 1.5 m) to assess the in-situ strength of the soils encountered. The soil sampling and testing sequences are shown on the borehole logs, Appendix B.

A SolidEarth geotechnical technologist monitored the drilling operations and logged the recovered soil samples from the auger cuttings and SPT samples. The soils were logged according to the Modified Unified Soil Classification System, which is described in the Explanation of Terms and Symbols in Appendix B. Due to the method by which the soil cuttings were returned to surface, the depths noted on the borehole logs may vary by ± 0.3 m from those recorded.

Following completion of drilling, the coordinates (northing, easting, and elevation) of the ground surface at the borehole locations were surveyed by SE Design and provided to SolidEarth. These coordinates are shown on the borehole logs.

Groundwater seepage conditions were monitored during and immediately following completion of drilling. All boreholes were backfilled with drill cuttings and cold mix plug following completion of drilling.

4.3 LABORATORY INVESTIGATION

All collected samples were submitted to the laboratory for further examination and testing. Laboratory testing included visual examination and determination of the natural moisture
content on all collected samples; and Atterbergs limits, and grain size distribution tests on selected samples.

5.0 SUBSURFACE CONDITIONS

The subsurface stratigraphy at the borehole locations generally consisted of cold mix asphalt, underlain by gravel at a few borehole locations, followed by clay fill, over peat, and underlain by clay till. A brief summary of the subsurface conditions encountered at the borehole locations is presented below. A detailed description of the subsurface conditions encountered at each borehole location is provided on the borehole logs.

Roadway Surfacing

Cold mix asphalt was encountered at the road surface at all borehole locations. The cold mix asphalt ranged in thickness from between 150 and 350 mm. At a few borehole locations, the cold mix was underlain by a thin layer (less than 150mm thick) of gravel base.

Due to the drilling method used in the investigation (auger drilling) the exact thickness of the roadway surfacing materials could not be accurately determined as the soils were ground and mixed by the auger during drilling.

Clay Fill

Clay fill was encountered below the roadway surfacing at all borehole locations, and extended to depths ranging between approximately 1.3 and 3.7 m below the existing road surface. The upper 1 to 2 m of the fill was generally mineral in composition.

The clay fill was generally classified as “clay, and sand, silty, trace gravel”, was low plastic, and brown to grey-brown in color. The clay fill encountered was generally moist, with some very moist zones.

In BH17-4, -5, and -7, the lower portions of the fill, below approximately 2.0 m below the existing road surface, became mixed with organics, and were very moist.

The moisture content of the majority of the upper portions of the clay fill ranged between approximately 8 and 12 percent, with an average of approximately 10 percent. Higher moisture contents in the order of 13 to 29 percent were measured in the lower portions of the clay fill in BH17-4, -5, and -7

Based on comparison with the plastic limit, it is expected that the majority of the upper portions of the clay fill (predominantly mineral in composition) was near to slightly above the optimum moisture content.
Peat/Organic Soil

Peat and/or organic soil was encountered at a few locations between the clay fill and clay till. In BH17-2 and -3, the southern end of the alignment, the peat/organic soil was less than 300mm thick. In BH17-4, -5, and -7, middle portion of the alignment, the peat/organic soil extended to depths ranging between 4.7 and 6.3 m below the existing road surface and was between 2.2 and 2.8 m thick.

Clay Till

Clay till was encountered below the clay fill and/or peat/organic soils at all borehole locations, and extended to beyond the exploration depths of all the boreholes. The clay till was generally classified as “clay, and sand, silty, trace gravel”, was low plastic, and grey-brown in colour.

Sand

Sand was encountered within the clay fill and/or below the peat at a few borehole locations. The extent of the sand appeared limited based on the findings at the borehole locations.

6.0 GEOTECHNICAL ANALYSIS AND RECOMMENDATIONS

6.1 FOREWORD

Based on the information provided to SolidEarth, it was understood that the reconstruction will involve the removal of the existing roadway surfacing, road widening, subgrade preparation (as required), and the construction of an asphaltic concrete pavement structure. It was further understood that the final vertical grades will be close to the existing road grades with some minor grade adjustment required.

6.2 CONDITION OF THE SUBGRADE

6.2.1 Subgrade Material, Moisture, Strength, and Stability

The existing near surface subgrade soils encountered at the borehole locations consisted of clayey soils. The upper portion of the clay fill was generally mineral in composition. The moisture content of the majority of the near surface clay fill soils was expected to be near or slightly above the soils’ optimum moisture content, with a few wet zones. The consistency of the upper portions of the clay was generally assessed to be very stiff.

6.2.2 Frost Susceptibility of Subgrade Soils

Frost heave of the subgrade soils is generally related to the particle size distribution of the soils, moisture content, and the presence of a relatively shallow groundwater table. The near surface soils encountered along the roadway alignment were generally of low to medium plasticity. The
Grain size distribution of the majority of the near surface soils generally consisted of approximately 26 to 29 percent by weight of clay size particles with the remaining portions as silt and sand size particles. Overall, the near surface clayey soils were generally considered to be moderately susceptible to frost heaving and formation of ice lenses in the presence of water.

The moisture contents of the near surface clayey soils were generally near to slightly above the soils’ optimum moisture content. However, very moist soils were also encountered at a few borehole locations. No long-term groundwater measurements were completed, as all of the boreholes were backfilled following drilling. Based on field observations during drilling and the road embankment height above natural grades, however, it was anticipated that the water table was between 1 to 2 m below the existing road surface.

Given the above, and with proper drainage and surface water management, the risk of frost heaving and formation of ice lenses was considered to be moderate. It is to be noted that poor surface drainage leading to water inundating the subgrade soils will significantly increase the risk levels.

Due to the general variability in the soil makeup and groundwater seepage paths in clay deposits, it is not possible to predict with certainty the magnitude of frost heaving at specific locations. It is generally recommended that an observational approach be adopted over the first two winter seasons to identify problematic areas.

Frequently, areas exhibiting the formation of ice lenses and frost heaving during one winter season will exhibit the same during subsequent winter seasons. If areas with problematic frost conditions are observed, then remedial measures may be implemented.

The most suitable remedial measure will have to be assessed on a case by case basis as it depends on the severity of the problem, service/use interruption of the affected area, and the sensitivity of the pavement structure to frost heaving. Remedial measures may include soil replacement, ground insulation, or periodic maintenance (in the case of low use areas).

6.3 CONSIDERATIONS FOR ROADWAY RECONSTRUCTION

6.3.1 Initial Site Grading and Subgrade Preparation

It is anticipated that the final design grades will be comparable to the existing grades, with some cut and fill requirements. The existing cold mix asphalt pavement should be stripped and removed. The thin layer of gravel base may be mixed with the clay subgrade and incorporated in the roadway subgrade.

Within the roadway alignment, the fill may be kept in place. Where near surface buried organics or weak and wet soils (resulting in poor subgrade performance) are encountered within the fill, subgrade replacement and/or improvement may be required. The extent of required subgrade improvement and modification will depend to a great degree on the amount of cut/fill required at
specific locations, and on field observations during construction. The extent of subgrade improvement is best determined in the field based on visual observation and proof-roll testing.

In general, it is recommended to maintain a minimum of 1.2 m of dry mineral clay fill between the roadway pavement structure and above peat deposits and/or organic soils. The existing mineral clay fill (upper portions of the fill) appeared to provide the minimum required separation above the peat. As such, it is recommended to maintain the fill and not sub-cut or lower the existing road grades.

Soft subgrade conditions are not anticipated to be a major concern during construction but may be encountered at some locations, where buried organics or wet soils are present at shallow depth from the road surface. If soft and wet subgrade conditions are encountered during construction, then subgrade improvement may be required. Subgrade improvement may include:

- placement of dry clay soil as engineered fill in areas requiring fill
- sub-cutting the existing subgrade, air drying the excavated soils, and re-compacting the subgrade as engineered fill, if good weather prevails during construction
- replacement of the cut material with dry low to medium plastic clay soils placed as engineered fill
- cement stabilization of the subgrade soils

It is recommended that following achievement of design rough grades in areas under cut, and prior to placement of grade raising fill, in areas under fill, the subgrade be inspected by the geotechnical engineer. The inspection may include a proof-roll test to confirm that deflections from construction traffic are minimal. Soft and weak areas identified during inspection, should be strengthened and improved.

Regardless of the above, it is recommended that, at a minimum, the upper 0.3 m of the final subgrade soil (below the underside of the granular base) along the roadway alignment should be scarified and compacted (or placed in the case of engineered fill) to a minimum of 98 percent of SPMDD. This would help create a more competent subgrade for the pavement structure.

### 6.3.2 Placement of Engineered Fill

All fill placed on site (from scarifying and re-compacting or imported material) should be placed as engineered fill. Engineered fill should consist of low to medium plastic clay or a well-graded granular material. Silt or sand which is uniformly graded, or which contains more than 10 percent passing the 0.080 mm sieve are not recommended as these materials are generally frost susceptible and are difficult to compact (require strict control of moisture content). All fill soils should be free from any organic materials, contamination, deleterious construction debris, and stones greater than 150 mm in diameter.
The majority of the low to medium plastic clayey soils encountered at the borehole locations generally appeared suitable for re-use as engineered fill. If any very moist soils are encountered they will need to be moisture conditioned before being used as engineered fill.

Engineered fill should be thawed and placed during non-frozen conditions. If winter construction is proposed, SolidEarth can provide additional recommendations at the time and once the overall development plan has been finalized.

All engineered fill should be compacted to a minimum of 95 percent of SPMDD. The standard of compaction should be increased to 98 percent of SPMDD for the upper 300 mm of the subgrade soil (below the underside of the granular base).

The engineered fill should be compacted in maximum lift thicknesses of 300 mm (loose), and within two percent of the soils' optimum moisture content. Fill placement procedures and quality of the fill soils should be monitored by geotechnical personnel on a full time basis. Field monitoring should include compaction testing at regular frequencies.

### 6.3.3 Surface Water Management Considerations

Provision of uniform and adequate grades for surface water drainage is potentially the most important design element for establishing long term stable pavement structures for roads. To minimize the potential for water ponding and seepage leading to saturation and degradation of the subgrade (during and following construction), a minimum grade of two percent is recommended at the subgrade level (cross slope or crowning the center of the road). The final pavement grade should also be adequately sloped to accommodate surface water runoff.

It is recommended that the pavement gravel base be allowed to drain (day-lighted) into the side ditches so that any accumulated water within the base gravel will be allowed to drain away and not pond on top of the subgrade. It is further recommended that the underside of the granular base be elevated at least 0.5 m above the bottom of the side ditches. This will reduce the potential of saturation and softening of the subgrade soils.

Positive drainage away from the road surface is particularly important during the spring thaw and snow melt season. If water from melting snow is allowed to remain on the road surface and subsequently freezes, significant damage to the road surface (and formation of potholes) may be encountered.

### 6.3.4 New Embankment Side Slopes

It was understood that the widened road embankment will be less than 3 m in height. Low areas and sloughs were observed along the majority of the alignment.

Detailed slope stability analysis is recommended along these areas to assess the optimum embankment configuration and to minimize the risk of potential base failure (slope failure in the...
road embankment). The slope stability analysis should address the required side slopes of the roadway embankment, backfill sequence and height above the peat, and buttress of the embankment toe.

In any case, it is recommended that the slope of the new embankment should not be steeper than 3 horizontal to 1 vertical (3H:1V). It is also recommended to stage the placement of fill above the peat to 1 m at a time and allow sufficient time for the peat to settle under the fill weight. This will reduce the risk of slope instability within the widened embankment.

6.4 ROADWAY PAVEMENT STRUCTURE

It was understood that the Municipal District of Bonnyville has a standard pavement structure that will be used for this project. As such, assessment of the required gravel and asphaltic concrete pavement structures based on anticipated traffic loading was not required.

Recommendations presented in Section 6.3 “Considerations for Roadway Reconstruction” regarding subgrade preparation and inspection should be followed. The granular base course material should only be placed on a stable and competent subgrade.

7.0 TESTING AND INSPECTION

Recommendations presented in this report may not be valid if adequate engineering inspection and testing programs during construction are not implemented. Testing and inspection programs would consist of full time monitoring and compaction testing during site grading and fill placement, and testing of the asphaltic concrete as per industry, local, and Alberta Transportation standards.
8.0 CLOSURE

The recommendations presented in this report were based on the results of soil sampling and testing at seven borehole locations along the existing road alignment as well as information provided to SolidEarth. Soil conditions by nature can vary across any given site. If different soil conditions are encountered at subsequent phases of this project, SolidEarth should be notified immediately and given the opportunity to evaluate the situation and provide additional recommendations as necessary.

The recommendations presented in this report should not be used for another site or for a different application at the same site. If the intended application of the site is changed or if the assumptions outlined in this report become invalid, SolidEarth should be notified and given the opportunity to assess if the recommendations presented should be modified.

This report has been prepared for the exclusive use of the Municipal District of Bonnyville, SE Design and Consulting Inc., and their authorized users for the specific application outlined in this report. No other warranties expressed or implied are provided. This report has been prepared within generally accepted geotechnical engineering practices.

Respectfully submitted,
SolidEarth Geotechnical Inc.

Thomas Feeley, P.Eng.
Geotechnical Engineer

Jay Jaber, M.Sc., P.Eng.
Senior Geotechnical Engineer
Managing Partner

APEGA Permit to Practice #11884
Figures

Figure 1: Key Plan
Figure 2: Borehole Location Plan
HUSKY Tucker Lake Facility
OSUM Orion Facility
Cold Lake North
Cold Lake South
Project Site
### Borehole Location Plan on a 2015 Aerial Photograph

**Geotechnical Investigation**

Proposed Highway 892 Reconstruction
Within Portions of E ½ 24-64-4 W4M and W ½ 19-64-3 W4M
North of Ardmore, Alberta

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- **Survey Points:**
  - NW 19-64-3 W4M
  - SW 19-64-3 W4M
  - NE 24-64-4 W4M
  - SE 24-64-4 W4M
  - BH17-1
  - BH17-2
  - BH17-3
  - BH17-4
  - BH17-5
  - BH17-6
  - BH17-7

- **Facility Access:** OSUM Orion Facility Access

- **Highway:** Highway 892
Appendix A

Site Photographs Taken During the Field Investigation
Geotechnical Investigation
Proposed Highway 892 Reconstruction
Within Portions of E ½ 24-64-4 W4M and W ½ 19-64-3 W4M
North of Ardmore, Alberta

Photograph 1: Near BH17-2 looking north

Photograph 2: Near BH17-4 looking south
Photograph 3: Near B17-6 (north end) looking south

Photograph 4: Near BH17-5 looking north
Geotechnical Investigation
Proposed Highway 892 Reconstruction
Within Portions of E ½ 24-64-4 W4M and W ½ 19-64-3 W4M
North of Ardmore, Alberta

Photograph 5: BH17-4 between 3.0 and 4.5 m below the existing road surface
Appendix B

Borehole Logs
Explanation of Terms and Symbols
**Material Description**

- **COLD MIX ASPHALT (~350 mm)**
- **FILL (GRAVEL) (~150 mm)**
  - Fill (CLAY), and sand, silty, trace gravel, very stiff, low plastic, grey-brown, moist
  - Organic inclusions/wood debris
- **SAND**, fine grained, clayey, trace silt, trace gravel, poorly graded, grey, wet
- **CLAY (TILL)**, and sand, silty, trace gravel, low plastic, grey-brown, very moist
  - Becoming brown

**COMPLETION DEPTH:** 4.6 m below ground surface

At Completion

No accumulation of water or slough material. Backfilled with drill cuttings and cold mix asphalt.

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**$	ext{Northbound Lane}$**

- **Liquid Limit:** 28%
- **Plastic Limit:** 9%
- **Grain Size Distribution**
  - **Gravel:** 3%
  - **Sand:** 47%
  - **Silt:** 24%
  - **Clay:** 26%

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**Additional Data & Notes**

Northbound Lane

- Liquid Limit: 28%
- Plastic Limit: 9%
- Grain Size Distribution
  - Gravel: 3%
  - Sand: 47%
  - Silt: 24%
  - Clay: 26%
COLD MIX ASPHALT (~175 mm)
FILL (CLAY), and sand, silty, trace gravel, very stiff, low plastic, grey-brown, moist

SAND, fine grained, clayey, trace silt, trace gravel, poorly graded, grey, wet

PEAT, highly decomposed, black, wood debris, saturated

CLAY (TILL), and sand, silty, trace gravel, low plastic, grey-brown, very moist

COMPLETION DEPTH: 4.6 m below ground surface

At Completion
Accumulation of water at 3.0 m below ground surface.
No accumulation of slough material.
Backfilled with drill cuttings and cold mix asphalt.
COLD MIX ASPHALT (~200 mm)
FILL (GRAVEL) (~50 mm)
FILL (CLAY)

ORGANICS, clayey, sandy, grey-black, wood debris

CLAY (TILL), and sand, silt, trace gravel, stiff, low plastic, grey, very moist, seepage

COMPLETION DEPTH: 4.6 m below ground surface

At Completion
Trace accumulation of water.
No accumulation of slough material.
Backfilled with drill cuttings and cold mix asphalt.

Southbound Lane

Liquid Limit: 26 %
Plastic Limit: 9 %

Soil Symbol

USCS

Material Description

Sample Symbol

SPT N Value

Sample N-Value

Southbound Lane

Liquid Limit: 26 %
Plastic Limit: 9 %
Material Description

- **COLD MIX ASPHALT (~200 mm)**
- **FILL (GRAVEL) (~150 mm)**
  - Fill (Clay), and sand, silty, trace gravel, very stiff, low plastic, grey-brown, gravel and sand pockets, moist - sand/gravel pockets
  - becoming stiff, very moist, brown
  - organic inclusions/wood debris, black, seepage

- **PEAT**, highly decomposed, brown-black, woody debris, moist
  - becoming clayey, black

- **SAND**, fine to medium grained, trace silt, trace clay, trace gravel, poorly graded, grey, wet

- **CLAY (TILL)**, and sand, silty, trace gravel, low plastic, grey, very moist, seepage

**COMPLETION DEPTH**: 7.6 m below ground surface

**At Completion**

- Accumulation of water to 6.1 m
- No accumulation of slough material.
- Backfilled with drill cuttings and cold mix asphalt.

** Liquid Limit**: 29 %
** Plastic Limit**: 9 %

**Grain Size Distribution**

- Gravel: 1 %
- Sand: 48 %
- Silt: 22 %
- Clay: 29 %
COLD MIX ASPHALT (~200 mm)
FILL (CLAY), and sand, silty, trace gravel, very stiff, low plastic, grey-brown, gravel and sand pockets, moist
- organic inclusions/wood debris, black, very moist

PEAT, highly decomposed, black, wood debris, saturated
- becoming clayey, sandy

CLAY (TILL), and sand, silty, trace gravel, low plastic, grey, very moist, seepage

COMPLETION DEPTH: 7.6 m below ground surface
At Completion
Accumulation of water at 6.1 m below ground surface.
No accumulation of slough material.
Backfilled with drill cuttings and cold mix asphalt.
COLD MIX ASPHALT (~150 mm)
FILL (GRAVEL) (~100 mm)
FILL (CLAY)
and sand, silty, trace gravel, stiff, low plastic,
brown, moist
- becoming, grey-black, organics/wood debris
CLAY (TILL)
and sand, silty, trace gravel, stiff, low plastic,
grey, very moist, seepage

COMPLETION DEPTH: 4.6 m below ground surface

At Completion
No accumulation of water or slough material. Backfilled with drill cuttings and cold mix asphalt.
COLD MIX ASPHALT (~175 mm) FILL (CLAY), and sand, silty, trace gravel, very stiff, low plastic, grey-brown, gravel and sand pockets, moist.

PEAT, highly decomposed, black, wood debris, saturated - becoming clayey, sandy

CLAY (TILL), and sand, silty, trace gravel, low plastic, grey, very moist, seepage

COMPLETION DEPTH: 6.1 m below ground surface

At Completion
Accumulation of water to 5.2 m
No accumulation of slough material.
Backfilled with drill cuttings and cold mix asphalt.
EXPLANATION OF TERMS & SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of the field investigation and laboratory testing are described on the following two pages.

1. VISUAL TEXTURAL CLASSIFICATION ON MINERAL SOILS

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<th>APPARENT PARTICLE SIZE</th>
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<td>Boulders</td>
<td>&gt; 200 mm</td>
<td>&gt; 200 mm</td>
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<td>Cobbles</td>
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<td>75 mm to 200 mm</td>
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<td>Gravel</td>
<td>4.75 mm to 75 mm</td>
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<td>Silt</td>
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<tr>
<td>Clay</td>
<td>&lt; 0.002 mm</td>
<td>Plastic particles, not visible to naked eye</td>
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2. TERMS FOR CONSISTENCY & DENSITY OF SOILS

Cohesionless Soils

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<td>Very Dense</td>
<td>&gt; 50</td>
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<td>Dense</td>
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<td>Compact</td>
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<td>Loose</td>
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Cohesive Soils

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<td>Hard</td>
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<td>Stiff</td>
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<td>8 to 15</td>
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<tr>
<td>Firm</td>
<td>25 to 50 kPa</td>
<td>4 to 8</td>
</tr>
<tr>
<td>Soft</td>
<td>10 to 25 kPa</td>
<td>2 to 4</td>
</tr>
<tr>
<td>Very Soft</td>
<td>&lt; 10 kPa</td>
<td>&lt; 2</td>
</tr>
</tbody>
</table>

* SPT “N” Values – Refers to the number of blows by a 63.5 kg hammer dropped 760 mm to drive a 50 mm diameter split spoon sampler for a distance of 300 mm after an initial penetration of 150 mm.

3. SYMBOLS USED ON BOREHOLE LOGS

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>N(■)</td>
<td>Standard Penetration Test (CSA A119 1-60)</td>
<td>SO₄²⁻</td>
<td>Concentration of Water-Soluble Sulphate</td>
</tr>
<tr>
<td>N_d</td>
<td>Dynamic Cone Penetration Test</td>
<td>C_u</td>
<td>Undrained Shear Strength</td>
</tr>
<tr>
<td>pp (★)</td>
<td>Pocket Penetrometer Strength</td>
<td>γ</td>
<td>Unit Weight of Soil or Rock</td>
</tr>
<tr>
<td>q_u</td>
<td>Unconfined Compressive Strength</td>
<td>γ_d</td>
<td>Dry Unit Weight of Soil or Rock</td>
</tr>
<tr>
<td>w (★)</td>
<td>Natural Moisture Content (ASTM D2216)</td>
<td>ρ</td>
<td>Density of Soil or Rock</td>
</tr>
<tr>
<td>w_p</td>
<td>Liquid Limit (ASTM D 4318)</td>
<td>ρ_d</td>
<td>Dry Density of Soil or Rock</td>
</tr>
<tr>
<td>w_p</td>
<td>Plastic Limit (ASTM D 4318)</td>
<td>□</td>
<td>Short-Term Water Level</td>
</tr>
<tr>
<td>I_p</td>
<td>Plastic Index</td>
<td>▼</td>
<td>Long-Term Water Level</td>
</tr>
</tbody>
</table>
## MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

<table>
<thead>
<tr>
<th>MAJOR DIVISION</th>
<th>GROUP SYMBOL</th>
<th>TYPICAL DESCRIPTION</th>
<th>LABORATORY CLASSIFICATION CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAVELS (MORE THAN HALF COARSE GRAINS LARGER THAN 4.75mm)</td>
<td>CLEAN GRAVELS (LITTLE OR NO FINES)</td>
<td>GW</td>
<td>WELL GRADED GRAVELS AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES</td>
</tr>
<tr>
<td></td>
<td>GRAVELS (WITH SOME FINES)</td>
<td>GM</td>
<td>SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES</td>
</tr>
<tr>
<td></td>
<td>CLEAN GRAVELS WITH LITTLE OR NO FINES</td>
<td>GW</td>
<td>WELL GRADED GRAVELS AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES</td>
</tr>
<tr>
<td></td>
<td>GRAVELS WITH LITTLE OR NO FINES</td>
<td>GM</td>
<td>SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES</td>
</tr>
<tr>
<td>COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75 µm)</td>
<td>GRAVELS</td>
<td>GP</td>
<td>POORLY GRADED GRAVELS AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES</td>
</tr>
<tr>
<td></td>
<td>SANDS</td>
<td>SW</td>
<td>WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES</td>
</tr>
<tr>
<td></td>
<td>SANDS WITH LITTLE OR NO FINES</td>
<td>SM</td>
<td>SILTY SANDS, SAND-SILT MIXTURES</td>
</tr>
<tr>
<td>SANDS (MORE THAN HALF COARSE GRAINS SMALLER THAN 4.75mm)</td>
<td>CLEAN SANDS (LITTLE OR NO FINES)</td>
<td>SW</td>
<td>WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES</td>
</tr>
<tr>
<td></td>
<td>SANDS WITH LITTLE OR NO FINES</td>
<td>SM</td>
<td>SILTY SANDS, SAND-SILT MIXTURES</td>
</tr>
<tr>
<td>FINE GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75 µm)</td>
<td>SILTS</td>
<td>ML</td>
<td>INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY</td>
</tr>
<tr>
<td></td>
<td>CLAYS</td>
<td>CL</td>
<td>INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY SANDY, OR SILTY CLAYS</td>
</tr>
<tr>
<td>ORGANIC SILTS &amp; CLAYS (BELOW 'A' LINE)</td>
<td>ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGHLY ORGANIC SOILS</td>
<td>PEAT AND OTHER HIGHLY ORGANIC SOILS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Soil Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Size Range (mm)</th>
<th>Descriptor</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobbles</td>
<td>&gt; 76</td>
<td>and</td>
<td>&gt; 35</td>
</tr>
<tr>
<td>Gravel</td>
<td>76 to 4.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse</td>
<td>76 to 19</td>
<td>-y, -ey</td>
<td>35 to 20</td>
</tr>
<tr>
<td>Fine</td>
<td>19 to 4.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>4.75 to 0.075</td>
<td>some</td>
<td>20 to 10</td>
</tr>
<tr>
<td>Coarse</td>
<td>4.75 to 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>2 to 0.425</td>
<td>trace</td>
<td>10 to 1</td>
</tr>
<tr>
<td>Fine</td>
<td>0.425 to 0.075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fines (Silt or Clay)</td>
<td>&lt; 0.075</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Plastcity Chart

[Plasticity Chart for Soils Passing 425 µm Sieve](chart)

**Laboratory Classification Criteria**

- $C_u = D_{60}/D_{10} > 4$
- $C_c = (D_{30})^2/(D_{10} x D_{60}) = 1$ to $3$
- **Atterberg Limits**
  - Below 'A' line, $l_I$ less than 4
  - Above 'A' line, $l_I$ more than 7
  - Other requirements

**CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)**

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SolidEarth Geotechnical Inc.
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