# GENERAL WASTE & RECYCLING, LLC
# SW-620 INDUSTRIAL WASTE LANDFILL

## DEMONSTRATION OF ENGINEERING CONTROLS INCORPORATED INTO DESIGN OF A CCR LANDFILL IN A POTENTIALLY UNSTABLE AREA

Prepared For:

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Project Number: 6385CC

"I certify under penalty of law that this document and all attachments were prepared under my direct supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete." I certify that this report has been prepared consistent with recognized and generally accepted good engineering practices and satisfies the requirements put forth in 40 CFR §257.64 'Unstable Areas.'

08-03-2018

Evan Johnson, P.E. Date
Geotechnical Engineer
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## 1.0 Project Overview

Northeast Technical Services, Inc. (NTS) is pleased to present this report for the above referenced project. Per the above mentioned regulation, any existing CCR landfill that is located in an area that is deemed to be potentially unstable must demonstrate that good engineering practice has been incorporated into the design to ensure that the integrity of the structural components of the CCR landfill liner will not be disrupted. This demonstration must be completed prior to October 17, 2018.

Because of the setting of the General Waste Industrial Landfill (the landfill) to be at least partially within a mine overburden stockpile, it is prudent to demonstrate that good engineering practice has been incorporated into the design as this location may be potentially unstable due to these human-made features.

This letter report describes the physical setting of the landfill and summarizes previously conducted investigations and how they demonstrate that proper assessment of the landfill subgrade has been completed for Cells A and B and engineering controls incorporated into the design.

## 2.0 Landfill Setting

The landfill is located in the southeast quarter of Section 25, Township 57N, Range 22W, an area where the topography has been highly modified by historical iron mining. The site is bounded on the north by U. S. Highway 169, and Keewatin, MN is located directly north opposite the highway. The west side of the site is bounded by a tailings basin containing hydraulic fill from Mesabi Chief Heavy Media plant which operated from 1928 to 1970 (end date is approximate) and more recently operated by Magnetation, LLC between approximate years 2011-2015. The east side of the site is bounded by Itasca County Road 571. South of the site, there is a cell phone transmission tower, an automotive salvage yard, and other terrain that review of historical photography indicates to be native landform.

The landfill design intersects a historical overburden stockpile of unconsolidated glacial deposits stripped from one of the nearby iron ore open pit mines. Stripping operations in the Keewatin vicinity mines is believed to have been started circa 1913. An air photo dated 1939 shows the stockpile was substantially completed by 1939. The primary method of placement likely consisted of constructing temporary railroads, side-dumping rail cars, and pushing the soil down inclined slopes that progressed across the site at the angle of repose. The lift heights during soil placement may be indicated by the stockpile's outer slopes, which are typically 30-40 feet. Several lifts appear to have been placed over the site with total fill depth up to about 80 feet.

The landfill subgrade is expected to be located with the overburden stockpile material, approximately 20 feet above what is thought to be native ground. Review of geologic setting resources and site boreholes indicate that the underlying native material consists of a dense silty, clayey sand with glacial till that is thought to be 100-200 feet in thickness overlying bedrock.

## 3.0 Completed Geotechnical Assessments

### 3.1 Initial Geotechnical Assessment of Liner Design

During initial permitting activities, an extensive soil boring program across the proposed landfill footprint was conducted that included 23 borings with the purpose of gathering hydrogeological and geotechnical data. In addition, 4 down-hole pressuremeter tests were conducted to assess compressibility of the predominant mine overburden stockpile materials to assist with settlement predictions for the proposed landfill.

This report determined the following items to be of primary concern with regard to landfill stability and liner integrity:

1.) Localized settlement caused by varying surcharge loads. Because the landfill base grade is to traverse stockpile limits, there is a significant difference in surcharge (or pre-loading) of base grade soils.
2.) Localized settlement caused by sloping lifts of poor fill materials such as buried debris, open graded gravel, excessively soft or loose materials, organic soils. Though not explicitly observed in the boring program, area knowledge causes one to consider that a variety of materials may end up in an overburden stockpile.
3.) Excessive settlement caused by weak subgrade soils in the stockpile material and large loads to be applied via placed waste.

To address item 1 and 2 above for the Cell A construction, the geotechncical assessment recommended conducting a 1 foot sub-cut of the liner subgrade, placing a geotextile fabric, and filling back to subgrade elevation with a compacted granular fill. In addition, it was recommended that detailed observation of excavated materials be conducted to assess the suitabilitity of the observed stockpiled materials for the landfill subgrade and to determine if significantly varying materials exist in placed sloping lifts.

Item 3 was addressed via conducting a predicted settlement analysis utilizing the pressurmeter test data as well as correlating blowcount data. This analysis showed that the more conservative method indicated that the expected settlement at the borehole locations would range from 3.8 to 13.4 inches of settlement. However, SB 12-03 (the location of highest expected settlement) is located on the outer extents of the perimeter berm where settlement would not likely damage liner integrity. Predicted liner settlement beneath the liner floor was found to be approximately 4 to 8 inches. It was deemed that total settlement or differential settlement across the liner should not cause over stressing or damage to the liner.

### 3.2 Cell A Construction Certification

During construction of Cell A, testing and inspection was completed for landfill certification as well as to document soil conditions and compare to those expected from the initial geotechnical assessment.[1] Materials encountered during excavation activities to Cell A subgrade elevation agreed with those observed in the geotechnical analysis.

### 3.3 Cell B Construction Subgrade Analysis

While excavating for the Cell B construction, 2 on-site inspections were conducted to assess the subgrade soils and determine the applicability of the previously utilized sub-cut and geotextile placement. Analysis of the Cell B liner floor surcharge was completed, 6 test pits performed across the Cell B floor, and soil gradation analyses completed to assess soil suitability and uniformity. The findings indicated that the in-situ subgrade was sufficient for liner construction provided specific conditioning of the soils be completed. This report can be seen attached as Appendix B.

## 4.0 Future Construction

This certification only applies to the constructed Cell A and Cell B of the landfill facility. It is expected that similar analysis will be completed during future landfill expansions to ensure that the geotechnical concerns identified in the initial assessment of the landfill site or those identified in future development be properly assessed by a licensed professional engineer.

[1] General Waste Disposal and Recovery Services Industrical Waste Landfill Cell 1A Liner and Leachate Collection System Construction Documentation Report, Liesch – A Terracon Company (November, 2014).

# Appendix A
# 2013 Initial Geotechnical Review

# Geotechnical Review of Proposed Industrial Landfill located near Keewatin, MN

## Description & Purpose

This geotechnical evaluation is being performed for a proposed Industrial Waste Disposal Facility (The "Facility") designed in compliance with Minnesota Rules 7035.2815 for Mixed Municipal Solid Waste Land Disposal facilities which require a composite liner consisting of a geosynthetic and compacted clay with a leachate collection system. The design, hydrogeologic evaluation and permit application are being submitted to the Minnesota Pollution Control Agency (MPCA) for review and approval prior to issuing a solid waste permit. The Facility will be a merchant landfill and accept a variety of industrial waste types, although the predominant wastes are expected to be lime precipitation solids, dry coal ash, slag, contaminated soils, and other wastes generated by the iron mining industry. The landfill is not a tailing basin and the containment berms are not designed to contain hydraulic fill.

The landfill is subdivided into eight cells which will be constructed and filled with waste in four phases. The first cell will be at the west end of the site, and subsequent cells will proceed eastward. The entire waste footprint is situated on an overburden stockpile. The containment berm surrounding the landfill varies in height from being cut to grade along some of the northern boundary, to fill exceeding 60 feet in height in the south-east corner. The landfill containment area will be excavated, with the liner grade ranging from about 8 to 40 feet below the existing ground surface. The maximum final grade of the cap at the center of the landfill will be approximately 100 feet above the liner grade.

Geotechnical concerns at the site include settlement of the foundation soils below the liner and containment berms, stability of the berms, and liner design. Settlement is a concern because of the existing overburden stockpile and associated abrupt changes in topography. The liner grade needs to maintain positive slope for leachate drainage; and differential settlement could tear the liner. This appendix provides recommendations concerning construction and operation to address these concerns.

## Site Conditions

The site is located in the southeast quarter of Section 25, Township 57N, Range 22W, an area where the topography has been highly modified by historical iron mining. The site is bounded on the north by U. S. Highway 169, and Keewatin, MN is located directly north opposite the highway. The west site of the site is bounded by a tailings basin containing hydraulic fill from Mesabi Chief Heavy Media plant which operated from 1928 to 1970 (end date is approximate). The east side of the site is bounded by Itasca County. Road 571, and there are other overburden lean ore and blast rock stockpiles east of County Road 16. The NSPC Initial Tailings Basin is about ½ mile to the southeast of the site. South of the site, there is a cell phone transmission tower, an automotive salvage yard, and other terrain that historical photography indicates to be native landform.

The landfill site contains a historical overburden stockpile materials obtained from stripping overburden from one of the nearby open pit mines. Stripping operations in the Keewatin vicinity mines is believed to have been started circa 1913. An air photo dated 1939 shows the stockpile was essentially completed by that date. The primary method of placement likely consisted of constructing temporary railroads, side-dumping rail cars, and pushing the soil down inclined slopes that progressed across the site at the angle of repose. The lift heights during soil placement may be indicated by the stockpile's outer slopes, which are typically 30-40 feet. Several lifts appear to have been placed over the site with total fill depth up to about 80 feet.

Figure 1. Proposed Landfill Site

The land directly west of the overburden stockpile contains a tailings basin. The tailings basin retains fine tailing slurry material pumped from the Mesabi Chief Plant located to the north. Air photos from 1939 and 1947 show the tailings basin was originally a wetland area; and the 1961 air photo shows the basin in operation. There is an access road grade that separates the tailing basin from the overburden stockpile, and acted as the containment dike of the tailings basin, so that slurry was deposited against the toe of the overburden stockpile.

The aerial photography (1939, 1947, 1961 and current) indicates the land south and east of the stockpile is mostly native topography. With elevations of surrounding land and buried topsoil observed in the borings, the native ground elevation below the stockpile appears to have been mostly in the range from 1450 feet to 1460 feet. Undulations in the original ground surface were likely gradual or knocked down to lay rail in the area during placement of the stockpile. The highest elevation of the stockpile shown on the site topography is about elevation 1532. Thus, the maximum thickness of the stockpile is about 80 feet.

The County Well Index includes data for six deep borings that have been advanced into bedrock within 1.1 miles of the site. The bedrock surface is typically slate ranging in elevation from 1297 feet to 1360 feet. If the bedrock surface remains within this range beneath the stockpile, then there is a significant overburden thickness of glacial till overlying the bedrock. This glacial till is presumed to be in the range of 100 feet to 200 feet thick.

**Table 1. Bedrock Borings Indicating Top of Rock Elevation**

| Minnesota Unique Well No. | Depth of Boring (feet) | Boring Surface Elevation (feet) | Indicated Depth of Bedrock (feet) | Bedrock Elevation (feet) | Distance From Overburden Stockpile (miles) | Approximate Direction From Site |
|---|---|---|---|---|---|---|
| 780828 | 970 | 1455 | 200 | 1355 | .4 | South-Southwest |
| 303997 | 311 | 1470 | 162 | 1308 | .4 | North |
| 303998 | 461 | 1479 | 139 | 1340 | .5 | North |
| 303995 | 755 | 1450 | 153 | 1297 | .6 | North |
| 250275 | 164 | 1481 | Not Encountered | <1317 | .75 | East-Northeast |
| 303999 | 633 | 1493 | 133 | 1360 | 1.1 | Northwest |

Prior to exploration for the industrial landfill site, NTS had installed 5 monitoring wells at the site and vicinity, which are shown on the boring location diagram.

**Proposed Construction**

The landfill will be completed in four phases, with 8 cells, as identified on the drawings. Each cell has a north-south oriented leachate collection pipe in the center of the cell that flows north to an east-west oriented collector drain along the north boundary of the landfill. Cell A on the west end will be constructed first, and subsequent cell development will proceed eastward. Each cell and a brief description of the site grading are provided below:

Cell A – There is an existing mine stockpile slope about 30' in height running near the N-S boundary between cells A and B. The toe of this slope is within Cell A, but for the purpose of generalizing conditions Cell A is typically below this slope and Cell B is typically above this slope. This difference in grade between cells A and B is a concern for differential settlement. The existing grade below the cell floor and perimeter berms is typically about elevation 1488 near the north end and 1494 near the south end. This will involve about 6 feet of cut to liner grade. The perimeter berms will be about 25 feet in height. Along the west perimeter, the berm will follow the alignment of an access road that separates the mine stockpile from a hydraulic basin containing fine tailings.

Cell B – The existing grade below the cell floor is typically about elevation 1516 near the north end and 1534 near the south end. This will involve about 35 to 45 feet of cut to liner grade. The existing ground is near the perimeter berm crest elevation, with a couple of feet of grading at the north end and up to about 5 feet of fill at the south end. The south boundary of the perimeter berm abuts the existing landfill.

Cell C – The existing grade below the cell floor is typically about elevation 1516 near the north end and 1530 near the south end. This will involve about 40 feet of cut to liner grade. The existing ground is near the perimeter berm crest elevation, with a couple of feet of grading at the north end and up to about 5 feet of cut at the south end. The south boundary of the perimeter berm abuts the existing landfill.

Cell D - The existing grade below the cell floor is typically about elevation 1514 near the north end and 1530 near the south end. This will involve about 35 to 40 feet of cut to liner grade. The existing ground is near the north perimeter berm crest elevation, where minimal grading is required. The existing upper stockpile ends near the south end of Cell D, and the grade drops about 20 feet near the berm. The south berm will require up to about 10 feet of fill.

Cell E - The existing grade below the cell floor is typically about elevation 1510 near the north end and 1530 near the south end. This will involve about 35 to 40 feet of cut to liner grade. The existing ground is near the north perimeter berm crest elevation, where minimal grading is required. The existing upper stockpile also ends near

the south end of Cell E. The south berm will require up to about 25 feet of fill. The east side of the berm skirts the existing stockpile slope.

Cell F – Similar to cells A/B, the upper existing mine stockpile approximately separates cells E and F with a slope about 30 feet in height running near the N-S boundary. This difference in grade between cells E and F is also a concern for differential settlement. The existing grade below the cell floor and perimeter berms is typically about elevation 1480 near the north end and 1478 near the south end. This will involve about 0 to 8 feet of cut to liner grade. The perimeter berms will be about 30 - 40 feet in height.

Cell G – Cell G is similar to Cell F with the ground surface gently dropping to lower elevations. The liner grade will range from about 5 feet of cut in the north end to about 5 feet of fill at the south end. The perimeter berms will be about 35 feet high at the north end and about 45 feet high at the south end.

Cell H – The eastern boundary of cell H drops in elevation, and requires the largest fill height. The fill height near the SE corner is near 65 feet above existing grade. The liner grade is generally within about +/- 5 feet of existing grade, but the SE corner will require up to about 15 feet of fill.

**Subsurface Exploration**

Twenty-one soil borings were advanced at the proposed landfill for the joint purposes of collecting hydrological data and subsurface exploration for geotechnical purposes. Soil boring logs are attached at the end of this appendix.

Thirteen borings were extended with a track-mounted Geoprobe 66-DT drill rig using a percussion hammer and standard Macrocore closed piston sampling barrel. The Geoprobe borings were installed to depths indicated in the Table below. These borings were primarily installed to determine the groundwater surface at the site. Six Geoprobe holes were backfilled with cuttings and 7 (those with a listed casing elevation in Table below) remain open temporary shallow piezometers.

**Table 2. Geoprobe Borings**

| Boring | Depth | Ground Elev | Casing Elev |
|---|---|---|---|
| SB12-02 | 21 | 1488 | N/A |
| SB12-05 | 25 | 1481 | 1482.96 |
| SB12-06 | 29 | 1493 | 1491.95 |
| SB12-09 | 24 | 1485 | N/A |
| SB12-11 | 27 | 1495 | 1497.23 |
| SB12-14 | 31 | 1483 | N/A |
| SB12-17D | 32 | 1473 | 1477.84 |
| SB12-17S | 20 | 1473 | 1477.52 |
| SB12-20 | 32 | 1495 | N/A |
| SB12-21D | 41 | 1487 | 1489.45 |
| SB12-21S | 15 | 1487 | 1489.32 |
| SB12-23 | 23 | 1496 | N/A |
| SB12-24 | 29 | 1481 | N/A |

Ten borings were drilled with a CME 750 drill rig. These holes were advanced using hollow-stem auger and collecting split spoon samples and SPT data (blow counts) every five feet. Standard penetration tests were completed using an automatic hammer in accordance with ASTM D 1586, “Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.” Once depth of boring neared the natural subsurface, continuous sampling was initiated in order to accurately determine the overburden-natural subsurface interface. These borings were filled with a mixture of Portland cement and bentonite grout.

**Table 3. SPT Borings**

| Boring | Depth | Ground Elev | Depth to Native Ground | Elev. Native Ground |
|---|---|---|---|---|
| SB12-03 | 67 | 1511 | 60.0 | 1451 |
| SB12-04 | 72 | 1513 | >45 | |
| SB12-07 | 62 | 1521 | >62 | |
| SB12-08 | 82 | 1534 | 67 | 1467 |
| SB12-13 | 66 | 1521 | 62 | 1459 |
| SB12-15 | 77 | 1529 | 76.5 | 1452.5 |
| SB12-16 | 77 | 1521 | 65 | 1456 |
| SB12-18D | 91 | 1526 | 65 | 1461 |
| SB12-19 | 94 | 1535 | 83 | 1452 |

For all borings, the penetration test samples were visually examined to estimate the distribution of grain sizes, plasticity, organic content, moisture condition, color, presence of lenses or seams, and apparent geologic origin. The soils were classified by type using the Unified Soil Classification System. A chart describing this classification system is attached.

Results of the field and laboratory tests were then plotted on boring logs. These logs are attached. Similar soils were grouped into strata on the logs. Please note that the strata contact lines represent approximate boundaries between soil types; the actual transition between soil types in the field may be gradual in both the horizontal and vertical directions.

Pressuremeter Testing – Two borings were extended near Cells A and B to check the foundation compressibility in the vicinity of the existing 30 foot stockpile slope. The pressuremeter testing was completed by American Engineering Testing. Testing data sheets are attached at the end of this appendix. The following parameters were determined from the pressuremeter testing:

**Table 4. Pressuremeter Test Results**

| Test | Boring | Depth of Test (feet) | Surface Elevation | Test Elevation | Limit Pressure, PL (tsf) | Menard Modulus (tsf) |
|---|---|---|---|---|---|---|
| PM-1 | SB12-26 | 46 | 1523 | 1477 | 12 | 72 |
| PM-2 | SB12-27 | 31 | 1523 | 1492 | 10 | 96 |
| PM-3 | SB12-28 | 10 | 1494 | 1484 | 10 | 117 |
| PM-4 | SB12-28 | 20 | 1494 | 1474 | 13 | 106 |

Laboratory Testing –Soil samples collected while drilling were stored in de-aired Ziploc baggies, and then placed in sealed five gallon buckets to preserve samples until laboratory tests were performed.

Laboratory tests consisted of conducting twenty-three moisture content analyses, eighteen Passing #200 sieve analyses, six grain size analyses, and two Atterberg tests. The soil samples to be tested were determined by assessing the preliminary base grade of the landfill liner, and then selecting samples below this grade. The laboratory results are attached in Appendix D.

**Soil Conditions**

The boring results indicate the mine stockpiles are predominantly medium dense, fine to medium grained sand with varying amounts of fines. There were some zones of stiff clay encountered, but the vast majority appears to be granular. Some zones of coarse gravel and cobbles were interpreted from blow counts, recovery data, drill action, and grout loss when backfilling holes. It is not typical for stockpiles to contain both overburden and lean ore or blast rock; but where blast rock zones occur they create “open work” gravel/cobble mixtures with open

void spaces. This "open work" material has been known to cause sinkholes within the stockpiles. There were some zones of high blows and no recovery, but these zones are consistent with gravelly zones in the overburden common to the region. Overburden stripped from a basal layer overlying bedrock likely contained richer amounts of gravel and cobbles. Statistically, the number of borings does little to define the likelihood of open work gravel in the stockpiles, and assessment of open work zones are based largely on the understood origin of the overburden stripping material and the purpose of the stockpile. It is therefore assumed that open work gravel zones may exist but are not prevalent at this site.

Drill action (as noted above) provides further evidence of the character of materials where the drilling was difficult and the blow counts were high. There were some zones where loss of return of cuttings occurred while advancing the hollow stem auger bit slowly. This was attributed to material balling up on the auger, as evidenced by extremely hot bits, indicating that the materials had been stuck in contact with the auger for a long period of time. There was no loss of cuttings return while drilling below the water table.

In general, the native sands below the buried native ground surface (generally occurring below about elevation 1445) have erratic blow counts (ranging from 30 to 180), indicating rocky material containing cobbles. As such, the relative density is difficult to infer from the SPT testing, but is inferred to be dense and highly over-consolidated

The generalized soil conditions for each landfill cell are described as follows:

Cell A – Borings 12-02, 12-06 and 12-11 were located on the lower mine stockpile surface in Cell A. These borings were extended 21, 29 and 27 feet in depth and all terminated within mine stockpile material. The soils consisted predominantly of clayey sand with gravel. The fines content of two laboratory tests ranged from 35 to 45%, and the material was generally plastic although not saturated. All three borings were Geoprobe borings and no data was obtained on the consistency other than visual estimates. Visual classification described the soils as moist to about 20 feet, and wet below.

Cell B – Borings 12-03, 12-07, 12-12, and 12-15 were located on the upper mine stockpile surface in Cell B. These were all hollow stem borings with SPT sampling. The upper stockpile material was encountered to depth of 25 to 30 feet in depth in borings 12-03, 12-07 and 12-15. The upper stockpile material consisted of gravelly sand, silty sand, and clayey sand, all of which were generally damp to moist and loose relative density. The lower stockpile material extending to elevation 1466 to 1473 generally consisted of medium dense clayey sand with gravel, but was silty sand in 12-03. In 12-12, the upper and lower stockpile was not separable. The northern boring 12-03 encountered black peat inferred to be the buried native ground surface at elevation 1451, and the southern boring 12-15 encountered similar line at 1452.5, while the central borings (12-07 and 12-12) did not extend to this depth. All four borings encountered a basal layer of sand, slightly silty sand, or silty sand of unknown origin overlying the buried native ground line. The basal layer may have been a third lift of mine spoil, but more likely a result of initial grading at the site to lay rail lines through the area.

Cell C – Cell C did not include any borings, but conditions can be inferred from neighboring Cells B and D.

Cell D – Borings 12-04, 12-13, and 12-18 were located on the upper mine stockpile surface in Cell D. Similar to Cell B, all noted a stratification change at 30 feet depth. The upper stockpile material varied with each boring, including slightly clayey sand, silty sand, and sandy clay. The lower stockpile included silty sand, clayey sand, and 12-04 included gravelly material as indicated by poor recovery. Cobbles are not likely as the blow counts were relatively consistent (ranging from 14 to 18) in five SPT tests through this zone. Boring 12-13 encountered a black peat layer inferred to be the buried native ground surface at elevation 1459. While the black peat was absent in borings 12-04 and 12-18 and the native ground surface is not obvious, native sands that show erratic SPT blow counts (likely from cobbles) were encountered below approximate elevations 1458 in each boring.

Cell E – Boring 12-19 was a hollow stem with SPT sampling extending through the upper stockpile, while boring 12-20 was a Geoprobe boring at the toe of the slope and outside the landfill boundary extending through the lower stockpile. The upper stockpile in boring 12-19 was brown to red silty sand to sandy silt with gravel (52% fines content at one sample), and the lower stockpile was grey to brown silty sand. The black peat layer, inferred to be the buried native ground surface, was encountered at elevation 1452.

Cell F – Borings 12-05, 12-09 and 12-14 located along the eastern toe of the upper stockpile and extended into the lower stockpile. Similarly, boring 12-20 was east of the upper stockpile and was located south of cell F, nearer cell E. These borings all encountered brown silty sand with gravel. Borings 12-14 and 12-20 noted some 1 foot thick clay layers of soft to medium stiff consistency. All four borings were Geoprobe borings and no data was obtained on the consistency other than visual estimates.

Cells G & H – No borings were obtained in these cells. Due to high embankments planned in this area, additional borings will be required to finalize plans and specifications in this reach. See below paragraph on 'Subsequent Phase Investigations' for further discussion.

**Settlement Analysis**

Settlement affecting the landfill should occur predominantly within the overburden stockpile. The native soils encountered were dense to very dense and are likely highly over consolidated by glacial ice. Therefore, for deep seated settlement occurring within the native glacial till, the magnitude and uniformity across the site should not affect performance of the landfill.

The settlement at the boring locations was estimated by correlations with the standard penetration tests, and determined to be up to about 5 inches beneath the higher portions of the final landfill cap in the range of elevation 1580. Because there was a high degree of uncertainty with the SPT correlations, further subsurface exploration was conducted by obtaining four pressuremeter tests in the Cell A area. Settlement predictions based on the pressuremeter data are slightly higher than the SPT correlation, but have much higher confidence since the SPT is an index test and the pressuremeter actually measures a modulus value (stress - strain relationship).

The settlement was estimated by each SPT interval in the borings and using the elevations in Table 5. Boring 12-03 was through the berm crest. Borings 12-04, 12-15, 12-16 and 12-19 were considered representative of soils at the liner floor although the borings were located through the landfill side slopes, so the elevations of the nearby liner floor elevation were used for the calculations.

**Table 5. Assumed Elevations at Boring Locations for Settlement Estimates**

| | Elevation (in feet) | | | Height (in feet) | |
|---|---|---|---|---|---|
| Boring | Initial Grade | Liner Grade | Final Grade | Preload (initial - liner) | Total Load (final - initial) |
| 12-03 | 1511 | 1513 | 1555 | -2 | 42 |
| 12-04 | 1513 | 1476 | 1540 | 37 | 64 |
| 12-07 | 1524 | 1485 | 1557 | 39 | 72 |
| 12-08 | 1534 | 1479 | 1567 | 55 | 88 |
| 12-12 | 1522 | 1482 | 1580 | 40 | 98 |
| 12-13 | 1521 | 1482 | 1580 | 39 | 98 |
| 12-15 | 1529 | 1488 | 1580 | 41 | 92 |
| 12-16 | 1521 | 1486 | 1550 | 35 | 64 |
| 12-18 | 1526 | 1488 | 1580 | 38 | 92 |
| 12-19 | 1535 | 1492 | 1550 | 43 | 58 |

SPT Correlations - The initial predictions of settlement were based on the correlation in Figure 1. The settlement was calculated from the vertical compressibility (mv) using the equations:

$m_v = 1.7/N^{1.4}$ [1/megapascal]

$\delta_b = (1/3)(12 \text{ in/ft})(\sigma_{vo})(m_v)Z$

and

$\delta_s = \delta_b + (12 \text{ in/ft})(\sigma_{vf} - \sigma_{vo})(m_v)Z$

where $\delta_b$ is the rebound from cutting the existing grade down to the liner grade, and $\delta_s$ is the vertical settlement after filling the landfill with waste and placing the cap. The mine overburden stockpile was assumed to be normally consolidated by the weight of the existing fill overlying the liner grade. Then the initial preconsolidation stress $\sigma_{vo}$ is the multiple of the unit weight of the stockpile and height of the existing ground surface above liner grade. The unload-reload settlement curve ($\delta_b$) was assumed to be 1/3 of the virgin compression. The final vertical stress on the liner is $\sigma_{vf}$. The difference ($\sigma_{vf} - \sigma_{vo}$) remains constant with depth below the liner, and is the multiple of the unit weight of waste and the height of waste above the liner.

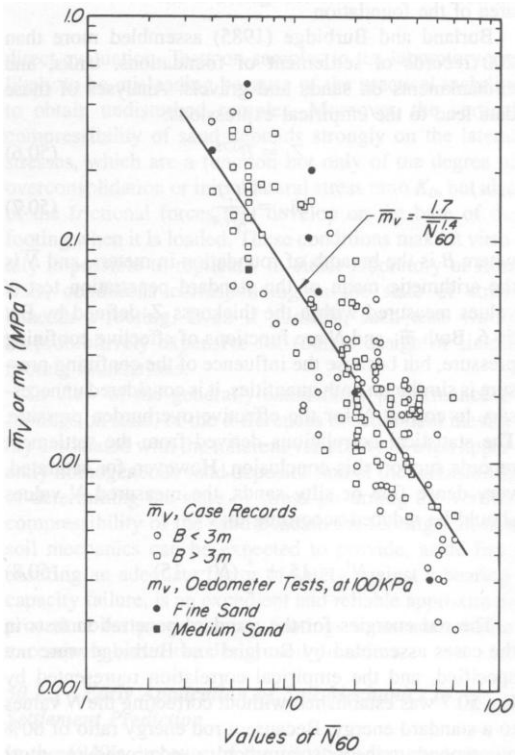


Figure 2. Relation between SPT and Vertical Compressibility (data from Burland and Burbidge 1985, Figure from Terzaghi, Peck and Mesri, "Soil Mechanics in Engineering Practice", 1996)

For example, assuming typical values at the maximum height of the cover of N=10 blows per foot, a 40 feet cut to liner grade and 100 feet of waste (including cap) above the liner,

$m_v$ = 1.7/(10^1.4)/20.9 (ksf/MPa) = 0.0032/ksf
$\sigma_{vo}$ = 40'(100pcf) = 4 ksf
$\delta_b$ = (1/3)(12 in/ft)(4ksf)(.0032/ksf)Z
$\sigma_{vf} - \sigma_{vo}$ = 100'(80pcf) – 40'(100pcf) = 4 ksf
$\delta_s = \delta_b$ + (12 in/ft)(4ksf)(.0032/ksf)Z
$\delta_s$ (inches) = 0.20 Z (feet)

For 30 feet of compressible soils (with N = 10) below the liner, the total settlement of the liner is about 6 inches.

The general method of settlement prediction was extended to each SPT in the 10 borings evaluated using a 5 foot depth increment, and using the elevations in Table 5. The predicted settlements are reported in Table 6.

**Table 6. Settlement Estimates**

| | SPT Estimate | | Modulus Estimate | |
|---|---|---|---|---|
| Boring | Rebound (inches) | Settlement (inches) | Rebound (inches) | Settlement (inches) |
| 12-03 | 0.0 | 7.8 | 0.0 | 13.4 |
| 12-04 | -0.7 | 1.4 | -1.9 | 3.8 |
| 12-07 | -1.0 | 2.3 | -1.7 | 3.8 |
| 12-08 | -1.2 | 2.2 | -2.5 | 4.4 |
| 12-12 | -0.6 | 2.4 | -1.5 | 5.8 |
| 12-13 | -1.1 | 4.7 | -2.0 | 8.1 |
| 12-15 | -1.3 | 3.6 | -2.7 | 7.9 |
| 12-16 | -1.1 | 2.6 | -2.3 | 5.8 |
| 12-18 | -0.9 | 3.1 | -2.5 | 9.1 |
| 12-19 | -1.8 | 2.0 | -3.7 | 4.1 |

Pressuremeter Correlations

Improved predictions of settlement were based on the elastic modulus of the soils. Several correlations of elastic modulus from SPT are available. For sands, a linear correlation is:

E (tsf) = 5 (N + 15), for unsaturated sands
E (tsf) = 2.5 (N + 15), for saturated sands

For saturated sands, this value is reduced by 2. Another natural logarithm correlation is:

E (tsf) = 50 ln(N).

These correlations are shown on Figure 2. The Menard modulus ($E_m$) has been shown to closely correspond to the elastic modulus, and the results of $E_m$ are also plotted on Figure 2. The five pressuremeter test results for $E_m$ all

plot between the liner correlations for E. The two lower values were tests 1A and 1B, where test 1A bursted the pressuremeter probe and was not completed. Using this data, an intermediate correlation is recommended of

E (tsf) = 3.75 (N + 15)

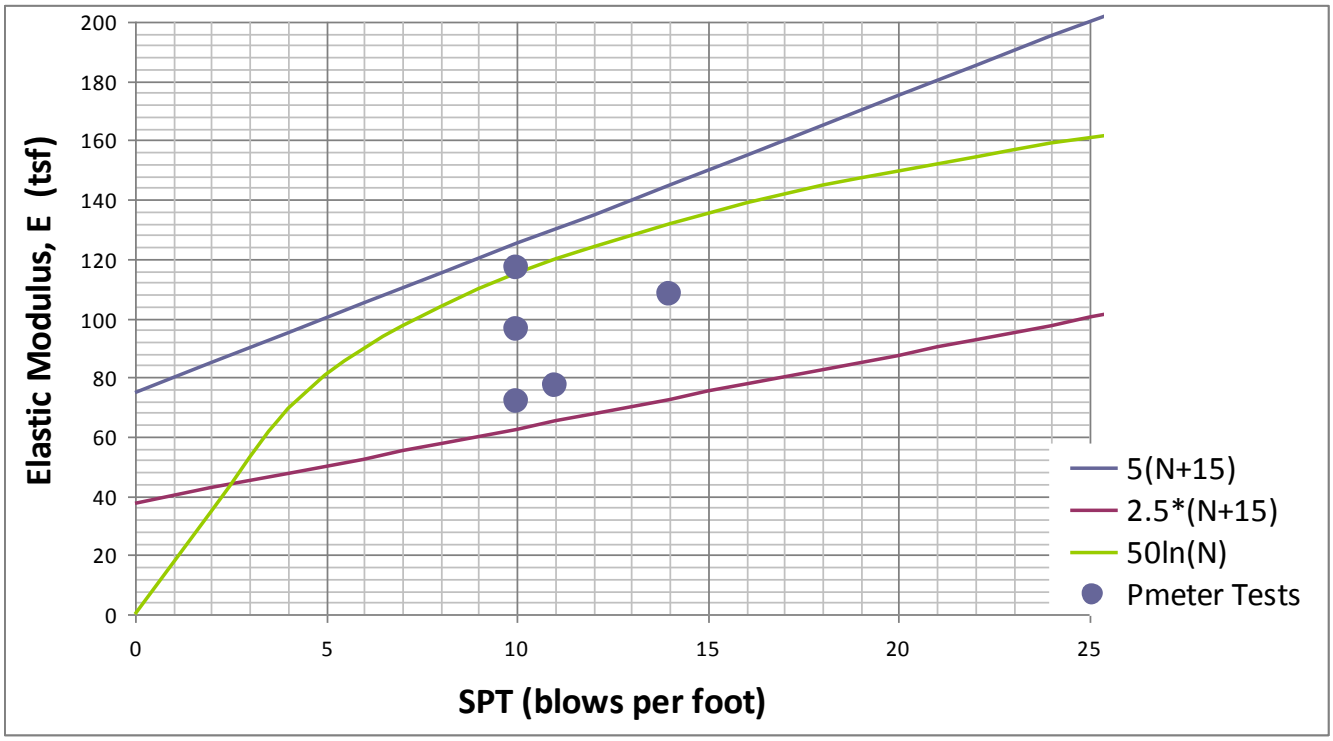


Figure 3. Elastic Modulus Correlations and Pressuremeter Results

The settlements were calculated in similar manner as the SPT ($m_v$) correlations using the following equations:

$$\delta_b = (1/3)(12 \text{ in/ft})(\sigma_{vo})Z/E$$

and

$$\delta_s = \delta_b + (12 \text{ in/ft})(\sigma_{vf} - \sigma_{vo})Z/E$$

Similar to the SPT ($m_v$) correlations, the settlement prediction based on modulus was extended to each SPT in the 10 borings evaluated using 5 feet depth increments, and using the elevations in Table 5. The predicted settlements are reported in Table 6. The modulus (E) predictions are generally about twice the compressibility (mv) predictions and are considered more defensible.

Conclusions on Settlement Analysis

Predicted liner settlement is about 4 – 8 inches over the liner floor. Differential settlement is expected to be on the order of 4 inches, occurring over distances of about 30 feet. The maximum differential settlement is most likely to occur transverse to the linear stockpile deposition shown on the 1939 and 1947 air photos (occurring primarily in a NW to SE direction, and fanning outward from the rail entrance at the NW corner of the stockpile. The stratification of the stockpile and elevation of the original ground surface is not known well enough to reliably map settlement over the landfill area, and these predictions should be considered to occur somewhat randomly. Settlement of the containment berm (as indicated by boring 12-03) could exceed one foot, but the liner

slopes are not susceptible to puddling of drainage, and the downdraft should not tension or tear the liner. Total settlement and differential settlement across the liner should not cause harm (over stress or damage) to the liner. Overall, the site is appropriate for construction of the landfill, given the recommendations in this report are followed.

**Recommendations**

The geotechnical conditions below the landfill footprint are controlled by the properties of the overburden stockpile, which was the focus of the data collection and analysis. Agreement in the settlement calculations from SPT data and pressure meter data provides reliability in maximum settlement provided in Table 6. These settlement values are considered acceptable to avoid ponding within the liner system or tensioning of the liner material. Recommendations for foundation preparation, fill placement, liner construction, and construction inspection are provided below to ensure limited settlement over the lifetime of the landfill. In addition, an instrumentation plan is included to provide design confirmation. The instrument plan should not be interpreted as a plan to compensate for design uncertainty, but rather good geotechnical practice.

Foundation preparation

Foundation preparation below the landfill footprint, where fill will be placed, should be graded with the following conditions prior to placing fill:

- All areas should include clearing and grubbing. Root balls shall be completely removed. Roots larger than 2 inches diameter shall be removed.
- All areas shall be stripped 6 inches to remove surficial vegetation and debris. If dense roots, organic soils, or material suitable for use as topsoil are encountered, these materials shall be removed to a suitable subgrade.
- Slopes should be cut back to no steeper than 3H:1V. Slopes 5H:1V or steeper shall be stepped with risers 3 feet in height and benches 9 to 15 feet in width during construction. Compaction equipment shall be run perpendicular to these slopes, run up against the slope, and backed off for each compaction lift. This will include significant excavation where the containment dike traverses the existing stockpile slopes (e.g. East leg of cell E) or crosses the existing stockpile (e.g. North and South legs of cell A).

Fill Placement

- Granular fill and pervious drainage layer should be placed in lifts not exceeding 1 foot in thickness and compacted with not less than 2 passes of a large self-propelled smooth-drum vibratory compactor. Soils should be compacted to not less than 95% of the standard proctor density defined in ASTM D-698. Granular fill should contain less than 20% passing the No. 200 sieve and no gravel larger than 1 inch.
- Compacted clay liner should be placed in lifts not exceeding 8 inches in thickness and compacted with not less than 3 passes of a sheep's-foot compactor. Soils should be compacted to not less than 95% of the standard proctor density defined in ASTM D-698. Moisture should be controlled during compaction to within -0% to +5% moisture content by dry weight from the optimum moisture content determined in D-698. If it is necessary to dry or wet soils, the soils should be disked or worked in accordance with guidelines in the Minnesota DOT standard specifications.
- The subgrade below the separation geotextile should be compacted with not less than 4 passes of a large self-propelled smooth-drum vibratory compactor, or until there is no further evidence of densification. The final pass should be inspected using a proof-rolling observation method and documentation. Areas where the vibration is damped or the subgrade does not densify relative to typical action of the compactor should be investigated.

Landfill Details

The landfill liner should include subgrade details to mitigate the potential for open graded gravel zones in the existing stockpile and to reduce localized settlement. The settlement below the landfill is expected to be less than 6 inches, with higher settlement zones located where fill depth will be the largest. There is a slight risk of localized zones of differential settlement due to differences in the existing stockpile height, changes in soil type, settlement of containment berms relative to the landfill floor, and unknowns regarding buried native soils and undulation in the original ground surface. These concerns are expected to be properly addressed by sub-cutting the liner 12 inches, thorough compaction of the subgrade, placement of a separation geotextile, and 12 inches of compacted granular fill below the clay liner. This subcut does little to change the total settlement, but will reduce differential movement and cracking caused by localized soft spots and subgrade material changes. The recommended typical landfill liner consists of the following zones from top to bottom:

- 12-inch pervious drainage layer for leachate collection
- 60-mil HDPE geomembrane liner
- 24-inch compacted clay liner
- 12-inches compacted granular fill
- separation geotextile, overlying compacted subgrade

The compacted granular fill should have less than 15% passing the No. 200 sieve, less than 20% retained on the No. 4 sieve, and no gravel retained on the 2" sieve. It is anticipated that this material will be available from the existing stockpile excavation zones, but will need to be borrowed selectively. Most of the soils classified as SP or SW on the boring logs should meet this specification.

The separation geotextile should meet the following requirements. Some fabrics that meet these specifications include Marifi 600X, and L & M Supply LM315.

| | | |
|---|---|---|
| Grab Tensile Strength | ASTM D 4632 | 300 pounds |
| Grab Tensile Elongation | ASTM D 4632 | 12% |
| Permittivity | ASTM D 4491 | 0.05/second |
| UV Resistance | ASTM D 4355 | 70% at 500 hours |

Near the drainage sumps, leak detection will include additional zones of 12 inches pervious drainage layer and 60-mil HDPE geomembrane will be inserted between the clay and granular fill.

The landfill has a storm water control plan to convey stormwater away from the landfill footprint. The advanced borings indicated zones of materials that will be excavated classified as CL. This material would be appropriate to use in the lining of storm water conveyance ditches and settlement ponds to form a low permeability layer.

Instrumentation Plan

The following instrumentation is recommended. Instrumentation should be installed prior to construction in the area in order to obtain baseline readings.

- Two inclinometers should be placed along the Cell A west boundary, near the stockpile toe and contact with the fine tailings. These should be installed to elevation 1430, or 5 feet into soils with SPT > 30 blows per foot (current ground surface is about 1490).
- Two settlement plates near the centerline of the Cell A containment berm, west leg. The settlement plates shall consist of 1-1/2 inch iron pipe, welded to a steel plate ¾ inch think and 24 inch square. The plates shall be set at existing grade (about elevations 1985 and 1490), and rise to the berm crest (about elevation

1525) by extending the pipes. It is important to survey the top riser immediately before and after each extension. The riser pipe shall be covered with a 2-1/2" PVC sleeve.

Construction Inspection

The west side of Cell A should be inspected during construction near the access road that separates the stockpile and the tailings basin. Any suspect locations that show cracking, bulging or movement during fill placement should be investigated to confirm the toe of the stockpile is not undercut or overlying soft plastic soils associated with the tailings basin.

The entire landfill storage volume excavated from the existing overburden stockpile should be observed for soil types, stratification, inclination and orientation of stratification. Specific attention should be given to excavated zones that are cohesive, open graded gravel zones, buried debris or peat, or zones that appear soft or loose; and any such observations should be documented for future reference. The liner subgrade should be mapped for soil types, including stratifications and orientation.

Staking or marking of stationing and cell boundaries should be maintained in order to document location and elevations of observations during construction.

Subsequent Phase Investigations

Additional subsurface investigation will be required at the containment berm in Cells G and H. This additional subsurface exploration should be completed to determine stripping depths, compaction requirements in the berm section, and quality control testing. These borings have not been completed at this time since constructability does not appear to be an issue due to the predominant granular soils and large amount of granular borrow available on this site. Since the berm in this reach encompasses a large amount of fill that will be obtained from excavation in prior cells, these borings will likely be required well before construction of Cells G and H.

If you have any questions or comments please call.

Sincerely,
NTS, Inc.

Doug Crum, P.E. Evan Johnson, EIT

# Soil Boring Logs

Northeast Technical Services
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# BORING NUMBER SB12-02



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/18/12 **COMPLETED** 10/18/12
**GROUND ELEVATION** 1494 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40's F; rainy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | MC | | (SC-SM) Silty clayey sand, medium stiff, brown to greyish brown, moist | 50 | | | | | | | |
| | MC | | | 50 | | 8 | | | | 37 | |
| 10 | MC | | | 50 | | | | | | | |
| | MC | | | 50 | | | | | | | |
| | MC | | | 75 | | | | | | | |
| 20 | MC | | | 100 | | | | | | | |
| | | | Bottom of borehole at 21.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-03



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/17/12 **COMPLETED** 10/17/12
**GROUND ELEVATION** 1512 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
▽ **AT TIME OF DRILLING** 45.50 ft / Elev 1466.50 ft
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 39 F; cloudy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | (SM) Silty Sand with gravel, brown, dry, some fines, little gravel, Mine Overburden | | | | | | | | |
| | SS | | | 75 | 6-8-8-8 (16) | | | | | | |
| 10 | SS | | | 75 | 5-4-4-5 (8) | 13 | | | | 35 | |
| | SS | | (SP-SC) Sand with silty clay, brown, moist, fine to medium grained sand, Mine Overburden | 88 | 3-4-4-4 (8) | | | | | | |
| 20 | SS | | | 88 | 4-5-5-6 (10) | | | | | | |
| | SS | | (SC-SM) Silty clayey sand, brown, moist, fine to medium grained sand, some fines, few gravel, Mine Overburden | 75 | 5-5-6-7 (11) | | | | | | |
| 30 | SS | | | 88 | 4-5-5-6 (10) | | | | | | |
| | SS | | | 100 | 4-5-5-6 (10) | 9 | | | | 32 | |
| 40 | SS | | | 50 | 5-6-8 (14) | | | | | | |
| | SS | | ▽ (SP-SM) Sand with silt, brown to 55 feet, gray from 55 to 60 feet, wet, fine to medium grained sand, few fines, few gravel | 75 | 4-4-5-5 (9) | | | | | | |
| 50 | SS | | | 50 | 5-5-6 (11) | | | | | | |
| | SS | | | 63 | 3-2-1-1 (3) | | | | | | |
| 60 | SS | | (OL) Peat, black, wet, Native Ground Surface | 88 | 5-8-9-11 (17) | | | | | | |
| | SS | | (SP-SC) Sand with silty clay, grey, wet, few fines, few gravel | 100 | 4-11-23-27 (34) | | | | | | |
| | | | Bottom of borehole at 67.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-04



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/17/12 **COMPLETED** 10/17/12
**GROUND ELEVATION** 1514 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
▽ **AT TIME OF DRILLING** 53.50 ft / Elev 1460.50 ft
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 51 F; rainy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | (SP-SC) Sand with clay and gravel, red to brown, moist, Mine Overburden | | | | | | | | |
| | SS | | | 13 | 4-5-5-5 (10) | | | | | | |
| 10 | SS | | | 88 | 2-2-3-4 (5) | | | | | | |
| | SS | | | 88 | 2-3-3-3 (6) | | | | | | |
| 20 | SS | | | 100 | 2-3-3-3 (6) | | | | | | |
| | SS | | (SC-SM) 19 % gravel, 50 % sand, 31 % fines Silty clayey sand with gravel, grey to brown, moist, some fines, little gravel, Mine Overburden | 100 | 3-4-6-8 (10) | | | | | | |
| 30 | SS | | | 13 | 4-6-9 (15) | | | | | | |
| | SS | | | 13 | 16-8-6 (14) | | | | | | |
| 40 | SS | | | 63 | 6-8-8 (16) | | | | | | |
| | SS | | | 75 | 9-9-9-9 (18) | 10 | | | | 31 | |
| 50 | SS | | No Recovery | 13 | 6-8-8 (16) | | | | | | |
| | SS | | ▽ (SC-SM) 12 % gravel, 59 % sand, 29 % fines Silty clayey sand, brown, wet, fine to medium grained sand, little fines, few gravel | 75 | 3-6-6 (12) | 13 | | | | 29 | |
| 60 | SS | | (OL) Peat, black, wet, Native Ground Surface | 75 | 5-15-15 (30) | | | | | | |
| | SS | | (SP-SC) Sand with silty clay, brownish grey, wet, medium to coarse grained sand | 75 | 20-25-30 (55) | | | | | | |
| 70 | SS | | (SP) Sand, brown, wet, medium grained | 100 | 6-7-7-8 (14) | | | | | | |
| | | | Bottom of borehole at 72.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-05



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/17/12 **COMPLETED** 10/17/12
**GROUND ELEVATION** 1479 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40s F; overcast
**AFTER DRILLING** 19.70 ft / Elev 1459.30 ft

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | MC | | (SP-SC) Sand with silty clay and gravel, brown, moist, few fines, little gravel | 75 | | | | | | | Casing Top Elev: 1482.96 (ft) |
| | MC | | | 50 | | | | | | | Grout |
| 10 | MC | | | 0 | | | | | | | |
| | MC | | | 75 | | | | | | | Bentonite Seal |
| | MC | | (SP-SC) Sand with silty clay and gravel, brown, wet, few fines, little gravel | 50 | | | | | | | Sand Pack |
| 20 | MC | | | 50 | | | | | | | |
| | MC | | Bottom of borehole at 25.0 feet. | 25 | | | | | | | |

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# BORING NUMBER SB12-06



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/18/12 **COMPLETED** 10/18/12
**GROUND ELEVATION** 1494 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40s F; rainy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1491.95 (ft) |
| | MC | | (SP-SC) Sand with silty clay and gravel, brown to greyish brown, moist, few fines, little gravel, fill material | 38 | | | | | | | Grout |
| | MC | | | 38 | | | | | | | |
| 10 | MC | | (SC) Clayey sand with gravel, brown to greyish brown, moist, some fines, little gravel, fill material | 38 | | | | | | | |
| | MC | | | 75 | | | | | | | Bentonite Seal |
| | MC | | | 75 | | 11 | | | | 47 | |
| 20 | MC | | | 75 | | | | | | | Sand Pack |
| | MC | | (SC) Clayey sand with gravel, brown to greyish brown, wet, some fines, little gravel, fill material | 100 | | | | | | | |
| | | | Refusal at 29.0 feet.<br>Bottom of borehole at 29.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-07



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/16/12 **COMPLETED** 10/16/12
**GROUND ELEVATION** 1522 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
**AT TIME OF DRILLING** ---
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 46 F; Cloudy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1524.73 (ft) |
| | SS | | (SP) Sand with gravel, brown to red, dry, little gravel, trace fines, Mine Overburden | 13 | 7-7-7-7 (14) | | | | | | |
| 10 | SS | | | 63 | 4-4-4-4 (8) | | | | | | |
| | SS | | | 88 | 3-3-3-4 (6) | | | | | | |
| 20 | SS | | | 88 | 3-3-3-3 (6) | | | | | | Grout |
| | SS | | (SC) Clayey sand with gravel, brown, dry, some fines, little gravel, Mine Overburden | 75 | 4-18-28-18 (46) | | | | | | |
| 30 | SS | | | 13 | 7-7-7-7 (14) | | | | | | |
| | SS | | | 100 | 4-5-6-8 (11) | | | | | | |
| 40 | SS | | (SP) Sand with gravel, brown, moist, little gravel, trace fines, Mine Overburden | 63 | 25-15-7-7 (22) | | | | | | Bentonite Seal |
| | SS | | (SC) Clayey sand with gravel, brown, moist, some fines, little gravel, Mine Overburden | 88 | 8-7-15-9 (22) | | | | | | |
| 50 | SS | | | 63 | 15-8-7-7 (15) | | | | | | Sand Pack |
| | SS | | | 100 | 3-4-4-5 (8) | | | | | | |
| | SS | | (SP) Sand with gravel, brown, wet, trace fines, little gravel, Mine Overburden | 100 | 3-4-4-4 (8) | | | | | | |
| | SS | | | 100 | 3-4-4-5 (8) | 12 | | | | 36 | |
| 60 | SS | | | 100 | 3-3-4-5 (7) | | | | | | |
| | SS | | (SP-SC) Sand with silty clay, brown, wet, few fines | 100 | 4-4-5-6 (9) | | | | | | |
| | | | Bottom of borehole at 62.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-08



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/17/12 **COMPLETED** 10/18/12
**GROUND ELEVATION** 1522 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
**AT TIME OF DRILLING** 60.00 ft / Elev 1462.00 ft
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 46 F; rainy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | (SP-SC) Sand with clay and gravel, red to brown, dry, Mine Overburden | | | | | | | | |
| | SS | | | 75 | 4-5-6 (11) | | | | | | |
| 10 | SS | | | 75 | 10-8-6-6 (14) | | | | | | |
| | SS | | | 63 | 4-4-5-5 (9) | | | | | | |
| 20 | SS | | (CL) Sandy clay, grey, moist, some sand, trace gravel, Mine Overburden | 100 | 2-2-4-4 (6) | | | | | | |
| | SS | | | 100 | 3-3-3-3 (6) | | | | | | |
| 30 | SS | | (SP-SC) Sand with clay, brown to grey, moist, little gravel, few fines, Mine Overburden | 88 | 3-4-6-7 (10) | | | | | | |
| | SS | | | 75 | 4-5-6-7 (11) | | | | | | |
| 40 | SS | | | 75 | 4-6-7-8 (13) | | | | | | |
| | SS | | | 50 | 5-8-9-11 (17) | | | | | | |
| 50 | SS | | | 100 | 5-8-10-11 (18) | | | | | | |
| | SS | | (SP) Sand with gravel, brown to grey, wet, fine to medium grained | 75 | 4-4-4-6 (8) | | | | | | |
| 60 | SS | | (SC-SM) Silty clayey sand, grey, wet, rock chips, little fines, few gravel | 75 | 4-5-7-7 (12) | | | | | | |
| | SS | | | 100 | 4-5-6-7 (11) | | | | | | |
| 70 | | | (SC-SM) Silty clayey sand, grey to brown, moist, some fines, Native Ground Surface encountered at 67 feet | | | | | | | | |
| | SS | | | 75 | 7-9-15 (24) | 14 | | | | 47 | |
| | SS | | | 88 | 11-15-18-25 (33) | | | | | | |
| 80 | SS | | (SP) Sand with gravel, brown, wet, fine to medium grained, trace fines, little gravel | 75 | 13-16-19-25 (35) | | | | | | |
| | | | Bottom of borehole at 82.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-09



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/17/12 **COMPLETED** 10/17/12
**GROUND ELEVATION** 1484 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
▽ **AT TIME OF DRILLING** 23.00 ft / Elev 1461.00 ft Approximate
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40s F; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | MC | | (SC-SM) Silty clayey sand with gravel, brown, moist, little fines, some gravel | 50 | | | | | | | |
| | MC | | | 50 | | | | | | | |
| 10 | MC | | | 50 | | | | | | | |
| | MC | | | 38 | | | | | | | |
| | MC | | | 75 | | | | | | | |
| 20 | MC | | ▽ | 0 | | | | | | | |
| | | | (SP-SC) Sand with silty clay and gravel, brown, wet, few fines, some gravel | | | | | | | | |
| | | | Refusal at 24.0 feet. Bottom of borehole at 24.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-11



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/18/12 **COMPLETED** 10/18/12
**GROUND ELEVATION** 1496 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40's F; rainy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1497.23 (ft) |
| | MC | | (SP-SC) Sand with silty clay and gravel, brown, moist, few fines, little gravel, fill material | 38 | | | | | | | |
| | MC | | | 25 | | | | | | | Grout |
| 10 | MC | | (SC) Clayey sand with gravel, brown, moist, stiff to very stiff, some fines, little gravel, fill material | 63 | | | | | | | |
| | MC | | | 100 | | | | | | | Bentonite Seal |
| | MC | | | 88 | | | | | | | |
| 20 | MC | | | 75 | | 11 | | | | 47 | Sand Pack |
| | MC | | (SC) Clayey sand with gravel, brown, wet, some fines, little gravel, fill material | 50 | | | | | | | |
| | | | Bottom of borehole at 27.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-12



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/16/12 **COMPLETED** 10/16/12
**GROUND ELEVATION** 1523 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
**AT TIME OF DRILLING** ---
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 66 F; sunny
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1523.88 (ft) |
| | SS | | (SP) Sand with gravel, brown, dry, little gravel, Mine Overburden | 75 | 5-9-6-7 (15) | | | | | | |
| 10 | SS | | (SC) Clayey sand with gravel, brown, moist, little fines, little gravel, Mine Overburden | 75 | 5-4-4-5 (8) | | | | | | |
| | SS | | | 50 | 3-3-3-4 (6) | | | | | | |
| 20 | SS | | | 50 | 3-4-3-3 (7) | | | | | | Grout |
| | SS | | No Recovery; rock or cobbles | 0 | 8-12-15-20 (27) | | | | | | |
| 30 | | | (SC) Clayey sand with gravel, brown, moist, little fines, little gravel, Mine Overburden | | | | | | | | |
| | SS | | | 50 | 4-5-6-8 (11) | | | | | | |
| | SS | | | 75 | 5-6-6-7 (12) | | | | | | |
| 40 | SS | | (SC-SM) 5 % gravel, 70 % sand, 25 % fines Silty sand with gravel, brown, moist, little fines, trace gravel, Mine Overburden | 100 | 5-6-7-8 (13) | | | | | | |
| | SS | | | 100 | 8-9-12-15 (21) | | | | | | |
| 50 | SS | | (SC-SM) Silty clayey sand, brown, moist, fine to medium grained sand, little fines, trace gravel | 75 | 8-11-7-7 (18) | | | | | | Bentonite Seal |
| | SS | | | 75 | 8-8-9-9 (17) | | | | | | |
| | SS | | (SP) Sand, brown, wet, fine to medium grained sand | 100 | 8-8-9-9 (17) | 10 | | | | 25 | Sand Pack |
| | SS | | (SP-SC) Sand with silty clay, brown, wet, fine to medium grained sand, little fines | 100 | 4-5-6-6 (11) | | | | | | |
| | SS | | | 75 | 5-5-6-7 (11) | | | | | | |
| | | | Bottom of borehole at 59.5 feet. | | | | | | | | |

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# BORING NUMBER SB12-13



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/18/12 **COMPLETED** 10/18/12
**GROUND ELEVATION** 1522 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
**AT TIME OF DRILLING** ---
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 51 F; rainy
**AFTER DRILLING** 59.40 ft / Elev 1462.60 ft

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | (CL) Sandy clay with gravel, brown to red, dry, medium grained sand, some sand, little gravel, MIne overburden | | | | | | | | Casing Top Elev: 1524.17 (ft) |
| | SS | | | 100 | 4-5-6-7 (11) | | | | | | |
| 10 | SS | | | 100 | 4-5-6-7 (11) | | | | | | |
| | SS | | | 100 | 1-2-2-3 (4) | | | | | | |
| 20 | SS | | | 100 | 2-3-3-4 (6) | | | | | | |
| | SS | | | 100 | 4-3-3-4 (6) | | | | | | Grout |
| 30 | SS | | (SC-SM) Sand with silt, brown to grey, moist, fine grained, Mine overburden | 75 | 3-4-5 (9) | | | | | | |
| | SS | | | 88 | 3-4-4-5 (8) | | | | | | |
| 40 | SS | | | 88 | 4-5-7-9 (12) | | | | | | |
| | SS | | (SC-SM) 7 % gravel, 65 % sand, 28 % fines Silty Clayey sand, brown to grey, moist, fine to medium grained sand, little fines, few gravel, Mine overburden | 100 | 4-4-4-4 (8) | | | | | | |
| 50 | SS | | | 63 | 6-8-9 (17) | 11 | | | | 28 | |
| | SS | | | 50 | 6-12-9-9 (21) | | | | | | Bentonite Seal |
| 60 | SS | | | 50 | 11-4-5 (9) | | | | | | Sand Pack |
| | SS | | (OL) Peat, black, wet, Native surface | 75 | 3-3-4-4 (7) | | | | | | |
| | SS | | (SP-SC) Sand with silty clay, grey, wet, fine to medium grained | 50 | 15-30-50 (80) | | | | | | |
| | | | (SP) Sand, gray, wet, medium grained | | | | | | | | |
| | | | Refusal at 66.0 feet. Bottom of borehole at 66.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-14



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/16/12 **COMPLETED** 10/16/12
**GROUND ELEVATION** 1481 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
▽ **AT TIME OF DRILLING** 24.00 ft / Elev 1457.00 ft Approximate
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 60s F; sunny
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | MC | | (SP-SC) Sand with silty clay and gravel, brown, moist | 38 | | | | | | | |
| | MC | | | 0 | | | | | | | |
| 10 | MC | | | 25 | | | | | | | |
| | MC | | | 25 | | | | | | | |
| | MC | | | 38 | | | | | | | |
| 20 | MC | | | 63 | | | | | | | |
| | MC | | ▽ (CL) Lean clay with sand, soft to medium stiff, brown to grey, moist | 63 | | | | | | | |
| | MC | | (SC-SM) Silty clayey sand with gravel, brown, wet, little fines, little gravel | 50 | | | | | | | |
| 30 | | | (SC) Lean clay with sand, soft to medium stiff, brown to grey, moist | | | | | | | | |
| | | | Refusal at 31.0 feet.<br>Bottom of borehole at 31.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-15



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/15/12 **COMPLETED** 10/15/12
**GROUND ELEVATION** 1529 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
▽ **AT TIME OF DRILLING** 57.40 ft / Elev 1471.60 ft
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 55 F; sunny
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1532.99 (ft) |
| | SS | | (SP) Sand with gravel, brown to red, dry, some cobbles at 22 feet, Mine overburden | 75 | 8-8-6-6 (14) | | | | | | |
| 10 | SS | | | 13 | 7-6-7-7 (13) | | | | | | |
| | SS | | | 63 | 4-4-4-4 (8) | | | | | | |
| 20 | SS | | | 50 | 5-4-4-4 (8) | | | | | | |
| | SS | | | 25 | 11-6-3-3 (9) | | | | | | Grout |
| 30 | SS | | (SC) 4 % gravel, 56 % sand, 40 % fines Clayey sand with gravel, light brown to 40 feet, gray from 40 to 50 feet, moist, some fines, trace gravel, Mine Overburden | 13 | 20-10-13-13 (23) | | | | | | |
| | SS | | | 50 | 6-5-6-6 (11) | 8 | | | | 40 | |
| 40 | SS | | | 88 | 4-4-6-8 (10) | | | | | | |
| | SS | | | 63 | 4-6-7-12 (13) | | | | | | |
| 50 | SS | | (SP) Sand, light brown, dry, fine to medium grained | 63 | 7-5-7-7 (12) | | | | | | Bentonite Seal |
| | SS | | (SC) Clayey sand, gray, moist, little fines | 100 | 4-6-6-7 (12) | | | | | | |
| 60 | SS | | ▽ (SP) Sand, brown, wet, fine to medium grained | 63 | 4-6-8-9 (14) | | | | | | Sand Pack |
| | SS | | | 88 | 5-5-7-7 (12) | | | | | | |
| 70 | SS | | (SP-SC) Sand with silty clay, brown, wet, fine to medium grained sand, little fines | 100 | 7-8-8-9 (16) | | | | | | |
| | SS | | (CL) Clay with sand, gray, moist, little sand, cohesive | 88 | 9-11-15-23 (26) | | | | | | |
| | | | (OL) Peat, black, wet, Native Surface | | | | | | | | |
| | | | Bottom of borehole at 77.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-16



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/18/12 **COMPLETED** 10/19/12
**GROUND ELEVATION** 1522 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
▽ **AT TIME OF DRILLING** 58.50 ft / Elev 1463.50 ft
**LOGGED BY** J. Holmes **CHECKED BY**
**AT END OF DRILLING** ---
**NOTES** 51 F; rainy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | (CL) Clay with sand and gravel, red to brown, dry, little sand, little gravel, Mine Overburden | | | | | | | | |
| | SS | | | 50 | 3-4-4-5 (8) | | | | | | |
| 10 | SS | | | 100 | 4-5-6-6 (11) | | | | | | |
| | SS | | (SC-SM) Silty clayey sand, red to brown, moist, little fines, Mine Overburden | 100 | 2-2-3-3 (5) | | | | | | |
| 20 | SS | | | 100 | 2-2-3-3 (5) | | | | | | |
| | SS | | | 100 | 2-3-4-4 (7) | | | | | | |
| 30 | SS | | | 100 | 4-4-4-4 (8) | 19 | | | | 24 | |
| | SS | | (SP-SC) Sand with clay, brown to gray, moist, fine to medium grained, Mine Overburden | 75 | 4-4-5-5 (9) | | | | | | |
| 40 | SS | | (SC-SM) Silty clayey sand, gray, moist, some fines, Mine Overburden | 88 | 5-5-5-6 (10) | | | | | | |
| | SS | | | 100 | 5-7-8-10 (15) | 13 | | | | 44 | |
| 50 | SS | | No recovery, rock | 0 | 8-12-12 (24) | | | | | | |
| | SS | | (CL) Sandy lean clay with gravel, brown to gray, moist, fine to medium grained sand, some sand, little gravel ▽ | 88 | 8-10-10-10 (20) | 15 | | | | 53 | |
| 60 | SS | | | 75 | 4-5-6 (11) | | | | | | |
| | SS | | (SP) Sand, brown, wet, fine to medium grained, Native Ground Surface | 75 | 7-8-8 (16) | | | | | | |
| 70 | SS | | (SC-SM) Silty clayey sand, grey, moist, some fines | 50 | 11-12-13 (25) | | | | | | |
| | SS | | | 0 | 15-50 | 14 | | | | 46 | |
| | | | Refusal at 77.0 feet.<br>Bottom of borehole at 77.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-17D



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 11/9/12 **COMPLETED** 11/9/12
**GROUND ELEVATION** 1475 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
▽ **AT TIME OF DRILLING** 15.00 ft / Elev 1460.00 ft Approximate
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 30s F; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1474.76 (ft) |
| | MC | | (SC) 25 % gravel, 60 % sand, 15 % fines Silty clayey sand with gravel, brown, moist, coarse sand, little fines, some gravel, 6 inch grey clay lenses at 3 feet and 10 feet | 75 | | | | | | | |
| | MC | | | 75 | | | | | | | |
| 10 | MC | | | 50 | | 5 | | | | 15 | Grout |
| | MC | | ▽ | 25 | | | | | | | |
| | MC | | (OL) Peat, black, moist, Native Ground Surface | 13 | | | | | | | |
| 20 | MC | | (SC-SM) Silty clayey sand with gravel, brown, wet, some fines, little gravel, 6 inch gray clay lense at 22 feet | 50 | | | | | | | Bentonite Seal |
| | MC | | | 25 | | | | | | | Sand Pack |
| 30 | MC | | (SP-SC) Sand with silty clay and gravel, grey, wet, coarse grained sand, few fines, little gravel | 13 | | | | | | | |
| | | | Bottom of borehole at 32.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-18D



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 11/8/12 **COMPLETED** 11/9/12
**GROUND ELEVATION** 1531 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
▽ **AT TIME OF DRILLING** 68.00 ft / Elev 1463.00 ft
**LOGGED BY** E. Johnson **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40s F; Overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1533.1 (ft) |
| | SS | | (SC) Clayey Sand, brownish red, moist, Mine Overburden | 50 | 6-6-6-6 (12) | | | | | | |
| 10 | SS | | | 50 | 5-7-6-6 (13) | | | | | | |
| | SS | | | 50 | 12-20-10-5 (30) | | | | | | |
| 20 | SS | | | 50 | 3-4-5-5 (9) | | | | | | |
| | SS | | | 13 | 6-9-8-6 (17) | | | | | | |
| 30 | SS | | (SC-SM) Silty clayey sand with gravel, brownish red, moist, some fines, little gravel, lenses of wet grey sand, Mine Overburden | 13 | 9-6-5-5 (11) | | | | | | |
| | SS | | | 50 | 9-7-5-5 (12) | 10 | | | | 33 | |
| 40 | SS | | | 50 | 7-7-6-6 (13) | | | | | | Grout |
| | SS | | | 50 | 9-9-8-8 (17) | | | | | | |
| 50 | SS | | | 88 | 7-10-9-9 (19) | 9 | | | | 30 | |
| | SS | | (SC-SM) Silty clayey sand with gravel, brown, moist, some fines, little gravel, similiar to above but darker, Mine Overburden | 63 | 7-10-11-15 (21) | | | | | | |
| 60 | SS | | | 88 | 5-10-10-10 (20) | 9 | | | | 31 | |
| | SS | | | 63 | 10-10-10-12 (20) | | | | | | |
| | SS | | (ML) Sandy Silt with gravel, blackish brown, moist, slight organic odor, possibly Native ground | 75 | 7-7-7-9 (14) | | | | | | |
| 70 | SS | | (SC) Clayey sand with gravel, grey, wet, little fines, little gravel, cobbles encountered at 67.5 feet, no sample from 67.5-70 | 100 | 4-6-11-12 (17) | | | | | | |
| | SS | | | 75 | 32-45-50 (95) | | | | | | |
| | SS | | (SP-SC) Sand with silty clay and gravel, brown, wet, very dense, few fines, little gravel, difficult drilling, likely gravel and cobbles | 75 | 11-18-22-22 (40) | | | | | | |
| 80 | SS | | | 88 | 18-28-28-30 (56) | | | | | | Bentonite Seal |
| | SS | | | 75 | 18-28-30-50 (58) | | | | | | |
| | SS | | | 50 | 35-70 | | | | | | Sand Pack |
| | SS | | | 75 | 20-70-50 (120) | | | | | | |
| 90 | SS | | | 13 | 70 | | | | | | |
| | SS | | Bottom of borehole at 91.0 feet. | 50 | 40-80-80 (160) | | | | | | |

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# BORING NUMBER SB12-19



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 11/7/12 **COMPLETED** 11/8/12
**GROUND ELEVATION** 1531 ft **HOLE SIZE** 4 inch
**DRILLING CONTRACTOR** STS
**GROUND WATER LEVELS:**
**DRILLING METHOD** 4 1 4" HSA
**AT TIME OF DRILLING** ---
**LOGGED BY** E. Johnson **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40's F; overcast
**48hrs AFTER DRILLING** 70.12 ft / Elev 1460.88 ft

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | (CL) Sandy lean clay with gravel, moist, brown to red, some sand, little gravel, Mine Overburden | | | | | | | |
| | SS | | | 88 | 9-9-9-10 (18) | | | | | |
| 10 | SS | | | 88 | 8-5-6-7 (11) | 21 | | | | 52 |
| | SS | | | 13 | 4-4-5-6 (9) | | | | | |
| 20 | SS | | (SC) Silty clayey sand with gravel, moist, brown to red, some fines, little gravel, Mine Overburden | 100 | 4-5-5-6 (10) | 16 | 38 | 14 | 24 | 43 |
| | SS | | | 63 | 5-5-5-6 (10) | | | | | |
| 30 | SS | | | 75 | 5-4-5-5 (9) | | | | | |
| | SS | | (SC) Clayey sand with gravel, moist, grey to brown, some fines, little gravel, Mine Overburden | 100 | 4-4-5-6 (9) | | | | | |
| 40 | SS | | | 100 | 4-5-5-6 (10) | | | | | |
| | SS | | | 100 | 4-5-5-8 (10) | 13 | 22 | 12 | 10 | 34 |
| 50 | SS | | | 88 | 5-5-5-6 (10) | | | | | |
| | SS | | | 100 | 5-6-7-8 (13) | | | | | |
| 60 | SS | | | 100 | 5-6-7-8 (13) | | | | | |
| | SS | | | 100 | 4-5-7-7 (12) | | | | | |
| 70 | SS | | | 100 | 5-6-7-8 (13) | | | | | |
| | SS | | (SC) Clayey sand, grey, wet, little fines, few gravel | 92 | 5-11-9-9 (20) | | | | | |
| | SS | | | 13 | 3-3-5-7 (8) | | | | | |
| 80 | SS | | | 100 | 4-7-8-11 (15) | | | | | |
| | SS | | | 100 | 15-8-10-15 (18) | | | | | |
| | SS | | (OL) Peat, black, wet, organic odor, Native Ground Surface | 100 | 5-8-10-18 (18) | | | | | |
| | SS | | | 100 | 6-12-20-28 (32) | | | | | |
| 90 | SS | | (SP-SC) Sand with clay and gravel, gray, wet, few fines, little gravel | 88 | 11-23-14-15 (37) | | | | | |
| | SS | | | 100 | 10-40-46-46 (86) | | | | | |
| | SS | | (SP) Sand with gravel, brown, wet, 3 feet of fine grained sand from 88 to 91 then 3 feet of coarse grained sand from 91 to 94, refusal on cobble/boulder | 50 | 120 | | | | | |

Refusal at 94.0 feet.
Bottom of borehole at 94.0 feet.

WELL DIAGRAM
Casing Top Elev: 1533.47 (ft)
- Grout
- Bentonite Seal
- Sand Pack

EVANS - GINT US.GDT - 2/7/13 17:23 - P:\GINT\GINT SERVER 03\PROJECTS\6385E GENERAL WASTE.GPJ

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# BORING NUMBER SB12-20



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/16/12 **COMPLETED** 10/16/12
**GROUND ELEVATION** 1491 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 50's F; sunny
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | MC | | (SP-SC) Sand with clay and gravel, moist, brown, few fines, little gravel | 50 | | | | | | | |
| | MC | | | 50 | | | | | | | |
| 10 | MC | | | 0 | | | | | | | |
| | MC | | | 50 | | | | | | | |
| | MC | | | 25 | | | | | | | |
| 20 | MC | | | 25 | | | | | | | |
| | MC | | | 38 | | | | | | | |
| | MC | | | 25 | | | | | | | |
| 30 | | | (CL) Lean clay with sand, soft to medium stiff, brown to grey, moist, little sand, trace gravel | | | | | | | | |
| | | | Refusal at 32.0 feet.<br>Bottom of borehole at 32.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-21D



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 11/13/12 **COMPLETED** 11/15/12
**GROUND ELEVATION** 1487 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 30's F; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | Casing Top Elev: 1489.4 (ft) |
| | MC | | (SC-SM) Silty clayey sand, black to redish black, moist, fine grained sand, some fines, Mine Tailings | 63 | | | | | | | |
| | MC | | | 63 | | | | | | | |
| 10 | MC | | | 50 | | | | | | | |
| | MC | | (SC-SM) Silty clayey sand, reddish black, wet, fine grained sand, some fines, Mine Tailings | 50 | | | | | | | Grout |
| | MC | | | 38 | | | | | | | |
| 20 | MC | | | 38 | | | | | | | |
| | MC | | | 50 | | | | | | | Bentonite Seal |
| | MC | | (OL) Peat, black, wet, Native Soil contact | | | | | | | | |
| 30 | MC | | (SP) Sand, brown, wet, coarse grained, 2 inch peat lense at 32 feet | 50 | | | | | | | Sand Pack |
| | MC | | | 100 | | | | | | | |
| 40 | MC | | (CL) Lean clay, grey, moist, medium stiff | 38 | | | | | | | |
| | | | (SP) Sand, brown, wet, coarse grained | | | | | | | | |
| | | | Bottom of borehole at 41.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-21S



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 11/13/12 **COMPLETED** 11/13/12
**GROUND ELEVATION** 1487 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 30s F; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | (SM) Silty sand,black,moist, fine grained sand, Mine Tailings | | | | | | | | Casing Top Elev: 1489.3 (ft) |
| 10 | | | (SM) Silty sand, reddish black, wet, fine grained sand, Mine Tailings | | | | | | | | Grout; Bentonite Seal; Sand Pack |
| | | | Bottom of borehole at 15.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-23



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/18/12 **COMPLETED** 10/18/12
**GROUND ELEVATION** 1496 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 40s F; rainy
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | MC | | (SC) Clayey sand with gravel, brown, moist, little fines, little gravel, Mine Overburden | 50 | | | | | | | |
| | MC | | | 25 | | | | | | | |
| 10 | MC | | | 63 | | | | | | | |
| | MC | | | 50 | | | | | | | |
| | MC | | | 38 | | | | | | | |
| 20 | MC | | | 0 | | | | | | | |
| | | | Refusal at 23.0 feet.<br>Bottom of borehole at 23.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-24



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 10/17/12 **COMPLETED** 10/17/12
**GROUND ELEVATION** 1462 ft **HOLE SIZE** 2 inch
**DRILLING CONTRACTOR** NTS
**GROUND WATER LEVELS:**
**DRILLING METHOD** MC
**AT TIME OF DRILLING** ---
**LOGGED BY** R. Fossell **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 50s F; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | MC | | (SP-SC) Sand with silty clay and gravel, moderately stiff, brown, moist, few fines, little gravel, Mine Overburden | 75 | | | | | | | |
| | MC | | | 75 | | | | | | | |
| 10 | MC | | | 75 | | | | | | | |
| | MC | | | 50 | | | | | | | |
| | MC | | | 75 | | | | | | | |
| 20 | MC | | | 50 | | | | | | | |
| | MC | | | 75 | | | | | | | |
| | MC | | Refusal at 29.0 feet. | 0 | | | | | | | |
| | | | Bottom of borehole at 29.0 feet. | | | | | | | | |

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# BORING NUMBER SB12-25



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 1/28/12 **COMPLETED** 2/7/12
**GROUND ELEVATION** 1523 ft **HOLE SIZE** 3 1/4 inch
**DRILLING CONTRACTOR** American Engineering
**GROUND WATER LEVELS:**
**DRILLING METHOD** 3 1 4" HSA
**AT TIME OF DRILLING** ---
**LOGGED BY** E. Johnson **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 20s F ; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| 40 | SS | | (SM) Silty sand, medium stiff, light brown, some fines, trace gravel, medium grained sand, moist | 100 | 3-6-5-5 (11) | | | | | | Pressure meter - failed |
| | SS | | | 78 | 4-5-5 (10) | | | | | | |
| | SS | | | | 5-5 (10) | | | | | | Pressure Meter 1 |
| | SS | | Bottom of borehole at 48.5 feet. | | | | | | | | |

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# BORING NUMBER SB12-25A



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 1/29/12 **COMPLETED** 1/29/12
**GROUND ELEVATION** 1523 ft **HOLE SIZE** 3 1/4 inch
**DRILLING CONTRACTOR** American Engineering
**GROUND WATER LEVELS:**
**DRILLING METHOD** 3 1 4" HSA
**AT TIME OF DRILLING** ---
**LOGGED BY** E. Johnson **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 20s F ; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| 30 | SS<br>SS | | (SM) Silty sand, brown, moist | | 5-5<br>(10) | | | | | | Pressure Meter 2 |
| | | | Bottom of borehole at 33.5 feet. | | | | | | | | |

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# BORING NUMBER SB12-26



**CLIENT** General Waste Disposal & Recovery Services
**PROJECT NAME** SW-620
**PROJECT NUMBER** 6385E
**PROJECT LOCATION** Keewatin, Minnesota
**DATE STARTED** 1/29/12 **COMPLETED** 1/29/12
**GROUND ELEVATION** 1494 ft **HOLE SIZE** 3 1/4 inch
**DRILLING CONTRACTOR** American Engineering
**GROUND WATER LEVELS:**
**DRILLING METHOD** 3 1 4" HSA
**AT TIME OF DRILLING** ---
**LOGGED BY** E. Johnson **CHECKED BY** J. Holmes
**AT END OF DRILLING** ---
**NOTES** 20s F ; overcast
**AFTER DRILLING** ---

| DEPTH (ft) | SAMPLE TYPE NUMBER | GRAPHIC LOG | MATERIAL DESCRIPTION | RECOVERY % (RQD) | BLOW COUNTS (N VALUE) | MOISTURE CONTENT (%) | ATTERBERG LIMITS: LIQUID LIMIT | ATTERBERG LIMITS: PLASTIC LIMIT | ATTERBERG LIMITS: PLASTICITY INDEX | FINES CONTENT (%) | WELL DIAGRAM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | | | | |
| 10 | SS<br>SS | | (SC-SM) Silty clayey sand, brown, moist, some fines, little gravel | | 5-5<br>(10) | | | | | | Pressure meter 3 |
| 20 | SS<br>SS | | (SM) Silty sand, greyish brown, moist, some fines, trace gravel, fine to medium grained sand | | 7-7<br>(14) | | | | | | Pressure meter 4 |
| | | | Bottom of borehole at 21.5 feet. | | | | | | | | |

# Labratory Testing Results

# PASSING 200/ MOISTURE CONTENT

**ASTM D 6913 AND D 2216**

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e-mail: nts@netechnical.com

**Project** General Waste
**Project #** 6385E

**Date Reported** 11/30/2012
**COC #** 210788

| Sample | COC # | Lab I.D. | % Moisture | % Fines |
|---|---|---|---|---|
| **12-8 (70-72)** | 210788 | M547512 | 13.7% | 46.5% |
| **12-3 (10-12)** | 210788 | M547513 | 13.3% | 34.5% |
| **12-3 (35-37)** | 210788 | M547514 | 8.8% | 32.0% |
| **12-7 (45-47)** | 210788 | M547515 | 11.9% | 36.2% |
| **12-2 (4-8)** | 210788 | M547516 | 8.4% | 37.3% |
| **12-11 (16-20)** | 210788 | M547517 | 11.4% | 46.5% |
| **12-18 (60-62)** | 210788 | M547520 | 8.5% | 31.1% |
| **12-18 (50-52)** | 210788 | M547519 | 9.3% | 30.4% |
| **12-18 (35-37)** | 210788 | M547518 | 9.7% | 33.3% |
| **12-16 (45-47)** | 210788 | M547503 | 12.8% | 44.3% |
| **12-16 (55-57)** | 210788 | M547504 | 15.0% | 53.0% |
| **12-16 (75-77)** | 210788 | M547505 | 14.3% | 45.8% |
| **12-16 (30-32)** | 210788 | M547506 | 18.9% | 23.7% |
| **12-19 (20-22)** | 210788 | M547507 | 16.3% | 43.3% |
| **12-19 (10-12)** | 210788 | M547508 | 20.5% | 52.2% |
| **12-19 (45-47)** | 210788 | M547509 | 13.3% | 33.5% |
| **12-20 (28-32)** | 210788 | M547510 | 14.6% | 32.9% |
| **12-17 (28-32)** | 210788 | M547511 | 11.4% | 30.0% |

Comments:

# GRAIN SIZE DISTRIBUTION REPORT

**ASTM D 422**

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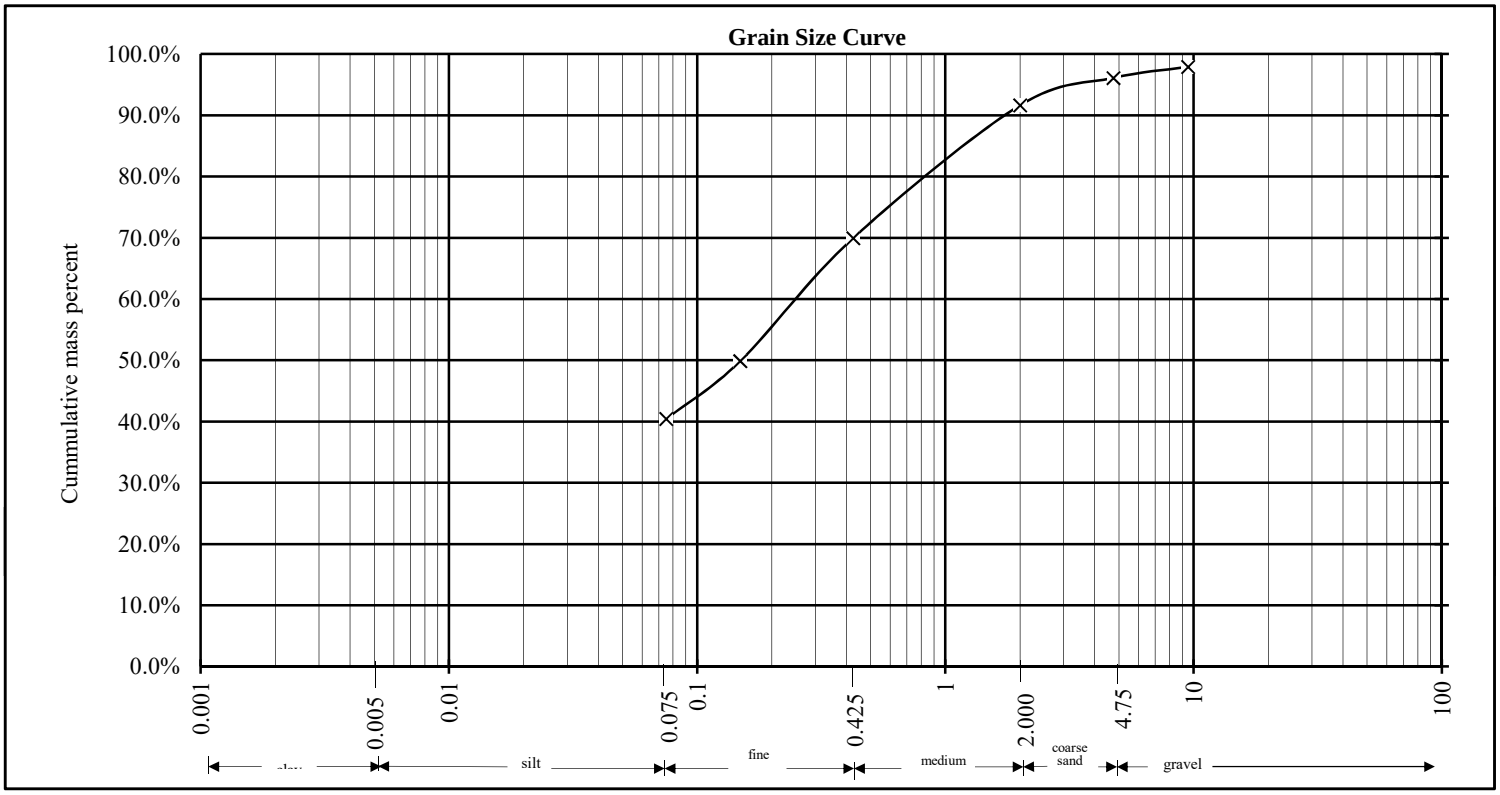
| | | | |
|---|---|---|---|
| **Project** | General Waste | **Date Reported** | 11/30/2012 |
| **Sample ID** | SB 12-15 (35-37) | **Lab ID#** | M547498 |
| **Project #** | 6385E | **COC #** | 210788 |
| **Date Collected** | 10/15/2012 | | |




| Size | Percentages | Specifications (% passing) | Percent Moisture | LL | PL | PI |
|---|---|---|---|---|---|---|
| | | | 8.2% | | | |
| **Silt/Clay** | 40.4% | | | **Specifications (LL and PI)** | | |
| **Fine Sand** | 29.5% | | | | | |
| **Medium Sand** | 21.7% | | | **USCS Classification** | | |
| **Coarse Sand** | 4.5% | | | | | |
| **Gravel** | 3.9% | | | (SC-SM) SILTY, CLAYEY SAND | | |

| | |
|---|---|
| Coefficient of Uniformity (Cu) | N/A |
| Coefficient of Curvature (Cc) | N/A |

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

**Page 2**

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**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547498

**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

| Sieve Size | Percent Passing | Required Specifications |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| 3\8 | 98% | |
| #4 | 96% | |
| #10 | 92% | |
| #40 | 70% | |
| #100 | 49.9% | |
| #200 | 40.4% | |

Tested in accordance with ASTM D 422

**Sample ID:** SB 12-15 (35-37)

**Date Sampled:** 10/15/2012

**Date Received:** 10/15/2012

**Date Analyzed:** 11/28/2012

**Sample Location:** SB 12-15 (35-37)

**Intended Use:**

**Pit/Source:**

**Sampled By:** J. Holmes

**Lab Technician:** EJ, JE

**Reviewed By:** JE

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

**ASTM D 422**

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VIRGINIA, MINNESOTA 55792
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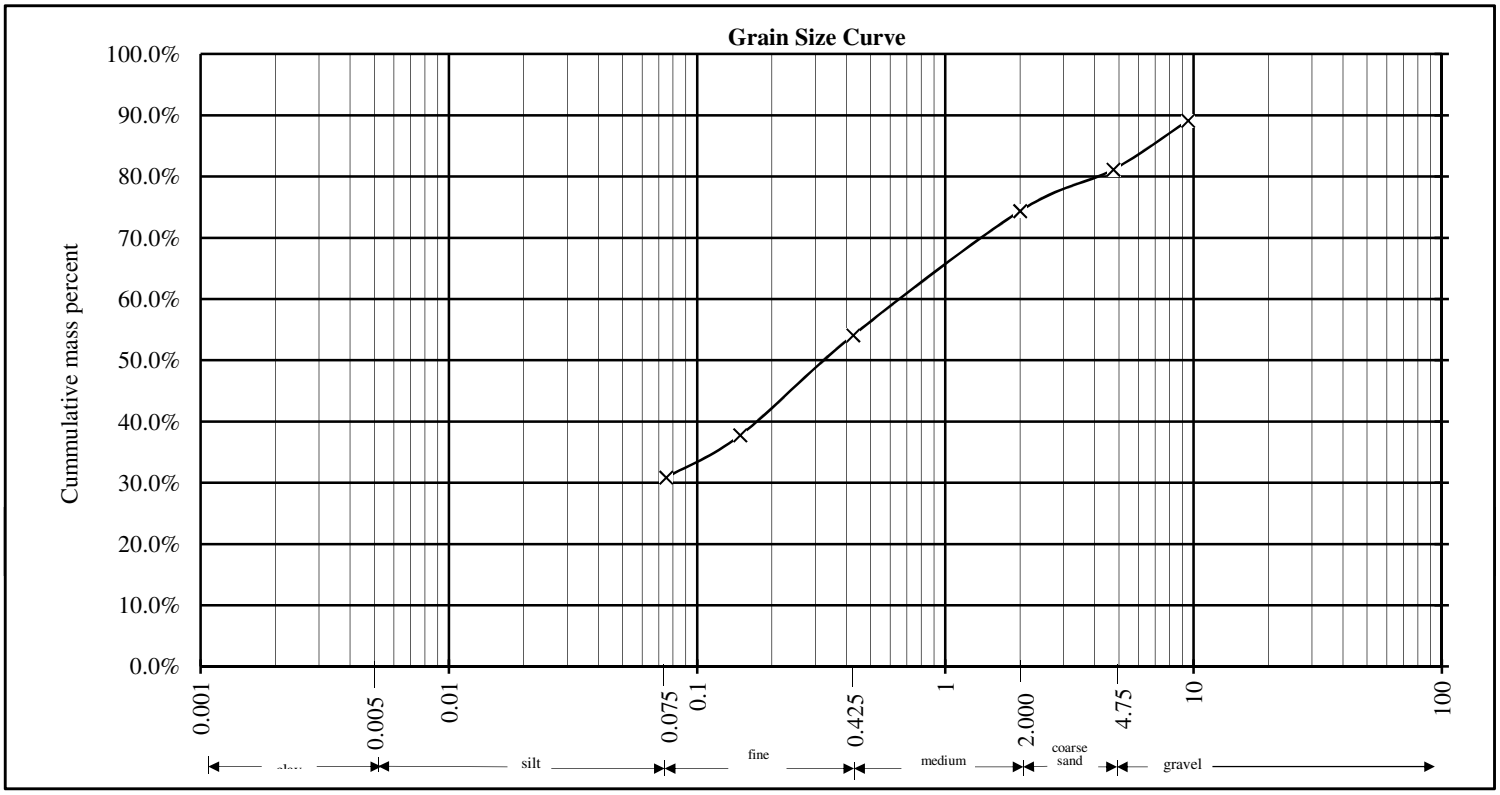
| | | | |
|---|---|---|---|
| **Project** | General Waste | **Date Reported** | 11/30/2012 |
| **Sample ID** | SB 12-4 (45-47) | **Lab ID#** | M547499 |
| **Project #** | 6385E | **COC #** | 210788 |
| **Date Collected** | 10/17/2012 | | |




| Size | Percentages | Specifications (% passing) | Percent Moisture | LL | PL | PI |
|---|---|---|---|---|---|---|
| | | | 9.9% | | | |
| **Silt/Clay** | 30.9% | | | **Specifications (LL and PI)** | | |
| **Fine Sand** | 23.2% | | | | | |
| **Medium Sand** | 20.3% | | | **USCS Classification** | | |
| **Coarse Sand** | 6.8% | | | (SC-SM) SILTY, CLAYEY SAND WITH GRAVEL | | |
| **Gravel** | 18.9% | | | | | |

| | |
|---|---|
| Coefficient of Uniformity (Cu) | N/A |
| Coefficient of Curvature (Cc) | N/A |

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

**Page 2**

NORTHEAST TECHNICAL SERVICES, INC.
526 CHESTNUT STREET
P.O. BOX 1142
VIRGINIA, MINNESOTA 55792
218-741-4290 FAX 218-741-4291
e-mail: nts@netechnical.com

**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547499

**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

| Sieve Size | Percent Passing | Required Specifications |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| 3\8 | 89% | |
| #4 | 81% | |
| #10 | 74% | |
| #40 | 54% | |
| #100 | 37.8% | |
| #200 | 30.9% | |

Tested in accordance with ASTM D 422

**Sample ID:** SB 12-4 (45-47)

**Date Sampled:** 10/17/2012

**Date Received:** 10/17/2012

**Date Analyzed:** 11/28/2012

**Sample Location:** SB 12-4 (45-47)

**Intended Use:**

**Pit/Source:**

**Sampled By:** J. Holmes

**Lab Technician:** EJ, JE

**Reviewed By:** JE

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

**ASTM D 422**

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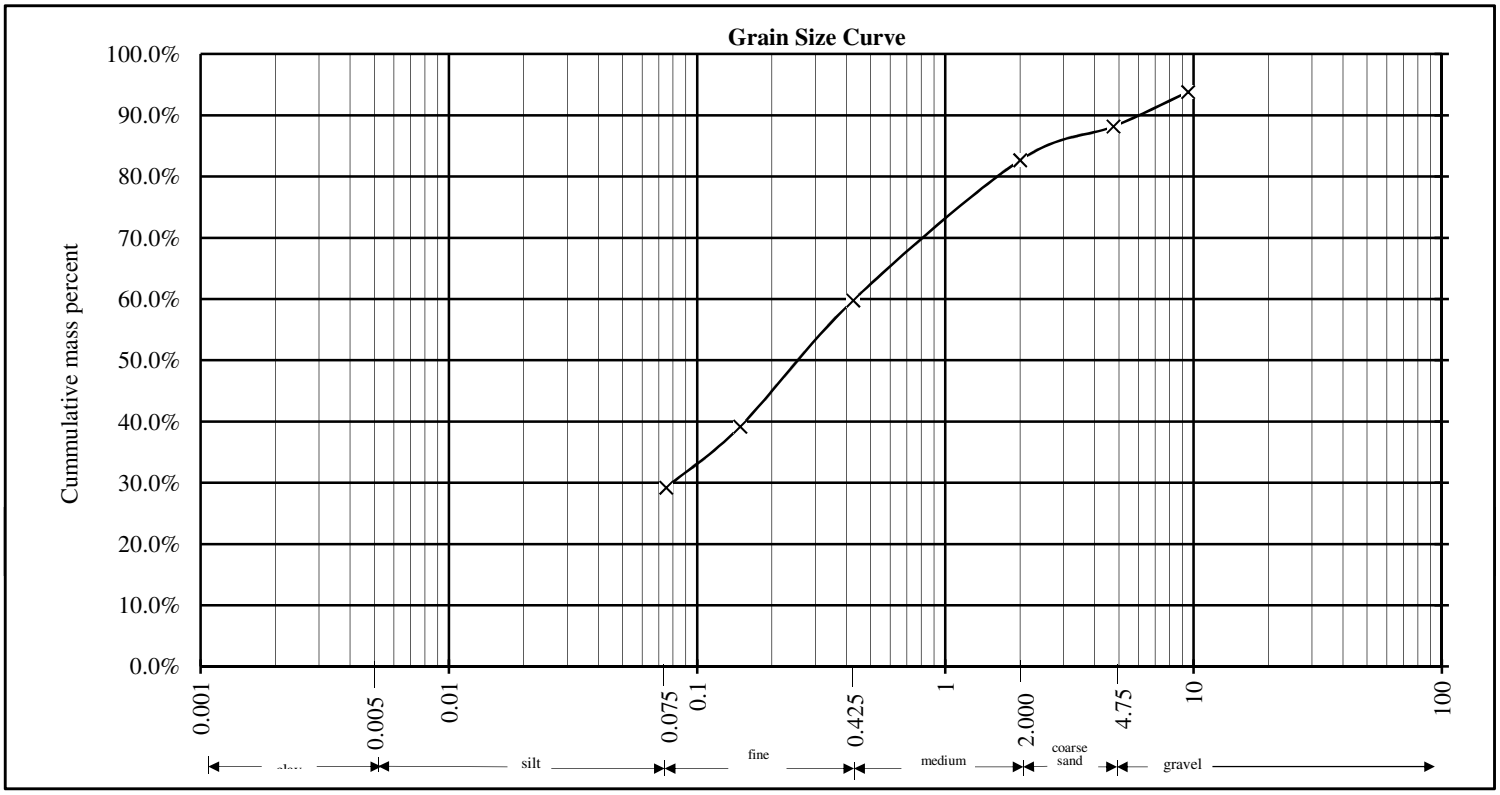
e-mail: nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | General Waste | **Date Reported** | 11/30/2012 |
| **Sample ID** | SB 12-4 (55-57) | **Lab ID#** | M547500 |
| **Project #** | 6385E | **COC #** | 210788 |
| **Date Collected** | 10/17/2012 | | |




| Size | Percentages | Specifications (% passing) | Percent Moisture | LL | PL | PI |
|---|---|---|---|---|---|---|
| | | | 12.6% | | | |
| **Silt/Clay** | 29.2% | | | **Specifications (LL and PI)** | | |
| **Fine Sand** | 30.6% | | | | | |
| **Medium Sand** | 22.9% | | | **USCS Classification** | | |
| **Coarse Sand** | 5.5% | | | | | |
| **Gravel** | 11.8% | | | (SC-SM) SILTY, CLAYEY SAND | | |

| | |
|---|---|
| Coefficient of Uniformity (Cu) | N/A |
| Coefficient of Curvature (Cc) | N/A |

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

**Page 2**

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e-mail: nts@netechnical.com

**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547500

**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

| Sieve Size | Percent Passing | Required Specifications |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| 3\8 | 94% | |
| #4 | 88% | |
| #10 | 83% | |
| #40 | 60% | |
| #100 | 39.2% | |
| #200 | 29.2% | |

Tested in accordance with ASTM D 422

**Sample ID:** SB 12-4 (55-57)

**Date Sampled:** 10/17/2012

**Date Received:** 10/17/2012

**Date Analyzed:** 11/28/2012

**Sample Location:** SB 12-4 (55-57)

**Intended Use:**

**Pit/Source:**

**Sampled By:** J. Holmes

**Lab Technician:** EJ, JE

**Reviewed By:** JE

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

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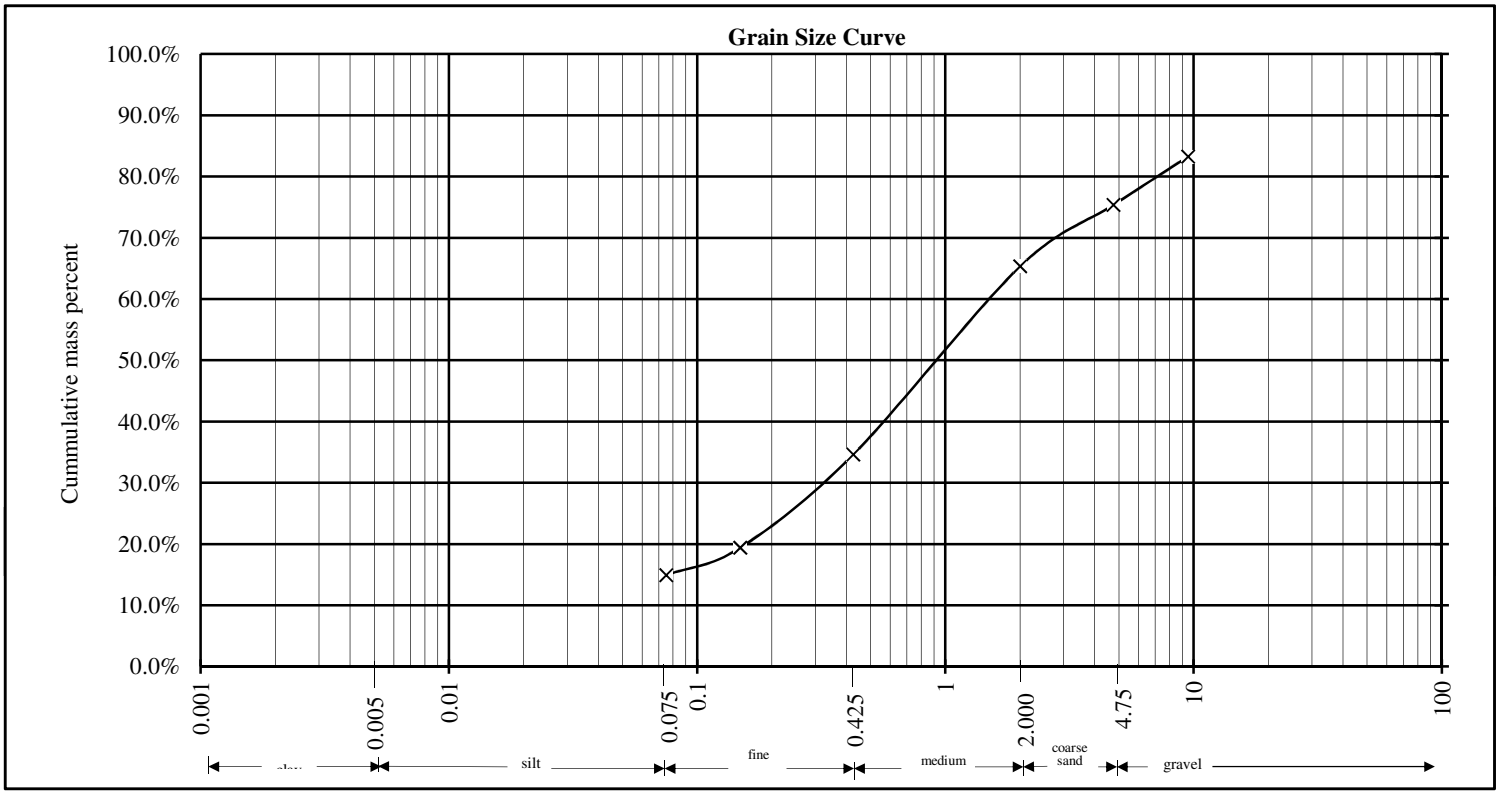
e-mail: nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | General Waste | **Date Reported** | 11/30/2012 |
| **Sample ID** | SB 12-17 (8-12) | **Lab ID#** | M547501 |
| **Project #** | 6385E | **COC #** | 210788 |
| **Date Collected** | 11/9/2012 | | |




| Size | Percentages | Specifications (% passing) | Percent Moisture | LL | PL | PI |
|---|---|---|---|---|---|---|
| | | | 4.8% | | | |
| **Silt/Clay** | 14.9% | | | **Specifications (LL and PI)** | | |
| **Fine Sand** | 19.7% | | | | | |
| **Medium Sand** | 30.7% | | | **USCS Classification** | | |
| **Coarse Sand** | 10.0% | | | (SC-SM) SILTY, CLAYEY SAND WITH GRAVEL | | |
| **Gravel** | 24.6% | | | | | |

| | |
|---|---|
| Coefficient of Uniformity (Cu) | N/A |
| Coefficient of Curvature (Cc) | N/A |

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

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e-mail: nts@netechnical.com

**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547501

**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

| Sieve Size | Percent Passing | Required Specifications |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| 3\8 | 83% | |
| #4 | 75% | |
| #10 | 65% | |
| #40 | 35% | |
| #100 | 19.4% | |
| #200 | 14.9% | |

Tested in accordance with ASTM D 422

**Sample ID:** SB 12-17 (8-12)

**Date Sampled:** 11/9/2012

**Date Received:** 11/9/2012

**Date Analyzed:** 11/28/2012

**Sample Location:** SB 12-17 (8-12)

**Intended Use:**

**Pit/Source:**

**Sampled By:** R. Fossel

**Lab Technician:** EJ, JE

**Reviewed By:** JE

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

**ASTM D 422**

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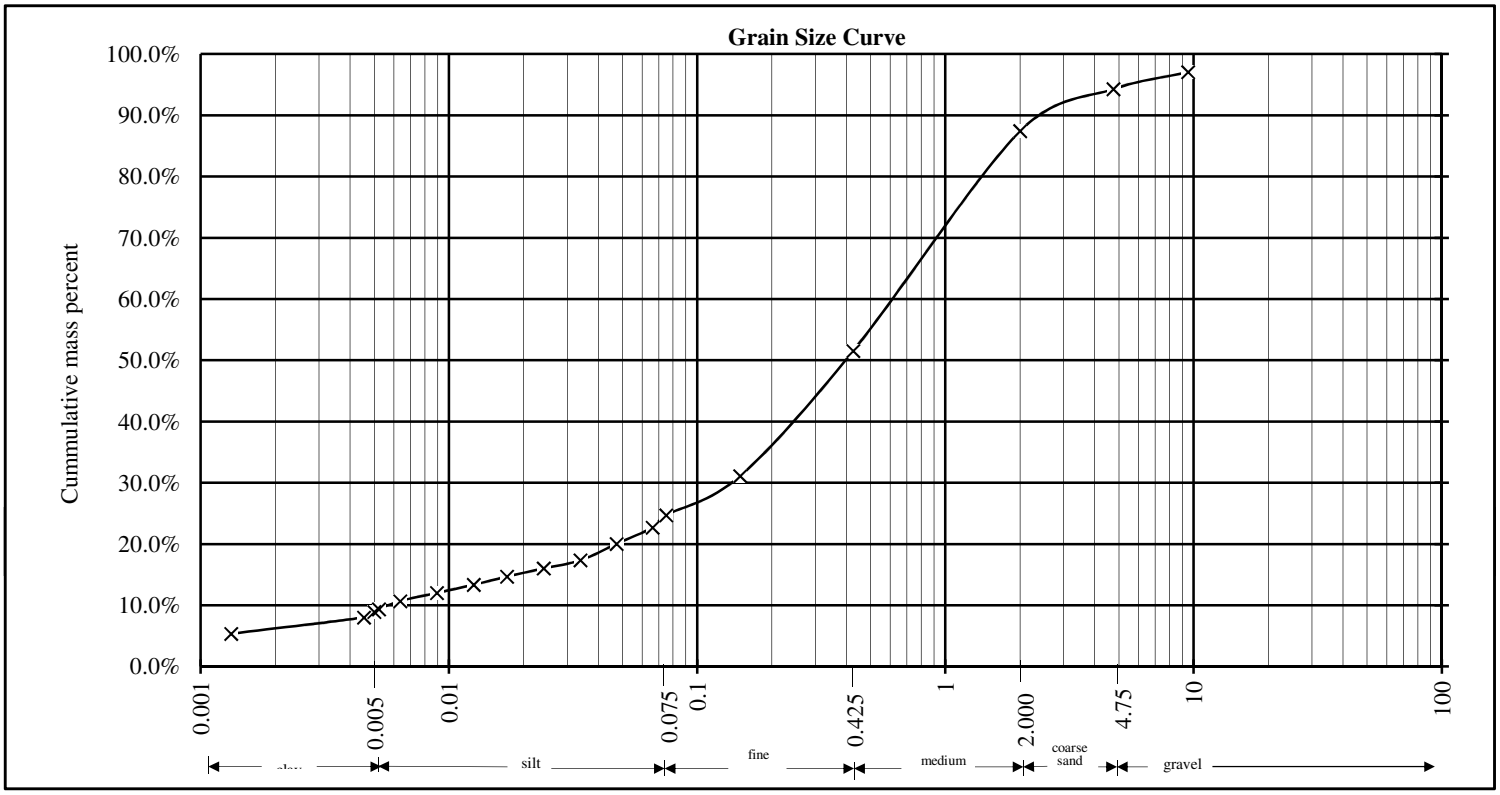
e-mail: nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | General Waste | **Date Reported** | 11/30/2012 |
| **Sample ID** | SB 12-12 (45-47) | **Lab ID#** | M547502 |
| **Project #** | 6385E | **COC #** | 210788 |
| **Date Collected** | 10/16/2012 | | |




| Size | Percentages | Specifications (% passing) | Percent Moisture | LL | PL | PI |
|---|---|---|---|---|---|---|
| **Clay** | 8.9% | | 9.9% | | | |
| **Silt** | 15.8% | | | **Specifications (LL and PI)** | | |
| **Fine Sand** | 26.8% | | | | | |
| **Medium Sand** | 35.9% | | | **USCS Classification** | | |
| **Coarse Sand** | 6.8% | | | | | |
| **Gravel** | 5.7% | | | (SC-SM) SILTY, CLAYEY SAND | | |

| | |
|---|---|
| Coefficient of Uniformity (Cu) | 106.45 |
| Coefficient of Curvature (Cc) | 4.97 |

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

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e-mail: nts@netechnical.com

**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547502

**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

| Sieve Size | Percent Passing | Required Specifications |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| 3\8 | 97% | |
| #4 | 94% | |
| #10 | 87% | |
| #40 | 52% | |
| #100 | 31% | |
| #200 | 24.7% | |
| Clay (<.005mm) | 8.9% | |

Tested in accordance with ASTM D 422

**Sample ID:** SB 12-12 (45-47)

**Date Sampled:** 10/16/2012

**Date Received:** 10/16/2012

**Date Analyzed:** 11/28/2012

**Sample Location:** SB 12-12 (45-47)

**Intended Use:**

**Pit/Source:**

**Sampled By:** J. Holmes

**Lab Technician:** EJ, JE

**Reviewed By:** JE

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

**ASTM D 422**

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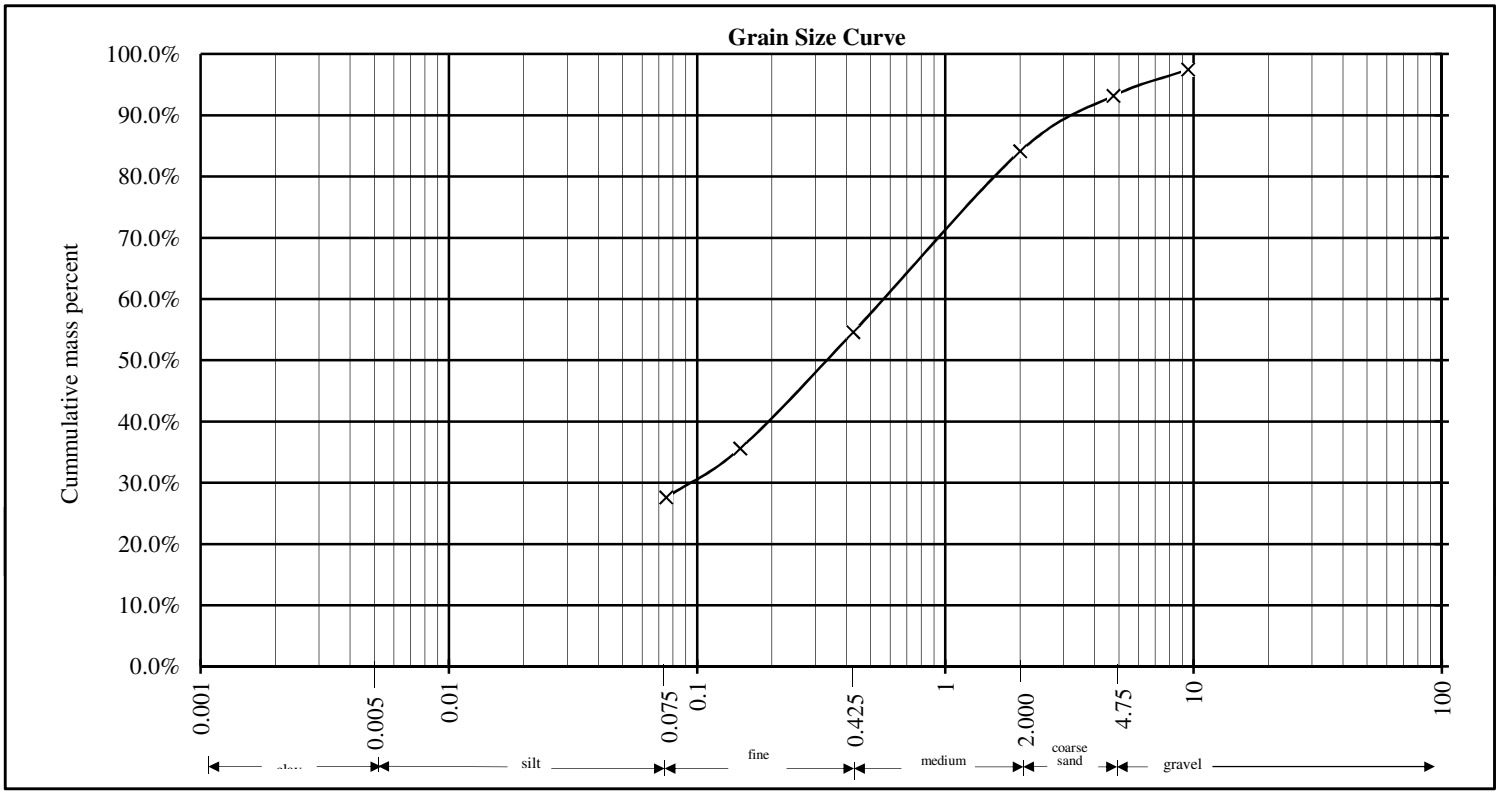
e-mail: nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | General Waste | **Date Reported** | 11/30/2012 |
| **Sample ID** | SB 12-13 (50-52) | **Lab ID#** | M547503 |
| **Project #** | 6385E | **COC #** | 210788 |
| **Date Collected** | 10/18/2012 | | |




| Size | Percentages | Specifications (% passing) | Percent Moisture | LL | PL | PI |
|---|---|---|---|---|---|---|
| | | | 10.5% | | | |
| **Silt/Clay** | 27.6% | | | **Specifications (LL and PI)** | | |
| **Fine Sand** | 27.0% | | | | | |
| **Medium Sand** | 29.5% | | | **USCS Classification** | | |
| **Coarse Sand** | 9.1% | | | | | |
| **Gravel** | 6.8% | | | (SC-SM) SILTY, CLAYEY SAND | | |

| | |
|---|---|
| Coefficient of Uniformity (Cu) | N/A |
| Coefficient of Curvature (Cc) | N/A |

**Comments:**

# GRAIN SIZE DISTRIBUTION REPORT

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e-mail: nts@netechnical.com

**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547503

**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

| Sieve Size | Percent Passing | Required Specifications |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| 3\8 | 97% | |
| #4 | 93% | |
| #10 | 84% | |
| #40 | 55% | |
| #100 | 35.6% | |
| #200 | 27.6% | |

Tested in accordance with ASTM D 422

**Sample ID:** SB 12-13 (50-52)

**Date Sampled:** 10/18/2012

**Date Received:** 10/18/2012

**Date Analyzed:** 11/28/2012

**Sample Location:** SB 12-13 (50-52)

**Intended Use:**

**Pit/Source:**

**Sampled By:** J. Holmes

**Lab Technician:** EJ, JE

**Reviewed By:** JE

**Comments:**

# Atterberg Limits Report

**ASTM D-4318**

NORTHEAST TECHNICAL SERVICES, INC.
526 CHESTNUT STREET
P.O. BOX 1142
VIRGINIA, MINNESOTA 55792
218-741-4290 FAX 218-741-4291
e-mail: nts@netechnical.com

**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547507

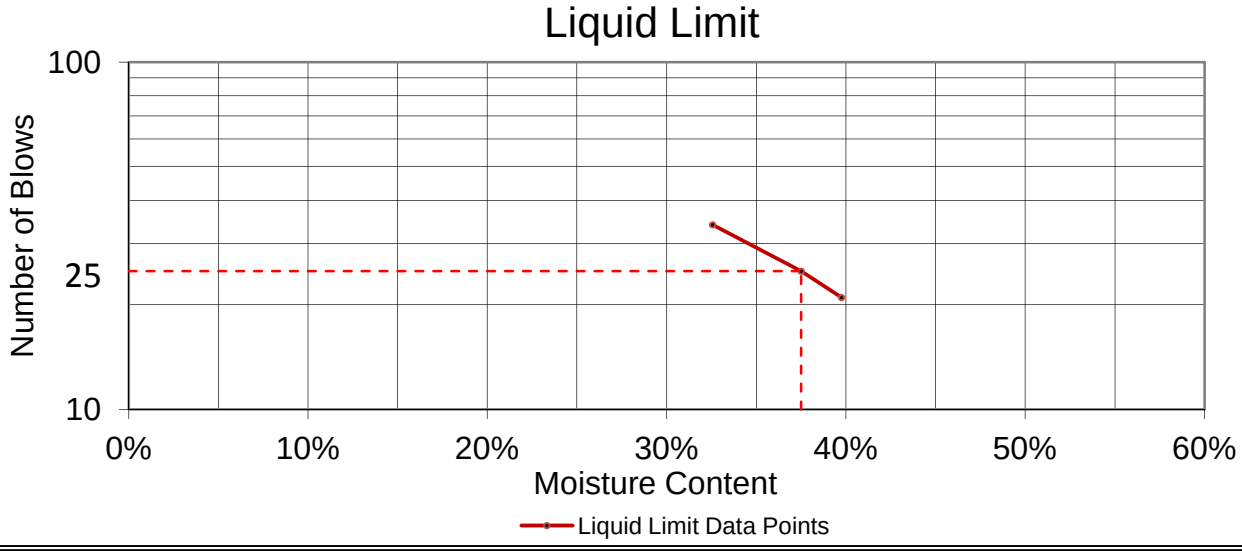
**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

**Sample ID:** GP 12-19 (20-22ft)

| Test Results: | | | | Specifications: | | | |
|---|---|---|---|---|---|---|---|
| Liquid Limit: | 38% | Plasticity Index: | 24% | Liquid Limit: | | Plasticity Index: | |
| Plastic Limit: | 14% | % Moisture: | 16.3% | Plastic Limit | | % Moisture: | |
| Passing #200 | 43% | | | Passing #200 | | | |
| Passing #4 | | | | Passing #4 | | | |




**Summary of Methods:**

Preperation: Wet Preperation Method
Liquid Limit: Method A
Plastic Limit: Hand Rolled Method

**Comments:**

# Atterberg Limits Report

**ASTM D-4318**

NORTHEAST TECHNICAL SERVICES, INC.
526 CHESTNUT STREET
P.O. BOX 1142
VIRGINIA, MINNESOTA 55792
218-741-4290 FAX 218-741-4291
e-mail: nts@netechnical.com

**Project #:** 6385E **COC #:** 210788 **Lab ID #:** M547509

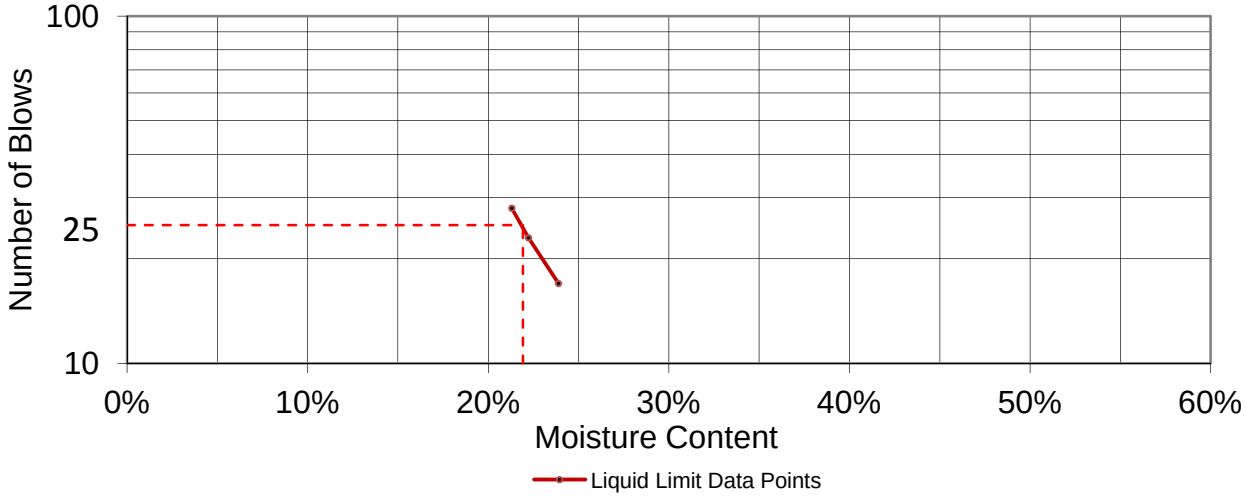
**Project:** General Waste

**Architect/Engineer:** -

**Contractor:** -

**Sample ID:** GP 12-19 (45-47ft)

| Test Results: | | | | Specifications: | | | |
|---|---|---|---|---|---|---|---|
| Liquid Limit: | 22% | Plasticity Index: | 10% | Liquid Limit: | | Plasticity Index: | |
| Plastic Limit: | 12% | % Moisture: | 13.3% | Plastic Limit | | % Moisture: | |
| Passing #200 | 34% | | | Passing #200 | | | |
| Passing #4 | | | | Passing #4 | | | |




**Summary of Methods:**

Preperation: Wet Preperation Method
Liquid Limit: Method A
Plastic Limit: Hand Rolled Method

**Comments:**

# Appendix B
# Cell B Subgrade Assessment

# GENERAL WASTE LANDFILL- KEEWATIN, MN
# CELL B SUBGRADE ASSESSMENT

## KEEWATIN, MN 55753

**PREPARED FOR:**
DEM-CON COMPANIES
13020 DEM CON DR.
SHAKOPEE, MN 55379

**PREPARED BY:**
NORTHEAST TECHNICAL SERVICES, INC.
526 CHESTNUT STREET
VIRGINIA, MINNESOTA 55792

**NTS PROJECT# 10882**

**OCTOBER 2017**

Environmental Science & Engineering

**PROFESSIONAL CERTIFICATION**

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA

Evan C. Johnson 10-4-17

EVAN C. JOHNSON, PE
GEOTECHNICAL ENGINEER
LICENSE NO. 53755

EVAN C. JOHNSON
LICENSED PROFESSIONAL ENGINEER
53755
STATE OF MINNESOTA

October 3, 2017

Mr. Mark Pahl
Chief Operating Officer
35005 Co Rd 571
Keewatin, MN 55753

**RE: Cell B Subgrade Assessment and Recommendations**
**NTS Project No. 6385ECA**

Dear Mr. Pahl

Northeast Technical Services, Inc. (NTS) is pleased to present this report for the above referenced project. This letter report includes the findings of 2 on-site inspections, 6 test pit locations, and soil laboratory results in regards to assessing the recommendation of conducting a 1 foot sub-cut of the Cell B subgrade and replacing with a compacted granular material.

After reviewing site design grades, pre-existing grades, 2013 geotechnical assessment report, and the acquired data from the on-site inspections, test pits and laboratory tests, it is the recommendation of NTS that a 1 foot subcut of the Cell B liner construction is not required, and that the existing in-situ subgrade is sufficient given the recommendations provided in this report are followed.

We have appreciated the opportunity to assist with this project. Please contact Evan Johnson by phone at 218-742-1022 or via email at ejohnson@netechnical.com if you have any questions or concerns regarding this letter or the recommendations made herein.

Sincerely,
Northeast Technical Services, Inc.

Evan C. Johnson, PE
Geotechnical Engineer

# Table of Contents



# Table of Figures



# Appendices

# 1.0 Project Description and Scope of Work

## 1.1 Project Overview

General Waste & Recycling LLC operates a facility that contains an unlined demolition and composite lined industrial landfill in Keewatin, MN. The industrial landfill is planned and permitted to be developed in individual cells, with Cell B construction occurring during the 2017 construction season. Per Cell a project specification, the subgrade on which the clay liner was placed on the cell floor was to be sub-cut 12 inches, a separation geotextile placed, and 12 inches of compacted granular material placed to bring the cell floor to subgrade elevation. This specification originated from a recommendation provided in the initial geotechnical evaluation of the facility for permitting purposes (Appendix A, *"Geotechnical Review of Proposed Industrial Landfill located near Keewatin, MN", p.12).*

This report was completed to assess if the specified 1 foot subcut and separation geotextile were appropriate for the Cell B construction.

## 1.2 Existing Site Conditions

The site is located in the southeast quarter of Section 25, Township 57N, Range 22W, an area where the topography has been highly modified by historical iron mining. The site is bounded on the north by U. S. Highway 169, and Keewatin, MN is located directly north opposite the highway. The west site of the site is bounded by a tailings basin containing hydraulic fill from Mesabi Chief Heavy Media plant which operated from 1928 to 1970 (end date is approximate) and more recently operated by Magnetation between approximate year 2010-2015. The east side of the site is bounded by Itasca County Road 571, and there are other overburden lean ore and blast rock stockpiles east of County Road 571. The NSPC Initial Tailings Basin is about ½ mile to the southeast of the site. South of the site, there is a cell phone transmission tower, an automotive salvage yard, and other terrain that historical photography indicates to be native landform.

The landfill site contains a historical overburden stockpile materials constructed with overburden from one of the nearby open pit mines. Overburden stripping operations in the Keewatin vicinity mines is believed to have been started circa 1913. An air photo dated 1939 shows the stockpile was substantially completed by that date. The primary method of placement likely consisted of constructing temporary railroads, side-dumping rail cars, and pushing the soil down inclined slopes that progressed across the site at the angle of repose. The lift heights during soil placement may be indicated by the stockpile's outer slopes, which are typically 30-40 feet. Several lifts appear to have been placed over the site with total fill depth up to about 80 feet.

Cell B is thought to be located completely within the extents of the placed stockpile, with the subgrade elevation thought to be 15-25 feet above the native surface.

### 1.3 Scope of Work Performed

NTS conducted a review of the 2013 geotechnical assessment, an analysis of the surcharge loading over the Cell B floor, an inspection of site soil conditions during excavation activities, an inspection of the subgrade condition with shallow test pitting conducted, and laboratory testing of the Cell B in-situ subgrade material.

### 1.4 Subsurface Exploration

Six tests pits spaced across the Cell B floor were dug to approximately 4 feet below subgrade elevation to analyze for varying soil conditions. Field notes and photos were collected and select soil samples obtained.

### 1.5 Laboratory Testing

In addition to the visual classification, laboratory analysis of the collected soils included four soil gradations (ASTM D6913) and moisture analyses (ASTM D4643). Testing results can be seen in Appendix B.

## 2.0 Cell B Analysis

### 2.1 Surcharge Loading

A review of the pre-existing grade in the Cell B footprint as compared to the design subgrade elevation for Cell B showed that surcharge loads vary from 34 to 48 feet across the Cell B floor footprint with 95% of the area falling into a tighter range of 36 to 46 feet of surcharge. This surcharge loading is quite uniform when compared to Cell A construction that exhibited a sharp change in elevation (edge of stockpile) in the middle of the cell floor. This uniform surcharge 'preload' equally consolidates underlying soils and reduces the possibility of localized differential settlement caused by future loading of waste to be placed in the cell footprint.

### 2.2 Inspection of Excavation, Soil Consistency

A site inspection was conducted on August 29, 2017 during excavation activities to bring the site to subgrade elevation. The site was currently being excavated from east to west with an approximate 8 foot tall bench. The lower area was still 8 feet above subgrade, and the upper area approximately 16 feet above subgrade.

Two predominant soil groups were visible across the site. The first was a brown silty sand with gravel (visual classification) and the second a red clayey sand with gravel (visual classification).

Based on observations of the sidewalls and center bench, the brown silty sand appeared to underlay the red clayey sand with the transition occurring approximately 10-15 feet above subgrade elevation.

Layering of material in the stockpile was expected to be angled near the angle of repose based on Cell A construction and site history. However, the interface between the brown silty sand and red clayey sand appeared to be much flatter with intersection line less than 10% grade. However, the exact orientation of the interface could not be clearly determined and flatter observed interfaces may be a result of the excavation intersecting the sloped interface perpendicular to the slope.

Soil samples were collected of the two observed materials for gradation testing.

## 2.3 Subgrade Inspection

On September 14, 2017 an inspection was conducted of the nearly completely excavated subgrade elevation. The predominant material observed at the subgrade elevation was a brown silty sand with gravel, which had been previously observed beginning at 10-15 feet above cell floor subgrade.

Six test pits were conducted to approximately 4 feet below subgrade elevation across the subgrade floor. The test pit sidewalls were inspected as well as the excavated material. The material in all six test pits indicated the brown silty sand with gravel, with fines content varying slightly. The greatest variation was observed in Test Pit #4 where a brown sand with silt was observed. Two soil samples were collected from the test pits representing the brown silty sand that appear to contain the most and least fines content. These samples indicated similar gradations with fines content ranging from 20-30%. These test pit sample gradations agreed well with the original brown silty sand gradation conducted following the August 29 inspection.

## 2.4 Review of 2013 Geotechnical Assessment

A review was conducted of the 2013 geotechnical assessment in light of the modified cell B footprint from the original design as well as recently acquired data and observations. Soil Borings SB 12-03, SB 12-07, SB 12-08, and SB 12-12 were all near or within the Cell B footprint. Soil samples collected from these boreholes indicated similar gradations as recently collected data near the subgrade elevation. These boring appear to indicate that the native surface is at approximate elevation of 1455 feet MSL, leaving approximately 15-25 feet between the subgrade floor and native ground. Native ground when encountered in borings indicated a dense to very dense sand with silty clay. The placed fill material remaining below the Cell B subgrade appears to be generally consistent material with borings indicating a brown sand, sand with silt, or silty clayey sand that is generally in a medium dense state. SB 12-07 indicated material in a loose state between elevations 1460-1470.

Estimated settlement from the initial analysis for Cell B floor area indicated settlement ranging from 3.8 to 5.8 inches based on the Menard Modulus ($E_m$) and 2.2 to 2.4 inches based on SPT correlation.

# 3.0 Recommendations

## 3.1 Subgrade Preparation

Based on assessment of the Cell B footprint and review of the previously conducted geotechnical assessment, the existing Cell B in-situ subgrade is appropriate for the proposed Cell B liner construction without the need for correction. This recommendation assumes the observed soil conditions across the floor area remain consistent with that which is described in this report. If observations or soil conditions are noted that do not align with those noted in this report, further investigation should be completed.

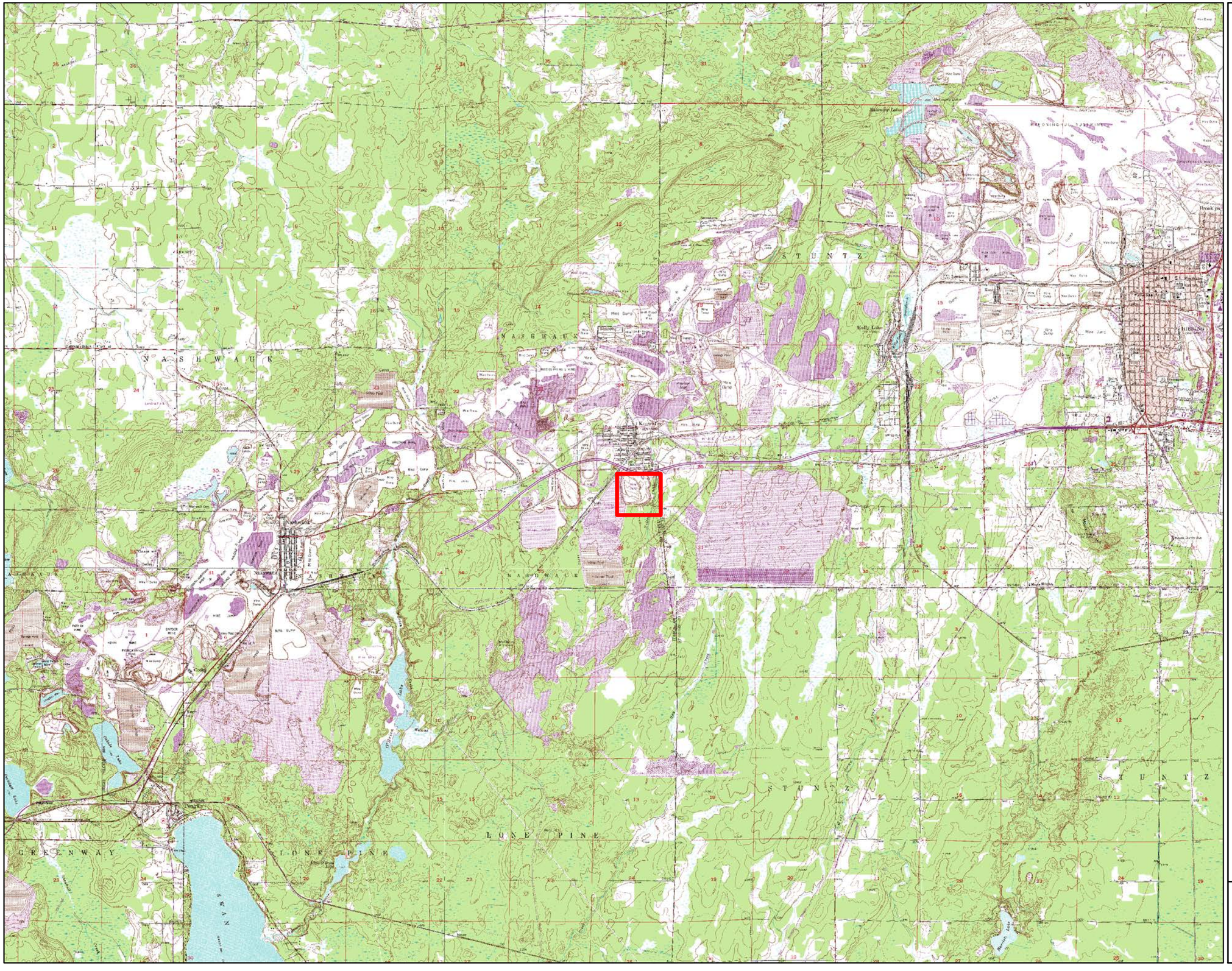
The in-situ subgrade should be moisture conditioned to be within 5% of optimum moisture for compaction (ASTM D698) and proof-rolled and shown to exhibit no greater than 2 inches of deformation under loading from a large vibratory smoot drum roller. If this cannot be achieved, further investigation should be conducted.

# 4.0 Qualifications

Recommendations provided herein are based on our professional judgment. The soil testing and geotechnical engineering services provided for this project have been conducted in a manner consistent with that level of skill and care ordinarily exercised by other members of the profession currently practicing in this geographical area under similar time and budget constraints. No other warranty is made.

The scope is limited to the specific project and location described herein, and our description of the project represents our understanding of the significant aspects relevant to soils and foundations. In the event that any changes in the design from the assumptions outlined in this report are planned, NTS should be informed so that changes can be reviewed.

# Figures




N

0 3,000 6,000 12,000

Feet

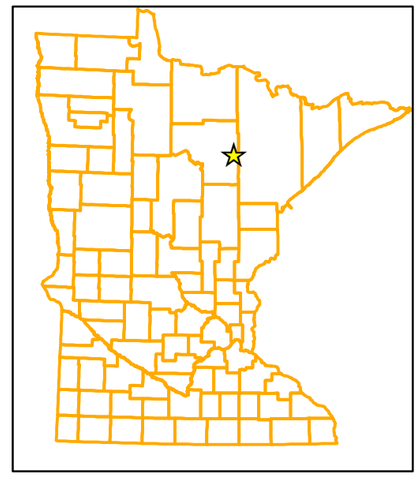
**1 Inch = 6,000 Feet**

## Legend

Project Location

**Notes:**

-Background image has been provided by MNGEO Web Services

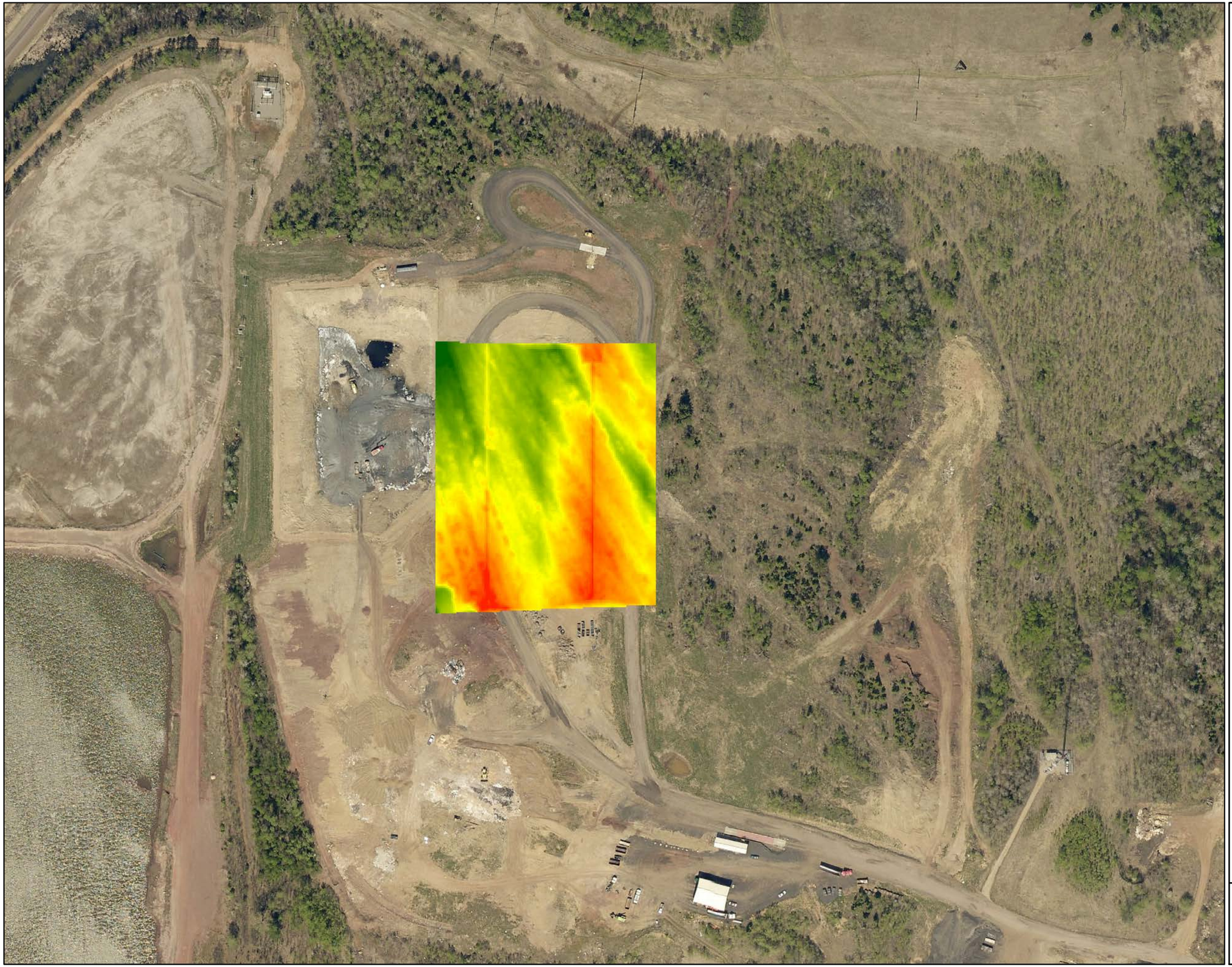


# Figure 1
# Site Location Map

**General Waste Industrial Landfill**
**Cell B Construction Subgrade Assessment**
**Keewatin, MN (St. Louis)**

Environmental Science & Engineering
www.netechnical.com

| | |
|---|---|
| Date Drawn : October 4, 2017 | |
| Drawn By : Evan Johnson | 1 |
| NTS Project #: 6385ECA | |



N

0 87.5 175 350

Feet

**1 Inch = 175 Feet**

## Legend

**Cell B Change in Elevation - Subgrade Floor**

48 Feet

34 Feet

**Notes:**

-Background image has been provided by St. Louis County Web Services. App. Image Date: May, 2016

# Figure 2
# Change In Elevation Map

**General Waste Industrial Landfill**
**Cell B Construction Subgrade Assessment**
**Keewatin, MN (St. Louis)**

Environmental Science & Engineering
www.netechnical.com

| | |
|---|---|
| Date Drawn : October 4, 2017 | |
| Drawn By : Evan Johnson | 2 |
| NTS Project #: 6385ECA | |


N

0 62.5 125 250

Feet

**1 Inch = 125 Feet**

## Legend

- Test Pit Locations
- Historic Boring Locations
- Cell B App. Subgrade

**Notes:**

-Background image has been provided by St. Louis County Web Services. App. Image Date: May, 2016

# Figure 3
# Test Pit Location Map

**General Waste Industrial Landfill**
**Cell B Construction Subgrade Assessment**
**Keewatin, MN (St. Louis)**

Environmental Science & Engineering
www.netechnical.com

| | |
|---|---|
| Date Drawn : | October 4, 2017 |
| Drawn By : | Evan Johnson |
| NTS Project #: | 6385ECA |

**3**

# Appendix A
# Field Notes/Site Evalution Photos

General Waste Subgrade Inspection Cell B Pg 1/2

7-29-17 Evan Johnson

1205 Prep at office, leave for site

1250 Arrive at site. Meet Mark at office.

1300 Drive to Cell B excavation. Observed 2 excavators cutting, 1 dozer pushing. One excavator working near center of floor, cutting material that is 8-18' above base grade. One excavator & dozer working on north wall, cutting to slope base grade. South & East slope graded to base grade elevation ~~where~~ above current excavation depth.

- A distinct material transition is evident between 2 materials. Material A observed more westerly in the cell is Brown Silty Sand with gravel, fine content ranging from 10-30%. Material B is observed higher in the mine dump material, and ~~and~~ in the eastern portion. Material B is Sandy Clay with gravel, Deep red, plastic, softer. (and in lower lifts)
- Soil samples of each were collected for gradation.
- Additional observations of bearing base grade material will be made once the excavation is brought to base grade ~~before~~ in the floor area.



7-29-17

1415 A determination of the need to conduct a subcut correction of the base grade will be made once we have additional gradation data & soil variability at the base grade can be observed.

1420 Leave site

**BRG:** 338°NW (T) **POS:** 15 T 494273 5248410 ±32.8ft

North bank, brown/red interface
NTS-Evan Johnson

6385 General Waste Cell B
29 Aug 2017, 13:27

**BRG:** 344°N (T) **POS:** 15 T 494120 5248877 ±3208.8ft

General Waste Subgrade Inspection Pg 1/2

8-14-17

930 Leave for site

1010 Arrive at site. Give Mark Pahl a call

1020 Meet at subgrade. Conduct test pitting to confirm consistancy of observed base grade material. Gradation of 'brown' soil meets subgrade correction criteria. 'Brown' material was observed to be a minimum of 6' above base grade.

Test Pit #1 - SW corner - 3' depth
- confirmed consistant brown silty sand w/ gravel

Test Pit #2 - NW corner - 3' depth
- same brown silty sand w/ gravel, 24" cobble

- Observed sump location, only slightly cut to collect run-off, not visible to determine soil content. Instructed Mark of Dem-Con to make close observation of lysimeter & sump to ensure consistant soil gradation through depth.

Test Pit #3 - North-central - 3.5' depth
Brown silty sand with gravel, moist, seem of higher fines at 1-2' below subgrade., 12" cobble,



8-14-17

Test Pit #4 - NE corner - 3.5' deep
slightly varying materials observed. Same brown silty sand w/ gravel, as well grey silty sand with gravel, slightly higher fines, more fine sand, 6" clay chunks intermixed.

Test Pit #5 - SE corner - 3.0' deep
brown silty sand, consistant

Test Pit #6 - South-central - 3.0' deep
brown silty sand w/ gravel, consistant

Collected samples from SE corner & NE corner for confirmation of gradation. Collected site photos showing transition of soils & general soil condition/ site condition

**BRG:** 291°W (T) **POS:** 15 T 494182 5248425 ±16.4ft

**BRG:** 290°W (T) **POS:** 15 T 494191 5248470 ±16.4ft

**BRG:** 213°SW (T) **POS:** 15 T 494227 5248464 ±16.4ft

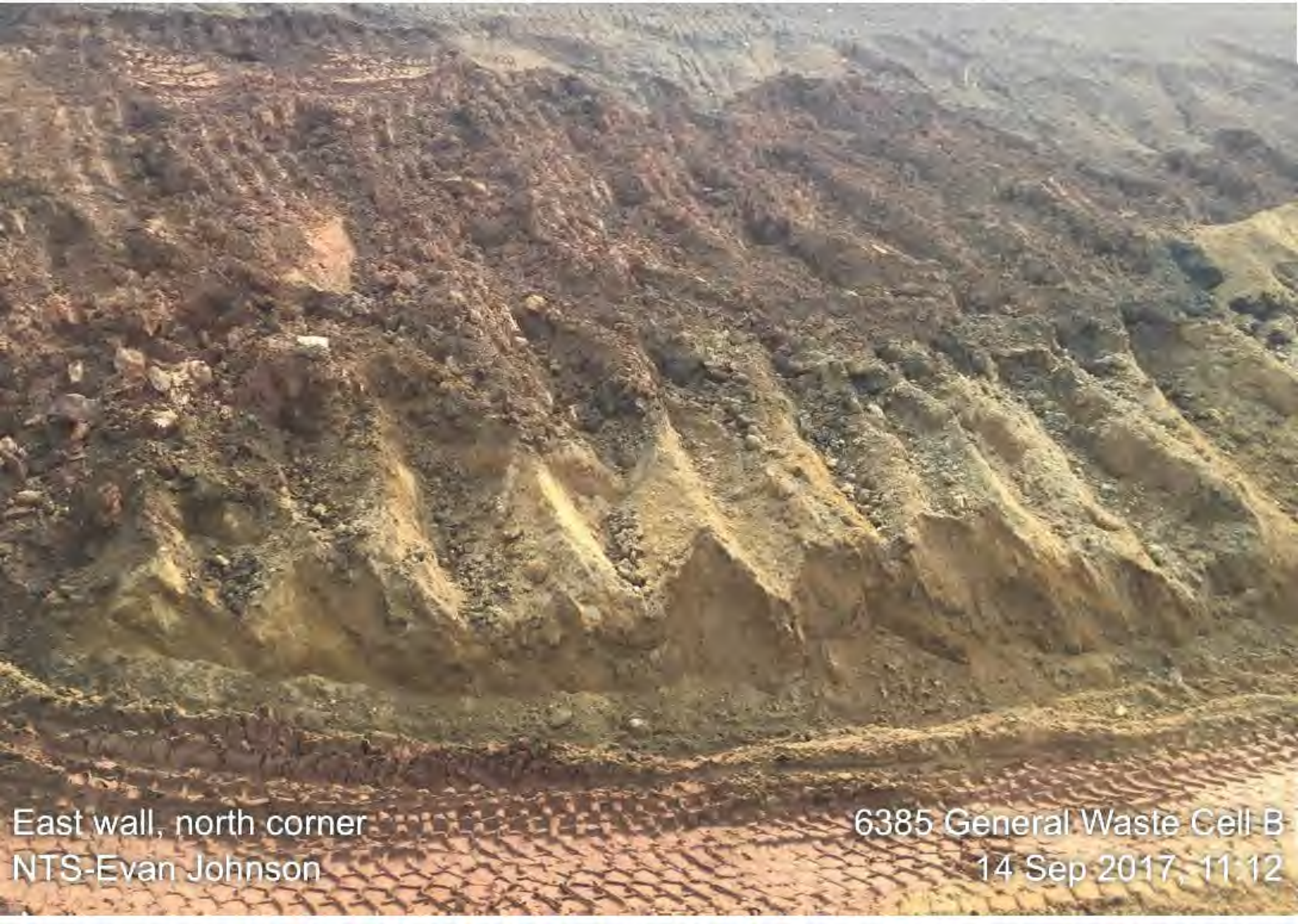
**BRG:** 2°N (T) **POS:** 15 T 494260 5248469 ±16.4ft

**BRG:** 84°E (T) **POS:** 15 T 494262 5248421 ±16.4ft

**BRG:** 125°SE (T) **POS:** 15 T 494209 5248408 ±32.8ft

**BRG:** 155°SE (T) **POS:** 15 T 494276 5248478 ±16.4ft

**BRG:** 89°E (T) **POS:** 15 T 494275 5248479 ±16.4ft



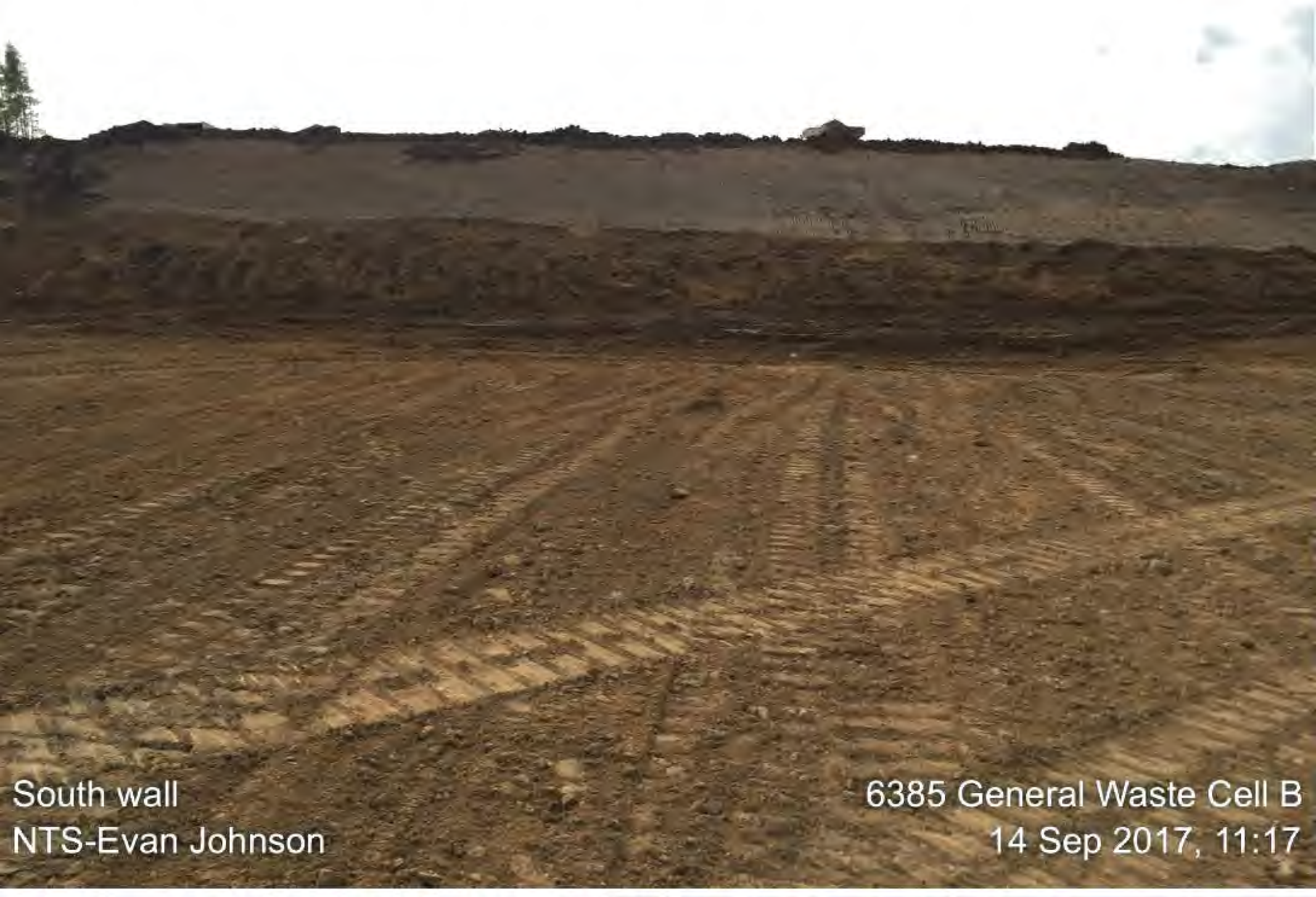
**BRG:** 324°NW (T) **POS:** 15 T 494267 5248468 ±16.4ft

**BRG:** 37°NE (T) **POS:** 15 T 494272 5248462 ±16.4ft

Northeast corner, contacting red material near basegrade
NTS-Evan Johnson

6385 General Waste Cell B
14 Sep 2017, 11:13

**BRG:** 173°S (T) **POS:** 15 T 494242 5248426 ±16.4ft



**BRG:** 37°NE (T) **POS:** 15 T 494151 5248395 ±16.4ft

**BRG:** 257°W (T) **POS:** 15 T 494153 5248395 ±16.4ft

Cell floor 2 (subgrade)
NTS-Evan Johnson

6385 General Waste Cell B
14 Sep 2017, 11:21

# Appendix B
# Laboratory Testing Results

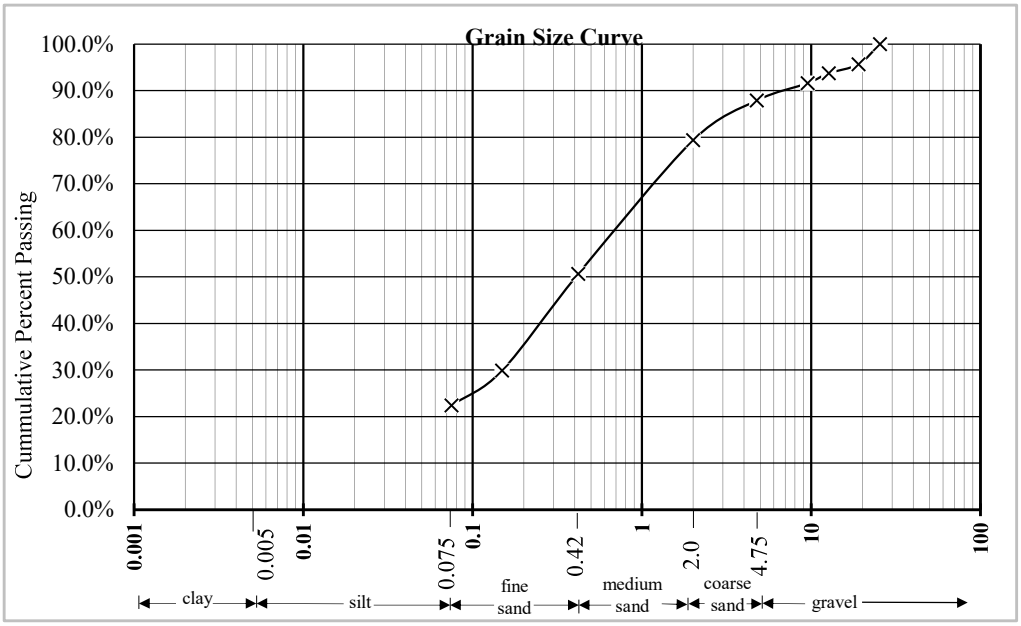
# GRAIN SIZE DISTRIBUTION REPORT

**(ASTM D 422)**

Northeast Technical Services, Inc.
526 Chestnut Street, PO Box 1142
Virginia, Minnesota 55792
Telephone: (218) 741-4290
nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | Cell B and C Liner Redesign | **Project #** | 6385EC |
| **Sample Description** | Brown Soil | **Lab ID #** | M562301 |
| **Date Reported** | | **COC #** | 259530 |
| **Client** | General Waste Disposal & Recov | | |
| **Sampled By** | Evan Johnson | **Lab Technician** | RRW |
| **Date Collected** | 8/29/2017 | **Date Analyzed** | 8/29/2017 |
| **Sample Location** | Brown Soil | | |

| Size | Percentage |
|---|---|
| **Gravel** | 12.1% |
| **Coarse Sand** | 8.5% |
| **Medium Sand** | 28.7% |
| **Fine Sand** | 28.3% |
| **Silt/Clay** | 22.4% |
| | |




| Sieve Size | Percent Passing | Specifications |
|---|---|---|
| **1** | **100%** | |
| **3/4** | **96%** | |
| **1/2** | **94%** | |
| **3/8** | **92%** | |
| **#4** | **88%** | |
| **#10** | **79%** | |
| **#40** | **51.0%** | |
| **#100** | **30.0%** | |
| **#200** | **22.4%** | |
| | | |
| | | |
| | | |

| Classification | | |
|---|---|---|
| **USCS** | **AASHTO** | **MNDOT** |
| (SC-SM) SILTY, CLAYEY SAND | A-1-b | |

| | |
|---|---|
| **Coefficient of Uniformity (Cu)** | **N/A** |
| **Coefficient of Curvature (Cc)** | **N/A** |

| Additional Information | | | |
|---|---|---|---|
| Sample Moisture | 6.5% | | |
| Permeability | | | |
| Atterberg Limits | LL | PL | PI |
| | | | |
| Additional Soil Descriptors | | | |

**Additional Comments:**

**Reviewed:** Gina Koski

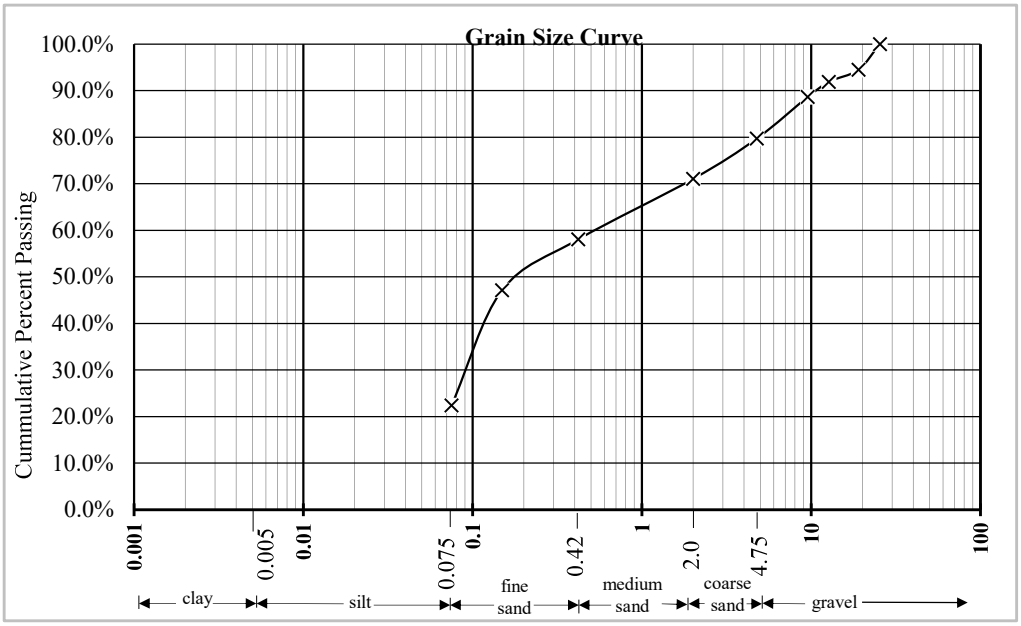
# GRAIN SIZE DISTRIBUTION REPORT

**(ASTM D 422)**

Northeast Technical Services, Inc.
526 Chestnut Street, PO Box 1142
Virginia, Minnesota 55792
Telephone: (218) 741-4290
nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | Cell B and C Liner Redesign | **Project #** | 6385EC |
| **Sample Description** | Red Soil | **Lab ID #** | M562302 |
| **Date Reported** | | **COC #** | 259530 |
| **Client** | General Waste Disposal & Recov | | |
| **Sampled By** | Evan Johnson | **Lab Technician** | RRW |
| **Date Collected** | 8/29/2017 | **Date Analyzed** | 8/29/2017 |
| **Sample Location** | Red Soil | | |

| Size | Percentage |
|---|---|
| **Gravel** | 20.3% |
| **Coarse Sand** | 8.7% |
| **Medium Sand** | 13.0% |
| **Fine Sand** | 35.6% |
| **Silt/Clay** | 22.4% |
| | |




| Sieve Size | Percent Passing | Specifications |
|---|---|---|
| **1** | **100%** | |
| **3/4** | **94%** | |
| **1/2** | **92%** | |
| **3/8** | **89%** | |
| **#4** | **80%** | |
| **#10** | **71%** | |
| **#40** | **58.0%** | |
| **#100** | **47.0%** | |
| **#200** | **22.4%** | |
| | | |
| | | |
| | | |

| Classification | | |
|---|---|---|
| **USCS** | **AASHTO** | **MNDOT** |
| (SC-SM) SILTY, CLAYEY SAND WITH GRAVEL | A-1-b | |

| | |
|---|---|
| **Coefficient of Uniformity (Cu)** | **N/A** |
| **Coefficient of Curvature (Cc)** | **N/A** |

| Additional Information | | | |
|---|---|---|---|
| Sample Moisture | 14.4% | | |
| Permeability | | | |
| Atterberg Limits | LL | PL | PI |
| | | | |
| Additional Soil Descriptors | | | |

**Additional Comments:**

**Reviewed:** Gina Koski

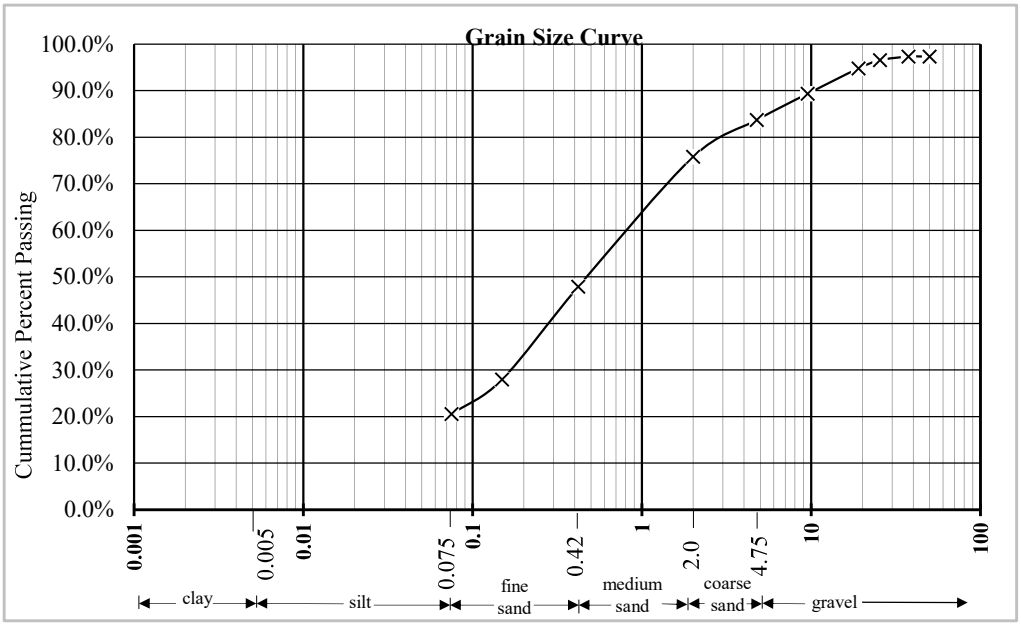
# GRAIN SIZE DISTRIBUTION REPORT

**(ASTM D 422)**

Northeast Technical Services, Inc.
526 Chestnut Street, PO Box 1142
Virginia, Minnesota 55792
Telephone: (218) 741-4290
nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | Cell B and C Liner Redesign | **Project #** | 6385EC |
| **Sample Description** | Test Pit #4 | **Lab ID #** | M563627 |
| **Date Reported** | | **COC #** | 259567 |
| **Client** | Cell B and C Liner Redesign | | |
| **Sampled By** | EJ | **Lab Technician** | RW |
| **Date Collected** | 9/14/2017 | **Date Analyzed** | 9/14/2017 |
| **Sample Location** | | | |

| Size | Percentage |
|---|---|
| **Gravel** | 16.3% |
| **Coarse Sand** | 7.9% |
| **Medium Sand** | 27.9% |
| **Fine Sand** | 27.3% |
| **Silt/Clay** | 20.6% |
| | |




| Sieve Size | Percent Passing | Specifications |
|---|---|---|
| **2** | **97%** | |
| **1 1/2** | **97%** | |
| **1** | **97%** | |
| **3/4** | **95%** | |
| **3/8** | **89%** | |
| **#4** | **84%** | |
| **#10** | **76.0%** | |
| **#40** | **48.0%** | |
| **#100** | **28.0%** | |
| **#200** | **20.6%** | |
| | | |
| | | |

| Classification | | |
|---|---|---|
| **USCS** | **AASHTO** | **MNDOT** |
| (SC-SM) SILTY, CLAYEY SAND WITH GRAVEL | A-1-b | |

| | |
|---|---|
| **Coefficient of Uniformity (Cu)** | **N/A** |
| **Coefficient of Curvature (Cc)** | **N/A** |

| Additional Information | | | |
|---|---|---|---|
| Sample Moisture | 8.8% | | |
| Permeability | | | |
| Atterberg Limits | LL | PL | PI |
| | | | |
| Additional Soil Descriptors | | | |

**Additional Comments:**

**Reviewed:** Casey Rogers

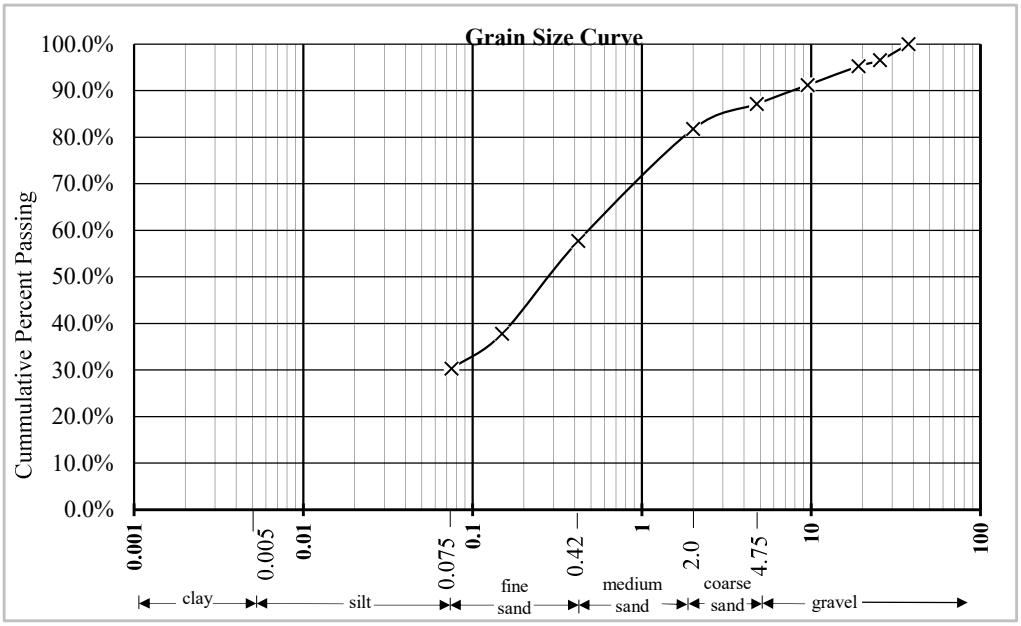
# GRAIN SIZE DISTRIBUTION REPORT

**(ASTM D 422)**

Northeast Technical Services, Inc.
526 Chestnut Street, PO Box 1142
Virginia, Minnesota 55792
Telephone: (218) 741-4290
nts@netechnical.com

| | | | |
|---|---|---|---|
| **Project** | Cell B and C Liner Redesign | **Project #** | 6385EC |
| **Sample Description** | Test Pit #1 | **Lab ID #** | M563628 |
| **Date Reported** | | **COC #** | 259567 |
| **Client** | Cell B and C Liner Redesign | | |
| **Sampled By** | | **Lab Technician** | RRW |
| **Date Collected** | 9/14/2017 | **Date Analyzed** | 9/14/2017 |
| **Sample Location** | Test Pit #1 | | |

| Size | Percentage |
|---|---|
| **Gravel** | 12.9% |
| **Coarse Sand** | 5.4% |
| **Medium Sand** | 24.1% |
| **Fine Sand** | 27.4% |
| **Silt/Clay** | 30.3% |
| | |




| Sieve Size | Percent Passing | Specifications |
|---|---|---|
| **2** | **100%** | |
| **1 1/2** | **100%** | |
| **1** | **97%** | |
| **3/4** | **95%** | |
| **3/8** | **91%** | |
| **#4** | **87%** | |
| **#10** | **82.0%** | |
| **#40** | **58.0%** | |
| **#100** | **38.0%** | |
| **#200** | **30.3%** | |
| | | |
| | | |

| Classification | | |
|---|---|---|
| **USCS** | **AASHTO** | **MNDOT** |
| (SC-SM) SILTY, CLAYEY SAND | A-2 | |

| | |
|---|---|
| **Coefficient of Uniformity (Cu)** | **N/A** |
| **Coefficient of Curvature (Cc)** | **N/A** |

| Additional Information | | | |
|---|---|---|---|
| Sample Moisture | 10.5% | | |
| Permeability | | | |
| Atterberg Limits | LL | PL | PI |
| | | | |
| Additional Soil Descriptors | | | |

**Additional Comments:**

**Reviewed:**

# Appendix C
# 2013 Geotechnical Assessment

Appendix information removed due to duplication in Appendix A of this document (CCR Stability Certification)
Evan Johnson, PE - Oct. 4, 2017

10-4-17